Local production and provision of ready-to-use therapeutic food (RUTF) spread for the treatment of severe childhood malnutrition

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Abstract

Background. *Ready-to-use therapeutic food (RUTF) spread has been shown to be very effective in the rehabilitation of severely malnourished children and facilitates home-based therapy of these children.*

Objective. *To describe how RUTF spread can be manufactured on a variety of production scales.*

Principles of production. *RUTF spread is an edible lipid-based paste that is energy dense, resists bacterial contamination, and requires no cooking. The primary production principles include grinding all ingredients to a particle size < 200 microns, producing the food without the introduction of water, and embedding the protein and carbohydrate components of the food into the lipid matrix. The most widely used RUTF spread is a mixture of milk powder, sugar, vegetable oil, peanut butter, vitamins, and minerals.*

Scale of production. *RUTF spread can be produced in quantities sufficient to treat several hundred children using a planetary mixer in a clinic. Production of larger quantities of RUTF spread can be achieved in partnership with local food companies. Production sufficient to meet the needs of several thousand children can be achieved with a dedicated production facility using technology appropriate for use in the developing world. Care must be taken to avoid aflatoxin contamination, and quality control testing of the product is essential.*

Conclusions. *RUTF spread can be safely and easily produced in small or large quantities in most settings worldwide. The local availability of the necessary ingredients limits its use in some settings, and further investigation of alternative ingredients is needed to overcome this limitation.*

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Introduction

Home-based therapy for severe childhood malnutrition has been successful in a variety of settings over the last 5 years [1]. The recent success of home-based therapy has been seen in conjunction with the availability of a novel food, a spread form of ready-to-use therapeutic food (RUTF) [2–5]. RUTF is a generic term including different types of foods, such as spreads or compressed products suitable for feeding severely malnourished children. Among RUTFs, spreads are prepared with a simple technology that has already been successfully transferred to developing countries with minimal industrial infrastructure. Hence, this paper will refer only to RUTF spreads, although other technologies could possibly be transferred to countries with more advanced industrial capacities.

The RUTF spread is made of powdered ingredients embedded in a lipid-rich paste, resulting in an energy-dense food that resists microbial contamination [6]. This RUTF is a mixture of milk powder, vegetable oil, sugar, peanut butter, and powdered vitamins and minerals. As the name implies, RUTF does not need to be prepared in any way prior to consumption, making it practical for use where cooking fuel and facilities are limiting constraints. RUTF has a very low water activity, and thus it is impossible for significant bacterial growth to occur in these foods [7]. This allows locally produced RUTF to be safely stored at ambient tropical conditions for 3 to 4 months. RUTF has a very high energy density, about 23 kJ/g (5.5 kcal/g). By consuming just a few spoonfuls of RUTF five to seven times a day, a severely malnourished child can achieve sufficient nutrient intake for complete recovery. RUTF must be consumed with water, but no other foods are necessary for the rehabilitation of the malnourished child.

Although the spread form of RUTF may not be the only therapeutic food that does not require cooking, it is the only one considered in this article, because it is the only one that has been locally produced in the developing world with the use of modest technologies. The term “RUTF” in this article refers specifically to the spread form of RUTF.

Production principles of RUTF

RUTF is a homogeneous mixture of lipid-rich and water-soluble foods. The lipids exist as a viscous liquid, and small particles of protein, carbohydrate, vitamins, and minerals are mixed throughout this liquid. In order to achieve a homogeneous mixture, a specific mixing procedure must be followed. The lipid elements of RUTF are first stirred and often heated; the powdered ingredients are then slowly added to the lipids during vigorous stirring. Once all the powdered ingredients have been added, the entire mixture is stirred at higher speeds for several minutes. As long as the powdered ingredients do not have a particle size that is larger than 200 μm, the mixture does not readily separate. When mixtures are made with larger particles, RUTF must be stirred briefly by hand just prior to consumption to temporarily suspend the large particles in the mixture. The use of oils that are liquids at ambient temperature facilitates the mixing process. RUTF can be packaged from factory bowls or funnels, by hand (by simply pouring it), or by using a mechanical device. Successful RUTF production has been achieved in Malawi, Niger, and Congo with the use of these principles.

Ingredients

The formulation of RUTF was derived from F-100 and uses the same ingredients, with the addition of peanut butter [8]. Peanut butter changes the physical properties of the food to those of a viscous liquid product instead of a powder. A typical recipe for RUTF is given in **table 1**.

Milk powder. Local supplies of milk powder exist throughout the world; however, the milk itself is often imported. Standard commercial techniques to produce milk powder yield a product that is suitable for RUTF production.

Vegetable oil. Several types of oil made by standard commercial methods may be used in RUTF, including soy oil, cottonseed oil, rapeseed oil, and corn oil. Rapeseed oil and soybean oil have the advantage of providing a good balance of essential fatty acids.

TABLE 1. A typical recipe for ready-to-use therapeutic food (RUTF)

Ingredient	% weight
Full-fat milk	30
Sugar	28
Vegetable oil	15
Peanut butter	25
Mineral–vitamin mix	1.6

Sugar. Commercial sources of granulated brown or white sugar can be used to make RUTF. The sugar must be ground into a fine powder, a product used in bakeries known as icing sugar or powdered sugar, to reduce the particle size to less than 200 μm.

Peanut butter. Peanut butter consists simply of peanuts that have been roasted and ground, without added oil, salt, or preservatives. In most areas of the world where peanuts are grown, there is a commercial food-processing company that makes peanut butter.

Powdered vitamins and minerals. This is a mixture of vitamins and minerals formulated to provide the same amount of micronutrients to the malnourished child as F-100, the standard therapeutic food. Currently it is available from a commercial supplier (Nutriset, Malaunay, France). The content of the mixture is listed in **table 2**.

The World Food Program (WFP) and UNICEF have donated ingredients for the production of RUTF in Malawi. The WFP has donated milk, sugar, and oil, and UNICEF has donated powdered vitamins and minerals. The RUTF is then used by projects supported and approved by these organizations.

TABLE 2. Mineral and vitamin contents of 100 g of powdered mix

Ingredient	Quantity
Vitamins	
Vitamin A	57 mg
Vitamin D	1 mg
Vitamin E	1.25 g
Vitamin K	1.30 mg
Vitamin B_1	37.5 mg
Vitamin B_2	116 mg
Vitamin B_6	37.5 mg
Vitamin B_{12}	110 mg
Vitamin C	3.3 g
Biotin	4.1 mg
Folic acid	13 mg
Niacin	332 mg
Pantothenic acid	194 mg
Minerals	
Potassium	36 g
Magnesium	587 mg
Iron	704 mg
Zinc	717 mg
Copper	92 mg
Iodine	5 mg
Selenium	1.54 mg

Scale of production

A mechanical mixer is required for all RUTF production. Although hand-mixing of the ingredients is possible for very small quantities, the quality of the product that is made by hand-mixing is so inconsistent that it cannot be reliably used.

The procedure and equipment used to mix RUTF depend on the quantities of RUTF needed. If a few hundred kilograms of RUTF are needed each week, small-scale production is possible. Small-scale production requires a small room dedicated to food production that is free of rodents and other pests. A 40-L planetary bakery mixer, such as the MacAdams SM 401, can be used to prepare the RUTF (**fig. 1**). Such mixers will mix a 25-kg batch of RUTF. The ingredients are added by volume to the batch. The containers used to measure the ingredients need to be carefully chosen and calibrated by accurately weighing the ingredients. Oil and peanut butter should be added directly into the mixing bowl and combined at a mixing speed of 105 rpm until homogeneous. The Z-shaped kneader blade, rather than a wire whisk device, should be used to minimize the amount of air included in the mixture. The sugar, milk powder, and mineral and vitamin mixture are first hand mixed as dry powders in a dedicated plastic drum and then emptied into the electric mixing bowl. The RUTF is then mixed at 105 rpm for 6 minutes, 210 rpm for 6 minutes, and 323 rpm for 6 minutes. These mixing times are necessary to ensure homogeneity of the RUTF and to prevent separation during storage. RUTF can be poured or hand-packed into plastic bottles containing 250 g, a typical daily dose for a malnourished child.

FIG. 1. Standard planetary bakery mixer

If 500 to 1,500 kg of RUTF is needed each week, production is best achieved by partnering with a commercial food-processing company that has machinery that can efficiently mix, grind, and package RUTF. This equipment is commonly found in industrial bakeries or pastry factories. Several planetary mixers or a larger-capacity customized barrel mixer can be used. Whole peanuts can be mixed in with the other ingredients, and this mixture is then run through the same grinder used to make peanut butter. A mechanical or pneumatic semiautomatic device that will fill a container with a prescribed amount can package the RUTF (**fig. 2**).

If more than 3,000 kg of RUTF is needed each week, an industrial production facility dedicated to RUTF will be required. This can be part of a larger food-processing company that has technical expertise in food production or an nongovernmental organization formed specifically for the purpose of making RUTF. The machinery required for large-scale production is custom-designed to mix batches of 200 to 500 kg and automatically package the product (**fig. 3**). Rather than typical "batch" production, the product can move continuously from the mixer to a grinder and then to a packaging device by the use of a series of mixing chambers. An operator is needed to add the ingredients to the initial mixing chamber and remove the final filled containers from the packaging device.

The scale of production will determine the methods of quality control and the cost. Quality control is more easily implemented at a lower cost with centralized, large-scale production. Economy of scale will come up for other aspects of RUTF production, and, if feasible, large-scale production should be considered as a long-term objective in countries where the level of severe malnutrition is high and where a sustained demand is likely. There are two resources that potential local producers can use to obtain technical assistance in establishing a production facility: Nutriset (Malaunay, France) and Valid International (Oxford, UK).

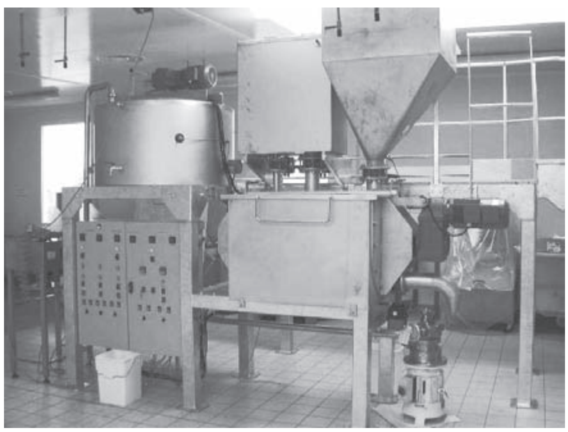

FIG. 2. Automatic packaging device for ready-to-use therapeutic food (RUTF)

FIG. 3. Single mixing and packaging unit for large-scale production of ready-to-use therapeutic food (RUTF)

Quality control

Choice of ingredients. Whatever scale of production is used, quality control is achieved by safe storage of the ingredients, adequate training and supervision of the production personnel, and testing of the product for composition and contaminants. Throughout the world, authorities set standards for food-production companies; those organizations involved in RUTF production should adhere to these standards [9]. The following are key issues in quality control:

Aflatoxin contamination. Aflatoxin is produced by an *Aspergillus* species of fungus that contaminates the peanuts after they have been harvested but before they have been ground into peanut butter. The fungus is ubiquitous; fungal growth can be curtailed by storing the peanuts in a cool, dry environment and can also be controlled by using chemical fungicides. Methods to prevent aflatoxin contamination have been described in detail elsewhere [10]. Peanuts should be purchased from a supplier that can ensure that steps to prevent contamination have been implemented during harvest and storage. Aflatoxin contamination is more likely in peanuts with black discoloration or with a shriveled, irregular appearance. Consumption of aflatoxin can result in hepatic oxidative stress and predispose to hepatic cancers. RUTF should conform to international standards for maximum aflatoxin content of 10 to 20 ppb [9]. Very high doses of aflatoxin can produce acute intoxication [11]. Moderate doses may depress child growth [12].

Bacterial contamination. The inherent microbiologic safety of RUTF allows it to be packaged under clean and dry, but not sterile, conditions. Care must be taken to prevent the introduction of water into RUTF during production. Increasing the water content of RUTF allows bacteria and mold to grow within the food, promoting product degradation and exposing the malnourished child to potential pathogens. Water is most likely to be introduced from residue left on the mixing bowls and containers after they have been washed. Therefore, it is better to limit the number of times the implements of production are cleaned with soap and water and to simply dry-wipe them clean instead. Typically, implements need to be cleaned with soap and water only once a week. If the containers in which the RUTF is to be dispensed are first washed, care should be taken to see that they are completely dry.

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

Prevention of oxidation. Oxidation of the fatty acids contained in the RUTF and of some vitamins, mainly vitamins A and C, is the main factor limiting the storage life of RUTF. During production, some preventive measures should be taken to avoid initiating the oxidation process [13]. Although it is helpful to heat the oils during the mixing process to achieve a homogeneous mixture, heating to temperatures over 45°C accelerates the oxidation of the lipids, which reduces the period of time that the product is stable after production (shelf life). To prevent oxidation, it is also better to use airtight containers and containers filled as much as possible so that the quantity of oxygen within the container is minimized. The shelf life of locally produced RUTF without airtight packaging is 3 to 4 months. When RUTF is packaged in airtight foil envelopes under a nitrogen atmosphere (devoid of oxygen), the shelf life can be extended to 24 months.

Composition of RUTF. Errors may be made during the mixing process, resulting in RUTF with a substantially altered nutrient content. Errors are best avoided by careful training of the workers who mix the food, the use of convenient measures for the ingredients of batches of RUTF, and periodic compositional testing of RUTF. Measuring a single mineral, such as potassium, by atomic absorption [14] is an inexpensive, reliable way to monitor the vitamin and mineral content, since the minerals are added as a premixed product. If an atomic absorption spectrophotometer is not available, a colorimetric assay for vitamin C can be substituted [15]. Measuring fat and protein content ensures that the other ingredients are being added in appropriate amounts.

Quality control is achieved by adopting operating procedures that are internationally accepted as standards for food production: the Codex Alimentarius [9] and the Hazard Analysis and Critical Control Point Program (HACCP) [16]. These procedures prescribe the procurement of raw materials, storage of ingredients, mixing of ingredients, and storage of finished product. In addition to international standards, every nation of the world has a Bureau of Standards that regulates the production of food. These bureaus also prescribe operating standards, conduct inspections of factories, and issue licenses to produce food. Product testing is used to verify the quality of the production process and should be performed on every large batch of finished product, and certainly every week. In Malawi, finished product is tested weekly for contaminating microbes (salmonella, staphylococcus, total flora of aerobic mesophilic bacteria, coliforms, *Escherichia coli*, yeast, and mold), aflatoxin, and product composition (fat, protein, and potassium). Testing is best done locally so that it can be used to identify lapses in production quality in a timely manner. Batches of RUTF should not be sent to consumers without verification of product quality. Almost every nation of the world has a laboratory associated with its Bureau of Standards that can conduct the independent testing.

Costs and sustainability

The primary costs associated with RUTF production are those of the ingredients, since the production process is relatively simple. Certainly the costs and availability of ingredients must be assessed at a local level. Reliable comparative cost data concerning RUTF production are lacking. The author has produced RUTF in Malawi from 2002 to 2005, and specific figures for Malawi are cited as an example. Currently in Malawi the costs of the ingredients per kilogram of RUTF are as follows: milk US$0.63, sugar US$0.17, peanut butter US$0.18, oil US$0.18, and vitamins and minerals US$0.26, for a total of about US$1.40/kg. These costs include the transport of the ingredients to the factory. The cost of packaging is also significant; in Malawi it is about $0.50/kg (in plastic bottles and cardboard boxes). Additional costs include labor, facility rental, and utilities. In Malawi the total cost of producing RUTF is about $2.60/kg. The cost savings that can be realized by local production are from reduced transport of ingredients and finished products and lower tariffs.

The cost of RUTF, even when it is locally produced, and even if some cost savings can be expected in the future with a modified recipe, is beyond the reach of the poorest families, among whom malnutrition is most prevalent. RUTF-based programs will be sustainable only if RUTF is purchased by social welfare programs supported by governmental or nongovernmental agencies. UN organizations, such as WFP and UNICEF, have donated ingredients in Malawi to lower the cost of producing RUTF, and this may be an option in other circumstances of crisis to make RUTF accessible to welfare programs.

The cost of the therapeutic food is just a portion of the total cost of rehabilitating a malnourished child. The expenses of maintaining inpatient units, staff to distribute the food and monitor the child's progress, and supplies needed to administer the feeding are considerable. It must be kept in mind that RUTF facilitates home-based therapy, which is less expensive than center-based therapy. Although the cost of RUTF may not be substantially less than that of foods used in center-based therapy (e.g., F-100), the overall cost of the therapeutic feeding endeavor may well be.

The notion that RUTF can be locally produced in circumstances of nutritional crisis is quite practical. The production process does not require large specialized machinery, nor do production workers require extensive training or skills that require a secondary school education. The advantages of local production in crisis situations are that production can be responsive to the dynamics of the crisis, and the amount of food produced can be controlled to meet the demands of the situation.

One notion about local production that is attractive is that locally grown peanuts, oil, and sugar can be purchased in the country in which they are being used and that this in some way will support the local economy. Although this is technically true, the economic impact of such local purchases is likely to be negligible, since the total amounts of peanuts, oil, and sugar used to make RUTF are not substantial when the scale of national agricultural outputs is considered.

This report considers only RUTF that is used for the treatment of childhood malnutrition. It is plausible, but not proven, that other formulations of RUTFs may prove very useful as food for malnourished HIV-infected adults, as supplemental food for vulnerable populations, and as complementary food for children at risk for the development of malnutrition. Local production of RUTFs for these other purposes could easily be done within the same factory using the same machinery. These potential other uses of RUTFs should be considered when establishing local production facilities, as several nutritional support programs may be supplied from one local production unit.

Formulations of RUTF without milk or the vitamin and mineral premix

The nutrient composition of RUTF is similar to that of F-100, the standard milk-based formula that has been demonstrated to be effective in the treatment of severe childhood malnutrition. RUTF contains significant amounts of milk powder, which has traditionally been used successfully for refeeding malnourished children. Nutrient compositions similar to that of the current RUTF could be achieved without the use of milk, and these formulations might be less costly to produce. To date these recipes have been made in laboratories and kitchens on a very small scale. A soy-based spread, highly fortified with iron and minerals, was tested for the prevention of anemia and stunting in a few hundred Saharawi children 3 to 6 years of age and was found to be well accepted and effective [17]. It has been demonstrated that these alternative recipes can be effectively mixed, that they are palatable, and that the nutrient composition can be made similar to that of F-100 [18]. Effectiveness trials of alternative formulations of RUTF in the treatment of severe childhood malnutrition are needed before they can be considered as substitutes for the milk-based RUTF. An area of concern is the high level of nondigestible carbohydrates and antinutrients in alternative formulations in which milk powder is replaced by legumes to provide proteins in the recipe. Their low content of absorbable phosphorus is also a concern. It is quite possible that an adapted mineral supplement could compensate for the poorer availability of added minerals in food mixtures containing legumes, but comparative trials are needed to test this option.

The only vitamin and mineral premix with which there has been any substantial experience has 18 micronutrients and is formulated by a single producer in Europe (Nutriset). Given the amounts, range, and diversity of micronutrients needed for RUTF, there is no combination of locally available, micronutrient-rich foods suitable for producing RUTF that can supplant this commercial product. Foods containing water cannot be used in RUTF recipes, which precludes the use of mineral-rich foods such as meat, organ meat, leaves, fruits, and vegetables, unless they are dried beforehand. Thus, local RUTF production is always likely to require the importation of a specialized micronutrient premix. Other commercial sources of a suitable micronutrient mix for RUTF are likely to emerge as the demand for this product increases.

Knowledge gaps and issues for future research

- » Alternative mineral and vitamin supplements adapted to RUTF prepared without milk need to be developed;
- » The effectiveness of recipes with a similar nutrient composition to that of F-100, but containing no milk, for therapeutic feeding of severely malnourished children needs to be evaluated;
- » The use and effectiveness of formulations of RUTF for supplemental feeding and other nutritional support programs need to be assessed;
- » Systematic cost comparisons and analyses of the different options of therapeutic feeding need to be performed;
- » Systematic cost comparisons of the different scales of production to meet local and regional needs for RUTF production need to be performed.

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