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Complementary Foods and Its Processing Methods: A Review

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ABSTRACT

The review was carried out to create awareness among individuals, government and non-governmental organizations on the roles of complementary foods for growth and development of infants in developing countries. Literature on complementary foods was critically assessed. Breast milk and complementary foods have been responsible for optimal growth and development of a young child. The period during which other foods or liquids containing nutrients are given to a young baby, along with breast milk, is considered to be complementary feeding. Information has been reported that breast milk becomes insufficient to meet the required nutrients for growth and development after six months. Therefore, the introduction of complementary foods is strongly required for sustainable growth. Unlike in developing countries, the use of complementary foods in the developed countries is well controlled, because of improved technologies, moderate to high incomes and government supports where needed. Conclusively, there is a need to sensitize nursing mothers on the importance of complementary foods for the growth and development of their children. Besides, there is also a need for government interventions to reduce the costs of such foods and to increase their accessibility, especially in the rural areas.

Introduction

Breast milk has been established as the most ideal food for infants during the first six months of life (UNICEF, 1999). Breast milk contains all the essential nutrients and immunological factors an infant requires to sustain optimal health and growth. However, after six months, the breast milk nutrient becomes insufficient to meet the nutritional requirements for the transitions of the infant. Therefore, nutritious complementary foods, also known as weaning foods, are introduced and they typically cover the period from the age of six to twenty-four months in developing countries (WHO/OMS, 2000). Improper and inadequate feeding can set up risk factors for ill-health. The lifelong impact of insufficient feeding may include low school performance, reduced productiveness, low intelligent quotient and social development or chronic diseases (Nestel et al., 2003). Hence, improved and adequate complementary foods at this period of life are substantive for the child's normal growth and cognitive development.

Complementary foods are foods deliberately prepared and given to infants with addition to breast milk when breast milk nutrients become insufficient to provide their calorie, micro and macro nutrients need (Onyekwere, 2007). Breastfeeding gives children the best beginning in life. It is estimated that over one million children die each year from diseases such as diarrhea, respiratory diseases and infections, because they are not adequately breastfed. Breastfeeding also helps to protect and save mothers' health from having cardiovascular disease and breast cancer (KNH, 1998). PAHO/WHO (2004), UNICEF (2002) and Linkages (2004) recommended that children should be

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breastfed until the age of two thereby complementing their needs with safe foods.

Advantages of breastfeeding

Reasons and advantages of breastfeeding for its recommendation are summarized below according to FAO (1997).

1. Breastfeeding is an easy food readily available for the infant and needs no special preparation or equipment to process it.
2. Breast milk contains adequate quantity of nutrients ideal for human infants.
3. Breast milk has got anti-infective constituents that help to limit infections during breast feeding.
4. Breastfeeding extends the duration of post-partum, ovulation and also assist mothers to delay conception.
5. Breastfeeding helps to create bonding and foster relationship between a mother and an infant.
6. The breastfed infants have a reduced risk of allergies, obesity and other health problems compared with those who are fed with infant formula.

The composition of breast milk

Breast milk includes all the essential nutrients that a baby needs for the first four and six months of life.

1. It contains the most ideal protein and fat for a baby in the right proportions.
2. It contains more milk sugar (lactose) and this is important to infants (Lucia, 2008).
3. It is rich in vitamins and as such there is no need to search for vitamins from fruit juices or vitamin supplements.
4. It contains enough iron for the baby which is well absorbed from the baby's intestine. Breastfed babies are usually immune against iron deficiency.
5. It contains enough moisture for rehydration.
6. It contains adequate amounts of salts, calcium and phosphate.

Complementary food

In most African countries, such as Nigeria, the introduction of complementary food usually begins between the fourth and the sixth month of child's life and it involves the use of a semi-liquid porridge prepared by the mother from local staple cereals or tubers (Bentley et al., 1991; Nout, 1993; Guptill et al., 1993).During that period infants would be fed with complementary foods from two to three times a day between six to eight months and two to four times daily between nine and eleven months of age (WHO, 2004). Complementary food can be given at an early or late stage in insufficient amounts to meet the nutritional needs of an infant (Onyango,2003; Muhimbula et al., 2011). The most common weaning food given to infant is called pap, which is referred to as 'Akamu' by Igbos, 'Ogi' by Yorubas or 'Koko' by Hausas. It can be processed from maize (Zea mays), millet (Pennisetum americanum), guinea corn (Sorghum species) or by combining these grains (Onofiok and Nnanyelugo, 1998). After the successful introduction of cereal gruel as complementary food, other staple foods are introduced to the child gradually. These include yam, rice, garri and cocoyam, which may be eaten with sauce or soup (Onofiok and Nnanyelugo, 2007; Ikegwu, 2010). Traditional complementary foods from cereals commonly given to infants are not enough to meet the daily nutrients, energy and micronutrient requirements and this has been the major cause of malnutrition in infants and young children in developing countries (WHO, 2002; Amina and Agle, 2004; Igyor et al., 2010). Malnutrition during this period of life may lead to permanent and total stunted growth (Onis and Blossner, 1997) which might have a serious effect on brain development and other functional effects in the body (Martorell et al., 1995). Protein-energy malnutrition refers to diseases arising from coincident lack in varying proportions of proteins and/or calories, which occurs most frequently in infants and young children and is commonly associated with some infections such as kwashiorkor and marasmus (Kayode et al., 2009; Mbaeyi and Onweluzo, 2010). Protein-energy malnutrition is a major health problem, especially in developing countries and contributes to death rate of infants, low physical and intellectual development of infants as well as reduced resistance to diseases and consequently stifles development (Jimoh et al., 2005). Protein-energy malnutrition generally occurs during the crucial process of change when children are weaned from liquid to semi-solid or fully adult foods (Amankwah et al., 2009). This could be the result of inflation, ignorance and high costs of animal sources of protein, thereby making it unavailable for the common man (Ijarotimi, 2012). Therefore, poverty and bad feeding practices have been attributed as the major factors responsible for this nutritional problem (Ijarotimi, 2008). Protein energy malnutrition also results in a moderate anemia, which is frequently cause by low iron bioavailability from the predominantly cereal- based diet. The low bioavailability of iron from cereal diets is due to the presence of different inhibitors such as phytate and tannin (Lorri, 1993).

Recommended characteristics of complementary foods

The recommended characteristics of complementary food are summarized below according to Malleshi (1988).

1. The meals should be rich in calories, good quality protein, vitamins, and minerals. When the food is stirred with cold or warm water or milk, the food should form a slurry or semi solid mass of soft consistency to enable easy swallowing by the child.
2. The prepared meal should be low in dietary bulk.
3. The food should be processed in such a way that it requires minimum preparation prior to feeding and is easily digested.
4. The food should be free from anti-nutritional factors and low in not digestible fibre content.

Raw materials for complementary food

The purpose of International Programme of Complementary Food Mixtures is to developed products whose ingredients are produced locally (FAO/WHO, 1991). In the selection of raw materials for complementary foods, the consideration should be given to the availability and costs of the raw material and processing methods employed, as this will affect the acceptability and the quality of the final product. The raw materials commonly used for complementary foods are always from plant and animal sources.

Plant sources as complementary food

Cereals

Cereals supply larger part of the food utilized by the humans. They are the least expensive source of food energy and carbohydrate in the developing countries. The main carbohydrate is starch and the percentage varies with the starch content depending on the type of the cereal and its variety (Tacer-caba et al., 2015). Cereals contain albumins, globulins, prolamines (gliadins) and glutelins (Colin et al., 2017). Lipids are present in the germ and bran layers than in other part of cereal grains. Cereals are deficient in lysine, but more abundant in leucine (Welch, 2005). All milled cereals are suitable for human consumption provided that they are processed in such a way as to reduce the fibre content, when necessary and to remove tannins or other phenolic compounds which can lower the protein digestibility (Michaelsen et al., 2003). Cereal processing involves heating and/or cooking, hydrolysis of enzymes, enriching with functional factors (such as iron, vitamin C and E, plant oils, skim milk, whey protein), and drying steps to improve their sensory qualities, digestibility, safety and shelf-life and enhancing the bioavailability of functional factors after the intake.

Legumes

Legumes are sources of needed proteins in many developing countries and tropical areas. Legumes are members of the family *Leguminosae*, and probably the second most important source of food and next only to the cereal grains of the family *Graminaeae*. The legume is an essential crop which could be produced with little or no nitrogenous fertilizers when compared with grains and fodder (Solomon, 2005; Ezeocha and Onwuka, 2010). Basically, there are three groups of legumes: food legumes, oilseeds and forage legumes. The most common food legume grains and pulses are groundnuts, cowpeas, bambara nuts, broad beans, pigeon peas, beans, jack beans and soya beans (Ikujenlola and Fashakin, 2005). Dried oil seeds are sources of vegetable oil, while the defatted meals are used as sources of protein. Legume grains, especially pulses, could be boiled, eaten or made into flour and used for various dishes. Legumes are rich sources of dietary protein. They are rich in lysine and tryptophan, but low in the sulphur-containing amino acids, methionine and cysteine (Anigo et al., 2009). Legumes are less expensive than animal products such as meat, fish, poultry, eggs and are consumed widely all over the world, especially in the tropical and developing countries as the major source of protein, where consumption of animal proteins may be scarce as a result of economic, social, cultural, or religious factors. According to Elegbede (1998) and Anigo et al. (2010), legumes are good sources of protein and energy. The protein content ranges generally from 20 to 40% for most grains while its carbohydrate content ranges from 23% in groundnuts to 66% in bambara groundnuts, pigeon peas, and lima beans. Legumes from oil seeds are low in protein content which ranges between 1 and 5%. However, oil seeds have a range of lipid content from about 18% in soybeans to as high as 43% in groundnuts as reported by Osagie (1998), Dewey and Brown (2003). All legume grains contain a larger amount of minerals and vitamins, fibres, antioxidants and some other bioactive compounds (Bouchenak and Lamri-senhadji, 2013). Cowpeas, soybeans, and bambara groundnuts are good sources of calcium and iron with their contents being higher than those of animal sources such as meat, fish or eggs. Legumes also contain more thiamin, riboflavin and niacin than whole milk and cereals, with the levels of these vitamins being comparable to those available from fish, beef and eggs (Elegbede, 1998; Ikujenlola and Fashakin, 2005). The quality of a protein is usually evaluated by comparing its amino acid profile to that of the standard amino acid pattern of FAO/WHO/UNU (1985) or by observing the growth performance and nitrogen balance of animals fed on a diet containing legumes as the only protein source. Thus, the addition of protein from legumes and cereals are always high in dietary proteins which have nutritive value similar to protein from animal source (Solomon, 2005; Martin et al., 2010). However, one of the hindrances against the use of legumes without proper and adequate treatment or processing is their anti-nutritional factor.

Fruits and vegetables

Most of fruits and vegetables are high in moisture content and always low in protein (3.5%) and fat (0.5%). The moisture content is generally greater than 70%. They are the most important source of both digestible and not digestible carbohydrates. The digestible carbohydrates are present in the form of sugars, starches, cellulose and pectin polysaccharides from the non-digestible carbohydrates. They are vital sources of minerals and certain vitamins such as vitamin A and C. They also contain several carotenes, phytochemicals and antioxidants such as ascorbic acid, tocopherol and polyphenolic compounds that are thought to be beneficial for health, and therefore, they are considered by some as a complementary food (Frias et al., 2005). In roots, such as carrots and sweet potatoes, they contain larger amount of carotene and it represents a major dietary source for complementary food development. Therefore, it is important to include/add raw fruits and vegetables or their products during complementary food processing so as to enhance complementary food enrichment (Temesgen, 2013).

Animal sources as complementary food

Products from animals are rich sources of protein, vitamins, most especially vitamin A, and they are easily absorbed. Foods from animals, birds (egg) and fish are rich sources of many nutrients, but are often expensive. Products from meat and fish animals are best sources of zinc (Rabia et al., 2018; Sujita et al., 2019), while dairy products, such as milk, are rich in calcium (Simum et al., 2012). Meat, fish and sea food all promote the absorption of non-heme iron. Literature has shown that meat consumption is associated with a reduced prevalence of iron deficiency. However, animal products are often expensive and eating excess protein is uneconomic and not sufficient as the extra protein will be broken down into energy and it is not immediately required by the body. If it is energy that is required, it is more efficient and advisable to obtain it from energy rich foods rather than from protein rich foods.

Oils, fats and sugars

Fats and oils should be included in the preparation/processing of complementary foods, if possible, for the purpose of increasing the energy density of the complementary food product (Gain, 2020) Sugar and honey are also energy rich and can be added to porridge and other foods in small quantities (National guidelines on infant and young child feeding, 2004).

Processing method for improving the quality of complementary food

The processing method of some complementary food has shown to have some significant effects on the viscosity, dietary bulkiness and its nutrient density. The major food ingredient in cereal based complementary foods is the starch component. It is also regarded to be the major water-binding component in most complementary foods and to a large extent; it determines the dietary bulk properties according to Svanberg (1987) and Akinsola et al. (2017). The processing of complementary food could be in the form of milling (dry and wet milling), thermal processing, germination, fermentation, roasting/cooking, soaking, autoclaving/sterilization and enzyme treatment.

Milling

Dry milling is a process where the whole grain is sorted, winnowed and milled into flour. The grain is used in powdery form thereby retaining all the nutrients present in the whole grain. It is nutritionally superior to dehulled cereal products. Traditionally, cereal crops such as maize, sorghum, millet and rice are dehulled first by pounding using mortar and pestle, followed by winnowing. The crushed grain is grounded on large grinding stones to produce dry flour. The co-products obtained from dry milling of maize include maize meal, maize flour and maize grits (Akingbala and Rooney, 1990; Bolade, 2009; Akinsola et al., 2017). Adeyemi (1983) and Akinsola et al. (2017) reported that dry milling of sorghum affects its texture compared to wet milling process of sorghum for the production of ‘ogi’. According to Akingbala and Rooney (1990), flour from smaller particle size produces softer ‘tuwo’ in acid, alkalis, or neutral medium than flour from larger particles.

Svanberg (1987) and Akinsola et al. (2017) reported that there are significant differences in bulk densities of dry milling process of cereal flour compared to germinated cereal flour. Akingbala and Rooney (1990) reported that dry milling procedure has many effects on flour properties, quality parameters and the amount of water required for agglomeration, while the effect of wet milling has been reported by several authors such as Akingbala et al. (1981), Matilda et al. (1993), Correia et al. (2005). However, the most common wet-milling processing of cereals, that has been studied so far, is the fermentation of maize/millet/sorghum/guinea corn/acha to obtain a product known as Ogi.

Thermal processing

Thermal processing may increase the bioavailability of micronutrients such as thiamin and iodine by eliminating certain antinutritional factors (e.g., goitrogens, thiaminases). It also degrades phytate, a potent inhibitor of iron, zinc, and calcium absorption, depending on the plant species, temperature, and pH. There is some available body of facts that boiling of tubers and blanching of green leaves induce average amount of losses of phytic acid (Erdman et al., 1994; Yeum and Russell, 2002; Yadav and Sehgal, 2002). Thermal processing can also improve the bioavailability of thiamin, vitamin B_6, niacin, folate, and carotenoids by releasing them from entrapment in the plant matrix (Rodriguez-Amaya, 1997; Yeum and, Russell 2002). However, to reduce the oxidation of carotenoids and loss in cooking water, shorter cooking times and the use of steaming, instead of boiling, are recommended (Rodriguez-Amaya, 1997).

Fermentation

Fermentation is one of the oldest means and the most inexpensive method of producing and preserving foods (Jeanne et al., 2005). It involves the process of anaerobic or moderately anaerobic oxidation of carbohydrates, especially sugars, by the action of microorganism enzymes to produce desirable biochemical changes. Ojokoh and Yimin (2009) reported that fermentation also modifies some physical characteristics of cereals and legumes, increases the level of some nutrients, digestibility and bioavailability (Ojokoh and Yimin, 2009), decreases levels of antinutrients, increases nutrient density (Nnam, 1999) and imparts some antimicrobial properties (Mensah et al., 1990). Fermentation of grains and oil seeds also results in an increase in the nutritional value and it may also lead to changes in vitamins (Ojokoh, 2014).

Germination

Germination reduces antinutrient factors such as oligosaccharides, lectins, tannins and phytate (Nzelibe and Onyeniran, 2001). Germination, as a processing method, breaks down proteins to peptides and amino acids by protease activity, carbohydrates to simpler sugars by amylase, phytic acid to inositol and phosphoric acid and tannin-protein complexes are broken down during the germination of seeds (Nout and Ngoddy, 1997). Germination also increases digestibility, bioavailability of vitamins and minerals, amino acids, proteins and phytochemicals and leads to the reduction of antinutrients and starch. However, flour produced from germinated grain might lead to increase between three and five times for the concentration of the gruel while the same viscosity is also maintained for gruel of ungerminated flour (Dewey and Brown, 2003).

Roasting

Roasting method is effective in eliminating the antinutritional factors (Nzewi and Egbuonu, 2011). Roasting coagulates proteins, ruptures fat depots and gelatinizes the starch granules. Onuorah and Akinjide (2004) reported that, during roasting, some chemical reactions lead to pyrolysis of proteins to amino acids, the elimination of the reducing sugar and the browning of food products and if it is not controlled, some of the essential nutrients, needed by the baby, could be misplaced through this process. Colour is also one of the vital quality indicators of the roasting process. Development of roasted flavour and aroma also depends on the temperature and the time of roasting, apart from the type and nature of grains and techniques applied. Many varieties of food for infants are made from grains using traditional processing techniques such as roasting and malting. Grains, such as cereals and legumes, are roasted in a hot frying pan more than direct heat at about 140-150ºC for 3 to 5 minutes. Siegel and Fawcett (1976) and Mridula et al. (2008) have reported that roasting helps to improve the flavour, texture, and nutritive value of the grains (cereals and legumes). During roasting, some volatile substances, including hexane, are eliminated by evaporation. The removal of such grassy smelling substances and the instantaneous beginning of Maillard reactions give rise to an attractive flavour. Roasting has a slightly reducing effect on the viscosity of some cereals, but this is insignificant in mixtures of cereals and pulses. The content of some antinutritional factors, such as tannins, phytic acid and oligosaccharides, cannot be reduced by roasting. However, roasting is always carried out in an industrial process to inactivate the Kunitz type of protein trypsin inhibitors, haemagglutenins and lectins. In soya beans, the enzyme urease is used as a sign for adequate and proper roasting. Excessive roasting has a negative result on the quality of protein of a particular product since the Maillard reaction reduces the amount of available amino acids plus lysine. For these reasons, time and temperature combinations during roasting should be kept under constant control. From microbiological point of observation, roasting strongly reduces the number of vegetative cells of bacteria and fungi. However, it does not protect the product from contaminations of post-processing (Nout, 1993).

Soaking

Soaking cereal and most legume in water can lead to inactive diffusion of water-soluble of the cereal which can then be removed by decanting the water (Perlas and Gibson, 2002; Hotz and Gibson, 2001). The degree of the phytate reduction depends on the species, pH, the extent and conditions of soaking. A simple soaking process suitable for rural subsistence households has been developed that can reportedly reduce the phytate content of unrefined maize flour by ~50% (Hotz and Gibson, 2001). Davidsson et al. (2004) have reported improvements in the absorption of minerals such as iron, zinc, and calcium in cereal based foods prepared with low phytate content. Some polyphenols and oxalates, that inhibit iron and calcium absorption, may also be lost during soaking (Erdman et al., 1994).

Previous research s carried out on complementary foods

Several works have been carried out by researchers on how to improve and increase the nutritional value of existing complementary food through a mixture of locally available under-utilized food crops. Nwabugwu (2005) developed a weaning food from pigeon pea and millet seed using three different processing methods, fermentation, sprouting and steaming process. The report shows that diet of fermented steamed millet and sprouted pigeon pea, which showed a high nutritional quality, could be an acceptable formula for infants and growing children in a developing country. Solomon (2005) also developed a complementary food from locally available cereals and legumes to evaluate their nutritional values and contrast with those of a proprietary formula and recommended daily allowance (RDA). The report further shows that complementary foods prepared from existing available food commodities have a great impact in providing nourishing foods that are aimed at fighting the problem of malnutrition among infants and children in developing countries.

Ijarotimi and Ashipa (2006) reported the use of sweet potato and soybean flour blends for complementary foods using the ratio of 10-50% dilution of sweet potato and soybean, respectively. The report shows that 30% soy flour substitution could satisfactorily meet the recommended dietary allowances (RDA) for children of 1-3years old and the soy-sweet potato diets were highly nourishing, cheap and can easily be prepared from locally available raw materials by using simple domestic processing methods. Nwam and Baiyeri (2008) also evaluated the nutrient and sensory properties of complementary food made from maize, soybean and plantain and the report further shows that the energy and protein level of these flour blends (maize, soybean, plantain) met the requirement of Codex Alimentarius Commission guidelines for formulating supplementary foods for older infants. However, the use of flour blends might be important in preventing protein energy malnutrition in infants and young children.

Onabanjo et al. (2009) formulated a complementary food from sorghum, sesame, carrots and crayfish. The reports show that the complementary food formulations yield products with improved functional characteristics and high nutritive value and as such they can be recommended to infants and young children. Martin et al. (2010) formulated a complementary food from soybean and the report shows that it could be used to complement baby's food. Oyarekua (2011) also studied the nutritional, viscous and microbial status of co-fermented cereal cowpea ogi. Cowpea ogi was analyzed for proximate and mineral safety index (MSI). The report shows that sorghum/cowpea had acceptable values of Ca, Mg, crude fibre and lipid contents. Millet/Cowpea ogi might be more desirable in terms of viscosity. Emmanuel-Ikpeme et al. (2012) also developed infant food from soybeans and tigernut tuber. The report shows that all formulation diets prepared from soybean seed and tigernut tuber meet the benchmark for infant food. Opara et al. (2012) also produce an infant complementary food from the blends of maize, plantain and soybean. However, all samples produced as infant complementary food were generally acceptable by the panelists. Makinde and Ladipo (2012) work on physicochemical and microbial quality of sorghum based complementary food fortified with soybean (*Glycine max*) and sesame (*Sesamum indicum*). Four complementary foods consisting of 50-80% sorghum ogi flour were prepared from flour blends of sorghum, soybean and sesame meal. The report further shows that there is a potential for using soybean and sesame in cereal based formulas to reduce malnutrition in children. Ijarotimi and Keshinro (2013) formulated a complementary food from the mixture of fermented popcorn, African locust and Bambara groundnut seed flour and the report shows that the formulated samples were sources of high quality protein of almost adequate or more than adequate essential amino acids and energy values. Hence, the formulated complementary foods are better than the traditional one, namely "ogi", and comparable to commercial complementary food such as Cerelac in terms of nutrient composition. Nwosu et al. (2014) also developed a complementary food from the blend of maize, soybean and Moringa oleifera leaves. Proximate composition, energy, mineral and β-carotene flour of the blends were assessed. The report shows that protein and carbohydrate of the blends differed, but ash, fat, crude fibre and energy of both blends were comparable. The mineral content of the blend was higher than that of the control blend. Kavitha and Parimalavalli (2014) also studied the development and the evaluation of extruded weaning foods. Extruded weaning food is prepared from composite flour of wheat, maize, green gram and groundnut. They therefore concluded that extruded weaning food produced from cereal and pulse mixture could be formulated to provide necessary nutrients required for weaning infants and children at low price. Ewuola et al. (2015) evaluated a complementary food from flour blends of maize, bambara groundnut and cowpea seeds and reported that diets formulated from the blends of complementary food were all acceptable, affordable and nutritionally adequate for animal growth. Abioye (2015) studied the proximate composition and sensory properties of moringa fortified with yellow maize to obtain a fermented gruel from 'ogi'. The moringa leaf was processed into powder and was substituted with yellow maize flour to produce ogi in these ratios: 100:0, 90:10 and 85:15. The report further shows that the enrichment of 'ogi' with moringa leaves at 10% substitution still enhanced the nutritional quality of ogi and it was generally acceptable by the panelists. Abiose et al. (2015) also produced complementary food from quality protein maize (QPM) using malting and fermentation processes. The flour obtained from maize was blended with soybean flour at a ratio of 70:30 (maize: soybean) to produce complementary food and the nutritional qualities were evaluated using animal assay. The report shows that the complementary food made up from QPM gave a better result and could improve the problem of protein and energy malnutrition thereby reducing the death rate among infants and children. Alawode et al. (2017) developed a complementary food from flour blends of orange flesh sweet potato, sorghum and soybean. The flour blends (orange flesh sweet potato, sorghum and soybean) were blended together at four different ratios of 40:40:20, 30:50:20, 20:60:60 and 10:70:20, respectively, while flour produced from 100% sorghum was used as a control sample. The study showed that the flour blend produced from the ratio of 40:20:40 had the most preferred functional properties and complementary food produced from it had the best sensory attributes in terms of taste, colour, viscosity and overall acceptability. Akinsola et al. (2017) also studied the effects of combined processing method on nutritional quality of maize, millet and soybean complementary food. Maize, millet and soybean grains were processed into flour using submerged fermentation, germination and roasting methods, single and combined. The report shows that the mixture of fermentation and germination with roasting methods enhanced nutritional value of complementary food produced from maize, millet and soybean for infants and young children. Adeoye et al. (2018) study the quality of complementary food made from corn, millet and soybean using roasting and fermentation methods. The blends from the processing method (roasting and fermentation) were analyzed for functional properties, chemical composition and protein quality, while the complementary foods, produced from the blends, were analyzed for sensory attribute. The report shows that complementary food produced by two methods (roasting and fermentation) was generally acceptable. Egbujie and Okoye (2019) also studied complementary foods formulated from sorghum, African yam bean and crayfish flours. The flour blends were evaluated for nutritional composition and pasting properties. The study showed that the nutrient content and pasting properties of sorghum-based complementary foods could be drastically improved by supplementing sorghum flour with African yam bean and crayfish flour for the preparation of complementary food for infants and young children. Ukeijima et al. (2019) produced complementary food from maize based supplement with garden pea flour. Maize ogi flour was substituted with garden pea flour in the ratio of 100:0, 90:10, 80:20, 70:30 and 60:40, respectively. The flour blends were analyzed for proximate composition, functional and sensory properties. The report shows that maize ogi flour incorporated with garden pea flour at 10% was the most preferred in all the sensory properties that were studied. Bello et al. (2020) also produced complementary food from maize-carrot-pigeon pea flour blends in the ratio of 100:0:0, 90:5:5, 85:5:10, 80:5:15 and 75:5:20, while commercial formula served as a control. The report shows that all the functional properties studied were low (bulk density, water absorption capacity, oil absorption capacity and swelling index). The sensory score shows that complementary food prepared from 100:0:0 was accepted by all panelists. Arinola et al. (2020) also developed a complementary food from breadfruit and soyflour blends. Breadfruit and soybean flour were mixed in the ratio of 100:0, 90:10, 80:20, 70:30 and 60:40, respectively. The flour blends were analyzed for proximate and mineral composition, while sensory properties of the complementary foods were determined from the flour blends. The result of the sensory evaluation shows that complementary food produced from 70% breadfruit and 30% soybean flour was the most preferred and acceptable in terms of all the sensory attributes that were studied. Olaleye et al. (2020) also developed a weaning food from blends of quality protein maize, Irish potatoes and avocado seed flours. The flour blends were analyzed for proximate and antinutritional composition, functional properties in the ratio of 65:15:20, 60:25:15 and 55:35:10, respectively, while sensory evaluation of the gruel was determined. The result of the sensory evaluation revealed that sample 65:15:20 was the most acceptable. Adebayo-Oyetoro et al. (2021) developed a complementary food from locally fermented maize flour blended with sprouted velvet bean flour. Fermented maize flour was blended, together with sprouted velvet flour in the ratio of 90:10, 80:20, 70:30, 60:40, 50:50, respectively, while 100% maize flour served as control. Proximate and antinutritional composition of the blends were examined, while sensory quality was carried out on complementary food produced from fermented maize and sprouted velvet bean flour. The report shows that complementary food prepared from 90% fermented maize flour and 10% sprouted velvet bean flour was the most acceptable in terms of all sensory attributes of the complementary food. Ikegwu et al. (2021) also examine different processing methods on complementary food from millet-soybean flour blends. Millets are subjected to processing methods such as germination, malting and fermentation. Simplex centroid mixture design was used to generate five runs of flour blends together with untreated millet and soybean flour. The report shows that complementary food could be produced from millet-soybean blends using combined processing methods. However, malting and fermentation treatments decreased the antinutritional composition of the flour blends, while bulk density and water absorption capacity of the flour blends were improved.

Conclusions

Complementary foods have been existing for infants and children over a long period of time. Studies revealed that complementary foods produced from traditional process are mainly based on cereal grains which could not satisfy protein and energy needs of young children, thereby leading to protein-energy malnutrition (PEM). However, previous studies have revealed that fortified cereal grains with legumes or fruits and vegetables can increase their protein quality and mineral content and hence enhance the growth rate of infants and young children. However, there is a need for careful/thorough processing, quality control and regulatory monitoring of complementary foods, especially the fortified complementary foods, so as to protect the health and physical condition of the consumers from unnecessary diseases.

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