Food Chemistry 140 (2013) 843–849

Contents lists available at SciVerse ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

State of the art of Ready-to-Use Therapeutic Food: A tool for nutraceuticals addition to foodstuff

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ARTICLE INFO

Article history:
Available online 12 November 2012

Keywords:
Therapeutic food
Ready-to-Use
RUTF
Severe acute malnutrition
Foodstuff
Nutrients
Functional food
Nutraceuticals

ABSTRACT

Therapeutic foodstuff are a challenge for the use of food and functional food ingredients in the therapy of different pathologies. Ready-to-Use Therapeutic Food (RUTF) are a mixture of nutrients designed and primarily addressed to the therapy of the severe acute malnutrition. The main ingredients of the formulation are powdered milk, peanuts butter, vegetal oil, sugar, and a mix of vitamins, salts, and minerals. The potential of this food are the low percentage of free water and the high energy and nutritional density. The high cost of the powdered milk, and the food safety problems connected to the onset of toxigenic moulds on the peanuts butter, slowed down considerably the widespread and homogenous diffusion of this product. This paper presents the state of the art of RUTF, reviews the different proposed recipes, suggests some possible new formulations as an alternative of novel recipes for this promising food.

1. Introduction

Data published by the Food and Agriculture Organization of the United Nations (FAO) relative to the trend of the hunger in the world from 2006 to 2009 are worrying: the number of individuals that suffer hunger increased of about two hundred millions, increasing from the about 850 millions in the year 2006 to almost one billion and fifty million in the year 2009. These data were partially modified in the year 2010, when the number of people suffering hunger in the world decreased to about one billion (Food and Agriculture Organization (FAO), 2010). It is also relevant to mention that children aged between zero and five, have a greater food need, due to both a greater energy and nutritional requirements, and to an immune system not completely developed yet. According to the (World Health Organization (WHO, UNICEF, & SNC, 2005)) and the United Nations Children's Fund (UNICEF, 2009) reports, about one hundred and fifty million of children from zero to five years are deeply underweight. Among these, about sixty millions are emaciated and/or are affected by various stages of malnutrition (World Health Organization, 2007; WHO, UNICEF, & SCN, 2006). About twenty millions suffer from severe acute malnutrition (SAM). The nutrients lack influence negatively all the body functions, dragging the individual to serious pathological conditions, e.g. edema, and death (World Health Organization, 2009). The fourth Millennium Development Goal (MDG), proposed to beat down of two third the mortality of the children under five years of age, in the time period from 1990 to 2015 and, although the good results achieved lately, the full achievement of the objective seems yet to be very far (Food and Agriculture Organization (FAO), 2010). The main factor that determined the failure of the interventions, in the last years is mainly due to the food used as approach to fight the malnutrition. Flour based foodstuff enriched of cereals and legumes, so far elective and preferred by the Governmental Organizations, are inappropriate with respect to some main problems that affect the most depressed areas of world, like the sub-saharian Africa and the southeastern regions of Asia. In these areas it should be taken into account, for example, the high environmental temperatures that favour the microbial proliferations in the food to be prepared or already cooked. Moreover, the water available to cook any food is often contaminated. It should be necessary to consider also that the populations insisting on these geographic areas of the world share culturally common practises of sharing foodstuff, being unaware of the most elementary rules of a correct hygienic routine. The onset in the last years of a new type of product called Ready-to-Use Therapeutic Food (RUTF) seemed to be a breakthrough for these problematic situations. This novel food mainly consists of peanuts, and is enriched with sugar, powdered milk, vegetal oil, vitamins, and mineral salts. Its peculiarity are: an high energy density (about 540 kcal/100 g), a complete nutritional contribution with mineral salts, vitamins, amino acids, and essential fatty acids, and a prolonged shelf-life with respect to

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http://dx.doi.org/10.1016/j.foodchem.2012.10.098

other products (up to 24 months due to the low percentage of water). Another major advantage of the RUTF composition is the possibility to use it on site within therapeutic programs, e.g. directly at home without the need to go to hospitals or to nutritional therapy centres for a proper use of this food. The RUTF, however, has also some problems. In the first place, the peanut butter can be contaminated by aflatoxins, carcinogenic molecules produced from *Aspergillus flavus* and *Aspergillus parasiticus* species toxigenic fungi, especially favoured when the cereals carioxides are not properly handled or stored (Awad, Ghareeb, & Böhm, 2012). Moreover, the presence of the powdered milk influences heavily (almost for one third) the final cost of the RUTF and, considering the price growing tendency of the raw material, in a few years the economical sustainability of this food would be compromised (UNICEF, 2009). For the above mentioned reasons, the scientific community should pledge itself in the development of new formulated RUTF, to reach higher safety standard and a proportional economic sustainability for the depressed areas where such product is destined. This paper is addressed to review and assess the available information, and to give some operating clues to try to give a strong stimulus for the search of alternative RUTF formulations that can include also nutraceutical compounds (Espín, García-Conesa & Tomás-Barberán, 2007) from vegetal origin (Wang & Weller, 2006), specifically addressed to health condition support and therapy. Nutraceuticals from natural sources have been investigated for their putative chemopreventive and cancer therapeutic properties for the last few decades. The interest in these compounds is in part due to their pleiotropic effects and relatively non-toxic nature and have recently become a hot topic for the commercial world and the biomedical community (Das, Eshani Bhaumik, Raychaudhuri, & Chakraborty, 2012). It is postulated that nutraceuticals are relatively non-toxic food supplements with many health benefits including prevention of cancer (Go, Harris, & Srihari, 2012). These aspects make them particularly appealing for the inclusion in RUTF formulations addressed to specific therapeutic use when needed.

2. RUTF: a new concept in food therapeutics

Since 1990, the need of a complete food necessary for underweight patients treatment stimulated the research of new formulations to fit the requirements of an high nutritional value food, easy to use and store and with minor risk due to possible contaminations and altering (Guimon & Guimon P., 2009; Hendricks, 2010). In 1997, Andrè Briend of the *Institut de Recherche pour Développment* of Parigi (France) and Michel Lescanne, of the *Nutriset* specialized in the field of nutritional food, prepared a cream enriched with nutrients to be used for the malnutrition acute syndrome in infants. This product a semi solid cream containing powdered milk, vegetal origin lipids, peanuts, sugar and minerals mixed with vitamins called Plumpy' Nut®, from the combination of two words: plump and peanut. This first prototype looked like a chocolate bar and had a composition similar to the therapeutic F-100 milk (100 kcals per 100 mL and high in energy, lipids, and protein content). The product was Ready-to-Use, did not need any preparation or cooking, and could be stored and consumed even with high outside temperatures. The bars however had an unpleasant taste when added with salts and vitamins, and had a low melting temperature (Guimon & Guimon, 2009).

In 2001, two years after the original idea development, the company Nutriset (http://www.nutriset.fr) started to produce this foodstuff and, at the same time, started a franchising market, transferring the production know-how of the Nutriset to industries directly operating in the Countries needing the product (Guimon & Guimon, 2012). The Plumpy' Nut® can be considered a typical RUTF. It is packaged in 92 g single unit packages, and has butter bar like aspect. The main ingredients are peanut butter, flour, sucrose, vegetal origin lipids, skimmed powdered milk, mineral salts and vitamins (A, C, D, E, B1, B2, B6, B12, biotin, folic acid, pantotenic acid, and niacin). Due to its high energetic content, about 500 kcal per 92 g package, this food allows to gain weight very fast, up to 500 g per week, as it would be necessary for a child to be treated for underweight pathology due to malnutrition (Nutriset, 2010). The daily dose to administer is about 200 kcal/kg per person, till the normal weight taking into account the age is achieved. Normally this happens in a 6–10 week time.

Table 1 reports the energetic-nutritional content and nutrients levels of the Plumpy' Nut®. The macronutrients average content can be indicated as lipids 36%, proteins 14%, carbohydrates about 43%. The biggest advantage of this foodstuff is that it does not need to be diluted with water and can be consumed directly from the envelope without the need to touch and possibly contaminate the content of the bag. Moreover, it can be stored for limited time for a subsequent use even if the bag has been previously opened. The extended shelf-life, about 24 months, as derived from manufacturing data (Nutriset, 2010), and the relatively small dimensions of each package make this product very easy to stock.

2.1. RUTF main components

Powdered milk is the main ingredient for the RUTF formulation. Even if milk sources are available worldwide, often this food is imported mainly in areas where cattle is difficult to breed. The normally adopted production techniques of long life powdered milk allow to guarantee its safe use to produce RUTF. Different vegetal oils could be used in the formulation, e.g. soy oil, cottonseed oil, colza or maize seeds oil. Considering however the balance of the essential fatty acids, the colza and soy oils seem to be the better ones in the RUTF formulations. Brown or refined fine powdered commercially available sugar (sucrose) can be used in the RUTF production. To facilitate the incorporation of the sugar particles in the fatty part of the RUTF the sucrose particles dimensions should be carefully controlled and stay below 200 μm. Peanut butter is obtained from high temperature toasted peanut seeds grinded without oil and with no addition of salt or preserving agents. Minerals and vitamins are added to the formulations as a complex of minerals and vitamins (CMV). The mixture of powdered vitamins and salts is the same used in the preparation of the F-100 milk. The CMV mixture it is usually the only imported main ingredient in the case of local production of the RUTF, while every other ingredient can be obtained from the local market, and mixed in the proportions according to the formulation to realise. The average composition (w/w) of a RUTF is 30% powdered whole milk, 28% powdered sucrose, 15% oil of vegetal origin, 25% peanut butter and 1.6% of CMV (Manary, 2006). From data reported in Table 1 it can be observed that the amount of each nutrient contained in the RUTF is higher with respect to the recommended daily allowance (RDA). This aspect is crucial as previously mentioned, when there is need to supplement the daily diet.

Table 2 reports the vitamin and mineral composition of the CMV complex on a 100 g basis. It can be observed that since the RUTF formulation are added usually with 1.6 g of the vitamin complex (Collins & Henry, 2004), the amount of vitamins and minerals supplemented is way above the RDA. Available data however do not refer to the same age group, making difficult to compare all available information. A relevant problem is connected to the raw products used. There could be a contamination risk due to the wrong manipulation of the raw materials, control programs in the production line should be implemented and monitored.

Table 1
Energetic, nutritional content and chemical composition of Plumpy' Nut® referred to 100 g (Dube et al., 2008). Values calculated and relative to a 92 g package (dose bag) are reported for reference. RDA, recommended daily intake, is referred to 1–3 age child (World Health Organization and Agricultural Organization of the United Nations, 2004).

Nutrient	RUTF		RDA		% RDA ref. 92 g
	In 100 g	In 92 g	RDA	% RDA ref. 100 g	
Energy (kcal)	545	500			
Proteins (g)	13.6	12.5			
Lipids (g)	35.7	32.8			
Carbohydrates[a] (g)	43.48	40.06			
Calcium (mg)	320	294	500 mg/day	64	59
Phosphorus (mg)	394	362	–	–	–
Potassium (mg)	1,111	1,022	–	–	–
Magnesium (mg)	92	85	60 mg/day	153	141
Sodium (mg)	189	174	–	–	–
Iron (mg)	11.5	10.6	0.27 mg/day	4,074	3,926
Zinc (mg)	14.0	12.9	4.1 mg/day	341	314
Copper (mg)	1.78	1.63	–	–	–
Iodine (μg)	110	101	72 μg/day[b]	152	140
Selenium (μg)	3.00	2.76	17 μg/day	17	16
Vitamin A (mg)	0.91	0.84	400 μg/day	227	210
Vitamin D (μg)	16.1	14.7	5 μg/day	320	294
Vitamin E (mg)	20.1	18.4	2.7 mg/day[c]	740	681
Vitamin C (mg)	53.0	48.8	30 mg/day	176	162
Vitamin B_1 (mg)	0.6	0.55	0.5 mg/day	120	110
Vitamin B_2 (mg)	1.8	1.65	0.5 mg/day	360	330
Vitamin B_6 (mg)	0.6	0.55	0.5 mg/day	120	110
Vitamin B_{12} (μg)	0.53	0.48	0.9 μg /day	58	53
Vitamin K (μg)	21	19	15 μg/day[d]	140	126
Folic acid (μg)	210	193	150 μg/day	140	129
Calcium pantotenate (mg)	3.1	2.8	2 mg/day	155	140
Biotin (μg)	65	60	8 μg/day	812	750
Niacin (mg)	5.3	4.8	6 mg/day	88	80
Water (g)	<5[e]	<4.6[f]	–	–	–

[a] Value calculated as a difference between 100 g of product, water and total dry residue.
[b] RDA (Recommended Daily Allowance) value (6 μg/day/kg) has been considered with reference to a 12 kg weight child.
[c] Value referred to a newborn child.
[d] Value referred to a 2 years old child.
[e] Data reported by Collins and Henry (2004).
[f] Value referred to 92 g based on data available (Collins & Henry, 2004).

Table 2
Minerals and vitamins complex (CMV) composition, referred to 100 g (Manary, 2006). RDA, recommended daily intake is referred to 1–3 age child (World Health Organization and Agricultural Organization of the United Nations, 2004).

Ingredient	Quantity (mg)	RDA
Vitamin A	57	400 μg/day
Vitamin D	1	5 μg/day
Vitamin E	1,250	2.7 mg/day[a]
Vitamin K	1.30	15 μg/day[b]
Vitamin B_1	37.5	0.5 mg/day
Vitamin B_2	116	0.5 mg/day
Vitamin B_6	37.5	0.5 mg/day
Vitamin B_{12}	110	0.9 μg/day
Vitamin C	3,300	30 mg/day
Biotin	4.1	8 μg/day
Folic acid	13	150 μg/day
Niacin	332	6 mg/day
Pantotenic acid	194	2 mg/day
Potassium	36,000	–
Magnesium	587	60 mg/day
Iron	704	0.27 mg/day
Zinc	717	4.1 mg/day
Copper	92	–
Iodine	5	72 μg/day[c]
Selenium	1.54	17 μg/day

[a] The reported value refers to a newborn child.
[b] The reported value refers to a 2 years old child.
[c] The reported value has been calculated considering the iodine RDA (6 μg/kg/day) reported for a 12 kg weight child (World Health Organization and Agricultural Organization of the United Nations, 2004).

2.2. RUTF production

The RUTF is normally a biphasic system constituted by a water-soluble component part and an hydrophobic phase (emulsion water/oil). The main ingredients used in a typical formulation usually must go through a pre treatment before the RUTF can be prepared. Fig. 1 indicates a flow diagram of the steps involved in the production process. Nuts or cereals to be used are heated in a roaster at a temperature of approximately 160 °C for 40–60 min. This is followed by grinding them into smaller particle sizes in a grinder such as a hammer mill. Skimmed milk powder, the ground peanuts or cereals, vegetal oil, powdered sugar, the minerals and vitamins are then blended in a planetary mixer with less than 0.1% emulsifiers and anti-oxidants. The paste is then homogenised to further reduce particle size (<200 μm) and is then packed. The shelf life of RUTF paste can be extended to 2 years by nitrogen-flush packaging, which has been shown to extend shelf lives of milk products (Lloyd, Hess, & Drake, 2009).

The mixing procedure is crucial to obtain the emulsion. Lipids are present as a high viscosity liquid phase that contains micro dispersed proteins, carbohydrates, vitamins and minerals. The stirring of the lipid component in presence of a mild heating is preliminary to the slow addition of the other powdered ingredients under stirring. The dimension of the particles should be about 200 μm, and an high speed stirring would be advisable to better homogenise the mixture. This way the natural separation process of the emulsion during a long storage time, is considerably slowed down (Black, Pahulu, & Dunn, 2009). The final packaging is realised using

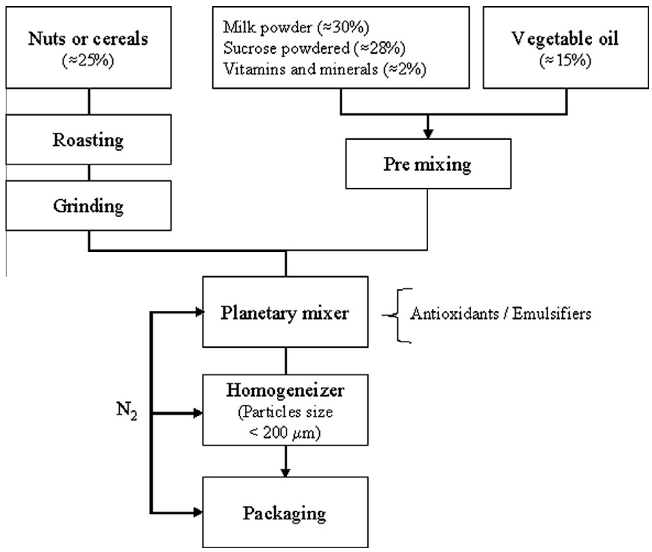

Fig. 1. Flow diagram illustrating the relevant steps involved in the RUTF production process.

industrial type funnels or mechanic devices (Manary, 2006). Depending on the production requirements, different machines and different process schemes can be adopted. A standard mixer similar to the ones used in bakeries, can be used, and allows to process up to 25 kg of RUTF per work cycle. The rotating speed of 105 rpm and the adding of the ingredients directly in the mixer allow to obtain an homogeneous product. Air is eliminated with a cutter Z shaped in the mixer. Usually sugar, powdered milk and the CMV are pre mixed before being added to the mixer device to obtain a better homogenisation and increase the contact between ingredients. An industrial process scheme could be to premix at a 105 rpm speed for 6 min, then mixing at 210 rpm for 6 min, and finally mixing at 350 rpm for 6 min. The time and speed of mixing can lead to obtain a homogeneous mixture and prevent the ingredients to separate during the storage. The obtained RUTF can be packaged in 250 mL plastic bottles (Manary, 2006) corresponding to one single day need of a child with severe acute malnutrition (SAM).

For weekly production in a range from 500 to 1500 kg, the machinery adopted can be different. A typical industrial mixing/packaging machine can allow to process higher quantities of RUTF.

For productions greater than 3000 kg/day, large scale mixer are used with a capacity from 200 to 500 kg and an automatic packaging system is adopted. Continuous flow process can be adopted for greater productions adopting also an automated packaging under nitrogen flow to prevent oxidation of the lipid component of the mixture (Manary, 2006).

The main aspect that requires attention during the manufacturing can be linked to the need of importing some necessary ingredients. This could determine risks connected to the safety of the product, due to the possible contamination of the imported products, e.g. when stored under inappropriate conditions. Other problems can derive from the oil used, e.g. vegetal oils, that can easily undergo oxidation and degradation when exposed to high temperatures. Moreover the storage of locally produced peanuts used in the RUTF formulation in non safe conditions can increase the contamination risk connected to the presence of aflatoxins (Bakırdere et al., 2012; Barberis, Dalcero, & Magnoli, 2012).

2.3. Technological aspect of the RUTF emulsion

RUTF can be considered a semi solid cream that, if compared to the common wheat or powdered foodstuff, e.g. milk, has a lower external contact surface with air oxygen, and lower humidity. The external contact surface diminishes with the increase of the quantity and particles dimensions (Briend, 2001). The powder dispersion in the lipid part can protect the vitamins from oxidation by coating the molecules and eliminating any possible contact with air and humidity that could causes the oxidation. RUTF does contain water, but in an amount <2%, differently from wheat for example where water content is in a range from 8% to 12% (w/w). For this reason, minerals water soluble contained in the RUTF formulations in form of salts, are prevented from reacting with vitamins, and hence the shelf life of the product is increased. The low water content is also important to prevent contaminant microorganisms to develop on the peanut butter or cereals used as main RUTF ingredient. *Escherichia coli* for example cannot develop even at a temperature of 40 °C in this product, and, has been observed that also if it is present after artificial inoculation, tend to diminish with time (Briend, 2001).

The lipid part of the product contributes to hide the unpleasant taste given by minerals like magnesium, and contribute to give the product a more pleasant taste. Moreover, the low soluble saline constituents do not form precipitates, and this way there are no or solid part inside the formulation. Nuts contains low amounts of the amino acid lysine, and for this reason soy wheat is added balancing for the content of this amino acid. However, it is also considered that soy cannot be added in high quantities, since it is rich in phytates, substances well known for their minerals bio availability preventing action (Briend, 2001; Weaver & Srimati, 2001).

The lipids added to the foodstuff need to be carefully chosen since the melting temperature depends mainly on the lipids composition. High melting point lipids are preferred to prevent the separation of the components of the RUTF during the storage at room temperature (Nestel et al., 2003). Anti oxidant substances e.g. tocoferols and L-ascorbilpalmitate, are generally added to the RUTF (Nestel et al., 2003) to better stabilize the final product. Particle dimension of the oil emulsion are crucial for the stability of the emulsion (McClements and Decker, 2000).

Proteins can act as antioxidant agents with respect to the free radicals action control, and to the chelating metals action, but also have a key role as emulsion forming agents and this way stabilizing the product structure (Nestel et al., 2003). In particular, the bioavailability of iron, could be lowered by interaction with proteins, whereby it is carefully considered by increasing the free iron content in the formulation or by micro incapsulating the metal. As an example, maltodextrin and lipophilic compounds that form complexes can protect also other ingredients and, at the same time, can also improve their optimum release and consequently their bioavailability (Nestel et al., 2003).

3. RUTF quality assessment and regulations

In principle, the bigger and more complex is the plant, the easier is to implement control systems on the production line. The exact composition of the final packaged RUTF is crucial, and frequent analyses are required to check and control the right composition. Different aspects need to be taken into account; the main one is constituted by the ingredients, by their origin and by their initial composition. A proper storage and handling are extremely important in the whole process especially in Countries where the production of RUTF is realised.

The possible microbial contamination even if the RUTF is intrinsically microbiologically safe for its composition must be considered. The areas where the RUTF is produced and packaged must be kept dry and clean and contact with water should be avoided carefully in every production step. The presence of water increases

Table 3
Microbiological criteria for finished product (powder); *n* is the number of samples, *c* is the maximum number of defective sample unit (2-class plan); *m* is the microbiological limit which separates good quality for defective quality. (Codex Alimentarius, 2008).

Microorganism	Class plan 2		Limit
	n	*c*	*m* (g)
E. sakazakii	30	0	0/10
Salmonella subsp. enterica	60	0	0/25

Table 4
Criteria of process hygiene; *n* is the number of sample that conform to the criteria; *c* is the maximum number of defective sample unites in a two class plan or that separates good quality from an acceptable quality in a three class plan; *m* is the microbiological limit which separates good quality for defective quality in a two class plan; *M* is the microbiological limit separating good quality from acceptable quality in a three class plan. CFU, colony-forming units (Codex Alimentarius, 2008).

Microorganism	Class plan	*n*	*c*	Limits	
				m	*M*
Mesophilic aerobic bacteria	3	5	2	500 CFU/g	5,000 CFU/g
Enterobacteriaceae	2	10	2	0/10 g	Not applicable

the possible onset of moulds and bacteria, increasing the possibility of the foodstuff decomposition (Manary, 2006). The enteric pathogens possible contamination needs to be considered also, and so the possible milk contamination by *Salmonella*. Also the lipids and vitamins used in the production can go through oxidation phenomena that limit the shelf life of the product. Oxygen presence in storage tanks should be avoided. The temperature during the mixing favours the homogeneity of the RUTF but a temperature higher than 45 °C can increase oxidation of lipids and the thermo degradation of vitamins in the mixture modifying the initial design of recipe (Manary, 2006). RUTF should comply the regulations established by the Codex Alimentarius Commission (Codex Alimentarius Commission, 1981). The microbiologic safety and hygiene of the RUTF must follow the guide lines as described in the Codex Alimentarius (CAC/RCP 66 – 2008) with reference to the practise for powdered formulae for infants and young children. The Codex Alimentarius CAC/RCP 66 – 2008 regulation (Codex Alimentarius Commission, 2008) fix also the safety microbiological criteria for the final product and also the methods to adopt if the contamination of the product, e.g. by *Salmonella enterica subsp. Enterica* e *Enterobacter sakazakii* (*Cronobacter*). Any step of the production is assessed according to the reference criteria as determined by the current regulations (CAC/RCP 66-2008) and reported for reference in Tables 3 and 4. All the recommendations indicated and detailed in the advisory lists of nutrient compounds for use in foods for special dietary uses intended for infants and young children, CAC/GL10-1979, should be also be addressed (Codex Alimentarius Commission, 1979). Moreover, the HACCP (hazard analysis and critical control points) procedures must be complied as well as any specific regulations existing in the country where the RUTF is produced (World Health Organization, 2007).

4. The Aflatoxin contamination problem

Aflatoxins produced by fungi of the species *A. flavus* e *A. parasiticus* (Guo et al., 2012) are contaminants of crops and food. Among the about 18 different aflatoxins so far identified, the most important are the Aflatoxins G_1, G_2, B_1, B_2 and M_1. The maximum accepted levels for these secondary metabolites in Europe are fixed by the European Commission Regulation 1881/2006 (Commission Regulation EC, 2006) amended in 2010. Aflatoxin B_1 is considered the most toxic one and, unfortunately, is also the most commonly occurring. Aflatoxins can develop on cereals, nuts, and peanuts after the harvest before they are grinded. The semi-dry weather conditions in general can favour the onset and develop of micro fungi contamination by *A. flavus* and *A. parasiticus* on grains (Naik & Sudini 2011). There are many procedures adopted by the producers to guarantee a low content of mycotoxins on cereals, peanuts and also on other different foodstuff, e.g. control storage conditions (relative humidity <70% and temperature between 0 and 10 °C) or use of fungicides on field. The maximum level of Aflatoxin B_1 in a RUTF is fixed in 5 μg/kg by the Codex Alimentarius, while the total aflatoxin amount allowed is fixed in 10 μg/kg (Codex Alimentarius Commission, 2010). It can also be mentioned that the Codex Alimentarius fixes also the practises for prevention and reduction of aflatoxins contamination in peanuts and cereals (Codex Alimentarius Commission, 2004). The regulation of the Codex Alimentarius CAC/RCP 55 (2004) is specifically addressed to limit the possible develop of toxigenic fungi on peanuts and cereals, e.g. suggesting to maintain a water activity below 0.70 at a temperature of 25 °C, to be compared with pure water activity ($a_w = 1$) at the same temperature. Water activity is referred to the ratio p/p_0 where p and p_0 are the partial pressure of water above the food and a pure solution under identical conditions, respectively.

5. Cost and sustainability

In general, the cost of the RUTF is high. Usually these foodstuff are purchased by Government Organizations or Non Government Organizations, and distributed by the local governments. The cost is mainly influenced in the case of a local production by the availability of the ingredients and their cost on the local markets (Manary, 2006).

As an example, vegetal oil, peanut butter, and sucrose are relatively easy to find local resources, but powdered milk and CMW usually are imported, and the price can vary much depending on the market (UNICEF, 2009). According to data reported by Valid International (http://www.validinternational.org) and by the Clinton Foundation for Malawi (http://www.clintonfoundation.org) the 68% of the total cost for the RUTF is due to the cost of the ingredients and, among these, the powdered milk contributes itself for the 42%. Powdered milk according to these data accounts consequently for about the 29% of the total RUTF cost. A breakthrough in the RUTF production to cut the cost down could be the replacement of the powdered milk in the RUTF recipe as suggested by UNICEF (UNICEF, 2009).

The United Nations suggestion to treat SAM with RUTF would require about 258,000 tonnes of therapeutic food per year. In 2007 the production has been of about 19,000 tonnes and the purchased quantity has been of about 8500 tonnes. This means that only 3% of the children with severe malnutrition condition has been treated with these therapeutic food (Médecins Sans Frontières, 2010). The main problems that influence the market of the RUTF locally produced or imported could be indicated in the high cost of the ingredients due to the market prices always rising, the impossibility to improve the original patented recipe by Nutriset, and the difficulty to control the possible aflatoxins contamination of the local produced RUTF. The imported RUTF, e.g. Plumpy' Nut®, has an average cost of about 3 €/kg, comparable to the cost of the same RUTF produced locally, about 2.60 €/kg (Nutriset, 2010; UNICEF, 2009). The RUTF market is actually controlled by the Nutriset, and for this reason the Médecins Sans Frontières Organization (MSF) asked the Nutriset to give manifacturing licences to possible producers at favourable conditions (Médecins Sans Frontières, 2010), but to cut down the cost of this food alternative formulations are needed.

Table 5
Main ingredients, nutritional composition (per 100 g) and energetic content (%) of the alternative RUTF preparations. Composition of Nutriset Plumpy' Nut® is reported as reference. CMV is the vitamin minerals complex used; a_w is the water activity (Collins & Henry, 2004).

Energy/nutrient	Nutriset Plumpy' Nut®		Rice–sesame based recipe		Barley–sesame based recipe		Corn–sesame based recipe	
	(100 g)	Energy (%)	(100 g)	Energy (%)	(100 g)	Energy (%)	(100 g)	Energy (%)
Energy (kcal)	530		551		567		512	
Energy (kJ)	2,218		2,307		2,373		2,142	
Proteins (g)	14.5	11	13.8	10	14.1	10	13.4	11
Carbohydrates (g)	43	32	43	31	39.9	28	50.2	39
Lipids (g)	33.5	57	36	59	39	62	28.6	50
Starch (g)	4	–	4.3	–	3.9	–	4.9	–
Humidity (g)	<5	–	2.9	–	3.1	–	2.9	–
a_w	0.241		0.290		0.279		0.260	
Ingredient	Composition (%, w/w)		Composition (%, w/w)		Composition (%, w/w)		Composition (%, w/w)	
Toasted rice flour	–		20.0		–		–	
Toasted barley flour	–		–		15.0		–	
Toasted corn flour	–		–		–		33.4	
Peanut butter	25		–		–		–	
Powdered whole milk	30		–		–		–	
Soyamin 90	–		8.0		9.0		27.0	
Toasted sesame seed butter	–		29.0		27.0		25.0	
Sunseed oil	–		19.4		24.0		12.0	
Vegetal oil	15		–		–		–	
Sucrose (powdered)	28		22		23.4		15.0	
CMV	1.6		1.6		1.6		1.6	
Total	100.0%		100.0%		100.0%		100.0%	

6. Alternative RUTF

It would be advisable, based on the previous considerations, to develop new formulations that do not contain peanut butter and milk both to reduce the mycotoxin exposure risk and to increase the economic sustainability of local production. Alternative RUTF formulations have been proposed (Collins & Henry, 2004; Collins et al., 2006), and are based on four main ingredients: a cereal as the main ingredient, a protein source that can be of vegetal origin (beans, legumes, etc.) or animal origin (milk, red or white meat, fish meat, egg, etc.), a mineral and vitamin supplement (derived from vegetal, fruits, or a mixture of both), and an energetic supplement (e.g. lipids, oil, sugar, etc.). The main requirement for these alternative RUTF is to limit the water content of the preparation and the necessity that any preparation must be ready to use and does not require cooking or a procedure of any kind before consumption (Collins & Henry, 2004). Table 5 reports three alternative proposed RUTF formulations (recipes) that contain as main ingredient toasted rice, barley, and corn flours (Dube et al., 2008).

Cereals, legumes and oil rich seeds included in the proposed formulations have been tosted before grinding to make the flour since all commodities can contain high levels of phytates and anti nutritional compounds. The sunflower seed oil has been included in all the proposed preparations for its content in essential fatty acids n-3 (range from 0.3% to 2.5%) e n-6 (range from 3% to 10%). Table 5 reports also the nutritional parameters of the three alternative RUTF different formulations. It can be observed that are comparable to Plumpy'Nut® macro and micro nutrients composition reported as reference in the same Table 5.

Table 6 reports the main minerals levels in the RUTF formulation. Data relative to Plumpy'nut® are reported as reference. The main difference comparing the reported data is in value for iron quantity (Collins et al., 2006) that can be adjusted in the CMV composition. The balance among the different components of RUTF can be modified by changing the ratio and/or the combination between cereals, legumes and oil seeds and the mixture of vitamins and microelements. The need of a reduced water content is crucial and a useful evaluation parameter could be the water activity determination. Table 5 reports water activity for the RUTF. It can be observed that all the values are in the same range, conforming to the requirement of a low water percentage and activity. RUTF is a versatile foodstuff that in principle can be added with nutraceuticals from vegetal origin (e.g. antioxidants, vitamins, etc.) from commodities or wastes from food industry available in Countries where the RUTF can be manufactured, could be a benefit in term of reducing cost and improving the range of action of new RUTF formulations supplemented with active compounds specifically addressed to pathologic conditions both as supplementing or therapeutic agents.

Table 6
Composition of main minerals in the RUTF alternative formulation. Data relative to Plumpy'nut® are reported as reference (Collins & Henry, 2004).

Minerals	Plumpy' nut ® mg/kg	Rice–sesame based recipe mg/kg	Barley–sesame based recipe mg/kg	Corn–sesame based recipe mg/kg
Copper (Cu)	1.7	2.1	2.1	1.8
Zinc (Zn)	13	10.9	10.9	10.2
Calcium (Ca)	310	338.1	338.1	209.8
Sodium (Na)	<290	256.5	256.5	189.9
Magnesium (Mg)	86	118.4	118.4	119.1
Iron (Fe)	12.45	5.6	5.6	4.4

7. Conclusions

In the last ten years the RUTF made possible to intervene locally and establish the right therapy for the severe malnutrition in children in areas where there is need, like Africa or South-East of Asia. This foodstuff is ready to use, does not need to be diluted with water or juices or cooked before use. Its composition makes it resistant to microbial contamination and gives to it a great energetic and nutritional content, allowing to obtain a the fast weight gain in severe malnutrition cases. Nowadays the only manufacturer of this preparation is the farm Nutriset, that patented internationally the Plumpy' Nut®. This Company works with National and non Governmental Organization to sell its product and making it available. The main problem concerns the international patent that actually limit the possibility of other Companies or no industrialised Countries to produce this RUTF. It seems then urgent the need to propose and study new RUTF formulations alternative to the Plumpy' Nut® that uses cheaper commodities available in the Countries where the RUTF could benefit the resident population. Moreover it should also be stressed that has been estimated that more than 2 billion people worldwide suffer from micronutrient malnutrition, also called the "hidden hunger" characterised by deficiencies of vitamins and minerals. The poor health and loss of human potential that arise from micronutrient deficiencies have often been over-shadowed by protein-energy malnutrition, chronic hunger and starvation. Micronutrient deficient children fail to grow and develop normally. A sustainable, food-based approach needs to be adopted that has multiple nutritional benefits. Such an approach recognises that, in general, diets deficient in one micronutrient are also likely to be deficient in other nutrients as well, including macronutrients like protein, carbohydrates, and lipids. The basic need is to improve total dietary intakes and reducing the production costs. Efforts to deal with micronutrients providing supplements and even adding nutraceuticals from waste and by products of the food industry to new formulated RUTF are important measures, that could represent a valid substitute for a more comprehensive solution to hunger and malnutrition problem worldwide.

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