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Research Review on Formulation and Sensory Evaluation of Complementary Foods from Cereals and Legumes in Ethiopia

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Abstract

Since infant food protein-energy malnutrition is a problem in Africa and other developing nations of the world. Food and Agricultural Organization's statistics also reveal that in Africa, more than one in four people are malnourished. Food cereal grains are a major staple in many African homes contributing significant amounts of energy protein, but limiting in essential amino acid of lysine. Legumes on the other hand are protein and amino acid rich foods, but also lacking in sulphur-containing amino acids. Hence, a combination of these two grain foods would improve the protein and nutrient density of the subsequent food products. Probably due to their high nutritional values, however, this review therefore, assesses various works in literature on the use of these crops to produce composite food products. Complementary foods in most developing countries are based on staple cereal or root crops. Although, commercial foods of high quality are occasionally available, they are often expensive and therefore unaffordable by low-income rural households. Different approaches are needed to offer families the opportunity to feed their infants on improved formulations using low cost and locally available staples, because of Protein-energy malnutrition among children is the major health challenges and it may be related to low nutritional quality of traditional complementary foods and high cost of quality protein based complementary foods. This review also aimed at the formulation, preparation and evaluation of low-cots, locally available products based on cereals and pulses.

Keywords: Blends Cereal-Legume; Complementary Foods; Infant Food; Nutritional Content; Sensory Acceptability

Introduction

Protein-energy malnutrition mostly among children is the major health challenges in developing countries [1,2]. This nutrition problem is attributed to the inappropriate complementary feeding practices, low nutritional quality of traditional complementary foods and high cost of quality protein-based complementary foods [3,4]. The formulation of a broad bean/legumes-containing porridge as complementary food produced a higher protein food with acceptable sensory characteristics compared to the customary porridge of the region [5]. While it was an evident that high prevalence of deaths each year among children aged less than five years old in the developing world is associated with malnutrition [2]. Nutrition is "a process whereby living organisms utilizes food for maintenance of life, growth and normal function of organs and tissues and the production of energy". Since Farmers in Ethiopia, similar to those in other African countries, use traditional storage facilities made from locally available materials which may lead to damage by insect and rodent pests. Such storage structures often fail to protect the stored grains and these pests affects or reduces their nutritional contents therefore making blending or formulation may improve/replace these nutrients that were damaged by these pests [6].

The alliance of poverty, poor health and poor complementary feeding practices has a multiplier effect on the general welfare of the children population and also contributes significantly towards growth retardation, poor cognitive development, illness and death amongst children in developing countries [7,8]. It is well known that high cost of fortified nutritious proprietary complementary foods in many parts of developing countries is always beyond the reach of most families [9]. Hence many families depend on inadequately processed and low-quality traditional complementary foods to wean their children. The level of under nutrition among children remains unacceptable throughout the world, with large number of children living in developing world [10].

Cereal-based gruels are generally low in protein and are limiting in some essential amino acids, particularly lysine and tryptophan. Supplementation of cereals with locally available legumes rich in protein and lysine, although, often limiting in sulphur amino acids, increases the protein content of cereal-legume blends and their protein quality through mutual complementation of their individual amino acids and the use of local foods formulated in the home and guided by the following principles: (a) high nutritional value to supplement breastfeeding, (b) acceptability, (c) low price, and (d) use of local food items [11,12].

According to WHO [13] Worldwide recommendations for appropriate feeding of infants and young children are: Breastfeeding should start early, within one hour after birth then breastfeeding should be exclusive for six months and Appropriate complementary feeding should start from the age of six months with continued breastfeeding up to two years or beyond.

The Food and Agriculture Organization (FAO) presents basic definitions regarding nutrition status, one which is the outcome of undernourishment, poor absorption and/or poor biological use of nutrients consumed as a result of a repeated infectious disease. Malnutrition on the other hand, is defined as an abnormal physiological condition caused by in adequate, unbalanced or excessive consumption of macronutrients and/or micronutrients [14].

Promotion of local foods through nutrient evaluation and formulations is important when addressing malnutrition in low income countries. The high cost of implementing programs that provides fortified blended food supplements to malnourished children makes them unaffordable by poor countries [9,15]. It is nowadays important to adopt a horizontal approach in implementing programs at community level. Sociocultural background of each community is therefore an essential baseline consideration for implementing nutrition health promotion programs. For instance, various strategies for 'home' fortification, or point-of use fortification, have been developed to ensure adequate micronutrient intakes by infants and young children [16]. Therefore, the objective the current writing was to review formulation and sensory evaluation of complementary foods from cereals and legumes for infant food.

Complementary Foods from Cereal-Legume Blends

Traditional complementary foods in Ethiopia and Kenya and other parts of Africa are mostly made from cereals, starchy roots and tubers that provide mainly carbohydrates and low protein quality [17]. Such foods are the leading cause of protein energy malnutrition in infants and preschool children in Africa [18].

According to Zebdewos, et al. [19] Malnutrition is the cause of the majority of deaths in children under five years old in Ethiopia and Micronutrient deficiencies such as iron, zinc and calcium, often seen in malnourished children, are major public health problems throughout Ethiopia.

Although nutritious and safe complementary foods produced by food multinationals are available in developing countries, they are far too expensive for most families. The economic situation in these countries necessitates the adoption of simple, inexpensive processing techniques that result in quality improvement and that can be carried out at household and community levels for the production of nutritious, safe and affordable complementary foods. The principle of complementing cereals with legumes has been used in the production of high protein-energy complementary foods using locally available food crops. Cereals are limiting in some essential amino acids, notably lysine and tryptophan and low in protein content. The protein quality of cereals can be improved by supplementing with locally available legumes that are high in protein and lysine, although often limiting in sulfur amino acids through mutual complementation of their individual amino acids [17].

Some of the Nutritional Benefits of Proper Complementary Food

A proper complementary feeding consists of foods that are rich in energy and in micronutrients (especially iron, zinc, calcium, vitamin A, vitamin C and folates), free of contamination (pathogens, toxins or harmful chemicals), without much salt or spices, easy to eat and easily accepted by the infant, in an appropriate amount, easy to prepare from family foods, and at a cost that is acceptable by most families of infants [20] (Table 1 & 2).

Nutrients	Maize	Sorghum	Pearl millet	Finger millet	African Rice
Protein %	9.5	11.6	11.5	7.3	7.1
Carbohydrates%	73	77	70	74	75
Fats %	4.6	3.4	4.7	1.3	1.8
Dietary fibre %	2.8	9.1-11.5	9.7	11.7	-
Ash %	1.2	1.6	2.3	2.6	3.5
Calcium /mg per 100g	48.3	29	36	35.8	23
Iron /mg per 100g	4.8	4.5	9.6	9.9	1.9
Energy /kg per 100g	1471	1374	1443	1396	1392
Lysine /g per 100g protein	2.7	2.3	3.1	2.5	4.1

Table 1: Typical Nutrient Value of African Cereal Grains [21].

Component	Chickpea	Pea	Lentil	Broad bean	Bean	Soybean	Peanut
Protein	23.6	21.9	20.6	26.6	21.3	36.9	24.8
Carbohydrate	62.3	52.5	56.4	35.4	47.8	6.1	19
Fibre	3.8	10.4	6.83	31.3	18.4	20.9	3.1
Lipids	6.4	2.3	2.15	1.8	1.6	18.1	49.7
Ashes	3.7	3	2.8	4.1	4	4.7	2

Table 2: Nutrient composition of the most-consumed legumes (g per 100 g) [22].

Energy Content

In most of the literatures estimations of total energy requirement for infants younger than two years are based on data from a cross-sectional study with U.S. infants, and are stratified according to the age of the infant, type of feeding (breastfed and non-breastfed) and gender [11]. According to the following authors the current total energy requirement estimated for healthy breastfed infants is of approximately 615 kcal/day from 6 to 8 months of life, 686 kcal/day from 9 to 11 months and 894 kcal/day from 12 to 23 months [11,23].

Protein Content

The recommended protein content (grams of protein per 100 kcal of food) for complementary food is of 0.7 g/100 kcal, from 5 to 24 months. In most countries, the protein requirements of infants are met when the energy intake is appropriate, except if there is a predominant intake of low protein foods (e.g. sweet potato and cassava) [24] (Tables 3 & 4).

Amino acid/g per100g protein	Wheat	Rice		Maize		Sorghum		
	Hard	Brown	Milled	Normal	High Lysine	Normal	High Lysine	Millet
Phenylalanine	4.6	5.2	5.2	4.8	4.3	5.1	4.9	5.5
Histidine	2	2.5	2.5	2.9	3.8	2.1	2.3	2
Isoleucine	3	4.1	4.5	3.6	3.4	4.1	3.9	3.8
Leucine	6.3	8.6	8.1	12.4	9	14.2	12.3	10.9
Lysine	2.3	4.1	3.9	2.7	4.3	2.1	3	2.7
Methionine	1.2	2.4	1.7	1.9	2.1	1	1.6	2.5
Threonine	2.4	4	3.7	3.9	3.9	3.3	3.3	3.7
Tryptophan	2.4	1.4	1.3	0.5	0.9	1	0.9	1.3
Valine	3.6	5.8	6.7	4.9	5.6	5.4	5.1	5.5

Table 3: Essential amino acid composition of cereal grains [25].

Indispensable Amino acid	Vicia faba	Pisum sativum	Lupinus albus	Lupinus angustifolius	Lupinus luteus	SBM
Arginine	26.4	21	39.3	33.5	38	39.7
Histidine	7.8	6.1	9.3	8.8	9.7	14.4
Isoleucine	11.8	10	15.3	12.7	14.2	24.3
Leucine	21.4	17.4	27.5	21.5	24.1	40.9
Lysine	18.4	17.3	18.2	15	16.3	33.1
Methionine	2.2	2.2	2.5	2	2	7.3
Phenylalanine	12.6	11.7	14.9	12.5	13.6	27.2
Threonine	10.5	9.1	13.3	10.9	11.9	21.3
Tryptophan	2.6	2.2	3	2.6	3	7.4
Valine	13.3	11.4	14.5	12.5	13.6	25.5

Table 4: The crude protein and amino acid contents of grain legumes compared to soybean meal [26].

Fat Content

Lipids in complementary foods should provide approximately 30 to 45% of the total energy required which is enough to guarantee the adequate intake of essential fatty acids, good energy intake and uptake of fat-soluble vitamins. Fat in the diet affects the general intake of nutrients and, if excessive, may exacerbate micronutrient malnutrition in vulnerable populations. Anecdotal evidence suggests that excessive fat intake predisposes to childhood obesity and cardiovascular diseases [27].

Mineral Content

To confirm the nutritional mineral requirements of infants, a variety of mineral-rich complementary foods should be offered, since the consumption of these foods is relatively small among infants/children aged between 6 and 24 months. From 9 to 11 months of life, the amount of minerals that should be provided by complementary foods is high: 97% for iron, 86% for zinc, 81% for phosphorus, 76% for magnesium, 73% for sodium and 72% for calcium [11].

Vitamin Content

Vitamin A: If the mother's diet has adequate vitamin A content, the offer of vitamin A rich foods easily meets the requirements of the nursing infant. If the mother lives in a vitamin A deficiency endemic area, she should receive special supplementation and her infant should be offered vitamin A-rich foods [28]. Preferably some time before or after breastfeeding in order to increase the uptake of carotene and retinol from the diet [29].

Vitamin D: Breast milk and complementary foods have very little to contribute to the supply of vitamin D requirements, since this vitamin basically depends upon direct exposure of the skin to sunlight. Its dietary intake is only important in case of inappropriate endogenous production or depletion of body stores. In exclusively breastfed babies unexposed to sunlight, vitamin D stores present at birth would probably become depleted within eight weeks [30]. However, a few hours of sunlight exposure in the summer 0.5 to 2 hours a week (17 minutes a day) with exposure of the baby's face and hands only, and 30 minutes a week (4 minutes a day) if the baby is wearing nothing but diapers produces enough vitamin D to avoid deficiency for several months. Dark-skinned infants require three to six times more exposure than fair-skinned babies to produce the same amount of vitamin D [31].

Formulation of Local Complementary Foods of High Nutritive Values: It is the activity of creating, design, fabrication of prototypes, for commercial products which have a use value. A formulated product is obtained by the association of various raw materials, either synthetized or extracted from natural products. The formulation and development of nutritional weaning foods from local and readily available raw materials has received a lot of attention in many developing countries. Legumes are principally replacing milk and other sources of animal proteins, which are expensive and not readily available in India as suitable substitutes for high quality protein. Thus, supplementing with legumes and other nutrient dense food products improves the nutritional quality of cereals by complementing their limited amino acids, lysine and tryptophan. Fruits and vegetables are valuable sources of these micronutrients. They could therefore provide significant quantities of the nutrients if properly processed and blended with the staple foods. Animal source foods like crayfish, egg and milk have further been suggested as source of enrichment [32-34]. A triple mix consisting of a staple grain 'acha' sesame and garden egg, formulated by Temple, et al. [33] was found to be superior in mineral content. Germination, sprouting and fermentation processes of plant foods have been suggested as other ways of improving the digestibility, nutrient densities and bioavailability of micronutrients [35]. Dietary diversification, supplementation, and fortification of locally available foods could also result in improved micronutrient intake by infants during complementary feeding period [36] (Table 5).

Cereal	Legumes	Composite food products	Protein/amino acid changes	Country
Wheat	Sesame	Flour/porridge	Significant protein increase (18.42-20.83)% Lysine increase (0.21-0.49)%	Sudan
Wheat	African yam bean, Cocoyam	Cookies	Significant protein increase (10.44 -14.73)%	Nigeria
Sorghum	Cocoyam, Pigeon pea	Cookies	Significant protein increase (73.86-95.46)%	Nigeria
Sorghum	Sugar beans	Porridge	Significant protein increase (13.33%)	Botswana
Maize	Cowpea	Porridge	Significant protein increase (2.19- 35)%	Nigeria
Sorghum	Marama bean	Porridge	Significant protein increase (61-96)% Lysine increase (2.7-3.1)%	South Africa
Maize	Groundnut	Porridge	Significant increase in protein	Canada
Sorghum	Cowpea,Pigeonpea, Groundnut, Sesame seed	Flakes/ weaning food	Significant protein increase (16.6-19.3)%	Sudan
Maize	Soyabean	Snack	Significant protein increase	Egypt

Table 5: Composites from cereal and legumes with reported increase in protein/amino acid content [37].

Some of the Challenges Associated with the Use of Cereals and Legumes in Infant Food

The Ant-Nutritional Factors: Inherently, cereals and legumes contain compounds that inhibits digestibility and bioavailability of important nutrients such proteins and minerals for infants. Such compounds can be generally ascribed as antinutritional factors which can be enzyme inhibitors, antivitamins, mineral binding agents or goitrogenic foods. They are responsible for deleterious effects related to the absorption of nutrients and micronutrients. For example, phytic acid, lectins, tannins, saponins, amylase inhibitors and protease inhibitors have been known to reduce the availability of nutrients and cause growth inhibition [38].

Mycotoxins: Cereals and legumes are highly susceptible to contamination by fungi, which usually, is accompanied by the production of mycotoxins, rendering the foods unsafe for consumption. Mycotoxins are secondary metabolites produced by widespread filamentous fungi, which colonise different food commodities [39].

Some of Indigenous Technology for Reducing Phytic Acid in Plant Foods

Germination: Germination has been an indigenous technique practiced in many of east African countries. Though the locals attribute the practice to solely improved taste of beverages made for germinated grain; the practice also improves their nutritional value of the foods. Germination increases endogenous phytase activity in cereals through de novo synthesis, activation of intrinsic phytase, or both. Tropical cereals such as maize and sorghum have a lower endogenous phytase activity than do rye, wheat, triticale, buckwheat, and barley [40]. The rate of phytate hydrolysis varies with the species and variety as well as the stage of germination, pH, moisture content, temperature (optimal range 45-57^{o}C), solubility of phytate, and the presence of certain inhibitors [40].

Soaking: Soaking has been an indigenous technique practice for cereal grains before cooking. It's said to soften the grain and therefore cooks faster. The practice has other advantages. Soaking cereal in water can result in passive diffusion of water-soluble phytates, which can then be removed by decanting the water [41].

Fermentation: Fermentation induces phytate hydrolysis via the action of microbial phytase enzymes, which hydrolyze phytate to lower inositol phosphates which do not inhibit non heme iron absorption [42,43]. Microbial phytases originate either from the microflora on the surface of cereals and legumes or from a starter culture inoculate [44].

Mechanical Processing: Household pounding of cereal grains has been practiced for a long time. It is used to remove the bran and/or germ from cereals, which in turn may also reduce their phytate content when it is localized in the outer aleurone layer (e.g., rice, sorghum, and wheat) or in the germ (i.e., maize) [45].

Sensory Properties of Complementary Foods: The sensory attributes of a new food product can be used to predict consumer perception of the composite flour products. When cowpea flour was substituted for wheat flour at low rates in another study the functional quality of cowpea fortified traditional African sorghum foods, the acceptability of the composite flour products did not differ from those from whole wheat using instrumental and descriptive sensory analysis [46]. However with increases in proportional substitutions in composite, the acceptability of the traditional foods declined. This was attributed to the higher proportions of substitutions negatively influencing color and texture [47]. A study on the acceptance of instant cowpea powder for complementary foods, found that complementary foods containing 20% cowpea by weight were comparable to traditional weaning foods. However, complementary foods containing 30% cowpeas got poorer scores for flavor, although this level was not significantly different [48].

Consumer Acceptability of Complementary Foods: Traditional foods are locally accepted and therefore pose no challenge to consumers. If a food is to be cooked to gruel, consistency has been found to affect acceptability [49]. Some studies have found that complementary food formulations with addition of sugar were found to be more tasty and appealing than those without sugar by mothers and infants [9,50].

Current Trends in Development of Complementary Foods: While an acceptable nutrient intake, especially of protein and micronutrients, enhances growth of children and decreases susceptibility to disease and the major contributing factors to malnutrition among infants and children are low purchasing powers of the family resulting in poor quality foods [5]. Complementary foods in developing countries have for a long time been cereal based. Recently in Africa, supplementation of cereals with locally available legumes as a protein source has been exploited such as soya bean, groundnut, cowpeas, pigeon peas, common bean and bambara nuts [9,49].

In addition, World Food Programme (WFP) has promoted corn-soy-blend plus (CSB^{+}) and corn-soy-blend plus plus (CSB^{++}), food supplements utilized in management of moderate acute malnutrition [51]. An observational study showed that school going children in many of African countries were consuming diets high in animal source foods grew better [52]. However, studies on complementary foods development with animal foods as ingredients are fewer or have not been widely reported. Existing work have been based on the use of fish [53,54] underutilization of animal foods in complementary foods and recommended the need to increase animal source foods. Foods made from some animal food sources are better sources of minerals such as calcium, iron and zinc, vitamins and lipids. There has been an awakening on utilization of edible insects to fight food and nutrition security [55].

Conclusion

Many of the current literature indicates nutritious, acceptable and affordable complementary foods for infants can be formulated using their locally available or household food items, and which can be comparable to the conventional proprietary infant formulations. Proper selection and combination of local household foodstuff can be used to formulate multi mixes that can be used as home-based complementary foods. The blends formulated in this review could be used by local and cheap to feed their infant and children during the complementary feeding period. It ensures availability and affordability as well as help in alleviating some economic and time related constraints faced in child feeding practices. Therefore, the consumption of bioactive compounds in cereal and legume composites can possibly address the problem of malnutrition. Even though, this is not only by increasing the availability of good quality affordable protein sources, but also driving the economy of the populace. While the development of cereal-legume composite products and other high protein foods can prevent protein energy malnutrition and other diseases. Finally, development of policies that would promote local production of indigenous crops at a small-scale farmer level is vital and necessary to achieve these goals.

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