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General Overview of Malnutrition under five children in low income countries and solution to mitigate

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Authors' contributions

This work was carried out in collaboration among all authors. Author AKD designed the study and wrote the protocol, CC and DK wrote the first draft, revised of the manuscript and performed all figures. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Malnutrition is a broad concept that includes both under- and over-nutrition. It is the most serious public health problem and the leading cause of child mortality. About a third of children in developing countries are either underweight or stunted. Micronutrient shortages affect more than 30 percent of the world's rising population. Under nutrition, there is a mechanism whose results are routinely spread not only in later lifestyles, but also into future generations. It is a severe problem that affects children under the age of five in developing countries, resulting in stunted growth, muscle weakness, and underweight. Vitamin and mineral deficiencies are still common, and they frequently occur in conjunction with a general lack of nutrients. Malnourished children are at risk of developing marasmus, kwashiorkor, anaemia, rickets, and blindness. Malnourished children have a higher risk of dying from diarrhoea, malaria, or pneumonia than children with perfect nutritional status. Effective malnutrition prevention and treatment, including the use of low-cost food available in communities, is urgently needed. These meals contain sufficient nutrients, such as protein, carbohydrates, fat, vitamins and minerals, to combat malnutrition in infants and children in developing countries. The focus of this review article is on promoting low-cost, locally available ingredients in groups to alleviate malnutrition in toddlers and children in low-income countries.

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1. INTRODUCTION

Malnutrition is a general concept that includes "all deviations from sufficient and optimal nutritional status [1] due to particular nutrient deficiencies or diets mainly focused on off-the-beaten-path combinations or proportions of meals." Malnutrition is classified into two types: over nutrition and under nutrition. Over nutrition is a form of malnutrition in which the body absorbs more nutrients than it requires per day. It's a form of malnutrition that occurs as a result of consuming too much energy over time, resulting in weight gain. Fats would be processed in the body as a result of eating more calories from sugar, carbohydrates, and protein. Obese and obesity are caused by the accumulation of excess fats. Obesity or overweight is a risk factor for cardiovascular disease, some types of cancer, and Type 2 diabetes. In established foreign locations, over nutrition is not uncommon. Under nutrition is a form of malnutrition that occurs when the body does not obtain enough nutrients on a daily basis. It may also be caused by infections that prevent key nutrients from being absorbed [1]. Inadequate consumption of macro nutrients (carbohydrates, protein, and fat) and micro nutrients (vitamins and minerals).A man or woman is categorized as acutely or chronically malnourished depending on the type of nutrition deficiency [2]. Acute malnutrition occurs when a person's food intake is suddenly decreased, resulting in rapid weight loss and a physical inability to satisfy the bodies active desires. Extreme wasting (disproportional weight for peak) and/or edoema describe acute malnutrition, which is the most common form of malnutrition (the retention of fluid). Acute malnutrition can cause stunting, immune dysfunction, fluid overload, heart failure, infection, and death [3]. The occurrence of acute malnutrition among displaced people is frequently used as a barometer for the severity of humanitarian crises [4].

1.1 Chronic Malnutrition

This is the result of insufficient nutrients over a long period of time, and it is not always as obvious as acute malnutrition. It can start in the womb with inadequate maternal nutrition and continue through insufficient feeding practices and poor food choices [5]. Frequent exposure to bacterial infections may also play a role [6]. Chronic malnutrition is most generally manifested by bodily stunting, a term that refers to people whose weight and height seem proportional but who are shorter and smaller than their full genetic capacity. Anthropomorphic tests are used to assess the severity of chronic and acute malnutrition. All of these types of malnutrition are widespread in low-income countries, affecting babies and young children [7,8,9]. In 2016, one-quarter of children under the age of five were stunted, accounting for 38 percent, while a quarter of children under the age of five were wasted, accounting for 27 percent, and one-quarter of children under the age of five were overweight, accounting for 24 percent in Africa [10]. Children who are chronically malnourished normally show signs of behavioural change and mental retardation over time. Even when treated, under nutrition can have long-term effects in children, resulting in intellectual disability and digestive disorders that can last a lifetime [11]. Vitamins A, C and B, as well as minerals like iron, zinc, fluoride, calcium and copper, are the most common nutritional deficiencies in Sub-Saharan Africa [12]. Marasmus, kwashiorkor, anaemia, rickets and blindness are all threats for malnourished children. According to the World Food Programme and a United Nations body, there are five distinct forms of malnutrition.

1.2 Protein Energy Malnutrition (PEM)

PEM is a severe lack of macronutrients in the diet, such as proteins, carbohydrates, and fats that affects the growth of children under the age of five and causes impairment due to their high energy and protein requirements [13]. An individual who is starving becomes skeletally thin and frail, placing them at risk of death. Growth height, cognitive growth, learning capacity, social activity and health are all impaired in infants, making them more vulnerable to infections [14]. Acute PEM is the most serious type of malnutrition that can lead to death in severe cases, with marasmus and kwashiorkor being examples [15]. The acuter PEM affected children have low body weight and wasting signs comparatively to normal children of the same age and height. Another type of chronic malnutrition is marasmus which caused by low intake of protein and calories and is characterized by emaciation [16-17]. Unlike marasmus, kwashiorkor is caused by a lack of protein in the diet. Kwashiorkor causes swelling in the hands, legs and feet of children who are infected [18,19]. According to Ahmed et al. [20] and Manary and

Brewster [21] reports, it also affects children's hair, causing it to turn a golden colour, fatty liver, electrolyte deficiency, desquamate rash and irritability symptoms. Children with kwashiorkor and marasmus are more vulnerable to infectious diseases such as acute respiratory, diarrhoea, and viral infections. PEM prevalence is high in developing countries, according to the World Bank [22], and it is passed on from generation to generation. In Kenya, Kotut et al. [23], Faber [24] and Mnakwe [25]; Ubesie and Ibeziakor [26] found a high prevalence of PEM linked to a lack of adequate nutrition, faulty weaning practices, poverty-related problems, and poor medical treatment. To combat PEM in infants and children, they should be fed low-cost, protein-rich, carbohydrate-rich, and fat-rich diets.

1.3 Iron Deficiency (ID)

Iron is a mineral that aids in the transfer of oxygen from the lungs to the rest of the body by red blood cells. Anemia is a disease in which the body does not produce enough red blood cells, resulting in weakness, difficulties regulating body temperature and a weakened immune system, making you more vulnerable to infections. In addition, Anemia is a global health issue that affects 43% of children under the age of five or approximately 273 million children [27]. Malnourished, iron-deficient and anaemic toddlers and children were found to be listless, lethargic, emotionally dull and less interested in exploring their surroundings [28,29].Children under the age of five who are anaemic have a lower mood and are less physically active than non-anemic children [30,31]. Anemia may be treated or avoided by consuming more iron-rich foods like eggs, nuts, whole grains, fruits and vegetables.

1.4 Vitamin A Deficiency (VAD)

VAD is one of the most common micronutrient deficiencies in the world, affecting predominantly children in developing countries [32]. According to Stevens et al. [33], about 30% of children under the age of five are vitamin A deficient and about 2% of all deaths in this age group are due to VAD. In addition, VAD is a leading cause of avoidable childhood blindness [32]. Despite a vitamin A supplementation programme with 95 percent coverage, in which at least one of the necessary two doses was given, the prevalence of VAD remains high [34]. This indicates that vitamin A supplementation alone will not have the desired effect unless it is combined with daily vitamin A consumption in the diet. Consumption of low-pro vitamin A carotenoid diets is a major contributor to VAD in a population, which contributes to a weakened immune system, blindness, dry skin, respiratory infections, and other diseases such as measles and diarrhoea [35].Consuming vitamin A-rich foods such as carrots, orange-fleshed sweet potatoes, green leafy vegetables, yellow-colored fruits, yellow vegetables (pumpkin) and vitamin A-fortified cereals will help to prevent vitamin A deficiency.

1.5 Iodine Deficiency Disorder (IDD)

Iodine is a vital nutrient for brain growth from the foetal stage to the first two years of a child's life. Iodine is also a chemical that the thyroid gland uses to make hormones that govern body metabolism. Iodine deficiency disorders are a major public health issue, particularly for pregnant women and children under the age of five. Increased perinatal mortality and mental retardation are the most severe consequences [36]. Iodine is a trace mineral that aids in the proper functioning of the brain as well as the metabolization of food energy. It protects women's breast and ovarian health, as well as their foetus from conception to two years of age. The iodine molecule is present in the thyroid hormones T3 and T4, which control the body's metabolism [37]. Iodine-rich foods allow the thyroid to regulate metabolism, detoxification, growth, and development. Iodine deficiency can be avoided by consuming iodine-rich foods like prunes, plums, bananas, potatoes, fish, dairy products, eggs, milk and using iodized salt.

1.6 Zinc Deficiency (ZD)

Zinc is an important trace element that is needed for immune cell activation and differentiation, as well as nearly all cellular functions such as proliferation, maturation, and apoptosis [38-43]. It also aids the body in wound healing by assisting cell division and development. Zinc deficiency increases susceptibility to autoimmunity, some tumours, allergies, graft versus host disease (GVHD), diabetes, and neurodegenerative diseases [44-54]. Infectious diseases such as tuberculosis, the human immunodeficiency virus (HIV), malaria, measles, and pneumonia have been related to zinc deficiency [55,56].Pneumonia is the leading cause of childhood death, accounting for 15% of all deaths in children under the age of five and 19% of all deaths in low-income countries [57,58]. To treat zinc deficiency and associated diseases such as pneumonia, tuberculosis, HIV, malaria, measles, hair loss, poor appetite and slow wound healing, Zinc-rich foods should be included in the diet, such as almonds, legumes, mushrooms, ladyfinger/okra, broccoli, asparagus, nuts, dark chocolate, yeast and whole grains.

2. FACTORS CAUSING MALNUTRITION IN INFANTS AND CHILDREN IN DEVELOPING COUNTRIES

Developing countries have a less developed industrial base and a lower Human Development Index (HDI) than other nations [59]. Because of their histories or geographies, they share certain characteristics. They frequently have low levels of access to clean drinking water, for example, when it comes to health risks, sanitation and hygiene; energy poverty; high levels of pollution (e.g., air pollution, indoor air pollution, water pollution); a high proportion of people suffering from tropical and infectious diseases (neglected tropical diseases); a high number of road traffic accidents; and generally poor infrastructure in certain instances, there is also widespread poverty, a lack of schooling, and limited access to family planning services, a large number of informal settlements, systemic corruption at all levels of government, and a lack of so-called good governance. Since most developing countries have a high "climate vulnerability," global warming (climate change) is projected to have a greater effect on them than on wealthier countries [60]. The life expectancy of people in developing countries is generally lower than that of people in developed countries. Infectious diseases, maternal mortality, child mortality, and infant mortality are all common causes of death. In developed countries, under nutrition is more common [61]. Under nutrition is more prevalent in some categories, including pregnant and breastfeeding mothers, children under the age of five, and the elderly. Children's hunger and stunting are the reasons why more than 200 million children under the age of five in developed countries are not developing to their full potential [62]. In 2013, it was estimated that 165 million children had stunted growth due to malnutrition. [63].Inadequate food intake during the supplementary feeding cycle after six months of exclusive breast feeding is the leading cause of malnutrition [64,65,66]. Nutrition in childhood has the greatest influence on infant growth, development, and survival [67,68].

2.1 Child Factors

Certain child factors, such as sex, age, illnesses, breastfeeding, and the child's place in the family, have a negative effect on the nutritional status of children under the age of five. Protein energy malnutrition (PEM) was identified in 58.3 percent of male children and 68.6 percent of female children in an epidemiological study conducted in Varanasi's urban slum region [69]. In their research, Nyaruhucha et al. [70] discovered that undernutrition was most prevalent among children aged 24-35 months, whereas children younger than a year were less vulnerable. Stunting has been shown to be closely related to children's sex and weight on their own [70]. According to a study conducted in India, children aged 13-24 months were more stunted (81.8%) and underweight (45.5%), while children aged 37-48 months were the most wasting (18.2%) [71]. This clearly shows that children over the age of one year are more likely to be malnourished than children under the age of one. Male children are given more priority than female children in some cultures, especially in Africa, because males will live to carry on the family name, while females will be married off, putting the female child at risk of malnutrition. According to Nyaruhucha et al. [70], slightly more than one-fourth of male household members were given food before females. According to Olack et al. [72], mild wasting was highest in children aged 6-11 months (4.1%) and lowest in children aged 48-59 months (1.1%). More than half of the girls (65.7 percent) in the same sample were more wasted than their male counterparts. Girls were slightly more inefficient than boys of the same age group [72]. According to Olack et al. [72], some health problems in infants, such as tuberculosis (TB), diarrhoea, measles, and others, can intensify malnutrition and a combination of these health issues can weaken the immune system.

2.2 Maternal Factors

One of the factors affecting the nutritional status of children under the age of five is maternal literacy. Children also need primary care from mothers/caregivers for the first 6 years of life, according to Asindi et al. [73] and the standard of care rendered by mothers/caregivers is largely dependent on the mothers' knowledge of basic health care practices and nutrition. It's also been documented that literate mothers are more likely to put off having children until later in life, decreasing infant mortality [74]. Children of uneducated mothers are at risk of stunting, according to Sufiyan et al. [75]. Ali et al. [76] discovered that children with illiterate mothers were 40.8 percent more likely to be stunted and underweight (57.9 percent) highest among children of mothers who had attained at least primary education and wasting (33.3%) was common among children of mothers who had tertiary education. Glewwe [77] highlighted that education can affect the child's health through direct transfer of health information from one generation to another; through via the ability to diagnose disease easily and administer care as well as educated mothers who are more receptive to orthodox medicine than uneducated mothers. The above ties have been identified because educated women are more likely to marry men with higher incomes live in better communities and receive higher-paying jobs, all of which affect child survival directly or in directlyas well as fitness [78]. According to a study conducted in Tanzania, children of older mothers are less likely to be malnourished than children of younger mothers [70].

2.3 Socio-Economic/Household Factors

2.3.1 Poverty

In the last two decades, the number of people living in severe poverty in Sub-Saharan Africa has nearly doubled, from 164 million in 1982 to 313 million in 2002. Since families are unable to afford enough food, poverty leads to malnutrition in infants and children.

2.3.2 Family size

According to Chaudhury [79], a rise in family size due to a decrease in per capita income can have an effect on children's nutritional status. That is, as the number of children in a household increases, the amount of food available to each child decreases, impacting the nutritional status of the children. Increased family size also makes it easier for couples to settle on having children.Large family size can have a negative effect on the nutritional status of children and household members, encouraging poor dietary habits, particularly in poorer households [79].

2.3.3 Household income and expenditure

The amount of food spending specifically defines a household's income level. Food expenditure is expected to grow as household income increases, increasing the rate of caloric and protein intake among children and household members [80]. Poor household income, on the other hand, can lead to lower food consumption and a lower standard of living. According to Chaudhury [79], dietary adequacy, dietary consumption and per capita expenditure have a synergistic relationship.

2.3.4 Household food security and insecurity

Household food security can be affected by a number of factors, including the location of the residence, the family's income level, and the size of the household. Food protection refers to the availability, nutritional quality, and safety of food consumed in a socially acceptable manner [81].Food insecurity, on the other hand, arises when one's ability to access healthy, nutritionally adequate food is limited or uncertain [81]. It has been observed that in most developed countries, the dietary habits of people who are food insecure aim to fulfill their energy needs but fall short of supplying enough nutrients to maintain good health and avoid infection. On the other hand, food insecurity exists when one's ability to receive safe, nutritionally sufficient food is reduced or uncertain [81]. People who are food insecure have been observed in most developed countries eating habits that strive to meet their energy needs but fall short of providing enough nutrients to maintain good health and prevent infection. Hence, it can be inferred that overnutrition and under-nutrition are strongly associated with food insecurity [82-83]. Factors such as poor academic performance, physical and mental ill-health, psycho-social problem and anaemia related to iron deficiency are consequences of food insecurity in children [84-85].

2.3.5 Educational status

The nutritional status of children is highly affected by the education of their parents. That is, parents with a higher educational status have improved child rearing and care practices. According to Chaudhury [86], children with parents who have completed a tertiary education are more likely to consume a healthy diet, regardless of income level, since their parents have a higher level of knowledge on basic child nutrition.Parents with higher educational attainment, on the other hand, may promote values at the cost of their children's health [86]. Women who work outside the home, for example, are less likely to breastfeed their babies exclusively and regularly, and are more likely to practice early weaning [86].

2.3.6 Lack of access to food

Food poverty is typically caused by people's inability to buy enough food, rather than by a shortage of food. According to Etim [87], weak road networks, food scarcity in markets and low family income levels are all factors that lead to food insecurity among the poor. Food importation is often essential for countries, particularly when there is a shortage of food in their own country [87]. According to Etim [87], food price fluctuations affect many people, especially the poorer populations. When food prices are low, farmers may produce less food products, which may not be proportionate to customer demand, resulting in market food scarcity [87].

2.3.7 Socio-demographic factors

Several demographic patterns in Sub-Saharan Africa are impeding the improvement of child malnutrition [87]. Rapid population growth, for example, has been described as a major demographic factor exacerbating malnutrition in children under the age of five [87]. It is widely found that the poor, who are more likely to be malnourished than those in the wealthier quintiles, have higher fertility [87]. Bad nutrition, on the other hand, affects the poorest urban and rural communities the most [87].

2.3.8 Environmental factors

The 95 percent of all malnourished people live in sub-tropical and tropical areas, where the climate is relatively stable. As a result, climate change is a critical factor to consider when ensuring sufficient food supply (food security) [88]. Temperature increases in the subtropics and tropics are very likely, according to a new study (climate change) Climate Change, 2007 [88].Climate change, according to a UN report conducted in over 40 developing countries, has a direct or indirect effect on agricultural development, resulting in a rise in the number of people suffering from hunger each year [89].For example, there was a 50% reduction in wheat production and an 80% loss of livestock products during the Central Asian drought [90]. Extreme weather conditions, such as drought, can reduce crop productivity in Sub-Saharan Africa, exacerbating the effect of malnutrition [90].

2.4 Other Factors

Food stability and access to food are greatly harmed in the face of internal conflicts and crises. Conflicts often result in the annihilation of farmlands and farm enterprises, as well as low food production and reduced internal food distribution. As a result, people are more likely to succumb to malnutrition, sickness and diseases induced by food insecurity. Water-related hardship was found to be a significant determinant of health and nutritional status of children under the age of five in a recent survey conducted in Afghanistan [91].

3. THE ROLE OF LOW COST COMPLEMENTARY FOODS TO ALLEVIATE MALNUTRITION IN INFANTS AND CHILDREN

Since cereals and legumes are widely used in the preparation of complementary foods, it may be difficult for children to achieve nutritional adequacy due to dietary factors [92]. Insufficient dietary variety and reliance on plant-based cereals in terms of nutrient content and bioavailability in children, complementary foods are some of the main factors that restrict the consistency of a complementary diet [93,94]. Furthermore, many conventional complementary foods eaten in developing countries have a low nutritional density. Low-income countries' conventional complementary foods are made up of starchy staples like maize, rice, and finger millet, as well as non-cereals like cassava, sweet potatoes, yamsand plantains [95]. Plant-based protein is usually less costly than animal-based protein. The best way to reduce malnutrition is to consume a nutrient-diverse and well-balanced diet, which will help to mitigate the symptoms of extreme and moderate malnutrition [15]. Children are most vulnerable to poor nutritional status during complementary feeding cycles when both macro and micronutrients are insufficient to sustain growth and improvement, resulting in malnutrition [96].Using a combination of dietary diversification, food fortification, and supplemen tary food assistance, various countries have been effective in reducing infant and young child hunger and malnutrition [22]. Plant-based supplementary foods can be a good way to tackle childhood hunger in developing countries if they are affordable to the majority of the population. Using low-cost conventional and indigenous foods to prepare complementary foods that are both hygienically and nutritionally appropriate to fulfill the needs of fast-developing infants and younger children is one way to minimize malnutrition in a sustainable way [97]. FAO/WHO/UNICEF [98] stressed the use of locally prepared foods rather than centrally prepared foods.

3.1 Formulations of Low Cost Complementary Foods

The World Health Organization describes the complementary feeding period as the time when other foods or liquids are provided to young children in addition to breast milk and any nutrient-containing foods or liquids given to young children during the complementary feeding period are known as complementary foods [99]. Weaning is the term for complementary feeding, which comes from the Anglo-Saxon word weaniang, which means accustom [100]. While the term "weaning" has come to be synonymous with the full cessation of breast feeding, there is no reason to conclude or assume that mothers should avoid breast feeding when complementary feeding is implemented. Complementary feeding (also known as weaning or transitional feeding) is characterized as the process of broadening the infant's diet to include foods and beverages other than breast milk or infant formula (Anonymous, 1994). This has an effect on the infant's growth potential and health. Weaning food should be high in calories, high-quality protein, vitamins, and minerals, as well as easily digestible, low in indigestible fibre, and free of antinutrients [101]. In addition, nutrient consumption is divided into two categories: Type 1 and Type 2. Type 1 nutrients are those in which a shortage of them triggers clinical symptoms. Vitamins and minerals such as calcium, iron, and selenium are among them. Type 2 nutrients, which include sulphur (mostly from protein), magnesium, phosphorus, potassium, and zinc, are needed for the growth of lean tissues [97]. In most cases, complementary food formulations combine maize (predominantly) with legumes such as soybean, cowpea, or groundnut. It is recommended that a complementary food be produced to counter all forms of malnutrition (PEM, IDD, ZD, VAD and ID). As a result, protein, carbohydrates, fats, vitamins, and minerals must all be included in formulations.The following are low-cost foods that can be used in baby and child complementary food formulations.To tackle hunger in low-income countries, all affordable foods should be used to the fullest extent possible. Onyeka and Dibia [102] developed nutritious and inexpensive infant weaning foods by roasting malted corn and soybean (50:15) for 30 minutes at 65°C, then adding roasted peanuts (100 or 150 g/Kg) and mashed banana (200-350 g/Kg). They discovered that the malting process enhances flavour, decreases dietary bulk, and boosts nutrient content in food products. Munasinghe et al. [103] blended brown rice (*Oryza sativa*), soybean (*Glycine max*), mung bean (*Vignaradiata*), and milk powder with yoghurt to make three extruded yoghurt-based weaning foods at various ratios to achieve the recommended amount of nutrients for toddlers aged 1-3 years. Mohamed et al. [104] developed a highly nutritive instant weaning mix of rice flakes, skim milk, butter, vitamin premix and sugar. Weaning mix was developed by Balasubramanian et al. [105] using malted and extruded pearl millet and barley flours. They came to the conclusion that developing highly nutritious and suitable weaning foods using locally available low-cost ingredients available in developing countries has a lot of potential. Haile and Getahun, 2018,[106] developed a mashed food by mixing orange-fleshed sweet potato (OFSP) and haricot bean in various proportions (70:30, 80:20, 90:10, and 100:00).Of all the formulated foods, mothers and preschool children preferred mashed food made from OFSP and haricot bean in a 70:30 ratio. Pandey and Singh [107] developed weaning foods for infants to combat protein-energy malnutrition.Two different types of kheer were processed and tested for infants aged 6-12 months and 9 months and up, using a multigrain and nut blend, as well as banana, apple and rice. Multigrain and nut mix kheer had crude protein and fat levels of 21.23 and 3.99 percent, 11.34 and 2.11 percent, respectively. Both weaning food formulations were well received organoleptically and nutritionally, suggesting that they should be used as weaning foods for children.

3.1.1Staple foods

These are traditional foods that are grown and consumed in all cultures. Cereals (rice, corn, millets), roots (cassava yam, potato), and starchy fruit are among them (plantain and bed fruit). Porridge is made by milling staples into flour and frying them. Staples provide nutrition (mostly from starch), but they also provide protein, although in limited amounts. They are deficient in minerals such as iron, zinc, and calcium. Pro vitamin A is abundant in golden maize/yellow maize, pumpkin and orange-fleshed sweet potatoes. To improve nutritional consistency, staples should be combined with other foods such as legumes and pulses, fruits and vegetables in the formulation of complementary foods for infants and children. In low-income countries, using unfortified cereal-legume blends as a supplementary food instead of unfortified cereal-only formulations has the potential to minimize the incidence of protein-energy malnutrition among infants and children. Cereal-legume blends are remarkably high in protein (each in an extraordinary amount) and strength since legumes provide lysine that cereals lack, and cereals provide cysteine and methionine that legumes lack [108].Weaning Mix, which contained 75% maize, 15% soybean, and 10% groundnut, had an energy value of 1820 kJ/100 g and a protein level of 15/100 g [109], compared to 100 kJ/100 g and 0.6/100 g for *koko*, a maize-only porridge made from fermented cereal dough (Lartey et al., 1997). While a cereal-legume blend has been recommended for infants and children to help reduce malnutrition, caution should be taken during processing to ensure that all anti-nutritive properties are extracted. The presence of phytates at 0.48/100 g of Weaning mix [110] may inhibit iron absorption, and zinc bioavailability has been shown to be dose-dependent. [111,112]; as a result, efforts have been focused on finding methods for lowering phytate levels in foods.

3.1.2 Legume, pulses and oil seeds

Legume, pulses, and oil seeds are rich in protein and contain many essential amino acids that cereals lack, such as lysine, methionine, cysteine, phenylalanine, tyrosine, threonine, tryptophan, and valine. To tackle malnutrition, various types of legumes and pulses can be used in the formulation of complementary foods for infants and children. Oil seeds may also be used as a source of fat and minerals in complementary food formulations. They lack vitamin A and vitamin C when dried, despite being a good source of protein. Oil seeds, unlike legumes and pulses, are rich in fat and minerals. When integrated into complementary food formulations, they provide the energy density that infants and children need. Phytates, on the other hand, are present in legumes, oil seeds, and pulses and they inhibit ion, zinc, and calcium absorption. In addition to phytates, most legumes and pulses contain anti-nutritional factors like trypsin inhibitors, isoflavones, and phytates, which prevent nutrients from being absorbed by the body. Because of the high phytate levels in cereal–legume dependent diets, low iron or zinc absorption has been related to deficiency [113-117]. These inhibitors require expert processing techniques to prevent protein absorption in the body, resulting in PEM [118]. Hotz and Gibson [114] found that after 86 hours of natural lactic fermentation of maize flour slurry, the phytate content was reduced by 12%.The conventional method of soaking maize flour in water and then decanting the excess water decreases phytate levels by just 57 percent [115].

3.1.3 Fruits and vegetables

Fruits and vegetables, unlike pulses, legumes, oil seeds, and staples, are low-cost foods available in any culture. They contain a variety of minerals and vitamins. Vitamin A, zinc, and iron shortages (micronutrients) can be alleviated if they are found in adequate quantities in complementary food formulations. To combat micronutrient deficiency, infants and children's complementary food formulations should contain a sufficient amount of fruits and vegetables, either fresh or dried (powders). Apart from their high nutritional value, they also improve the immune system when eaten all year. There is evidence that weaning mix satisfies the growth demands of infants using weight gain as an index [109]; however, it is insufficient to satisfy the demand for vitamin A [119], iron, or zinc [109]. [109,120]. Low levels of vitamin A (about 2.0 g retinol equivalents/100 kJ) compared to the recommended range of 14 to 43 g retinol equivalents/100 kJ could be to blame for the infants' poor vitamin A status [109,121]. One of the "issue nutrients" in weaning mix has been described as vitamin A. [122]. Low-cost plant foods rich in pro-vitamin A (β-carotene) such as pumpkin, papaya, golden maize, orange-fleshed sweet potatoes, and other low-cost plant foods with high pro-vitamin A (β--carotene) content should be used as much as possible in the formulation of complementary foods for infants and children to fight VAD.

3.1.4 Weaning foods for infants and children

In several developing countries, the formulation and production of nutritious weaning foods using locally available raw materials has gotten a lot of attention [123]. Weaning food is meant to bridge the gap between breast-feeding an infant and having a 'adult' family [124].Weaning simply refers to the process of acclimating (an infant, a young animal) to food other than its mother's milk. During the weaning period, the young child's diet moves from milk alone to a range of foods based on the family's daily meals [125]. Multi-mixes are recipes with four essential ingredients that are more suitable for the weaning cycle and feeding. The first ingredient is a staple, preferably a cereal; the second is a protein supplement derived from a plant or animal product (beans, milk, meats, etc.); the third is a vitamin and mineral supplement (vegetable and/or fruit); and the fourth is an energy supplement derived from fat, oil, or sugar to increase the energy concentration of the mix.

The use of cereals and pulses together takes advantage of the fact that cereals are low in lysine, while pulses are high in lysine. As a result, the protein content is greatly improved [125].Traditional weaning methods, re-evaluation of indigenous foods, research into producing low-cost weaning foods, and a focus on home-made children foods derived from the family meal could contribute to changes in infant and young child feeding and as a result, a reduction in infant and young child mortality [126].

4. RECOMMENDATION TIPS FOR LOW COST COMPLEMENTARY FOOD FORMULATIONS

- All complementary food formulations must include a mixture of staple grains/seeds that have been standardized in standard procedures to extract anti-nutritive influences, then roasted and milled.
- Both legumes, pulses, and oil seeds must be processed according to industry requirements to eliminate anti-nutritive factors before being roasted and milled.
- Both fruits and vegetables must be processed according to normal protocols before being dehydrated and ground into powder.
- Before being served to children, complementary foods are packaged as dried items that must be reconstituted with liquid (water) to form porridge/gruel.
- In accordance with the WHO's [127] guideline for processing complementary food for infants and children, formulations must make use of locally available resources.

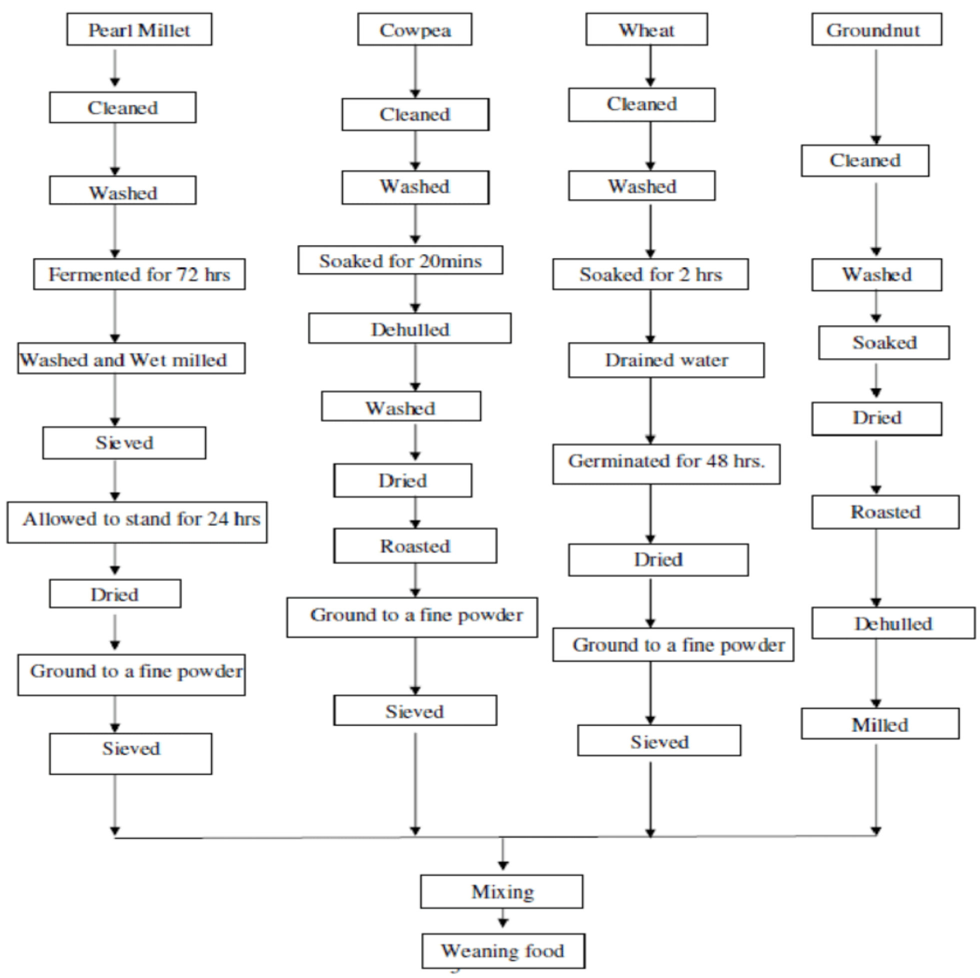

Fig. 1. Process flow sheet for cereal-legume-oil seed blends used in the preparation of infants and children weaning foods

- The majority of the formulations must follow the Codex criteria for complementary food's energy (1670 kJ/100 g) and protein (15/100 g) specifications [128].
- All formulations must conform to a healthy diet (all types of low-cost food sources must be used in complementary foods).
- To prevent contamination and health problems such as diarrhoea in children after ingestion, high hygienic standards must be practiced during the preparation of raw materials to finished goods.
- All food formulations must be packaged in tightly sealed containers and labeled with the nutritional content of each ingredient used in the formulations as well as the food's expiration date [129].

4.1 Standard Procedures Ofeliminating Anti-Nutritional Factors in Foods Before Formulation of Complementary Food for Infants and Children

The typical procedures for eliminating anti-nutritional factors in legume, cereal, and oil seed before preparing weaning mix for infants and children are summarized in Fig. 1. Washing, soaking, germination, drying, roasting, boiling, fermentation, grounding/milling are some of the various processing methods used to extract anti-nutritional factors from cereals, legumes, pulses, oil seeds, fruits and vegetables such as phytic acid, phenolic compounds, enzyme inhibitors, saponins, lectins and haemagglutins.

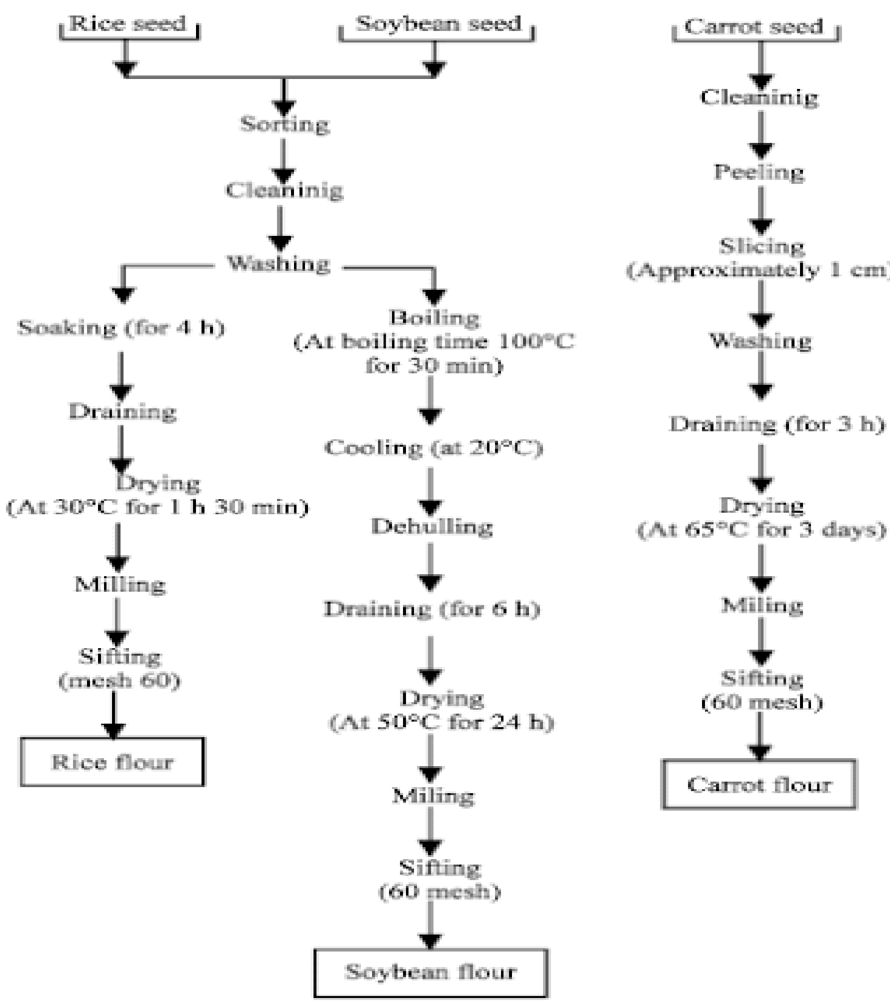

Fig. 2. Process flow sheet for making weaning foodfor infants and children out of cereal-vegetable flour

5. CONCLUSION

In low-income developed countries, all attempts should be made to tackle malnutrition in infants and children. From the moment they are weaned until they are five years old, babies and children can follow a well-balanced diet. Low-cost complementary foods, such as staples, yellow and green leafy vegetables, legumes and pulses, seasonal fruits, oil seeds, and milk, should be included in baby and child formulas and other food stuff which are locally available in communities. A healthy childhood represents a healthy adulthood and offers good results in academics as well as other facets of life such as socially, politically, and economically. When good nutrition is regarded as the cornerstone of good health, the mortality rate of babies and children is decreased. This analysis is recommended to low-income countries in order to assist in the elimination of hunger by using low-cost food products readily available in their societies to cultivate complementary foods for babies and children

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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