Ready-to-Use Therapeutic Foods (RUTFs) for Remedying Malnutrition and Preventable Nutritional Diseases

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Abstract

The research extensively evaluated the challenges posed by malnutrition and outlined efficiency of using Ready-to-use therapeutic foods (RUTF) to address these challenges. The ingredients, production process, quality control, and principles for the production of RUTF were discussed exhaustively. Malnutrition results from consuming a diet in which at least one nutrient is either not enough or is too much such that the diet causes health problems and can lead to preventable nutritional diseases, particularly in severe acute malnutrition (SAM). Some of the effects of malnutrition include kwashiorkor, marasmus, stunting, increase susceptibility to infection, scurvy, rickets, hypoglycemia, moon face, pale conjunctiva, Bitot's spots, anemia, angular stomatitis, cheilitis, glossitis, spongy bleeding gums, etc. Malnutrition can be undernutrition or overnutrition; undernutrition is of more grave concern than overnutrition. It can affect individuals of all ages, especially children under the age of five. Major causes of malnutrition include poverty, high food prices, dietary practices, agricultural productivity, etc., with many individual cases being mixture of many factors. A major burden in developed countries is clinical malnutrition, such as cachexia. Malnutrition can also be a consequence of health issues. One in every twelve people worldwide is malnourished; one in four of the world's children is chronically malnourished. Food and nutrition security, economic improvement, world population restriction, food sovereignty, improving health facilities, education, and breastfeeding are the major ways to prevent malnutrition. One major way to mitigate undernutrition is by the use of Ready-to-use therapeutic foods (RUTF). Therapeutic foods are designed for specific nutritional, therapeutic purposes as form of dietary supplement. Therapeutic foods are used in emergency feeding of malnourished children or to supplement diets of persons with special nutrition requirements, such as pregnant women and the elderly. Ready-to-use therapeutic food are high in energy, fortified, ready-to-eat foods, and suitable for the treatment of children with SAM. These foods should be crushable or soft and should be easy for young children to consume without further preparation. At least 50% of proteins contained in the RUTF should come from milk products. As RUTF does not need to be prepared in any way prior to consumption, it is practical for use where cooking facilities and fuel are limiting constraints. RUTF is very effective against malnutrition.

Keywords: Malnutrition, Ready-to-use therapeutic foods, Therapeutic foods, Undernutrition, Preventable nutritional diseases

1. Introduction

Food and nutrition insecurity, and nutritionally related diseases are among the leading challenges facing the world, especially those in the developing, and underdeveloped countries of Asia, Africa, and southern America. Poor access to adequate health facilities, food shortage, and the prevalence of nutritionally related diseases have taken center stage among the global challenges, especially in most developing and underdeveloped countries in African, Asia, and Southern America. Undernourishment is most usually due to not enough high-quality food available to eat. Often, this is related to high food prices and poverty (United Nations Children's Fund, 2010). A lack of breastfeeding can contribute, as can a number of infectious diseases such as: pneumonia, malaria, measles, and gastroenteritis which increase the requirements for nutrients. There are two major types of undernutrition: dietary deficiencies and protein-energy malnutrition. Protein-energy malnutrition has two severe forms: kwashiorkor (a lack of just protein) and marasmus (a lack of protein and calories). Common micronutrient deficiencies include lack of iron, iodine, vitamin A (Young, 2012), vitamin B2, etc. Due to the body's increased need during pregnancy, deficiencies may become more common in pregnant women. In some developed and developing countries, overnutrition in the form of obesity is beginning to present in the same communities as undernutrition. Anorexia nervosa and bariatric surgery are other causes of malnutrition.

The efforts to improve nutrition are part of the major effective forms of development aid. Exclusive breastfeeding can reduce the rates of malnutrition, infant mortality, and death in children, and the efforts to promote the practice increase rates of breastfeeding (Bhutta *et al.*, 2013). In young children, giving food (along with breast milk) between 6 months and 2 years of age improves the outcomes. There is sufficient evidence supporting the supplementation of several micronutrients to pregnant women and among children in the developing world (Bhutta *et al.*, 2013). To get food to individuals who mostly need it, both distributing food and providing money so individuals can buy food in local markets are effective (UK Department for International Development, 2012). Simply feeding students at school alone is not sufficient. Management of severe acute malnutrition (SAM) within the individual's home with ready-to-use therapeutic foods (RUTF) is likely much of the time (Bhutta *et al.*, 2013). In those who have severe acute malnutrition complicated by other health issues, treatment in hospital settings is recommended. It usually involves managing body temperature and low blood sugar, gradual feeding, and addressing dehydration (Bhutta *et al.*, 2013). Routine antibiotics are often recommended because of the high risk of infection often encountered. Longer-term measures are improving agricultural practices (Jonathan *et al.*, 2011), empowerment of women, reducing poverty, and improving sanitation. Some substances such as antioxidants in medicinal plants may also help to improve the health status of individuals (Awuchi, 2019a).

In 2018, there were 821 million undernourished individuals in the world, representing10.8% of the total population of the world (FAO, 2019). This is a reduction of around 176 million people since the year 1990 when 23% were undernourished, however an increase of around 36 million since 2015, when 10.6% of the world population were undernourished (FAO, 2018). It was estimated in 2012that another billion individuals had a lack of many vitamins and minerals (UK Department for International Development, 2012). In 2015, protein-energy

malnutrition (PEM) was estimated to have led to 323,000 deaths—a reduction from 510,000 deaths in 1990 deaths (GBD 2015 Mortality and Causes of Death, Collaborators, 2016). Other nutritional deficiencies, which include iron deficiency anemia and iodine deficiency, result in another 83,000 deaths of people (GBD 2015 Mortality & Causes of Death, Collaborators, 2016). In 2010, malnutrition caused 1.4% of all the disability adjusted life years (UK Department for International Development, 2012). Data published by the FAO relative to the hunger trend in the world from 2006 to 2009 were worrying; the number of people that suffer hunger in this period increased by about 200 millions, increasing from the around 850 millions in 2006 to almost 1.05 billion in 2009. In 2016, the number of undernourished individuals stood at 804 million. The number could be higher, as many cases and incidences are likely to be unreported. Climate change may worsen the situation and increase the number in 2020 and beyond. A third of deaths in children are considered to be due to undernutrition, though the deaths are seldom labelled as such. It was estimated in 2010 to have contributed to around1.5 million deaths in children and women (Lim *et al.,* 2012), although some estimated the number could be greater than 3 million (Bhutta *et al.,* 2013). Another 165 million children were reported to have stunted growth due to malnutrition in 2013 (Bhutta *et al.,* 2013). Undernutrition is more common in developing (Liz, 2002) and underdeveloped countries. Some groups have higher rates of undernutrition, including children under five years of age, the elderly, and women (in particular during pregnancy or breastfeeding). In the elderly, undernutrition is more common due to psychological, physical, and social factors (Ronnie *et al.,* 2011).

Ready-to-use therapeutic foods are fortified, high energy, ready-to-eat foods suitable for treatment of children (and sometimes other vulnerable groups) with severe acute malnutrition (SAM). At least half of the proteins in the foods should come from milk or milk products. The food should be crushable or soft, and easy for young children to consume without any preparation. Children, zero to five years old, have a greater need for food, due to both greater energy and nutritional requirements for growth and development, and also due to developing immune system. Millions of people suffer from severe acute malnutrition (SAM). The nutrients lack has negative influence on all body functions, causing serious pathological conditions, such as edema, and death (Vijay, 2018).

Even with the efforts of the defunct MDGs and the current efforts of the Sustainable Development Goals (SDGs), more still need to be done to address the problem of malnutrition, hunger, and food insecurity, especially in developing and underdeveloped countries. The research critically focused on malnutrition and its consequences, as well the use of Ready-to-use therapeutic foods to address these problems.

2. Malnutrition

Malnutrition is health condition that results from the consumption of diet wherein one or more nutrients are not enough to meet up the body requirements or are too much that the diet results to health problems. It often takes time for malnutrition to manifest. It may involve calories, carbohydrates, protein, vitamins or minerals (United Nations Children's Fund, 2010) or combination of two or more of these. Not enough nutrients is known as undernourishment or

undernutrition while too much is known as overnutrition (Young, 2012). Malnutrition is normally used to specifically refer to undernourishment (or undernutrition) where individual is not getting enough protein, calories, or micronutrients (Young, 2012). If undernutrition occurs before two years of age or during pregnancy, it can result in permanent problems with mental and physical development (United Nations Children's Fund, 2010) which may affect the individual for life. Starvation, known as extreme undernourishment, may have symptoms that include thin body, a short height, swollen legs and abdomen, and very poor energy levels (United Nations Children's Fund, 2010; Young, 2012). People also often get numerous infections and are frequently cold. Often, the symptoms of micronutrient deficiencies depend on the micronutrient that is lacking (Young, 2012).

> *Type 1 nutrients are those nutrients whose deficiencies translate into characteristic clinical symptoms associated with the dysfunction of a particular biochemical pathway; e.g. vitamins. Type 2 nutrients are those nutrients required for growth of lean tissues.*

2.1. Undernutrition vs. overnutrition

Malnutrition is caused by consuming a diet in which the nutrients are not enough or may be too much such that it leads to health problems (Nikolaos, 2011). It is a category of nutritional diseases that includes undernutrition and overnutrition (WHO, 2012). Overnutrition can result in being overweight and obesity. In some developed and developing countries, obesity caused by overnutrition is beginning to present in the same communities as undernutrition. Nevertheless, the term malnutrition is often used to refer to undernutrition only (Nikolaos, 2011).

Except specifically mentioned otherwise, the term malnutrition hereinafter refers to undernutrition for the remaining part of this research article. Malnutrition may be divided into two types, which are SAM (severe acute malnutrition) and MAM (moderate acute malnutrition) (Sathish *et al.,* 2014).

2.2. Protein-energy malnutrition (PEM)

Undernutrition is at times used as synonym of protein–energy malnutrition (PEM). Whereas others include both micronutrient deficiencies and PEM in its definition. It is different from calorie restriction given that calorie restriction may not cause negative health effects. Hypoalimentation means underfeeding. The term severe undernutrition or severe malnutrition is often used to refer specifically to protein–energy malnutrition (PEM). PEM is usually associated with micronutrient deficiency (Duggan *et al.,* 2008). Two forms of protein–energy malnutrition are marasmus and kwashiorkor, and they usually coexist.

2.2.1. Kwashiorkor

Kwashiorkor is generally caused by prolonged inadequate intake of protein. The main symptoms are liver enlargement, wasting, hypoalbuminaemia, steatosis, possibly depigmentation of skin and hair, and edema(Nikolaos, 2011). Kwashiorkor is additionally identified by the swelling of the belly, which is deceptive of the actual nutritional status. The

term "Kwashiorkor" means "displaced child" in Ghana and is derived from a Ghana (West African country) language, meaning the sickness acquired by the older one when the next baby is given birth to, because this is often when the older child is stopped from breastfeeding and weaned to diet composed largely of carbohydrates (Stanton, 2001).

2.2.2. Marasmus

Marasmus (to waste away) is generally caused by prolonged inadequate intake of energy and protein. The main symptoms are severe wasting, minimal subcutaneous fat, leaving little or no edema, non-normal serum albumin levels, and severe muscle wasting (Nikolaos, 2011). Marasmus may result from a sustained diet of inadequate protein and energy, and the metabolism adapts to a prolong survival. It is traditionally seen in more severe cases of anorexia or famine significant food restriction (Nikolaos, 2011). Conditions are characterized by a gaunt expression and extreme wasting of the muscles.

2.3. Undernutrition and hunger

Undernutrition encompasses wasting, stunted growth (stunting), and deficiencies of essential vitamins and minerals (jointly referred to as micronutrients). The word "hunger", describing a feeling of discomfort or discomposure from not eating food, is used to describe undernutrition, particularly in reference to food insecurity (Black *et al.*, 2008), food scarcity, and famine.

Gómez and Galvan in 1956 studied factors associated with the death in a group of undernourished children in a hospital in the Mexico City, Mexico and defined the categories of malnutrition as first, second, and third degree (Stevenson and Conaway, 2011). The degrees were based on the weight below a specified percentage of the median weight for age (Grover and Ee, 2009). The risk of death increases with the increasing degree of malnutrition (Stevenson and Conaway, 2011). An adaptation of the Gomez's original classification is still in use today. While it offers a way to compare malnutrition between and within populations, the classification has faced many criticisms for not considering overweight as a form of malnutrition and for being arbitrary. Moreover, height alone may not be best indicator of malnutrition; the children born prematurely may be regarded short for their age even when they have good nutrition.

Another classification for malnutrition was established by John Conrad Waterlow. Instead of using just the weight for age measurements, Waterlow's classification combines height-for-age (showing the stunting that results from the chronic malnutrition) with weight-for-height (indicating the acute episodes of malnutrition) (Watts, 2010). One advantage of the Waterlow's classification over the classification by Gomez is that weight for height can be evaluated even if ages are unknown.

2.4. Effects of malnutrition

Malnutrition increases the risk of infection, infectious disease, and weakens the immune system. For instance, it is major risk factor in onset of active tuberculosis (Schaible and Kaufmann, 2007). Protein-energy malnutrition and the deficiencies of specific micronutrients,

such as vitamins, iron, and zinc, increase the susceptibility to infections. Malnutrition affects the transmission of HIV by increasing the risk of mother-to-child transmission and the increasing replication of the virus (Stillwaggon, 2008). In areas or communities lacking access to safe drinking water, the additional health risks present critical challenge. Impaired function of the brain and lower energy also represent downward spiral of malnutrition as then victims are less able to perform tasks they need to earn an income, gain an education, or acquire food. Scurvy and rickets are examples vitamin-deficiency-related diseases.

Hypoglycemia (low blood sugar) may result if a child does not eat for 4 to 6 hours. Hypoglycemia has to be considered if there is limpness, convulsion, loss of consciousness, or lethargy. If blood sugar can be measured instantly and quickly, carry out a finger or heel stick.

2.4.1 Malnutrition signs

In those with malnutrition several signs of dehydration differ. However, children may still want to drink, have decreased urine output, may be cool to touch, and have reduced interaction with the world around them (WHO, 2005).

Table 1: Signs of malnutrition

Site	Sign
Abdomen	Distended – hepatomegaly with fatty liver, ascites can be present
Behavior	Lethargic, apathetic
Cardiovascular	Bradycardia, reduced cardiac output, hypotension, small vessel vasculopathy
Eye	Dry eyes, periorbital edema, pale conjunctiva, Bitot's spots (vitamin A)
Face	Simian facies (marasmus), moon face (kwashiorkor)
Hair	Overall thinning of the hair follicles, dull, sparse, flag sign (alternating bands of light and the normal color), brittle hair, hypopigmentation, broomstick eyelashes, alopecia
Hematological	Pallor, petechiae, bleeding diathesis
Mouth	Angular stomatitis, spongy bleeding gums (vitamin C), cheilitis, glossitis, parotid enlargement
Musculature	Muscles wasting, mainly in the buttocks and thighs
Nail	Koilonychia, fissures or ridges, thin and soft nail plates
Neurologic	Global development delay, poor memory, loss of knee and ankle reflexes
Skeletal	Deformities often a result of vitamin D, calcium, or vitamin C deficiencies
Skin	Shiny and edematous (kwashiorkor), loose and wrinkled (marasmus), patchy hyper- and hypopigmentation, dry, follicular hyperkeratosis, erosions, poor wound healing
Teeth	Enamel mottling, delayed eruption

2.4.2. Cognitive development

Protein-calorie malnutrition can lead to cognitive impairments. For humans, the critical period varies from final third of gestation to first 2 years of life (Laus *et al.*, 2011). Iron deficiency anemia in the children under the age of two years may likely affect their brain functions

acutely and possibly also chronically. Folate deficiency is linked to neural tube defects (Kenton, 2013).

Malnutrition due to the deficiency of iodine is the most common preventable and avoidable cause of mental impairment worldwide (McNeil, 2006). Even moderate deficiency, especially in infants and pregnant women, reduces intelligence by 10 – 15 I.Q. points, shaving innumerable potential off the development of a nation. The most severe and visible effects—disabling goiters, dwarfism, and cretinism—affect a tiny minority, often in mountain villages. But 16% of the world's population have at least mild goiter; swollen thyroid gland in the neck (McNeil, 2006).

2.5. Causes of malnutrition

The major causes of malnutrition are poverty and food prices, agricultural productivity and dietary practices, with many individual cases being mixture of many factors. Clinical malnutrition, such as the cachexia, is also a major burden in developed countries. Numerous scales of analysis have to be considered to determine the sociopolitical causes of malnutrition. E.g., the population of communities and villages within poor governments, may perhaps be at risk if the areas lack health-related services, but on smaller scale some individuals or households may be at a higher risk due to the differences in access to land, income levels, or levels of education (Fotso and Kuate-Defo, 2005).

2.5.1. Diseases

Malnutrition may be a consequence of health problems such as gastroenteritis (Mandell *et al.*, 2010) or chronic illness, particularly the HIV/AIDS pandemic. Also, diarrhea and other infections may cause malnutrition by reducing the absorption of nutrients, increasing metabolic requirements, decreasing intake of food, and direct nutrient loss (Musaiger *et al.*, 2011). Parasite infections, especially intestinal worm infections (helminthiasis), may also cause malnutrition. A leading cause of intestinal worm infections and diarrhea in children in developing and underdeveloped countries is lack of proper hygiene and sanitation.

Individuals can become malnourished as a result of abnormal nutrient loss due to diarrhea or a chronic illness affecting small bowel. These conditions can include untreated coeliac disease or Crohn's disease (Newnham, 2017). Also, malnutrition may occur as a result of increased energy expenditure (secondary malnutrition).

2.5.2. Dietary practices

Undernutrition

Lack of adequate breastfeeding results in malnutrition in infants and children, linked with the deaths of estimated one million children per year. Illegal advertising of substitutes for breast milk contributed to malnutrition three decades after its prohibition in 1981 under the *WHO Int'l Code of Marketing Breast Milk Substitutes* (Brady, 2012). Also, maternal malnutrition may factor into the death or poor health of a baby. Over 800,000 deaths of neonates have occurred due to deficient growth of fetus in the womb of the mother.

It is not just the total quantity of calories that matters but the specific nutritional deficiencies such as iron deficiency, zinc deficiency, or vitamin A deficiency can also increase risk of death (UNICEF, 2013).

Deriving too much of individuals diet from one source, such as eating nearly exclusively rice or corn, can lead to malnutrition. This may either be from only having access to one food source or from lack of education about proper nutrition (Burchi *et al.,* 2011).

Overnutrition

Overnutrition caused by eating too much is a form of malnutrition. In the US, more than 50% of all adults are currently overweight— like hunger, overweight increases susceptibility to disease and disability, lowers life expectancy, and reduces worker productivity (Gardner and Halweil, 2000). In the United States and some other developed countries, where for the majority of individuals access to food is not issue, overeating is much more common. Many parts of the world have increased access to surplus non-nutritious foods, with increased sedentary lifestyles. Kelly Brownell, Yale psychologist, calls this situation a toxic food environment where sugar and fat laden foods have taken the precedence over healthy nutritious foods (Gardner and Halweil, 2000). The issue in these developed nations is often choosing the right kind of food. Nowadays, more fast food is eaten per capita in the US than in any other nation. The reason for this massive consumption of fast food is its accessibility and affordability. Often fast food, low in nutrition and cost, is heavily promoted and high in calories. When these feeding habits are combined with the increasingly automated, urbanized, and more sedentary lifestyles and habits, it becomes clear why weight gain appears to be difficult to avoid (Gardner and Halweil, 2000).

Not only does increasing obesity seen in developed countries, the problem also occurs in developing nations in areas where the income is on the rise. Also, overeating is a problem in countries where poverty and hunger persist. In China, the consumption of foods high in fat has increased while the consumption of rice and other foods has decreased (Gardner and Halweil, 2000). Overeating leads to various diseases, such as diabetes and heart disease, which may lead to death.

2.5.3. Poverty and food prices

In some countries like Bangladesh, Uganda, South Sudan, etc., the poor socioeconomic position was associated with a chronic malnutrition as it inhibits purchase of very nutritious foods such as poultry, fruits, milk, and meat (Khan and Kraemer, 2009). As much as food shortages can be one of the contributing factors to malnutrition in the countries with lack of technology, the Food and Agriculture Organization has estimated that 80% of malnourished children living in the developing countries live in nations that produce food surpluses (Gardner and Halweil, 2000).

It is argued that the commodity speculators are increasing cost of food. As the real estate bubble in countries such as the United States, Canada, etc., was collapsing, trillions of dollars have been moved to invest in the food and primary commodities, resulting in the 2007/2008 crisis in food price. The use of biofuels as a substitute for traditional fuels contributes to food scarcity and increases the price of foods. Jean Ziegler, the UN special

rapporteur on right to food, proposes that agricultural wastes, such as banana leaves and corn cobs, rather than crops themselves, be utilized as fuel (Ferrett, 2007).

2.5.4. Agricultural productivity

Local food shortages may be caused by adverse weather, lack of arable land, lower farming skills like crop rotation, or by lack of technology or resources required for the higher yields found in the modern agriculture, such as machinery, fertilizers, pesticides, storage facilities, and irrigation. As a result of widespread poverty, governments cannot provide or farmers cannot afford the resources required to improve local yields. Some wealthy donor countries and the World Bank also press countries that depend on aid to eliminate or cut subsidize agricultural inputs such as fertilizer, all in the name of free market policies even though Europe and the United States extensively subsidized their own farmers (Dugger, 2007). Many, if not majority, farmers cannot afford fertilizer at the market prices, resulting in low agricultural production and poor wages, and unaffordable high food prices. Reasons for the unavailability of the fertilizer include the moves to stop fertilizer supply on environmental grounds, cited as obstacle to feeding Africa by Green Revolution pioneers Norman Borlaug & Keith Rosenberg (Dugger, 2007).

2.5.5. Present and future threats

There are several potential disruptions to world food supply that may cause widespread malnutrition. Global warming is of significance to food security, with 95%of all malnourished individuals living in the relatively stable climate regions of tropics and sub-tropics. According to the latest reports by IPCC, temperature increases in these tropical and sub-tropical regions are very possible. Even small changes in temperatures may lead to increased occurrence of extreme weather conditions. A lot of these have great impact on nutrition and agricultural production. For example, the 1998 to 2001 central Asian drought brought around 80% livestock loss and 50%reduction in barley and wheat crops in Iran (Battisti, 2008). Similar figures were found in other nations. Even without an increase in extreme weather events, any simple increase in temperature decreases the productivity of several crop species, also reducing food security in these regions (Black, 2010). In regions such as Sub-Saharan Africa, an increase in extreme weather conditions such as drought would have even higher consequences in terms of the level of malnutrition. Colony collapse disorder is situation where bees die in great numbers. Since various agricultural crops are pollinated by the bees, this represents a threat to food supply.

2.6. Malnutrition prevention

Food and nutrition security, economic improvement, world population restriction, food sovereignty, improving health facilities, education, and breastfeeding are the major ways to prevent malnutrition.

2.6.1. Food and nutrition security

The effort to bring the modern agricultural techniques used in the West, such as the nitrogen fertilizers and pesticides, to the East such as Asia, called the Green Revolution, lead to increased food production and the corresponding decreases in the prices and malnutrition like those seen earlier in the Western countries. This was possible due to the existing institutions and infrastructure that are in inadequate supply in Africa, such as system of roads and public seed companies which make seeds available (Dugger, 2007). Investments in agriculture, such as subsidized seeds and fertilizers, increase food harvest and at the same time reduce food prices (Barclay, 2008). For example, in Malawi, almost 5 million of its 13 million population used to need emergency food aid. But, after the government changed policies, introducing subsidies for fertilizer and seed against the World Bank strictures, the farmers produced record-breaking corn harvest as production leaped from 1.2 million in 2005 to 3.4 million in 2007, making Malawi a major food exporter. As a result, this increased wages for farm workers and lowered food prices. Such investments in agriculture are still required in other African countries such as the Democratic Republic of the Congo (DRC). The DRC has one of the highest prevalence cases of malnutrition despite the fact that it is blessed with huge agricultural potential (John *et al.,* 2013). Proponents for investing in the agricultural sector include Jeffrey Sachs, who championed the idea that wealthy nations should invest in seed and fertilizer for Africa's farmers (Baker and Dugger, 2009).

In many developing (and underdeveloped) countries like Nigeria, imported Ready to Use Therapeutic Foods (RUTF) have been used to treat malnutrition. In the Northern Nigeria, *Soy Kunu*, a locally sourced and prepared food blend consisting of peanut, soya beans, and millet may also be used (Chinedu, 2018).

New agricultural production technologies also have great potential to combat undernutrition (Li *et al*., 2010). By improving agricultural yields, farmers may reduce poverty by increasing income and open up area for the diversification of crops for household use. World Bank itself claims to play part in the solution to malnutrition, stating that the best way for nations to succeed in breaking the cycle of malnutrition and poverty is to build export-led economies which will provide them the financial means to purchase foodstuffs on the global market.

2.6.2. Economic impacts

There is growing realization among the aid groups that giving cash vouchers or cash instead of food is a cheaper, more efficient, and faster way to deliver help to the hungry, especially in areas where foods are available but unaffordable. The United Nations World Food Program (UN WFP), the biggest non-governmental food distributor, declared that it will begin distributing vouchers and cash instead of food in various areas, which the WFP's executive director, Josette Sheeran, described as revolution in food aid (World Food Programme, 2008).Concern Worldwide, an aid agency, is piloting a method through Safaricom, a mobile phone operator, which runs money transfer program that allows sending cash from one part of country to the other.

However, for individuals in a drought living with limited access to markets or a long way from markets, delivering food may be most suitable way to help. Fred Cuny suggested that chances of saving lives at outset of relief operations are significantly reduced when food is imported. Before it reaches the country and gets to individuals, many will have lost their lives. The law in

the U.S., which requires purchasing food at home rather than where those hungry live, is inefficient since about half of what is spent is used for transport. Cuny further pointed out that studies of each recent famine have indicated that food was available in-country—although not often in the immediate the food deficit area and even though according to local standards the prices are very high for the poor people to purchase it, it would typically be cheaper for the donor to buy the hoarded foods at the inflated prices than to import it from overseas.

Soup kitchens and food banks address malnutrition in places where individuals lack money to purchase food. A basic income has been recommended as a way to make sure that everyone has money enough to buy food and a number of other basic needs; it is form of social security where all residents or citizens of a country regularly receive sum of money unconditionally, either from the government or other public institution, along with any income received from somewhere else.

Ethiopia has been pioneering program that has now come to be part of World Bank's prescribed method for managing food crisis and had been perceived by the aid organizations as a model of just how to best help hungry countries. Through the nation's main food assistance program, the PSNP (Productive Safety Net Program), Ethiopia has been giving the rural residents who are under chronic food shortage, a chance to work for cash or food. Foreign aid organizations like the WFP (World Food Program) then were able to buy food locally from the surplus areas to distribute in the areas with food shortage. Brazil has established recycling program for the organic waste that benefits urban poor, farmers, and the city in general. Residents of the city separate the organic waste from their garbage, put it in bag, and then exchange it for fresh and wholesome fruit and vegetables from local farmers. Consequently, the country's waste is reduced in addition to the urban poor getting a steady nutritious food supply.

2.6.3. World population restriction

Restricting the population size is a proposed solution to malnutrition. Thomas Malthus argued that the population growth may be controlled by voluntary limits through moral restraint and by natural disasters. Robert Chapman suggested that an intervention through the government policies is a required ingredient of restraining global population growth. The complementarity and interdependence of population growth with malnutrition and poverty (and also the environment) is also recognized by the UN. More than 200 million women globally have inadequate access to family planning services. The World Health Organization stated that family planning is important to slowing unsustainable population growth and its resulting negative impacts on the environment, economy, and regional (and national) development efforts.

However, many believe that the world has enough and even more than enough resources to sustain its growing population. Theorists point to the unequal distribution of resources and the under- or unutilized arable lands as the cause of malnutrition problems. For instance, Amartya Sen suggested that, no matter how famine is caused, the methods of breaking it require a large food supply in the public distribution system. It does not only apply to organizing rationing and control, but also apply to undertaking work programs and other methods of increasing the

purchasing power for those hit by the shifts in exchange entitlements ina situation of general inflation.

2.6.4. Food sovereignty

One recommended policy framework to resolve the access issues is called food sovereignty—the right of people to define their own fisheries systems, food, agriculture, and livestock, in contrast to having food mostly subjected to international market forces. The Food First is one of the primary think tanks which work to build support for the food sovereignty. Neoliberals advocate for increasing role of free market.

2.6.5. Improving health facilities

Increasing access to the health facilities to rural parts of the world would be another likely long term solution. These facilities could monitor undernourished children, provide education on dietary needs, and act as supplemental food distribution centers. These types of facilities have proven very successful in nations such as Peru and Ghana (Waters *et al.*, 2006; Nyonator *et al.*, 2003).

2.6.6. Breastfeeding

As of 2016 it is estimated that the deaths of about 823,000 children less than 5 years old could be prevented globally each year through more widespread breastfeeding (Victora *et al.*, 2016). Along with reducing infant death, feeding with breast milk provides an essential source of micronutrients, proven clinically to bolster the children's immune system, and provide long-term defenses against allergic and non-communicable diseases (Lessen and Kavanagh, 2015). Breastfeeding has also been indicated to improve the cognitive abilities in children, with strong correlation to individual educational achievements (Lessen and Kavanagh, 2015; Balogun *et al.*, 2015). As previously noted, the lack of proper breastfeeding is major factor in the rates of child mortality, and a primary determinant of the development of diseases for children. The medical communities recommend exclusive breastfeeding of infants for 6 months, with continued breastfeeding and nutritional whole food supplementation up to 2 years or even older for overall optimal health outcomes (Balogun *et al.*, 2015). Exclusive breastfeeding is defined as giving an infant only breast milk for 6 months as the source of food and nutrition (Cai *et al.*, 2012). It means no other liquids, including semi-solid foods or water.

Barriers to breastfeeding; breastfeeding is well-known as one of the cost effective medical interventions for providing the beneficial nutrients for child health. While there are substantial differences within developed and developing countries: social norms, access to healthcare, income, and employment were found to be the universal determinants of whether a mother formula or breast fed their children (Balogun *et al.*, 2015). Community based healthcare workers have assisted in alleviating financial barriers faced by the newly made mothers, and offered a viable alternative to the traditional and expensive hospital based medical cares (Balogun *et al.*, 2015). Recent studies based on surveys conducted from 1995 to 2010 shows the rates of exclusive breastfeeding have gone up globally, from 33% - 39%.Despite the growth rates, the medical professionals acknowledge need for improvement given the significance of exclusive breastfeeding (Cai *et al.*, 2012).

2.7. Treatment of malnutrition

In response to child malnutrition, Bangladeshi government recommends ten steps for the treatment of severe malnutrition. They are to treat or prevent dehydration, low body temperature, infection, low blood sugar, micronutrient deficiencies, and correct electrolyte imbalances, in addition to start feeding cautiously, provide psychological support, achieve catch-up growth, and prepare for discharge as well as follow-up after recovery. Nutritional support improves protein, calorie intake, health and weight among those who are hospitalized (Bally *et al.,* 2016).

2.7.1. Micronutrients

Treating malnutrition, mostly by fortifying foods with vitamins and minerals (micronutrients), improves lives at a shorter time and a lower cost than other forms of aid. The Copenhagen Consensus, which survey a variety of development proposals, ranked the micronutrient supplements as number one (Kristof, 2009). In individuals with diarrhea, once an initial 4-hour rehydration period is completed, a zinc supplementation is recommended. The daily zinc increases the chances of lessening the severity and reducing the duration of the diarrhea, and also continuing with daily zinc for 10 to 14 days makes diarrhea less possible recur in the next 2 to 3 months (WHO, 2005a).

In addition, malnourished children require both magnesium and potassium. This can be obtained through following the recommendations above for a dehydrated child to continue eating food within 2 to 3 hours of starting rehydration (WHO, 2005a), and including potassium rich foods as above. Low potassium in the blood is worsened when the base (as in Ringer's/Hartmann's) is taken to treat acidosis without providing potassium simultaneously. As above, available home products like salted and unsalted vegetable broth, salted and unsalted cereal water can be given early in the course of a child's diarrhea together with continued eating (WHO, 2005a). Vitamin A, zinc, potassium, and magnesium should be added with other micronutrients (vitamins and minerals) if available. In case of a malnourished child with diarrhea cause by any factor, this should include potassium rich foods such as bananas, unsweetened fresh fruit juice, and green coconut water.

2.7.2. Food

There is poor evidence for the benefit of supplementary feeding. This is because of the small amount of research carried out on this treatment. Specially formulated foods such as RUTF do however appear useful and suitable in those from the developing countries with moderate acute malnutrition (Lazzerini *et al.,* 2013) and severe acute malnutrition. In young children with severe acute malnutrition sometimes it may not be clear if ready-to-use therapeutic food (RUTF) differs from a normal diet (Schoonees *et al.,* 2013). They have some usefulness in humanitarian emergencies as they are often eaten directly from the packet without further preparation, do not require mixing with clean water or refrigeration, and can be stored for many years.

In severely malnourished individuals, feeding too much too rapidly may result in refeeding syndrome (a metabolic disturbance that occurs as a result of reinstituting nutrition to

individuals who are severely malnourished, metabolically stressed due to severe illness, or starved. Cardiac, neurological, and pulmonary symptoms may be signs of refeeding syndrome). This can result regardless of the route of feeding and can present itself a few days after eating with heart failure, confusion, and dysrhythmias that can result in death (Viana *et al.,* 2012). Manufacturers are currently fortifying everyday foods with micronutrients that are sold to consumers, such as the iodization of salt, the fish sauce in Vietnam, and the wheat flour for the Beladi bread in Egypt. For instance, flour has been fortified with folic acid, thiamine, riboflavin, niacin, vitamin B12, iron, and zinc.

2.7.3. Diarrhea

The World Health Organization recommends rehydrating severely undernourished children who have diarrhea relatively slowly. Preferred method is with the fluids by mouth using oral rehydration solution (ORS). The ORS is both slightly salty and slightly sweet and the one recommended for those with severe acute malnutrition should have half the normal sodium and greater potassium. The fluids by nasogastric tube may be used in individuals who do not drink. Intravenous fluid is recommended only in people who have significant dehydration because of their potential complications, which include congestive heart failure. With time, ORS developed into oral rehydration therapy (ORT) which focused on increasing the fluids by supplying salts, water, and carbohydrates. This switch from the type of fluid to the amount of fluid was important in order to prevent the dehydration from diarrhea (Victora and Bryce, 2000). Breast feeding and food consumption should resume as soon as possible. The drinks such as fruit juices, sweetened teas, and soft drinks are not recommended because they contain too much sugars and can worsen diarrhea (WHO, 2005b). Broad spectrum antibiotics are recommended for all the severely undernourished children with diarrhea needing admission to hospital.

For dehydration prevention, readily available fluids, if possible with a modest amount of salt and sugars such as salted rice water or vegetable broth, may be used. Drinking of clean water in addition is also recommended. As soon as dehydration develops oral rehydration solutions (ORSs) are preferred. As much of the drinks as the individual wants can be given, except there are swelling signs. If vomiting occurs, the fluids can be paused for 5 to 10 minutes and then restarting rather more slowly. Vomiting rarely prevents the rehydration as fluids are still absorbed and vomiting rarely last long (WHO, 2005b). Severely malnourished children with conditions that appear to be dehydration but who have not had diarrhea have to be treated as if they (the children) have infection.

For babies, dropper or syringe without needle may be used to put small quantities of fluid in their mouth; for children under the age of 2, a teaspoon every 1 to 2 minutes; and for the older children and adults, directly sipping frequently from a cup. After first two hours, rehydration has to be continued at a slower or the same rate, determined by any ongoing diarrheal loses and how much fluids the child wants. After the first 2 hours of rehydration it is recommended to alternate between food and rehydration.

2.7.4. Hypothermia

Hypothermia may occur. To prevent or treat the occurrence of hypothermia, the child may be kept warm with a covering including of the head of the child or by direct contact (skin-to-skin)with the mother/father and then covering both child and parent. Prolonged medical exams or prolonged bathing should be avoided. Warming methods are often most vital at night.

2.7.5. Hypoglycemia (Low blood sugar)

Hypoglycemia, whether suspected or known, can be treated with a mixture of water and sugar. If the child is conscious, initial dose of sugar and water should be given orally. If the child is unconscious, glucose by intravenous or nasogastric tube should be given. If seizures occur after even with glucose, rectal diazepam is recommended. The blood sugar level should be re-checked on a 2 hour intervals.

2.8. Epidemiology of malnutrition (the Global Hunger Index)

The Global Hunger Index (GHI) is multidimensional statistical tool used in describing the state of hunger situation in countries. The GHI measures the progress and the failures in global fight against hunger. The Global Hunger Index is updated once per annum. The data from the 2015 report indicates that Hunger levels have dropped 27 percent since 2000. Additionally, 52 countries remain at alarming or serious levels. In addition to the most recent statistics on the Hunger and Food Security, GHI also features different special topics every year. The 2015 report included an article related to conflict and food security (von Grebmer *et al*., 2015).

2.8.1. Individuals affected

The UN estimated that there were 821 million malnourished (undernourished) individuals in the world in 2017. This used the United Nations' definition of 'undernourishment', where it is referred to as insufficient consumption of raw calories, and therefore does not necessarily include individuals who lack micronutrients (vitamins and minerals). The undernourishment occurred despite world farmers producing abundant food (Jean, 2010). As of 2010, malnutrition was the cause of 1.4 percent of all the disability adjusted life years.

Table 2: Number of undernourished globally

Year	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Number (millions)	945	911	877	855	840	821	813	806	795	784	784	804	821	820	820
Percentage	14.5%	13.8%	13.1%	12.6%	12.2%	11.8%	11.5%	11.3%	11.0%	10.7%	10.6%	10.8%	10.8%	10.9%	10.6%

Table 3: Number of undernourished in the developing world

Year	1969–71	1979–81	1990–92	1995–97	2001–03	2003–05	2005–07	2010–12	Currently (2019/2020)
Number (millions)			820	790	825	848	927	805	795
Percentage	37%	28%	20%	18%	17%	16%	17%	14%	12.9%

(FAO, 2016)

2.8.2. Mortality

Mortality due to malnutrition accounted for the 58% of total mortality in 2006: In the world, all causes of death combined, around 62 million people die per year. One in twelve people globally is malnourished. According to the 2012 report of the Save the Children, one in every four children is chronically malnourished worldwide. In 2006, more than 36 million individuals died of hunger or the diseases due to deficiencies of micronutrients (Ziegler, 2007). Currently, one every nine people is hungry worldwide. In 2010 protein-energy malnutrition (PEM) resulted in around 600,000 deaths down from the 883,000 deaths in 1990. The other nutritional deficiencies, which include iron deficiency anemia and iodine deficiency, result in another 84,000 deaths (Lozano *et al.*, 2012). In 2010, malnutrition caused approximately 1.5 million deaths in children and women.

According to the WHO, malnutrition is the biggest cause of child mortality, present in the half of all cases. About 6 million children die due to hunger each year. Intrauterine growth restrictions and underweight births cause 2.2 million child deaths every year. Poor or non-existent breastfeeding causes additional 1.4 million deaths. Other deficiencies, such as lack of zinc or vitamin A, for instance, account for 1 million deaths. Malnutrition in the first 2 years is irreversible. The malnourished children grow with worse health, lower education achievement, poor cognition, and other various health and developmental challenges. Their own children have a tendency to be smaller. Previously malnutrition was seen as a condition that exacerbates the problem of diseases such as diarrhea, measles, and pneumonia, but malnutrition in reality causes diseases, and may be fatal.

2.9. Special populations (Special needs)

Undernutrition is an important determinant of the maternal and child health, accounting for over one third of child deaths and more than 10% of the total global disease burden.

2.9.1. Children

The WHO estimates that malnutrition accounts for 54% of child mortality worldwide, around 1 million children (Manary *et al.*, 2013). Another estimate also by the WHO states that childhood underweight causes about 35% of all the deaths of children under5 years worldwide. Since underweight children are much more vulnerable to nearly all infectious diseases and illnesses, the malnutrition indirect disease burden is estimated to be the order of the magnitude higher than disease burden of the malnutrition direct effects (Prüss-Üstün *et al.*, 2008). The combination of indirect and direct deaths from malnutrition resulting from unsafe WASH (water, sanitation and hygiene) practices is estimated to cause 860,000 deaths every year in children under 5 years of age.

2.9.2. Women

In 2003, the researchers from Centre for World Food Studies found the gap between levels of undernutrition in women and men to be generally small, but reported that the gap varies from one region to another and from one country to another. These small-scale studies indicated that the rates of prevalence of female undernutrition exceeded male undernutrition prevalence rates in the Latin America and South/Southeast Asia and were lower in the Sub-Saharan Africa

(Nubé and Van Den Boom, 2003). Datasets for Zimbabwe and Ethiopia reported undernutrition rates between 1.5 to 2 times higher in the men than in the women; however, in Pakistan and India, datasets rates of undernutrition were 1.5 to 2 times much higher in the women than in men. Also, intra-country variation occurs, with frequent high gaps between the rates of regional undernutrition (Nubé and Van Den Boom, 2003).Gender inequality in nutrition in various countries such as India is present in all stages of life. The studies on nutrition about gender bias in households look at the patterns of food allocation, and a study from 2003 reported that women usually receive a lower share of the food requirements than men (Nubé and Van Den Boom, 2003). Gender discrimination, social norms, and gender roles affecting women may lead to close birth spacing, early marriage and childbearing, and undernutrition, all contribute to malnourished mothers.

Within the household, there could be differences in the levels of malnutrition between women and men, and these differences have been reported to significantly vary from one region to another region, with problem areas indicating relative deprivation of women (Nubé and Van Den Boom, 2003). In 2008, samples of 1000 women in India demonstrated that malnutrition in women is connected with poverty, illiteracy, and lack of development and awareness. The same study indicated that gender discrimination within households can prevent women's access to sufficient healthcare and food. Najma Rivzi explained how socialization affects women health in Bangladesh, in an article about a study program on this topic (Najma, 2013). In some cases, such as in some parts of Kenya in 2006, the rates of malnutrition in the pregnant women were higher than the rates in children. Women in a number of societies are traditionally given less foods than men since the men are perceived to have much heavier workloads.

Pregnancy and breastfeeding: During breastfeeding and pregnancy, women should eat sufficient nutrients for their child and themselves, so they need more protein and calories significantly during these periods, along with more vitamins and minerals (especially folic acid; vitamins A, C, and K; iron; iodine; and calcium). Folic acid prevents neural tube defects, among other functions. In 2001, the UN FAO reported that the deficiency of iron afflicted 43% of women in developing nations and increased the risks of death during childbirth. A review of interventions in 2008 estimated that universal supplementation with folic acid, calcium, and iron during pregnancy can prevent 105,000 maternal deaths (23.6% of all maternal deaths) (Bhutta *et al.,* 2008). Malnutrition affects three quarters of UK women aged 16 to 49 years, indicated by them having lesser folic acid than the recommended levels by the WHO (Denis, 2014). Frequent pregnancies with short intervals in-between them and prolonged periods of breastfeeding add additional nutritional burden.

Physiology: Women have unique nutritional requirement, and in most cases require more nutrients than men; e.g., women need two times as much calcium as men.

Educating children: According to the UN FAO, women are often responsible for food preparation and have the opportunity to educate their children about the beneficial foods and health habits, availing mothers another great opportunity to improve nutrition of their children.

2.9.3. The elderly

Malnutrition and underweight are more common in elderly than in adults of other age groups. If elderly people are active and healthy, the aging process alone does not often cause

malnutrition. However, the changes in organ functions, body composition, ability to eat or access food, and adequate energy intake are associated with aging, and may contribute to malnutrition (Bulent *et al.,* 2010). Sadness or depression also plays a role, causing changes in appetite, weight, well-being, digestion, and energy level. A study on relationship between malnutrition and the other conditions in elderly found that malnutrition in elderly can result from the endocrine system disorders, gastrointestinal disorders, loss of taste and smell, inadequate dietary intake, and decreased appetite (Bulent *et al.,* 2010). Poor dental health, chewing and swallowing problems, and ill-fitting dentures can make eating difficult. Consequent to these factors, malnutrition is found to develop more easily in elderly.

Rate of malnutrition tend to rise with age with less than 10%of the young elderly (of up to age 75 years) malnourished, while 30% to 65%of the elderly in home care, acute hospitals, or long-term care facilities are malnourished. Many elderly individuals require assistance in eating food, which can contribute to malnutrition. However, the mortality rate caused by undernourishment may be reduced (Milne *et al.,* 2009). Because of this, one of the key requirements of the elderly care is to give all essential nutrients and an adequate diet. Providing the different nutrients such as energy and protein keeps even small but stable weight gain. In the United Kingdom, hospital admissions for malnutrition have been associatedwith insufficient social care, where vulnerable individuals in care homes or at home are not helped to eat (Home care Insight, 2019).

Malnutrition or risk of malnutrition in Australia occurs in 80% of elderly individuals presented for admission to hospitals. Malnutrition and weight loss may contribute to sarcopenia with loss of muscle function and lean body mass. Weight loss or abdominal obesity coupled with sarcopenia lead to skeletal disorders, insulin resistance, immobility, hypertension, metabolic disorders, and atherosclerosis (Bulent *et al.,* 2010). A paper from *Journal of the American Dietetic Association* stated that routine nutrition screenings represent one major way to detect and as a result decrease the prevalence of malnutrition in elderly.

3.Ready-to-use therapeutic food (RUTF) as solution to malnutrition

This RUTF is a mixture of peanut butter, milk powder, vegetable oil, sugar, and powdered vitamins and minerals. RUTF does not need preparation in any way before consumption, making it practical and ideal for use where cooking facilities and fuel are limiting constraints.

Table 4: Nutritional composition of a typical RUTF

Nutrient	Composition
Energy	520-550 Kcal/100g
Lipids	45 to 60% total energy
Moisture content	2.5% maximum
Proteins	10 to 12% total energy
Calcium	300 to 600 mg/100g
Copper	1.4 to 1.8 mg/100g
Iodine	70 to 140 μg/100g
Iron	10 to 14 mg/100g
Magnesium	80 to 140 mg/100g
Phosphorus (excluding phytate)	300 to 600 mg/100g
Potassium	1100 to 1400 mg/100g
Selenium	20 to 40 μg
Sodium	290 mg/100g maximum
Zinc	11 to 14 mg/100g
Vitamins	
A	0.8 to 1.1 mg/100g
D	15 to 20 μg/100g
E	20 mg/100g minimum
K	15 to 30 μg/100g
B1	0.5 mg/100g minimum
B2	1.6 mg/100g minimum
C	50 mg/100g minimum
B6	0.6 mg/100g minimum
B12	1.6 μg/100g minimum
Niacin	5 mg/100g minimum
Pantothenic acid	3 mg/100g minimum
Folic acid	200 μg/100g minimum
Biotin	60 μg/100g minimum
n-3 fatty acids	0.3% to 2.5% of the total energy
n-6 fatty acids	3% to 10% total energy

3.1. Composition of therapeutic foods

Therapeutic foods are often made of a mixture of protein, carbohydrates, lipids, and vitamins and minerals. They are usually made by grinding and mixing all the ingredients together. The mixing process allows for components of protein and carbohydrate of the food to be driven into the lipid matrix (Manary, 2006). The protein, carbohydrates, lipids, and other components of the RUTF improve its functional properties (Awuchi *et al.*, 2019; Awuchi, 2019b), including its refractive index (Awuchi *et al.*, 2018). The size of the food particles in the mixture should be less than 200 μm for the food mixture to maintain its consistency (Manary, 2006). Using this method, the therapeutic foods are produced and packaged without the use of water, which would eliminate spoilage issue. Some therapeutic foods require addition of water before

administering (reconstitution), while others are consumed as-is. Therapeutic foods are carefully designed and manufactured to make sure that they are ready to be eaten straight from the packaging. They require no cooking and resist bacterial contamination (Manary, 2006).

Ready-to-use therapeutic food (RUTF) is a subset of therapeutic foods which is energy-dense and micronutrient-enriched pastes that have nutritional profile similar to traditional F-100 milk-based diet and food used in the inpatient therapeutic feeding programs and are usually made of peanuts, sugar, oil, and milk powder (Isanaka *et al.*, 2009).

RUTFs are homogeneous mixture of water-soluble and lipid-rich foods. The lipids used in the formulation of RUTFs are in a form of viscous liquid. The other ingredients are in small particle sizes and are often mixed through the lipid. Other ingredients are carbohydrates, protein, vitamins and minerals. The mixture requires homogeneity for it to be consumed effectively. To do this, specific mixing process is required (Manary, 2006). The lipid component of the ready-to-use therapeutic food is first heated and stirred. The heat has to be maintained for the lipid to maintain the optimum form for mixing in other ingredients. Then the powdered carbohydrates, protein, and vitamins and minerals are slowly and gradually incorporated to the lipid, as the lipid is being stirred vigorously. After all the ingredients are incorporated and vigorous stirring is sustained, the mixture is then stirred for several minutes with more speed (Manary, 2006). If the powdered ingredients have particle size larger than 200 μm, the mixture will start to separate; particle size needs to be less than 200 μm (Manary, 2006).

The most common ready-to-use therapeutic foods are made of four ingredients: oil, sugar, dried skimmed milk, and vitamin and mineral supplement. Other qualities RUTFs ought to have include a soft or crushable texture and a taste suitable and acceptable for young children. RUTFs have to be ready to eat without been cooked. An important characteristic is that the ready-to-use therapeutic foods should be resistant to micro-organism contamination and have a long shelf-life, without need for expensive packaging. AS the ingredients need being suspended in liquid, the liquid used for production of RUTFs needs to be lipid/fat. 50% of the protein forming ready-to-use therapeutic foods should come from milk/dairy products.

UNICEF specifications for RUTFs require that the vitamins and minerals premix must be obtained from any of the following dealers authorized by the World Food Program: Nicholas Piramal Healthcare Limited (now Piramal Group), DSM Nutrition/Fortitech, Hexagon Nutrition, the GAIN premix facility, and BASF (Stern Vitamin) (Caron, 2013).RUTFs are used by the UNICEF Kid Power malnutrition program, which usually use celebrities to go on their global missions to help save the impoverished areas in Africa (UNICEF, 2016).

3.2. Production Principles of RUTF

RUTF is a uniform mixture of water-soluble and lipid rich foods. The lipid exists as a viscous liquid, and small particles of carbohydrate, protein, vitamins and minerals are thoroughly mixed with this liquid. In order to achieve homogenous mixture, specific mixing procedure must be adhered to. The lipid elements of the RUTF are first stirred and usually heated; then the powdered ingredients are added slowly and gradually to the lipids while stirring vigorously. Once all powdered ingredients are added, entire mixture is stirred for several minutes at higher

speeds. The mixture does not readily separate provided that the particle size of the powdered ingredients is not larger than 200 microns (Manary, 2006). When mixtures are produced with larger particles, the RUTF must be briefly stirred by hand just prior to the consumption, to temporarily suspend large particles in the food mixture. The use of oils which are liquids at ambient temperature facilitates mixing process. Packaging of RUTFs can be done from factory funnels or bowls, using a mechanical device or by hand (simply pouring it). Successful RUTF production has been accomplished in Malawi, Congo, and Niger using these principles.

3.3. Ingredients for RUTF

The formulation of RUTFs was derived from the F-100 and makes use of the same ingredients with addition of peanut butter (World Health Organization, 1999). Peanut butter changes the physical and functional properties of the food to viscous liquid product rather than a powder.

Table 5: A typical recipe for Ready to Use Therapeutic Food

Recipe	% weight
Full fat milk	30
Peanut butter	25
Sugar	28
Vegetable oil	15
Mineral Vitamin Mix	1.6

Milk powder – The local supplies of milk powders exist all over the world, however the milk itself is usually imported. The standard commercial techniques used in the production of milk powder yield a desirable product suitable for the production of RUTF.

Peanut butter – The peanut butter is simply peanuts that are roasted and ground, without addition of oil, preservatives or salt. In most of the areas of the world where peanuts are cultivated, commercial food processing companies make peanut butter.

Sugar – Commercial sources of granulated white or brown sugar can be used to produce RUTF. The sugar must be properly ground into fine powder, a product used in the bakeries referred to as powdered sugar or icing sugar, to decrease the particle sizes to less than 200 microns.

Vegetable oil – Many types of oil made using the standard commercial methods can be used to make RUTF, including rapeseed oil corn oil, soy oil, and cottonseed oil. Soybean oil and rapeseed oil have the advantage of providing good balance of the essential fatty acids.

Powdered vitamins and minerals – This comprises of mixture of vitamins and minerals made to provide the same amounts of micronutrients to a malnourished child as the F-100, the standard therapeutic food.

At present it is available from Nutriset (Malaunay, France), a commercial supplier. The UNICEF and the World Food Programme (WFP) have donated the ingredients required for the production of RUTFs in Malawi. The WFP has donated milk, oil, and sugar, and UNICEF donated powdered vitamins and minerals. The RUTFs are then used by the projects approved and supported by these organizations.

3.3. Scale of production

A mechanical mixer is necessary for all RUTF productions. While mixing the ingredients with hand is possible for very small amounts, the product quality of the hand mixed RUTF is so inconsistent that it cannot be used reliably. The equipment and procedures used to mix RUTF are contingent upon the quantities of RUTF required. If only a few hundred kg of RUTFs is required each week, a small scale production is likely. Small scale production needs a small room dedicated to production of food and must be free of rodents, insects, flies, and other pests, and any other potential contaminants. A 40 L planetary bakeries mixer, such as Mac Adams SM 401, may be used to prepare RUTF. Such mixers mix a 25 kg batch of RUTFs. Ingredients are added via volume to the batch. Containers used to measure ingredients need to be chosen and calibrated carefully by accurately weighing the ingredients. Oil and the peanut butter should be directly added into the mixing bowl and then combined using mixing speed of 105 rpm till homogenous. A Z-shaped kneader blade, instead of a wire whisk device, should be made use of to minimize the quantity of air impregnated in the mixture. Milk powder, sugar, and vitamin and mineral mixture are mixed first hand as dry powders in dedicated plastic drum, and emptied into electric mixing bowl (Manary, 2006). Then the RUTF is mixed for 6 minutes at 105 rpm,6 minutes at 210 rpm, and 6 minutes at 323 rpm. These mixing times are required to prevent separation during storage and to ensure homogeneity of the RUTFs. The RUTF can be hand-packed or poured into 250 g plastic bottles, the typical daily dose for any malnourished child. If 500 to 1500 kg of RUTF is required each week, the production is best achieved by partnership with commercial food processing company which has machinery that can efficiently and effectively mix, grind, and package RUTFs. This equipment is often found in pastry factories and industrial bakeries. A larger capacity customized barrel mixer or several planetary mixers can be used. Whole peanuts can be mixed with the other ingredients, and then the mixture is run through the same grinder used for making peanut butter. Mechanical or pneumatic semi-automatic device that fills a container with prescribed amount can package the RUTFs (Manary, 2006).

If more than 3000 kg of ready-to-use therapeutic foods are needed each week, industrial production facilities dedicated to RUTF are required. This can be part of an NGO formed specifically for making RUTF or a larger food processing company that has technical and professional expertise in food production. The machinery required for the large scale production is designed to mix batches of 200 to 500 kg and package the product automatically. Instead of typical batch production, the products can move continuously from mixer to grinder and then to packaging device, by the use of series of mixing chambers (Manary, 2006). A skilled operator is required to add the ingredients to initial mixing chamber and remove final filled containers from packaging device. The production scale will determine the quality

control methods and the cost. The quality control is independent on overall quantity of RUTFs produced, and will be rather more easily implemented at lower cost with a centralized, large scale production. The economy of scale comes up for other aspects of RUTFs production, and, if feasible, the large scale production have to be considered as long term objective in the countries with high level of severe acute malnutrition (SAM) and where there is possibility of a sustained demand. The two resources potential local producers may use to get technical assistance in the establishment of a production facility are Valid International (Oxford, UK) and Nutriset (Malaunay, France).

3.4. Quality Control

Choice if ingredients: Whichever scale of production used, quality control is achieved by the safe storage of the ingredients, product testing for composition and contaminants, and adequate training and supervision of production personal. Throughout the world, relevant authorities set standards for the food production companies; the organizations involved in the production of RUTFs should adhere to these standards (according to Codex Alimentarius, FAO/ WHO food standards). The key issues in quality control are enumerated as follows.

Bacterial contamination: The intrinsic microbiological safety of RUTFs allows them to be packaged under dry and clean, but not sterile, conditions. Extreme care must be taken to prevent introduction of water into RUTFs during the production. Increasing the moisture content of RUTFs allows mold and bacteria to grow in the food, causing product degradation and also exposing the malnourished child to potential intoxication and infections by pathogens. Water is most likely to come from residue left on the mixing containers and bowls after they have been washed (Manary, 2006). Therefore, it is better to reduce the number of times the implements and equipment of production are cleaned with water and soap, and to simply dry-wipe clean instead. Normally implements need to be cleaned with water and soap once a week only. If the containers in which the RUTFs are to be dispensed were first washed, care should be observed to ensure their complete dryness.

Enteric bacterial contamination is more likely to occur during the mixing process and also from the fecal contamination of stored ingredients. Care should be taken to store ingredients in areas free of rodents and insects. Workers should wash and dry their hands thoroughly before handling the RUTF, wear clean plastic gloves, protective coats, and hair coverings during production of RUTF. RUTF and Milk should be checked periodically for salmonella contamination using standard microbiological methods in reliable laboratories.

Aflatoxin contamination: Aflatoxinsare toxins produced by an *Aspergillus* species of the fungus, which contaminates grains such as peanuts before and after harvested, but before they are ground to peanut butter. The mold is ubiquitous, the fungal growth can be curtailed by storing peanuts in cool, dry environment, and also can be controlled using fungicides. Methods to prevent the aflatoxin contamination have been described in details elsewhere (Turner *et al*., 2005). Peanuts should be bought from a supplier that can ensure the steps to prevent contaminations have been implemented during the harvest and storage of the peanuts.

Aflatoxin contamination is most likely to be seen among nuts that have shriveled, irregular appearance, and in the peanuts with black discoloration. Consumption of aflatoxin can predispose individual to hepatic cancers and can cause hepatic oxidative stress. RUTFs should conform to international standards for maximum aflatoxin in foods, 10-20 ppb (according to Codex Alimentarius, FAO/ WHO food standards). Very high doses of aflatoxin can cause acute intoxications. Moderate doses can depress child growth (Gong *et al*., 2004). Aflatoxin B_1 is the most toxic among aflatoxins (B_1, B_2, M_1, M_2, G_1, G_2).

Prevention of oxidation: The Oxidation of fatty acids contained in the RUTFs and of some vitamins, mostly vitamin A and C, is the major factor limiting the shelf life of RUTFs. During the production, a number of preventive measures have to be taken to avoid initiating oxidation process (Fellows, 2004). While it is helpful to heat oils during mixing process to achieve homogenous mixture, heating to the temperatures above 45ºC accelerates oxidation of lipids, which reduces the shelf life (period of time the product is stable after production). To prevent oxidation, it is also good to use hermetically sealed or airtight containers and the containers filled as much as possible so the amount of oxygen in the container is substantially minimized. The shelf life of locally made RUTF without airtight (or hermetically sealed) packaging is 3 to 4 months. When RUTFs are packaged in airtight or hermetically sealed foil envelopes under nitrogen atmosphere (devoid of oxygen), their shelf life can be extended to 2 year (24 months).

Composition of RUTF: There may be errors during the mixing process, which may result in RUTF with a substantially different nutrient content. These are best avoided by carefully training the workers mixing the foods, use of convenient ingredients measures for RUTF batches and intermittent compositional testing of RUTFs. Measuring a single mineral, such as zinc, potassium, by atomic absorption (AOAC, 2000) is reliable, inexpensive way to monitor vitamin and mineral content, since minerals are added as premix product. If an atomic absorption spectrophotometer (AAS) is unavailable, a colorimetric assay for Vitamin C may be substituted (Arya *et al*., 1998). Measuring fat and protein contents guarantee that other ingredients are being added in appropriate quantities.

Quality control (QC) is achieved by adopting standard operating procedures that are accepted internationally as the standards for production of food, the Hazard Analysis Critical Control Point (HACCP) and the Codex Alimentarius Program. These procedures prescribe storage of ingredients, raw material procurement, mixing of ingredients, and the storage of finished products. In addition to internationally accepted standards, every country has Bureau of Standards that regulates the production of food. The Bureaus also conduct inspections of factories, prescribe operating standards, and issue licenses to produce food (Mark, 2005). Product testing is used to verify and authenticate the quality of the production process, and have to be done with all large batch of finished products, certainly every week. In Malawi, the finished product is tested every week for contaminating microbes (salmonella, total flora of aerobic mesophilic bacteria, staphylococcus, coliforms, mold, *E. Coli*, yeast), product composition (fat, potassium, and protein), and aflatoxins. Testing is best locally done so that it could be used to identify the lapses in production quality in timely manner. RUTF batches should not be sent to the consumers without verification of the quality of the product. Almost

every country has laboratory associated with its Bureau of Standards that may conduct the independent testing. Waste from the production of RUTF should be managed and properly disposed as recommended by Awuchi and Igwe (2017).

3.5. Formulations of RUTFs without milk and/ or the vitamin and mineral premix

The nutrient composition of the RUTF is similar to the F-100, the standard milk-based formula demonstrated to be very effective in treatment of severe childhood malnutrition. RUTFs contain significant amounts of milk powder that has traditionally been successfully used in re-feeding malnourished children, especially those under age of 5 years. Similar nutrient compositions to the current RUTFs can be achieved without milk or milk products, and these formulations maybe less costly to produce, but provide the required nutrients for individuals with SAM or PEM. To date these recipes have been produced in laboratories and the kitchens on a small scale. The soy based spread, which is highly fortified with minerals such as iron, was tested to prevent stunting and anemia in a few hundreds Saharawi children with aged 3 to 6 years and was found well effective and accepted (Manary, 2006). It has been shown that these alternative recipes and ingredients can be mixed effectively, that they are palatable and pleasant and the nutrient composition made similar to F-100 (Manary, 2006). Effectiveness trials of alternate formulations of RUTFs in the treatment of the severe childhood malnutrition or SAM are required before they may be considered as substitutes for milk-based RUTF. One area of concern is the high levels of anti-nutrients and indigestible carbohydrates in alternative formulations in which the milk powder is replaced by the legumes to provide proteins in the recipes. Their low content of absorbable and utilizable phosphorus is also a concern. It is quite likely that adapted mineral supplement may compensate for the poorer bioavailability of added minerals in the food mixtures containing the legumes, but comparative trials are required to test this alternative. The only vitamins and minerals premix that there has been some substantial experience with has 18 micronutrients (vitamins and minerals) and is formulated by single producer in Europe, called Nutriset. Given the quantities, diversity, and range of the micronutrients required for RUTFs, there is a no reliable combination of locally available micronutrients (vitamins and minerals) rich foods suitable for producing RUTFs that could supplant this commercial product (Mark, 2005). Notably, water containing foods cannot be used to prepare the recipes for RUTF, which precludes use of mineral rich foods such as organ meat, leaves, meat, fruit and vegetables, unless previously dried. Thus local production of RUTF is always likely to need the import of a specialized micronutrients (vitamins and minerals) premix. Other commercial sources of suitable micronutrient mixture for RUTF are likely to surface as there is increasing demand for this product.

3.6. Dietary method of treatment of children with SAM/PEM

The standard treatment of malnutrition in childhood is administered in two phases. The phase one usually deals with the children who are severely malnourished (SAM) and as a result very ill. The therapy used in this phase one is F-75, a milk-based beverage or liquid food containing moderate amounts of protein and energy (0.9 g protein/100 mL and 75 kcal/100 mL) and the administration of the parenteral antibiotics (Ciliberto *et al.,* 2005). When an improvement in the appetite of the child and clinical condition is observed or detected, the child is entered into

the second phase (phase two) of the treatment. The second phase uses the F-100. The F-100 is specially formulated, high-protein, high-energy (2.9 g protein/100 mL, 100 kcal/100 mL) milk-based liquid food (Ciliberto *et al.,* 2005). The child is in second phase until he/she is no more wasted [WHZ (weight-for-height z score) 2] (Ciliberto *et al.,* 2005).Phase two begins while the child is still at the hospital but is often completed when the child goes home. The parents are then responsible for feeding the child flour supplement made of legumes and cereal as a replacement for milk-based foods used in the first and second phases (Ciliberto *et al.,* 2005).Ready to use therapeutic food (RUTF) within the individual's home for the treatment of severe acute malnutrition (SAM) in children under the age of five years may be effective at improving recovery and weight gain when compared to the alternative dietary approaches (Schoonees *et al.,* 2019).

The WHO's standards for treatment of malnutrition in children stipulate the use of two formulas (F-75 and F-100) during initial treatment. These formulas contain mixture of sugar, powdered milk, and other ingredients designed to give an easily absorbed mix of the carbohydrates and essential micronutrients (vitamins and minerals). They are usually provided as powdered mixes which can be reconstituted with water. The World Health Organization recommends the use of these F-75 and F-100, with the gradual introduction of some other foods, until the child reaches a normal weight (WHO, 1999).RUTF also serves this purposes.

3.7. Effectiveness

Ready to use therapeutic food (RUTF) within the individual's home for the treatment of severe acute malnutrition (SAM) in children under the age of five years may be effective at improving recovery and weight gain when compared to the alternative dietary approaches (Schoonees *et al.,* 2019). The effectiveness of RUTF on overall mortality or on potential relapses is not clear (Schoonees *et al.,* 2019).As of 2013, Plumpy'nut was used to relieve malnutrition in many African children, gaining approval as therapeutic food from the WHO (Morrison, 2013).

Examples

- BP-100, a nutrient-fortified wheat-oat bar designed to provide similar nutritional profile to F-100 by World Health Organization
- Citadel spread, a paste of peanuts, sugar, milk powder, and oil in use since 1971
- K-Mix 2, a high energy food, made by UNICEF in the 1960s
- Medika Mamba, a therapeutic food enriched with peanut butter produced and distributed by the Meds and Food for Kids, Haiti since 2003
- Nutribun, a fortified bread product made by USAID and distributed under Food for Peace program
- Plumpy'nut, a solid RUTF, produced in France since 1996 for the treatment of severe acute malnutrition

4. Conclusion

Malnutrition is a condition that caused by eating a diet in which either one or more nutrients are not enough or are very much such that the diet causes health problems and leading to preventable nutritional diseases, particularly in severe acute malnutrition. Some of

the effects of malnutrition include kwashiorkor, marasmus, stunting, increase susceptibility to infection, scurvy, rickets, hypoglycemia, moon face, pale conjunctiva, Bitot's spots, anemia, angular stomatitis, cheilitis, glossitis, spongy bleeding gums, etc. Malnutrition can be undernutrition or overnutrition; undernutrition is of more grave concern than overnutrition. It can affect individuals of all ages, but especially children under five years of the age. Major causes of malnutrition are poverty and food prices, dietary practices, agricultural productivity, etc., with many individual cases being mixture of many factors. Clinical malnutrition, e.g. cachexia, is also a major burden in developed countries. Malnutrition can be a result of health issues such aschronic illness, gastroenteritis, especially HIV/AIDS pandemic. Diarrhea and other infections may cause malnutrition through decreased absorption of nutrients, decreased intake of food, increased metabolic requirements, and direct nutrient loss. Mortality due to malnutrition was responsible for 58% of the total mortality in 2006: Approximately 62 million people globally, all causes of death combined, die every year. One in twelve individuals worldwide is malnourished and one in four of the children worldwide are chronically malnourished. Food and nutrition security, economic improvement, world population restriction, food sovereignty, improving health facilities, education, and breastfeeding are the major ways to prevent malnutrition. One major way to mitigate undernutrition is by the use of Ready-to-use therapeutic foods (RUTF). Therapeutic foods are designed for specific, often nutritional, therapeutic purposes as form of dietary supplements. The primary instances of therapeutic foods are used in emergency feeding of malnourished children and to supplement the diets of individuals with special nutrition requirements, e.g., pregnant women, the elderly, etc. Ready-to-use therapeutic foods are fortified, high energy, ready-to-eat foods suitable for the treatment of children with severe acute malnutrition. These foods should be soft or crushable and should be easy for young children to consume without any further preparation. At least 50%of the proteins contained in the foods should come from milk products. RUTF does not require preparationin any way prior to consumption. This makes it practical for use where cooking facilities and fuel are limiting constraints.

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