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# Nutritional Status of Ethiopian Weaning and Complementary Foods: A Review

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## Abstract

This paper reviews the available literatures and research findings on the traditional and commercially available weaning and complementary foods in Ethiopia. Weaning foods in Ethiopia can be made from locally available cereals and legumes and many types of weaning food are feed for infant. Weaning and complementary feeding improvement should be of highest priority for nutrition of infant and young children because of its crucial role in preventing mortality and enhancing children development. Formulation and development of nutritious weaning foods from local and readily available raw materials has received a lot of attention in many developing countries. The global strategy for infant and young child feeding states that, infants should be exclusively breastfed for the first six months of life to achieve optimal growth, development and health, and thereafter, receive nutritionally adequate and safe complementary foods while breastfeeding continues for up to two years or beyond.

Protein-energy malnutrition generally occurs during the crucial transitional phase when children are weaned from liquid to semi-solid or fully adult foods. During this period, children need nutritionally balanced, calorie-dense supplementary foods in addition to mother's milk because of the increasing nutritional demands of the growing body. Thus, weaning food plays a great role on child growth and development. Traditional weaning food can be improved by fortification of popularly consumed staple foods and combining locally available foods that complement each other which need to be changed or modified to improve their nutritional status. Ethiopian, complementary food given to infants by mothers or caretakers, are deficient both in macro nutrients (protein, carbohydrates and fat) and micro-nutrients (minerals and vitamins). This leads to PEM and specific micro nutrient deficiency or both. Therefore, adequate nutrition and health care during the first several years of infant life is fundamental to prevent malnutrition and child death. The purpose of this paper is to study the nutritional status and formulation of Ethiopian weaning and complementary foods and nutrition.

**Keywords:** Traditional; Weaning foods; Fortification; Nutritious; Malnutrition

## Introduction

Ethiopia is one of the countries in Sub-Saharan Africa with the highest rates of malnutrition in children. It results from the interaction between poor diet and disease and leads to most of anthropometric deficits observed among children in Ethiopia [1]. Nutrition play crucial role in determining the body defense mechanism against infection. Protein–energy malnutrition (PEM) is still the major nutritional disorder among preschool (below age five) children of the developing country and always accompanied by infection illness. High morbidity because of acute and chronic infection can increase mortality resulting from [2]. The general infant and child feeding trends in Ethiopia are the followings.

## Breast Feeding Practices

Breast feeding is nearly universal in Ethiopia ranging from 93% in Addis Ababa to 99% in Harari. The complementary foods are not introduced in timely fashion for many children. At 6-8 months of age, 14% of children continue to be exclusively breast fed, 9% receive plain water in addition to breast milk, 6% consume other water based liquids, 20% consume other milk, and 50% consume complementary foods. The proportion of exclusive breastfed children by age 9-11 months is only 5% [3].

During the weaning period (4-6 months) exclusive breast feeding is recommended. Too early introduction of any other liquid or solid food has been shown in a wide variety of socioeconomic conditions to reduce breast-milk production and increased risk of infection [4]. WHO recommends that children should continue to be breast-fed up to two years of age or beyond, while receiving nutritionally adequate and safe complementary foods [5]. Infants and children upto 2 years of age are vulnerable groups in general and almost in every country and in particular in developing countries such as Ethiopia [6]. Scientifically, it has been proved that breast milk is the perfect food for the infant during the first six months of life. It contains all the nutrients and immunological factors an infant requires to maintain optimal health and growth. Furthermore, breast milk also protects infants against the two leading causes of infant mortality, upper respiratory infections and diarrhea [2,5].

However, at the age of six months and above when the child's birth weight is expected to have doubled, breast milk is no longer sufficient to meet the nutritional needs of the growing infant. Moreover, infancy is a period of rapid physical growth as well as physiological, immunological and mental development when nutritional requirements are at their highest [6].

## Exclusive Breast Feeding

Children need a variety of food to ensure that nutritional needs are met. Diet that lack animal source food (meat, poultry, fish, or eggs, plus milk product) cannot meet the nutritional requirement for children ages 6 to 24 months unless fortified foods or supplement are used. If

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milk and other animal source foods are not taken in adequate amounts, both grain legumes should be consumed daily, preferably within the same meal, to ensure adequate protein quality [4].

The growth and survival of a child continue after birth by deriving its nutrition through breast feeding for the first six months of life. It was noted that during weaning time the child needs high energy and about twice as much protein in relation to body weights of adult's. This necessitated for the provisions of adequate weaning diets for the child caring practices apart from socio-cultural, economic and demographic factors. Somehow, these practices constitute one of the most neglected determinants of young child malnutrition in spite of their important role in growth pattern of children.

Exclusive breast feeding for the first four to six months, with appropriate complementary feeding for at least the first year of life, could prevent the death of an additional estimated 1.3 million infant each year. An exclusive breast feeding infant is about 14 times less likely to die from diarrhea, nearly 4 times less likely to die from respiratory disease and almost 3 times less likely to die from other infections than the non breast fed infants [2]. The use of appropriate breast feeding and exclusive breast feeding practices can reduce malnutrition in children. Feeding practice such as time of introduction and type of complementary food quality and quantity of foods given have been identified as one of the most important factors for the child's nutritional status.

Moreover, various food processing techniques have the potential to enhance the nutrient bioavailability; palatability and convenience of supplement foods suitable for weaning foods including roasting, germination, milling, baking, drying, fermentation and extrusion.

In Ethiopia, the most important nutritional problems in weaning foods consumed by the children in many parts are protein energy malnutrition and deficiency in essential macronutrients and micronutrients [7]. The high cost and inadequacy in production of protein-rich foods have resulted in increased protein energy malnutrition among children and other vulnerable groups in the developing world.

Malnutrition in children results in growth retardation limited intellectual abilities that diminish their working capacity during adulthood, decreased resistance to disease and infections and ultimately ill health and death. It also delays in motor and mental development and exposes to frequency attacks of diarrheal disease, most importantly it can interfere with attainment of full human potential [7]. To minimize the hardships of malnutrition, processing of low–cost infant supplementary food have been reported in various parts of the world [8].

Protein energy malnutrition in children is associated with poverty and poor nutrition knowledge resulting in early weaning, delayed introduction of complementary foods, a low-protein diet and severe or frequent infections [9]. The vulnerability of infants to problems associated with weaning process is globally concerned, but more importantly in economically developing countries [10].

## Complementary Feeding Practices in Ethiopia

Adoption of recommended breastfeeding and complementary feeding practices and access to the appropriate quality and quantity of foods are essential conditions for fulfilling optimal nutrition for infants and young children [11]. Complementary feeding period is the time when malnutrition starts in many infants contributing significantly to the high prevalence of malnutrition in children less than 5 years of age worldwide [11]. Many factors contribute to the vulnerability of children during the complementary feeding period. The complementary foods are often of low nutritional quality and given in insufficient amounts. When given too early or too frequently, they displace breast milk [5]. In Ethiopia poor feeding practices and shortfall in food intake are the most important direct factors responsible for malnutrition and illness amongst children [5] and a combination of nutritionally inferior diets and improper feeding practices are major contributing factors to the development of childhood malnutrition [12]. Complementary feeding improvement should be of highest priority for nutrition of infant and young children because of its crucial role in preventing mortality and enhancing child development [11].

### Major grain-based traditional complementary foods

| Complementary foods | Raw Food Items Used |
|---|---|
| Gruel | Teff, Sorghum, Barley, Maize, Wheat, emmer wheat, and enset |
| Porridge | Teff, sorghum, barley, maize, wheat, emmer wheat and enset |
| Fetfet[1] | Teff, sorghum, barley, maize, wheat, broad beans, chick-peas, field peas, and lentil |
| Kitta[2] | Teff, sorghum, barley, maize, wheat, enset and chick peas |
| Dabo[3] | Teff, sorghum, barley, maize, wheat and emmer wheat |

### Prevalence of child malnutrition in Ethiopia

Malnutrition is the major nutritional disorder among preschool children of African country such as Ethiopia, because of inadequate consumption of balanced diet and high disease burden [1]. The most important nutrition problems documented in Ethiopia are protein energy malnutrition and micronutrients deficiency (vitamin C, vitamin A, iodine, iron and zinc deficiencies) [1]. Children malnutrition in Ethiopia constitutes big challenges as the country had a 17% under five mortality rates in 2001 of which an estimated 57% was linked to severe and mild to moderate malnutrition [13].

According to Firmin et al. [3] regional variation in nutritional status of children is substantial. Children in Benishangul Gumuz are least likely to receive vitamin A supplement compared with children in the other region, while households in Dire Dawa are most likely to consume salt that is adequate in iodized while least in Benishangul Gumuz. Moreover, percentage of children aged 6-59 months classified as having anemia, by background characteristics. More than half (54%) of Ethiopian children 6-59 months old are anemic, with 21 percent mildly anemic, 28 percent moderately anemic, and 4 percent severely anemic [3].

The level of malnutrition is significantly with nearly one in two (47%) Ethiopian children under five years of age (stunted-short for their age), 11% wasted (thin for their height) and 38% underweight [3]. In general, rural children and children of uneducated mothers are more likely to be stunted, wasted, or under weight than other children [1]. However, when data in between 2005 EDHS and 2000 EDHS were compared there have been some improvement in the nutritional status in the past five years. The percentage of stunted children fell by 10% from 52% in 2000 to 47% in 2005. Similarly percentage of children under weight was declined by 19% from 47% in 2000 to 38% in 2005. There was, however, no change over the five years period in the percentage of children wasted [14].

This is because of; children in Ethiopia are introduced directly to the regular household diet made of cereal or starchy root crops. This introducing directly into the family meal; option creates a problem, as

the child may not be able to eat enough adult diet to meet his or her nutritional needs [15].

Inadequate complementary food is a major cause for the high incidence of child malnutrition. The weaning period is the most critical period in a child's life as infants transfer from nutritious and uncontaminated breast milk to the regular family diet with chance of vulnerable to malnutrition and disease. Second reason for high prevalence of child malnutrition is also due to traditional complementary feeding. Traditional infant foods made of cereals and legume may be low in several nutrients including protein, vitamin A, zinc and iron. Furthermore, the bulkiness of traditional weaning foods and high concentrations of fiber and inhibitors are major factors in reducing their nutritional benefits. Feeding cereals and legume foods to child contains anti-nutritional factors that reduce the bio-availability of nutrients.

## Weaning Period

Weaning is the process of introducing semi-solid or solid foods to the breast or formula-fed child to meet extra nutritional needs for rapid growth and development. It is influenced by socioeconomic status, cultural and religious beliefs and practices [10]. Infant feeding is with references to "weaning period" - transition from breast-feeding to complete reliance on other foods [15]. The low nutrient density and high bulk of weaning foods, early introduction of solid foods, and unhygienic practices predispose infants to malnutrition, growth retardation, infection, and high mortality [15]. Apart from protein and energy, weaning diets of infants in developing countries require more calcium, vitamin A and D, iron and some important trace elements. These can be obtained by combining the local staples available in the country. Combination of commonly used cereals with plant protein sources like legumes can be used.

### Facts of weaning foods

According to the Protein Advisory Group guidelines for weaning foods, protein content should be 20%, fat levels up to 10%, moisture 5% to 10%, total ash not more than 5% [5]. Weaning food is a gradual withdrawal of feeding with the mother's milk and starts feeding it with solid food. The transition from milk to solid or adult food is critical period in the life of a child as weaning practices by the mother profoundly determines child growth and development [16]. Weaning food is the semi-solid foods that are used in addition to breast milk and not only replace it. It is prepared in the form of thin porridges. Legumes in the diet are found to improve nutrient density of food and improve nutrient intake, which results in the prevention of malnutrition problems [17].

### Nutrient requirement of infants' complimentary foods

According to Eschleman [5] qualified weaning food should fulfil the following features: high energy content, low viscosity (i.e. of an acceptable thickness or consistency), balanced protein (containing all essential amino acids) content, required vitamins and minerals (Iron, folic acid, calcium) content, no (safe level) anti-nutritional components and pleasant taste (palatable).

**Energy:** For a new born infant exclusively breast-fed, breast-milk provides the entire required calorie (95–145 kcal/kg (150 ml)) for the first 6 months. By 6 months, energy needs increases for a very good-nurtured infant by 32 kcal, and a restless infant by 60 kcal. It is reported that energy density of weaning food should be 4 kcal per gram on dry weight basis [18]. Infants and young children have a limited gastric capacity and an energy requirement per unit body weight about three times as high as for the adults. If a diet has a very low energy density children may not be able to eat adequate amounts because of the bulkiness of the diet. The energy density is most important for children with wasting, as they have an increased energy need for catch-up growth [19]. Low energy density weaning foods caused by high bulk gruels have long been implicated in protein-energy-malnutrition.

**Proteins:** Proteins are major sources of essential amino-acids and source of energy during times of energy deprivation, although fat and carbohydrate are utilized preferentially by the body [5]. Protein deficiency is almost always accompanied by inadequate energy intake and the two together leads to protein–energy malnutrition, one of the commonest forms of malnutrition worldwide. Severe protein–energy malnutrition results in the clinical syndromes of marasmus, kwashiorkor or marasmic-kwashiorkor. To maintain cellular integrity and function and to ensure health and growth, an adequate supply of dietary protein is vital. Cereals, legumes and/or oil seed flours, alone or preferably mixed, can constitute an appropriate source of proteins. Provided they are prepared in such a way that in the finished product the proteins in the mixture should fulfil the protein digestibility-corrected amino acid score (PDCAAS) should not be less than 0.70 and the energy from protein content should not be less than 10% of the total energy from the product [18].

**Fat:** Dietary fats provide the infant and young child with energy, essential fatty acids and the fat soluble vitamins A, D, E and K. Fat not only provides energy in the diet, but also has an important role for promoting good health in humans [5]. Fat accounts for approximately 50% of the energy in breast-milk and is the main source of energy for infants less than 6 months old. With the introduction of complementary food, fat is gradually overtaken by carbohydrate as the chief energy source, and together they meet the energy needs of the growing child. The range of proportions of energy from fat in the diets of infants and young children has been suggested is 30-45% [18].

**Carbohydrates:** Starch is likely to be a major constituent of many complimentary foods for older infants and young children. To ensure that its energy value is realized, this starch should be provided in a readily digestible form [18]. Increasing the intake of dietary fibers increases stool bulk, may cause flatulence and decrease appetite. Fiber load also can affect the efficiency of absorption of important nutrients from diets with marginal nutrient contents. The dietary fiber content of fortified complementary food should therefore be reduced to a level not exceeding 5 g per 100 g on a dry weight basis [18].

**Vitamins and minerals:** Vitamins and mineral are micronutrients, which are needed in minute quantities for the normal functioning of the body. They are normal chemical components of foods in their active forms or as precursors of the active forms. They form components of enzymes or co-factors needed for metabolic reactions in the body [19]. According to Codex Alimentarius Commission Recommendation, when a food is supplemented with one or more of these nutrients, the total amount of the added vitamin(s) and/or mineral(s) contained in 100 g of the food on a dry matter basis should be at least 50% of the reference daily requirements [18].

**Total mineral content:** Adequate intakes of micronutrients such as iron, zinc, and calcium are important for ensuring optimal health, growth, and development of infants and young children [18]. In Indonesia, dietary intakes of iron, zinc, and calcium are low, especially among young children living in rural areas and probably contribute to high prevalence of iron deficiency anemia and mild zinc deficiency among this age group. Cereals and legumes are important food sources of iron, zinc, and calcium for young rural infants and children. Notwithstanding, phytic acid; a dietary factor found primarily in

unrefined cereals, grains, legumes, and oil seeds are a potent inhibitor of iron, zinc, and calcium absorption. Hence, to ensure absorption of these minerals from a meal, it is important to consider the molar ratios of phytate: mineral of each plant based food in it. The desirable phytate: mineral molar ratios, for mineral absorption, are less than one for phytate: iron [20] and less than 0.17 for phytate: calcium [21]. Moreover, in Asia, there is a lack of information on the phytate and mineral concentrations of manufactured infant cereals, despite their increasing use for infant feeding.

**Dietary fiber:** Dietary fiber fits the definition of functional food that can affect one or more targeted function in the body in positive manner. Higher fiber content of weaning food may inhibit mineral absorption and reduce the digestibility of protein in foods [10]. There is much evidence that dietary fiber (DF) may contribute to present future health benefits in young children. For example, DF has a major influence on the bacterial colonization of the gastrointestinal tract and its maturation, in promoting laxation, and in establishing healthy eating patterns while eating foods high in DF is recognized as important, controversy over recommendations for infant DF intake exists [22]. Few organizations have quantified their recommendations, avoiding setting specific values by proposing that individuals introduce a variety of fruits, vegetables, and easily digested DF in the very young infant. Recently, the Institute of Medicine in the United States has recommended a specific value of 19 g/d for children between 1 and 3 years of age. This value, based on TDF intakes of 3.3 g/1000 kJ (14 g/1000 kcal), is based on a reduced risk of coronary heart disease in adults aged 19 years and older [23].

### Weaning foods development in Ethiopia

Weaning food can be generally produced following traditional technologies such as malting, popping and fermentation and modern food processing technologies such as roller drying and extrusion cooking [8]. Mostly weaning prepared in the form of tin porridge or gruels are used for ready consumption [24]. The choices of complementary foods are affected by factors like family dietary pattern, influence of elders, cultures, customs, beliefs of food taboos, previous experience of feeding patterns, agriculture, inadequate nutritional knowledge, geography and climates [24]. Development of complementary food is guided by high nutritional value to supplement breast feeding, acceptability, low price and use of local food items.

The concept of improved feeding of infant and young children is not well understood by most families in Ethiopia. The point at which infants begin the actual weaning process i.e. the introduction of grain based solid foods is not the same throughout the country. It varies considerably with the ethnic make-up of the population the degree of urbanization and the socio economic status of the families [25]. In general infants in the rural areas starts very late from 8 to 12 months of age whereas urban infants begin at about 5 months [3,14]. When mothers introduce solid foods to their infants, they traditionally give gruel made from a variety of cereals. As the infants grow, porridge is given in addition to gruel and both foods are given together until about the end of the 2nd year. When the child is about 2 years of age "fetfet "ketta" and "dabo" are given; soon afterwards the child is introduced to an adult diet consisting mainly of thin leavened bread (*Injera*) with hot sauce (wot) made from legume (split or ground and spiced). Wherever available, butter is added to all these weaning foods either toasted or boiled whole cereals, legumes or both are also given as small meals to older children who are able to chew it thoroughly.

Generally, weaning foods in Ethiopia are made from cereals or starchy tubers such as maize, sorghum, millet, rice and yam, potato, barley and yam. Traditional complementary food gruels or porridge are based on starchy staple foods, such as wheat, rice, maize, barley, oat, tef, millet or sorghum but in some areas also forms starchy roots or tubers that produce viscous porridges that are difficult for children to consume [26]. As a result, mothers commonly dilute the porridge with water to reduce its viscosity. Such dilution, however, also reduces the energy density of the mixture. Since young children have small gastric capacities, they are unable to consume enough of the diluted porridge to meet their energy requirements and consequently may become malnourished. This problem of high viscosity, low energy density, or both in complementary food is often referred to as "dietary bulk" [27]. Children consuming these foods grow poorly and have higher mortality rates. Increasing the nutrient density of complementary foods is a strategy commonly recommended for improving child nutrition.

It is possible to achieve an adequate nutrient intake by increasing the daily intake of such low nutrient-dense foods, but the volume of the food to be consumed may be too large to allow the child to ingest all the food necessary to cover nutrient needs. For instance, an infant aged 4–6 months would need about 62 g of corn gruel to meet daily need of energy of 740 (kcal), and protein need of 13 g [27]. This is an impossible target considering the size of an infant's stomach.

## Legumes, Cereals and Tubers best for Weaning or Complementary Food Formulation

### Common bean *(Phaseolus Vulgaris L)*

It is known as haricot bean, navy, french bean, kidney bean and green bean [28]. Haricot beans are pea-sized beans that are creamy white in color. They are mild flavored, dense and creamy, and are the type usually used to make baked beans. It is an ancient world origin, cultivated in many parts of the world. It was originated and domesticated in Latin America [29]. The crop was introduced to Africa from Brazil in the past Colombian era and its establishment as food crop is said to have been started in pre colonial era. It is assumed that beans were introduced to Ethiopia in the 16th century by the Portuguese while consumption of black and navy bean was shown to reduce azoxy methane induced colon cancer in rats [30].

Beans are an important food in many traditional diets. Epidemiological studies have indicated that the consumption of dry edible beans is beneficial to human health. Dry pinto beans are a good source of dietary copper with respect to both concentration and bio availability. Dry beans can provide fiber and various nutrients such as proteins, amino acids, carbohydrates and vitamins. Phenolic compounds that are mainly found in the hull of the bean seed are efficient free radical scavengers.

Dry beans are extensively consumed in the central rift valley of Ethiopia in the forms of traditional dishes and are considered to be one of the most nutritious beans. However, dry beans are known to contain several anti nutritional factors which could limit their consumption [28]. Meals prepared from beans are potential source of protein and energy for children. Numerous studies have demonstrated the diversity of approaches taken to achieve suitable weaning food products. Drum-dried bean meals prepared from split beans, a low-grade by-product of whole bean markets, demonstrated potential for pre-cooked, prolonged shelf-life weaning food formulations, which can provide both protein and energy to the infants as well as offer preparation convenience. During the sprouting period, starch content decreased; reducing and non-reducing sugars increased; tannins, trypsin inhibitor and phytates decreased; and *in vitro* digestibility increased. Therefore, sprouted bean is advantage for complementary food formulation.

## Barley

It is one of the most important staple food crops in the high lands of Ethiopia. Currently, barley is widely consumed as a food grain with desirable nutritional contents consumed as a foods and snacks are increasingly available, driven by recent research findings, which show that barley fibers contains beta–glucans and tocotrineols, chemical agents known to lower serum cholesterol level [31]. In Ethiopia barley is the fifth most important cereal crop next to maize, tef, sorghum and wheat. It is the staple food grain for Ethiopian high lands who mange the crop with indigenous technologies and utilized different parts of the plants for various purposes.

Barley is used as flour, as semolina, and as whole-dehulled grain. A large variety of dishes, including soups, bread, and couscous are made from barley products. Preparations include both product from fully mature grains and grains harvested at physiological maturity (*Azenbou*). Some recipes, such as *Besso* (fine flour of well-roasted barley grain moistened with water, butter or oil), *Zurbegonie* (same type of flour used for *Besso* dissolved in cold water with sugar) and *Chiko* (*besso* soaked with butter and spice), which have long shelf life, can only be prepared from barley grain. Other recipes, such as *Genfo* (thick porridge), *Kolo* (de-hulled and roasted barley grain served as snack), *Kinche* (thick cooked) are most popular when made from barley grain, but can be prepared from other cereals also. Barley is the one preferred grain, after tef, for making the traditional bread called *Injera*, which can be used either solely or in combination with tef flour or other cereal flours. Other recipes, such as *Dabbo* (bread), *Kitta* (thin, unleavened, dry bread) and *Atmit* (gruel) can be prepared with barley or blended with other cereal flours. Among local beverages *Tella* and *Borde* are prominent, and best made from barley grain. Barley spikes both unripe at milk or dough stage and ripe and dry are also roasted over flame and the grain is consumed as snack called *Eshete* or *Wotelo* if the spikes are unripe, or *Enkuto* if the roasted barley spikes are dry [32]. Barley is also traditionally used in the preparation of gruel utilized as weaning food. Barley is mainly used as a source of carbohydrates, although the protein content is also important [32]. Barley protein is composed of 19 amino acids, but low in lysine and methionine. This might be the reason why most traditional barley recipes are prepared or consumed along with legumes or animal products to supplement the deficient amino acids.

## Oats *(Avena sativa)*

Oats have numerous uses in food. Most commonly, they are rolled or crushed into oatmeal, or ground into fine oat flour. Oat widely used for the production of ready to eat breakfast cereals, bakery goods, snacked food, infant food, and other products. Oat posses a number of unique features it can be used as whole groat products that impart a characteristic nutty flavor, of a comparatively high nutritional value. However, oat lack gluten and it is thus not possible to produce high quality leavened bread from oat without the addition of wheat [32].

Oats are generally considered "healthy", or a health food, being considered commercially as nutritious. The discovery of the healthy cholesterol-lowering properties has led to wider appreciation of oats as human food. Oat bran is the outer casing of the oat. Its consumption is believed to lower LDL ("bad") cholesterol, and possibly to reduce the risk of heart disease [33].

Oats have higher oil content and thus a higher energy density. Oat protein has relatively high amino acid balance and oats also contains significant amounts of dietary fiber which is high in soluble fiber. This soluble fiber, which is composed mainly of β-glucan, is also known as oat gum. Oats also contribute significant amounts of dietary minerals (Mg, P, Fe, Cu and Zn) and vitamins (thiamin, vitamin E, folate, niacin) [34].

Oat is the only cereal containing a globulin or legume-like protein. Globulins are characterized by dilute salt solution and water solubility. Oat protein is nearly equivalent in quality to soy protein, which has been shown by the World Health Organization to be equal to meat, milk, and egg protein. The protein content of the hull-less oat kernel (groat) ranges from 12–24%, the highest among cereals. Oats is a well-adapted fodder crop grown for a long period of time in the highlands of Ethiopia [33]. It is produced by some pre-urban dairy cattle producers and by smallholder farmers who own crossbred dairy cows [34]. Oats being an annual forage crop is highly useful for integration into the prevailing mixed crop- livestock farming systems of the highlands on accounts of its short-term yielding characteristics, use in overcoming seasonal feed shortages, convenience in crop rotations and its fodder conservation characteristics. Moreover, farmers can easily grow it because its husbandry is similar to that of other cereals such as barley and wheat.

In view of its good nutritional profile, low allergy bearing, flavor compatibility, and cost, oats are a useful component of infant foods oat flour is often the ingredient of choice, and specifications include low levels of free fatty acids and absence of hull when flour is used for infant nutrition [34]. This shows that blending oat in weaning food formulation is good sources of essential nutrients.

## Teff *(Eragrostisis tef* (Zucc) Trotter)

This is one of the major and indigenous cereal crops in Ethiopia, where it is believed to have originated and has the largest share of area under cereal crop production. According to Central Statistics Authority teff accounts about 34,340,420.63 quintal of production in an area of 2,722,739.42 ha with grain yield 12.61 qt/ha [3]. It provides over two-thirds of the human nutrition in the country. This cereal is considered high in nutritional quality, but limited information is available about its usefulness in weaning blends. Teff flour is primarily used to make a fermented, sour dough type, flat bread called *Injera*. The crop is also an excellent source of fiber and iron, and has high amount of calcium, potassium and other essential minerals found in an equal amount than in other cereal grains. While the reported high iron content of teff seed has been refuted by some works, the lack of anemia in Ethiopia is considered due to the available iron from *Injera* [35]. Teff flour blending in all weaning and complementary food will enrich the products with iron and other essential minerals.

## Groundnut (*Arachis hypogaea*)

It is a useful source of thiamine, niacin, vitamin E and folic acid. However groundnut contains some anti-nutritional factors including trypsin inhibitors, haemagglutinnis, goitrogens, saponins and phytic acid which could be destroyed or reduced to minimum level through traditional cooking and processing techniques such as soaking in water and roasting [36]. Although, legumes are deficient in sulfur-containing amino acids, they can be used to enhance the protein content of cereal-based diets and improve the nutritional status by supplying lysine. Combination of commonly used cereals with inexpensive plant protein sources like legumes can be used. Cereals are deficient in lysine but have sufficient sulphur containing amino acids which are limited in legumes [37] whereas legumes are rich in lysine. The effects of pretreated ground nut products supplementation to weaning food are highly beneficial, since nutritive value of the product is also improved.

## Finger millet (*Ragi, Eleusine coracana*)

It is rich in protein, iron, calcium, phosphorus and vitamin content.

The calcium content is higher than all the food grains and best quality protein with the presence of essential amino acids, some pro-vitamin A, vitamin B and phosphorus [36]. Thus ragi is a good source of diet for growing children, old age people and patients. Finger millet grain has good taste and an excellent dietary source of methionine lacking in the diets of many peoples of the poor who live on starchy foods. Due to this finger millet have good source of diet for growing children and an important preventative fact against malnutrition.

## Fruits and Vegetables as Complementary Food Fortification

Besides being a rich source of vitamin and mineral, and other valuable nutrients fruits and vegetables also contains several carotene, photochemical and antioxidants such as ascorbic acid, tocopherol and polyphenolic compounds that are thought to be beneficial for health, and therefore it is considered by some as a complementary food [36]. In roots such as carrots and sweet potatoes that contain a high amount of carotene and represent a major dietary source for complementary food development. Therefore, it is important to include raw fruits and vegetables or their products during weaning food and complementary food preparation. Particularly, yellow and orange fruits and vegetables such as mango, papaya, peaches, prunes, acorn, winter squash and oranges are recommended for complementary food fortification.

## Traditionally Available Complementary Foods in Ethiopia

A common feature of plant foods is their high content of water, fiber, low energy and micronutrient densities [6]. This characteristic becomes particularly cause of worry during the complementary feeding period in infants and children. Hence, traditional weaning foods from plant staples often fail to meet the nutritional needs of the infants, due to stiff consistency and high volume which combine to offer a low-cost filling meal that often lacks adequate nutrients [36]. They are therefore, known to poorly support growth and development.

Poor combination and formulation has partly contributed to the poor performance of traditional complementary foods. A number of researches [6,26] have shown that a combination of cereals and legumes or tubers with fruits, vegetables and animal sourced food rather than the single diets, can better support growth and development.

The presence of non-nutrient constituents (anti-nutritional factors) in plant-based foods has been shown to also negatively influence the bioavailability of nutrients. The best documented being oxalic acid which forms oxalate precipitates with dietary calcium, while phytic acid forms insoluble phytates with Ca, Fe, Zn and possibly other metals. For instance the relatively poor availability of the fairly high Fe content of cereals is mainly due to their correspondingly high phytic acid levels [27].

Poor processing methods and hygiene have also been identified as other factors responsible for low nutrient density in local complementary foods due to lack of knowledge about simple processing techniques to produce nutritious food. The simple traditional house hold technologies have been used to process the cereal in order to improve the nutritional quality. These include roasting, germination or sprouting; fermentation, cooking and soaking that greatly influence their nutritive value. Of these, cooking and germination plays an important role as it influences the bioavailability utilization of nutrients and also improve palatability which can result in enhancing the digestibility and nutritive value [38].

### Anti-nutritional factors in complementary food

The nutritional value of grain legumes depends primarily on their nutritional contents and presence or absence of anti-nutritional and/or toxic factors. Nutritional value is the ability of food to provide usable forms of nutrients, protein, carbohydrate, vitamins and minerals. Thus anti-nutrition are those that lower the bio-availability of trace elements, starch and protein. Anti-nutritional compounds include (trypsin, chymotrypsin and amylase inhibitor, phytic acid, tannins, other phenolic compounds and saponins). These constituents play an important role in the biological function of plants. Some of these compounds bear potential health benefits associated with control of anti-nutritional cardiovascular disorders (blood cholesterol reaction) and anti oxidant activities. Anti-nutritional factors can be classified broadly as those nutritionally present in the grain and due to contamination which may be of fungal origin or may be related to soil and other environmental influence [38]. These factors modify the nutritional value of the individual grains and some of them having very series consequences on health of consumers.

### Phytic acid, phytate and phytin

Phytic acid (myo-inositol hexaphosphate) is of wide spread occurrence in plant food such as cereals grain and legume seeds. The formation of minerals-phytate complexes in the gastro intestinal tract is a major mechanism by which phytate reduces the mineral bio availability [36]. Phytate: is the salt of phytic acid very common in plants and cereal grain and legume. It may range 1-5% on dry matter basis. The phytate is regarded as anti-nutritional because it binds the micro nutrient elements such as Ca, Zn, Fe and Mg. Phytin: is a complex salt of phytic acid, inorganic cations and proteins. This is the form in which most phytic acid occur in plants [36].

Phytic acid is formed during maturation of the plant seeds. In dormant seeds it represents 60-90% of the total phytate. Phytate are therefore a common constituent of plant food used. Depending on the amount of plant derived food in the diet and the level of food processing, the daily intake of phytate is estimated between 200-2600 mg for vegetarians' diet and diet of inhabitants of rural areas in developing country and about 150-140 mg for mixed diets [36]. Phytic acids binds trace elements and macro-elements and form a complex with protein, protease and amylases of the intestinal track, thus inhibiting proteolysis. Moreover, the phosphorus in phytate has been considered to be largely unavailable to the organism because of the limited capacity of mono gastric species to hydrolyze phytate in the small intestine.

The anti-nutritional effect of phytic acid is primarily related to its strong chelating ability with minerals and proteins. It is the association with its six reactive phosphate group. Multivalent actions are particularly susceptible and form insoluble and indigestible complex. Phytate also effect enzyme activity with a negative effect for key digestive enzymes including amylase, pepsin and trypsin [36]. The reduction of phytate content of a complementary cereal based food from 1150 to 660 mg/100 g on dry weight leads to increased *in vitro* iron solubility from 4.8% to 18.8% but showed insignificant effect on hemoglobin status of an infant from 6-12 months. So, increase *in vitro* iron solubility after incomplete phytate degradation does not guarantee an increase in iron status of humans consuming phytate containing foods. To have better hemoglobin status, more reduction of the phytate is important.

Phytic acid has been degraded to significant level in weaning cereals by adding commercial exogenous phytase or by activating the native phytase by a combination of soaking, germination and fermentation process [20]. Hydrolysis of phytate may occur in the gastrointestinal tract prior to the intestinal site of absorption. Because most of the essential minerals and trace elements are absorbed in the duodenal or jejunai part of the small intestine, the site and degree of

phytate degradation can affect the nutritional value of high phytate diet. Furthermore, enzymatic hydrolysis of phytate in the gastrointestinal tract leads to the formation of specific isomer of inositol phosphates formed during food processing or degradation in the gastrointestinal or precursors to these are absorbed in the alimentary tract of human which may have important health implications [20].

### Phenolics and tannins

Tannins are very complex group of plant secondary metabolites, which are soluble in polar solution and are distinguished from other polyphenolic compounds by their ability to precipitate proteins and other macro and micro elements, particularly iron [39]. The suggested mechanism behind this is the supposition that feed tannins and saliva proteins form complexes in the mouth, thereby giving an unpleasant astringent taste, and also that the tannins can affect digestion enzymes [20].

Tannins have been reported to inhibit the digestive enzymes and lower the digestibility of most nutrients, especially protein and carbohydrates [39]. Tannins are classified into two groups: condensed tannins which are polymers of flavones and yield antho-cyanidins when heated in acid solution, and hydrolysable tannins which produce gallic acid as a degradation product [40]. The latter are easily eliminated with the action of the gastric juices and do not represent a high significant problem in animal feeding. Flavan, the basic structural unit of condensed tannins is made up of two benzene rings linked together by a three carbon atom fragment [40]. This unit is also the basic structure of anthocyanidins and their glycosides (anthocyanins), the latter generally being responsible for the scarlet, red, mauve, purple and blue colors in plants organs [41].

Tannins if ingested in excessive quantities inhibit the absorption of minerals such as iron which may, if prolonged, lead to anemia [40]. This is because tannins are metal ion chelators, and tannin-chelated metal ions are not bio-available. Tannins have been shown to precipitate proteins which inhibit in some ruminant animals, the absorption of nutrients from high-tannin grains such as sorghum. There is an important difference in the way in which the phenolic compounds interact with different hydroxylation patterns (gallic acid, catechin, chlorogenic acid) and the effect on iron absorption. The content of the iron-binding galloyl groups may be the major determinant of the inhibitory effect of phenolic compounds [38].

## Commercially Available Weaning Foods in Ethiopia

Food industries like Fafa made in Ethiopia which contains wheat, chick peas, soybean flour and 5% DSM (Dried Skimmed Milk) is an example CSA. Furthermore, currently this factory use barley, oat, maize, pre cooked wheat flour, vitamins and mineral pre mix, enzyme (α-amylase), vanilla flavor, iodized salt, calcium and sugar as an ingredient.

According to Sachdev and Choudhury [8], nearly 100 varieties of the low–cost processed weaning foods have been developed and tested. Some has been produced commercially; some have their largest outlet through institutions; health centers, schools, lunch programs or religious and other organizations. Some food industries in Ethiopia have been used to process in large quantities as emergency foods for refugee camps. Other products such as, edget, cerifam, barley mix, famix and favena are developed as complementary food.

The different types of low-cost mixtures include those based on local cereals with the addition of a vegetable protein concentrate and those based on wheat with a high percentage of precooked peas and lentils to provide most of the protein this mixture contains 10% skimmed milk powder [42]. Those based on a mixture of a cereal and a legume with the addition of a vegetable protein concentrate and dried skimmed milk.

## Complementary Foods and their Quality Attributes

Functional properties, such as solubility, gelation, viscosity, water and fat binding properties will reflect the level of protein interaction with water, while fat absorption and emulsion are influenced by protein and fat interaction. Nitrogen solubility is a good index of the functional potential of protein-rich products [43] in high-protein drink, solubility is important and this keeps viscosity low, inhibits settling and eases problems of uniform distribution. Viscosity is an important functional property of foods that affects mouth-feel and textural quality of fluid food which has shown that viscosity is a function of not only the solid concentration, but also the type of starch and protein the product bears [44]. When starch granules are heated in water they swell and gelatinize forming a viscous bulky water retaining paste on cooling such thick feed, the gruel will be too thick and viscous for young infant to consume the product [43]. This has reported that protein concentration, especially the globulin fraction, interaction, with carbohydrate and lipids will influence the properties of protein concentrates. This interaction is responsible for the gelation capacity of legume and oil seed protein. Water binding by proteins is a function of several parameters, including size, shape, conformational characteristics, steric factors, and hydro-philic-hydrophobic balance of amino acids in the protein molecules, lipids and carbohydrates associated with the protein [44]. Oil absorption is related to the physical entrapment of oil and to the number of non-polar side chains on the proteins that bind hydrocarbon chains on the fatty acids [44].

## Effect of Processing Conditions on Anti-Nutritional Factors of Complementary Food

Cooking and pre-treatment such as sprouting, germination, and fermentation can alter the content, physical–chemical properties of the components and reduce anti-nutrient level. House food processing method including soaking, germination plays an important role since it influence the bio availability, utilization of nutrients and also improves palatability that may results in enhancing the digestibility and nutritive value [33].

### Effect of fermentation

Fermentation is traditional processing of food subjected to the action of micro-organisms or enzymes so that desirable biochemical changes cause significant modification of food [35]. It is a very interesting process used in plant foods to increase the nutritional quality and remove undesirable compounds. Fermentation involving lactic acid bacteria offers potential for widespread applications, particularly with respect to the preservation of cereals, legumes and root crops and the provision of safe, low-cost weaning foods for developing countries. Fermentation of cereal-legume blend is potentially important processing method that can be expected to improve nutritional value of weaning foods by reducing water binding capacity of cereal flour. This allows the porridge to have a free-flowing consistency even with a high proportion of flour [35]. The poor starch and protein digestibility of cereals is caused by phytic acid and polyphenols that bind to enzymes in the digestive tract and thus inhibit utilization of proteins and carbohydrates. Fermentation and germination improves digestibility by partial hydrolysis of storage proteins and carbohydrates by endogenous and microbial enzymes. This adverse effect can be overcome by fermentation and germination.

### Effect of roasting

Roasting is one of the processing steps to improve the flavor,

color, texture and overall acceptability of the product. The textural characteristic of the whole-kernel is affected by the roasting condition to some extent. During roasting, the moisture content of most grain is reduced and the texture became more crumble and fragile (less hard). The roasting condition of whole-kernels should be properly controlled because it does not only contribute to development of flavor and aroma but also to the color of the product. Color is an important quality indicator of the roasting process. Development of roasted flavor and aroma depends upon the temperature and time of roasting beside the type of grains and techniques applied. A variety of foods, including those for infants are made from grains using traditional processing techniques such as roasting and malting [34]. Traditional roasting of grains is used primarily for reduction of anti-nutritional factors and extension of storage life [34]. Roasting produces pasty product with increased viscosity over other processing methods (fermentation and germination). Increase in viscosity contributed to the differences in percent moisture content of the component flours. Millet is particularly rich in zinc and iron when compared to other cereals. However, due to the presence of hard seed coat and high fiber content, it has poor consumer appeal. In addition, the presence of anti-nutritional compounds such as phenols and tannins reduces its preference and for this reason, it is not ideal in the preparation of weaning foods. It has been suggested that various processing methods could reduce the anti-nutritional factors and improve the nutritional quality of millet. Therefore, roasting is one simple method of making weaning foods using diverse and locally available raw materials at low cost.

### Effect of germination

Germination is a natural process occurred during growth period of seeds in which they meet the minimum condition for growth and development [35]. It is a food processing method by which the quality of a cereal and legumes can be improved for both digestibility and physiological function. During germination, enzymatic activity and bioactive compounds increased within the seed. It is induced by rehydration of the seed, which increases both respiration and metabolic activity that allow the mobilization of primary and secondary metabolites. The process of germination comprises three unit operations, steeping, germination and drying [45]. Germination is practical, cost-effective, and sustainable process for production of weaning foods with minimum paste viscosity, and high energy and nutrient density. Weaning foods with a higher energy density at an acceptable apparent viscosity could be prepared from germinated seeds of cereals. Germination of legume seeds is one of the processing methods to increase nutritive value and health promoting qualities. By this simple and inexpensive method different seeds have been germinated for human consumption. These include legumes like (soybean, lentils, and beans), cereals (rye, wheat, barley and oats) and seeds of some vegetables [35]. Germination has been suggested as an effective treatment to remove anti-nutritional factors from legumes and mobilizing secondary metabolites. Therefore germination is cheap and more effective in improving nutritional value, it is hoped that this can contribute to nutrition of infants.

## Good Hygienic and Safety Practices

Infants may be exposed to food contaminants through infant formula and complementary foods and are thus subjected to the food safety problems experienced by the general population. Because infants and young children are especially susceptible they are at a great risk of acquiring infections. When recurrent to persist for a long period of time, infectious disease have an adverse effect on nutritional status. The scope of food safety problems is broad and diverse. It encompasses problems due to micro-organisms (bacteria, parasitic and viral) and a chemical hazard that may either be naturally present in foods or appears as contaminants as a result of pollution or poor agricultural practice. Moreover, throughout preparation, mixing, cooking, packaging, and transporting care is required to be taken to prevent contamination of the product [46].

Contaminated complementary foods are the major route of transmission of diarrhea among infants. For this reason, the higher incidence of diarrhea in the second semester of life coincides with the increase in the intake of these foods. Proper maternal practices regarding the management, preparation, administration and storage of complementary foods may reduce their contamination [4]. Under domestic conditions; it will be difficult to avoid microbial contamination of the porridge during feeding. Fortunately, the presence of one or two live microorganisms like aerobic flora, total coliforms, molds, yeast and salmonella in the porridge at the time of feeding is usually not a matter of concern. On the other hand, if storage facilities are inadequate and the porridge is kept at ambient temperature for some time those few microorganisms will multiply rapidly, causing spoilage, public health hazards or both.

## Conclusion

As clearly discussed in the above review, malnutrition, infant mortality and morbidity as principal nutritional problems among children aged less than five years in developing countries. The reason is of the most common weaning foods used to feed infants in developing countries are starchy gruels produced from traditionally refined cereal grains or tubers. Starchy foods are lack of adequate protein quality or essential amino acids and have high viscosity that limits intake, especially infants. Commercial infant food is very expensive and unaffordable to low-income families in developing countries. Therefore, developing weaning foods that are easily digestible, nutritionally balanced of low dietary bulk and high in calorie density are required [44]. Traditional weaning food could be improved by combining locally available foods that complement each other and need to be changed or modified to improve their nutritional status. Fortification of popularly consumed staple foods, such as protein quality is improved through a mutual complementation of their limiting amino acids. Cereal-legumes mixtures of weaning food development are very significant contribution towards the alleviation of protein-energy malnutrition [47,48]. Several strategies may be used to the nutritive value of weaning foods. Legumes are largely replacing milk and other sources of animal protein, which are expensive and not readily available, as stable substitute for high-quality protein. Commercial weaning foods are designed to help to provide healthy mixed diet for babies. Many weaning foods are developed using expert medical nutritional advice and follow current UK legislation and Department of Health recommendations for daily amounts of the major nutrients.

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