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Introduction

Food is the basic need of humans for survival. The study on food consumption pattern is very important as it is related to poverty and standard of living of the society (Pavithra *et al*., 2009). According to Venkaiah *et al* (2011), proper intakes of foods as well as nutrients are the major factors responsible for maintaining good health of an individual.

Even though the diet across India has not been assessed broadly, numerous studies shows that India is in the midst of a "nutrition transition," where the dietary changes are interrelated to increasing economy and rapidly progressing non- communicable diseases (Misra *et al*., 2009). World's largest urban population having income below poverty line resides in India. Across India, the food consumption pattern varies considerably within the North - South regions as well as within the districts of a state.

Regional diets are the diets in a specific region of a country that are evolved from the daily lives and kitchens of people over an extended period of time based upon national, state or local regions. Regional diets vary according to the traditions, cultural practices followed, food availability, weather, and income levels (http://www.diet.com/g/regional-diet-american).

In India, the food consumption patterns are mostly based on spiritual, cultural and family ideals which are passed on from one generation to the next generations. The vegetarian foods consumed by Indians mainly include a wide variety of cereals and millets, dhals and pulses, vegetables, green leaves, fruits, spices as well as condiments. Indian foods are also subjected to different cooking methods and seasonings. Moreover, the vessels used for cooking foods vary from mud pot to modern cooking wares.

According to the reports of Popkin *et al* (2012), in India, since 1970s, the intakes of cereals, pulses, vegetables and fruits reduced while the intakes of

refined grains, meat and its products, cola drinks as well as processed foods increased. At present, Indian population is undergoing a rapid transition in every phase of life such as socio-economic, demographic, health and nutrition. The rate of transition may also vary between every state, urban and rural population and as well as income groups (National Sample Survey Organization, 2012).

India is the first developing country to take-up the National Nutritional Anaemia Prophylaxis Programme of iron folic acid supplementation to all pregnant women and children to prevent anaemia among pregnant women and children. In spite of all these efforts, still anaemia continues to be a major health problem affecting all segments of the population.

The micronutrient malnutrition also referred to as hidden hunger is the result of the deficiency of essential vitamins and minerals in the diets of the population. As per the reports of Centers for Disease Control and Prevention (2013), the global prevalence of micronutrient malnutrition is estimated to be two billions. Reports of World Health Organization (2008) points out that, one out of three people residing in the developing countries suffer from vitamin as well as mineral deficiencies. One sixth of the global population resides in India, and among them, around two billion people suffers from micronutrient malnutrition.

According to WHO (2008), in India, the prevalence of micronutrient malnutrition are extensively seen among the reproductive age women. Review studies conducted by Torheim *et al* (2010), among the reproductive age women in Asia on micronutrient intake, found that the micronutrient intakes were less than the Estimated Average Requirement (EAR).

The Micronutrient Initiative (2009), pointed that, the major micronutrient deficiencies existing among the global population includes iron deficiency anaemia, vitamin A deficiency disorders, iodine deficiency disorders, folic acid deficiency, and zinc deficiency are the leading five causes of micronutrient deficiencies which constitute a global public health problem. Deficiency of a particular micronutrient not only leads to specific deficiency diseases, but also acts as causative factors for other infectious as well as chronic diseases, affecting morbidity, mortality, and quality of life.

Among the micronutrient malnutrition prevailing, the most devastating one is the iron deficiency anaemia. According to World Health Organization (2009), anaemia is defined as "the state in which the Red Blood Cells (RBCs) or their oxygen carrying ability is inadequate to meet physiological requirements of the body". In the development of iron deficiency anaemia, dietary factors play a major role.

Globally, iron-deficiency anaemia is the major problem prevalent and it is the most neglected micronutrient deficiency disorder seen among children, adolescent girls, and pregnant women. Iron deficiency anaemia suppresses human productivity as well.

According to the reports of Arnold *et al* (2009), as per the National Family Health Survey (NFHS-3), conducting the household survey expected to have a national and state representative data on population health and nutrition; the prevalence of anaemia was 70 per cent in children in the age group of six months to five years, 55 per cent females in the age group of aged 15 to 49 years, and 24 per cent among males in the age group of 15 to 49 years. According to the reports of the District Level Household and Facility Survey (IV) carried out in the year 2012 - 2013, in Tamil Nadu, 60.20 per cent of the children in the age group of six months to five years and 49.20 per cent of the females in the age group of aged 15 to 49 years, were anaemic.

According to Radhika *et al* (2011), among the Indian population, a considerable proportion of all segments find it difficult to consume the five daily servings of fruits and vegetables as recommended by the World Health Organization.

Among the essential trace elements, iron (Fe) and zinc (Zn) occupies a major role in human nutrition and the deficiencies in the diet leads to major public health problems worldwide. Iron deficiency anaemia is a severe public health concern in developing countries. In India, among adolescent girls, the prevalence of anaemia is 90 per cent (Toteja*et al.*, 2006). Iron and zinc deficiencies occur concurrently since the same foods serve as the sources for both iron and zinc.

The absorption of iron and zinc are also hindered by the same dietary substances. Non-haeme iron absorption is inhibited by calcium, phytates in cereals and legumes and the phenolic compounds present in tea, coffee, and other beverages (Geissler and Singh, 2011).

Iron deficiency mainly affects children and women. More than half of the children living in developing countries in the age group of six months to two years are deficient in iron, and about 40 per cent of young women suffer from iron deficiency anaemia. In developing countries, apart from iron deficiency, frequent attack by malaria and worm infestations also leads to anaemia.

The definition of adolescence given by World Health Organization (2008), as the period of life spanning between 10 years to 19 years. The world's adolescent population is projected to be more than one billion, yet they remained as the largely neglected group as well as considered to be a nutritionally vulnerable segment of the population. India has the leading population of adolescents of 243 million followed by China (207 million) and United States (44 million). In India, the prevalence of anaemia among adolescent girls is 90 per cent (Shilpa *et al*., 2012).

Adolescence forms a crucial period when major physical, psychological, and behavioral changes take place (Mala e*t al*., 2007). The nutritional status of female adolescents contributes to the nutritional status of the community (Parimalavalli and Sangeetha, 2011).

Within India, the prevalence rate of anaemia varies, with the lowest prevalence of 33 per cent in Andhra Pradesh to highest of 98 per cent in Rajasthan (Kaur *et al.,* 2011). Cross sectional surveys conducted in India have exposed the prevalence of anaemia as 70 to 80 per cent among different age groups of both sex, and physiological groups (NNMB, 2012).

Adolescent girls are extremely vulnerable group due to insufficient intake of iron and zinc which fail to meet their highly demanding physiological requirements for growing body tissues, expanding red cell mass, and onset of

menarche. Apart from these factors, non-dietary factors such as excessive menstrual blood losses, tiring exercise, low socio-economic status and ethnicity may also increase their risk of both iron and zinc deficiencies.

Anaemia, results in reduced cognitive and motor development and causes fatigue and thereby low productivity (Balarajan *et al.,* 2011). Outcomes of micronutrient malnutrition includes increased death rates particularly in women and children; poor pregnancy outcomes; increased morbidity rates; impaired mental and physical growth in school going children; and reduced work output in adults (Black *et al*., 2008).

Moderate to severe zinc deficiency is linked with growth retardation, respiratory infection and diarrheoa especially in children. In developing countries like India, marginal zinc deficiencies are prevalent. Due to lack of sensitive and specific biomarkers, the assessment of zinc deficiency is restricted (King, 2011).

Micronutrient malnutrition forms the major hindrance to socio-economic development and contributes to the vicious circle of poverty. It has long-ranging effects on health, learning capacity and work efficiency. It can also lead to severe public costs and unpleasant loss of human potential. Overcoming micronutrient malnutrition is a requirement for ensuring rapid and appropriate development. Policies and programmes must be developed to assure availability of goods and access to enough variety and amount of good-quality foods for the people around the globe.

Nutritional iron (Fe) deficiency and consequent anaemia arises when physiological requirements cannot be met by iron absorption from the diet (Kalasuramath *et al*., 2013).Iron and zinc deficiencies prevalent in developing countries are the result of consuming plant-based cereal diets. These micronutrients are not completely available for performing physiological functions in the body. Only a fraction of iron and zinc consumed from diets can be utilized because of interference by other food constituents. The non-nutrient food constituents like phytate and polyphenols present in plant based diets hinder the bioavailability of non-haeme iron and zinc present in the diets.

According to Fairweather-Tait (1993), Bioavailability is referred to as the fraction of nutrients or bioactive compound ingested that is available for using in the physiological functions or to be stored. Benito and Miller (1998) defined bioavailability as the proportion of a nutrient in a given food or diet which the body can use. Bioavailability is a key concept for nutritional effectiveness [10], irrespective of the type of food being considered (functional or not). Only certain amounts of all the nutrients and bioactive components in food will be used effectively by the organism. , Thus, the term "bioavailability" includes availability for absorption, absorption, metabolism, tissue distribution. Whereas Bioaccessibility is defined as the fraction of nutrient that is released from its matrix in the gastrointestinal tract and thereby available for intestinal absorption, enters the blood stream (Blenford, 1995).

Haeme iron obtained from non-vegetarian food sources are absorbed more efficiently from the diet than non-haeme iron which is present usually in plant and cereal based food sources.

Review done by Nair and Iyengar (2009), reported that, Indian diets which is mainly cereal and plant based contributes to 90 to 95 per cent of the non–haeme iron which is poorly absorbed. Studies conducted by Geissler and Singh (2011) reported that, a number of dietary components have been shown to increase or reduce non-haeme iron absorption from single test meals. The main enhancers of non-haemeiron bioavailability are meat, and ascorbic acid found in fruit and vegetables. The main inhibitors of non-haeme iron bioavailability are calcium and phytates present in the cereals and legumes and phenolic compounds found in tea, coffee, and other beverages.

Habitual Indian diet provides about 9 to 11 mg of zinc and a considerable proportion (52 per cent) of which comes from cereals (Nair and Choudhary, 2013). Studies conducted by Nair *et al* (2013) on zinc absorption using stable isotopes among adolescents identified that the fractional absorption of zinc is in the range of 27 to 30 per cent and the major inhibitor that inhibits zinc absorption is phytate.

Usually micronutrient malnutrition prevails when diets lack variety. Though short-term interventions have a role in providing specific target groups with micronutrient supplements at definite times, only food-based approaches can prevent micronutrient malnutrition in a sustainable way for most of the population.

Combinations of strategies are necessary to guarantee a positive and significant effect on micronutrient adequacy. Numerous age old domestic household food processing as well as preparation methods can be used to improve the bioavailability of micronutrients in cereal and plant based diets. These methods includes thermal processing such as roasting, mechanical processing such as milling, soaking, fermentation, and germination/malting. These strategies aim at enhancing the physico - chemical accessibility of micronutrients and decrease the antinutirents such as phytate, and enhance the content of compounds that improve bioavailability.

Micronutrient malnutrition can be addressed though food based approaches coupled with nutrition education. Households should be educated and trained to increase the production of dark green leafy vegetables, papaya, trained to adopt good cooking practices to minimise loss of micronutrients and to adopt best processing methods to enhance bioavailability of micronutrients.

Green leafy vegetables forms an important place among the food crops as these provide adequate amounts of many micronutrients for humans. They are rich source of carotene, ascorbic acid, riboflavin, folic acid and minerals like calcium, iron and phosphorous. Although, in nature, there are many underutilized greens providing enough nutrients, which can nourish human population, many of them are resilient, adaptive and tolerant to adverse climatic conditions. Though, they can be raised at low management costs even on poor marginal lands, they have remained underutilized due to lack of awareness and popularization of technologies for utilization, such efforts are not done.

The main strategies which can be implemented to overcome micronutrient malnutrition consist of dietary improvement including increased production and

consumption of micronutrient-rich foods; food fortification; supplementation; and global public health and other disease control measures. These are the most sustainable approaches to increasing the micronutrient status of populations.

Inorder to combat micronutrient malnutrition, one of the best solutions is having mixed diets. The eradication of these deficiencies will occur only when the diets of vulnerable groups contains all essential nutrients in the appropriate amounts. Programmes in many countries have demonstrated that comprehensive, well-designed food-based strategies can improve diets of vulnerable groups in a relatively short time and that these improvements can be sustained.

Various countries have confirmed that micronutrient malnutrition can be eradicated when government policies and programmes are aimed at the goal of increasing production and access to vitamin and mineral rich foods and when associated marketing and educational activities improve consumption of these foods. There are also several instances where fortification of certain staple foods provides micronutrients to large populations in a manner that is fully integrated with prevailing food production, processing and distribution patterns on a self-sustaining basis.

The incorporation of special foods to a rice-based diet can achieve nutritional adequacy for those micronutrients that are mostly deficient in populations. The foods selected for the diets are representative of foods that are commonly included in South Indian diets (Thankachan *et al*., 2007).

India is the first country in the world to initiate the National Nutritional Anaemia Prophylaxis Programme (NNAPP) in the year 1972 in which iron and folic acid tablets were supplemented to all pregnant women and children to prevent anaemia among pregnant women and children. In India, inspite of the existing massive national nutritional intervention programmes for anaemia and vitamin A namely, Nutritional Anaemia Prophylaxis Programme, Vitamin A Deficiency Prophylaxis Programme, Iodine Deficiency Disorders Prophylaxis Programmes , the prevalence of anaemia, vitamin A, Iodine deficiency disorders and zinc deficiencies appear to be a major public health problem.

Except the national food surveys by National Nutrition Monitoring Bureau (NNMB), National Sample Surveys Organization (NSSO), there are only a very few up-to-date assessments of regional Indian diets (NSSO, 2012). Also, data on the impact of different processing methods and cooking in the form of regional diets on the bioavailability of micronutrients especially iron and zinc are not available in India. Hence, the need for the present study.

The specific objectives of the study are: To

- Assess the consumption pattern of the regional diets by the households of selected districts in Tamil Nadu
- Evaluate the nutrient potentials of the regional diets.
- Assess the *in-vitro* bioaccessibility of iron and zinc from the regional diets and
- Assess the *in-vivo* bioavailability of iron and zinc from the Ready To Eat (RTE) food among adolescent girls.