Innovations in Ready-to-Use Food Products to Address Acute Malnutrition in Low-Income Countries

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Fig. 1. A malnourished child receives RUTF through a UNICEF project in Burundi funded by Food for Peace.

Credit: USAID

Executive Summary

Ready-to-Use Therapeutic and Supplementary Foods (RUTFs/RUSFs) are transformative food-aid products to address acute malnutrition in different settings, especially during emergencies. These nutrient-dense, palatable pastes do not require preparation, benefit from a long shelf-life, and can be easily consumed. Commercial RUTF/RUSFs are made of peanuts, milk solids, sugar, vegetable oil, and a micronutrient premix. Improvements in the basic formulation, specifically on inexpensive, efficacious nutrient sources is a way to reach more children.

Food Science in Action

Bringing together food science and engineering is critical for the development of new products aimed at addressing acute malnutrition, especially during emergencies.

- Product development
- Ingredient science
- Nutrition

Introduction

Malnutrition affects individuals in every single corner of the world. In 2019, it was estimated that close to 47 million children suffered the most devastating form of malnutrition called wasting (UNICEF et al., 2020). Over half of those suffering from wasting live in low- and middle-income countries located in Southern Asia. Wasting is the rapid manifestation of hunger and it can be moderate or severe based on weight for height indicators.

In simple terms, wasting means the child is too thin for her height. It is estimated that 14.3 million or 30% of the children under 5 years with wasting suffer from severe acute malnutrition (SAM), with the remaining suffering from moderate acute malnutrition (MAM). The rapid onset of food insecurity, as well as diseases such as tuberculosis, measles, diarrhea, and malaria, are among the leading causes of SAM in children under five (Bhutta et al., 2008). In turn, wasting is associated with an increased risk of opportunistic diseases and death. Though objectively measuring wasting requires simple tools such as a measuring tape, balance, and stadiometer, addressing it requires a complex approach that brings together several disciplines including: food science, human nutrition, social science, implementation science, marketing, economics, and logistics and supply chain management to name a few.

The development and implementation of ready-to-use therapeutic and supplementary foods (Box 1), combined with community-based management of acute malnutrition (CMAM) have revolutionized our ability to face this grand challenge (WFP & UNHCR, 2011). Currently, UNICEF and its partners use RUTFs/RUSFs based on peanuts (~22%), milk solids (50% of proteins), sugar, oil, and a micronutrient premix. These sweet pastes allow the treatment of MAM at homes directly by caregivers, do not require refrigeration, benefit from a long shelf life (24 months), and are ready to consume (Fig. 1).

Box 1. Definitions of specialized nutrition products used for relief in emergencies.

RUTF or ready to use therapeutic foods currently come as lipid-based, energy-dense, mineral- and vitamin-enriched food specifically designed to treat SAM in children 6 to 59 months. RUTF has a similar nutrient composition to F100, does not require cooking, is safe for in-home consumption, and can be stored for 24 months under adequate temperature conditions.

RUSF or ready to use supplementary food has a similar nutritional profile as RUTF, but one of its formulations is specifically designed to treat MAM in children 6 to 59 months.

FBF or fortified blended foods are blends of partially precooked and milled cereals, soya, beans, and pulses fortified with vitamins and minerals, and may contain vegetable oil or milk powder.

F75 and F100 are therapeutic, ready to disperse milk-based formulas that are used in inpatient treatment of SAM. These formulas provide 75 or 100 kilocalories for every 0.1 liter, respectively.

Rehydration solution for severe malnutrition (ReSoMal) is an oral rehydration solution, ready to be dissolved in water and created specifically for severely malnourished children. Its osmolarity is 300 mOsm/L.

Combined Mineral and Vitamin Mix such as Sprinkles can be used at homes to fortify meals in order to prevent micronutrient deficiencies.

Unfortunately, approximately only 1 in 4 children with SAM receive RUTF and even fewer children with MAM receive any supporting ration. Though the number of producers of RUTF/RUSF has increased from 1 in 2011 to 21 in 2019, their capacity to reach all children with SAM is quite limited.

The cost of treating SAM per child is about US$44.10. This is the cost of a carton of RUTF containing 150 sachets (92 g) which are given to children for 7 weeks (3 sachets per day). UNICEF, the largest procurer of RUTF (at 75-80% of the market), now procures over 50% of its RUTF through local companies, albeit at a higher cost. On average, local procured RUTF is 12-14% more expensive than that procured overseas. This higher price is due to importation costs of ingredients such as milk powder, micronutrient premix, and packaging materials

(UNICEF, 2019). In addition to cost, there are populations for whom peanuts or dairy are not familiar foods, so they are reluctant to accept them. Alternate ingredients as the protein sources for various formulations would boost RUTF to a greater acceptance among the diverse populations in different parts of the world. Developing different versions of RUTF can also make RUTF more affordable and facilitate the production of RUTF to meet the demands for RUTF around the world.

Despite their many advantages and use of RUTFs for over two decades, new research has aimed at enhancing the properties, ingredients, and functionalities of RUTFs/RUSFs to improve their acceptance by specific targets, cost, packaging, and bioactivity (Dibari et al., 2013; Dibari et al., 2012; Gaur et al., 2017; Manary & Callaghan-Gillespie, 2020). UNICEF recognizes improvements in new formulations as renovation, novel, and innovation products. Renovation products are those modifying or completely changing peanuts and non-dairy protein sources such as soy, chickpeas, and lentils but keeping the nutrient composition (e.g., 50% proteins from milk powder) as stated by the Joint Statement issued in 2007 by the WHO, WFP, UNICEF, and the UN System Standing Committee on Nutrition (UNICEF et al., 2007). Novel products focus on modifying specific nutrients, for example, using amino acids to replace dairy protein or better and more bioavailable sources of iron and vitamin C. Innovation products are those that use alternative sources of protein besides milk and modifying the current recommendations (UNICEF, 2019).

Two examples of RUTF/RUSF renovation products are Wawa Mum and Acha Mum.

Response

In the summer of 2010, Pakistan was in a crisis after a monsoon flooded 20% of the country and displaced millions of its population. Malnourishment among displaced children skyrocketed. Scientists at the UN World Food Programme (WFP) were prompted to find a quick and effective nutrition solution for the region. A paste-form meal replacement product made of chickpeas was created using local resources and facilities. The product was named Wawa Mum, translated from the Pashto meaning "Good food, Mom!", actual words from the children who ate it. At 50 grams per serving, which costs cents on the dollar, Wawa Mum supplies the daily amount of nutrients needed for a child of 6-23 months of age. It is nutritious, tasty, convenient, ready to eat, and does not require water to mix. One ton of Wawa Mum can feed 20,000 children(WFP, 2017, 2021).

The main ingredient, chickpea, is a staple food known and liked throughout South Asia. Chickpea contains a variety of vitamins and minerals, as well as a decent amount of protein and fiber. To make Wawa Mum, chickpeas are blended with a micronutrient premix, milk powders, and vegetable oils.

Another advantage is safety. Aflatoxin contamination in peanuts is a significant challenge in low-income settings—a problem far less common in chickpeas. This renovation product, when made locally, still requires the importation of a micronutrient premix and/or dairy solids. Though renovation products offer some advantages, there are challenges in their design.

Years later, Wawa Mum production continues and has expanded beyond Pakistan. Products similar to Wawa Mum are now produced in Afghanistan, India, and other South Asian countries. Acha Mum (acha means "nice") has since been developed and provided by WFP for children 6-59 months.

Lessons Learned

Direct replacement of main ingredients in the formulation, though technically feasible, requires evaluation beyond nutrient composition, including efficacy, effectiveness, and accessibility in low-income settings. Acha Mum's nutrient composition is shown in Table 1 and compared against the standard RUTF/RUSF specifications. In this case, the oil content of chickpeas (<10% w/w) is lower than in peanuts (50% w/w), whereas the carbohydrate content in chickpeas (~60% w/w) is almost four times higher than that of peanuts (~16%). Beyond source and composition, these macronutrient changes inevitably will result in physical-chemical changes in the final product (e.g., color, consistency, and water activity) and impacts on stability, particularly in high temperature and humidity environments that are not the most conducive for nutrient dense products. Overall, the use of new ingredients will affect the final characteristics of RUTF/RUSF products and cost. Therefore, these should be carefully selected and evaluated in situ.

Table 1. Nutrient requirements for Ready-to-use Foods (per 100 g).

Macronutrient	Unit	(RUSF-MQ*) Min (Qty)	(RUSF-MQ*) Max (Qty)	RUTF Min (Qty)	RUTF Max (Qty)	Acha Mum
Energy	Kcal	510	560	520	550	520
Protein	%	11	16	12.8	16.2	13
Fat	%	26	36	26	36	32.2
ω-3 fatty acids	g	0.30	1.80	0.2	1.5	1.6
ω-6 fatty acids	g	2.6	6.1	1.8	6	7.8
Micronutrients						
Retinol (Vit A)	µg	550	1150	800	1100	1150
Vitamin B1 (Thiamin)	mg	1.0		0.5		1.12
Vitamin B2 (Riboflavin)	mg	2.1		1.6		2.3
Vitamin B3 (Niacin)	mg	13		5		13.2
Vitamin B5 (Pantothenic Acid)	mg	4.0		3		6.23
Vitamin B6 (Pyridoxine)	mg	1.8		0.6		1.5
Vitamin B7 (Biotin)	µg	60		60		21.6
Vitamin B9 (Folic acid)	µg	340		200		256
Vitamin B12 (Cobalamin)	µg	2.7		1.6		3
Vitamin C (Ascorbate)	mg	60		50		121.9
Vitamin D (Cholecalciferol)	µg	15	20	15	20	23.7
Vitamin E (Tocopherol)	mg	16		20		22
Vitamin K	mg	27		15	30	61.3
Calcium (Ca)	mg	535	750	300	600	773.9
Copper (Cu)	mg	1.4	1.9	1.4	1.8	0.54
Iodine (I)	µg	100	140	70	140	117
Iron (Fe)	mg	10	14	10	14	15
Magnesium (Mg)	mg	150	225	80	140	167.7

*MQ: medium quantity RUSF

Future Research Areas

The source of proteins in RUFT/RUSF is a key example of the intricacies of product development for relief efforts, currently under debate. The quality and quantity of proteins used in these formulas are critical for their efficacy and cost. Casein, the main dairy protein, has a unique profile of essential amino acids and a recognized protein quality similar to egg albumin. Original RUTF/RUSF formulas use milk solids and have shown efficacy in several trials in the management of acute malnutrition (Das et al., 2020; Manary & Sandige, 2008).

Despite their quality and efficacy, full-fat or defatted milk solids might be more expensive to procure from local sources. Though plant-based sources of proteins might be more accessible in low-income countries, their quality in terms of amino acid profile and digestibility have been the main arguments against their use without complementation with animal-source proteins in RUTF formulas. Due to its amino acid profile and cost, current efforts have focused on using soybeans as a main source of protein for these formulas. The main problem of using soy-based protein, which is the case for all plant-based sources, is its digestibility and antinutrient content (e.g., phytic acid and lectins). Recent evidence, however, has shown that soy-based RUTF can improve wasting outcomes in children similar to traditional RUTF (Bahwere et al., 2017; Irena et al., 2015). With the advent of accessible amino acid synthesis and extraction technologies, alternative strategies have evaluated the addition of single or more amino acids (e.g., lysine, sulfur-containing amino acids, or branched chain) to improve the protein quality of soy-based RUTFs (Bahwere et al., 2017; Sato et al., 2018). Overall, the use of inexpensive ingredients without affecting quality and efficacy can result in increased reach of RUTFs/RUSFs to populations in need.

Different fat sources such as ghee (Gaur et al., 2017) and shea butter (Sloffer et al., 2017) have been evaluated as well, though at a bench scale, and shown potential for their use for populations in India and sub-Saharan Africa, respectively. The incorporation of encapsulated bioactive agents, such as those from plant essential oils, might be useful to address both nutrient deficiencies as well as parasitic infection (Gaur et al., 2018). Although the efficacy and effectiveness of these products require further evaluation before they can be used in relief programs, they serve as examples of the untapped potential of the food science and engineering community to bring transformative, fit-to-purpose solutions to address undernutrition everywhere.

The development of foods for emergency relief is at the intersection of several disciplines including food science and engineering, nutrition, medicine, social sciences, and implementation sciences to mention a few. It is important that food scientists understand the limitations in this interdisciplinary and dynamic field as well as the variety of opportunities to directly contribute with improved and safe formulations that better address the needs of populations at risk for or suffering from acute malnutrition. Food science is essential for creating products with optimal nutrition, food safety, convenience, cost effectiveness, proper packaging, long shelf life, cultural appropriateness, and consumer acceptability.

Cited Literature

Bahwere, P., Akomo, P., Mwale, M., Murakami, H., Banda, C., Kathumba, S., Jere, S., Sadler, K., & Collins, S. (2017). Soya, maize, and sorghum-based ready-to-use therapeutic food with amino acid is as efficacious as the standard milk and peanut paste-based formulation for the treatment of severe acute malnutrition in children: a noninferiority individually randomized controlled efficacy clinical trial in Malawi. *Am J Clin Nutr*, *106*(4), 1100-1112. https://doi.org/10.3945/ajcn.117.156653

Bhutta, Z. A., Ahmed, T., Black, R. E., Cousens, S., Dewey, K., Giugliani, E., Haider, B. A., Kirkwood, B., Morris, S. S., Sachdev, H. P., Shekar, M., & Group, M. a. C. U. S. (2008). What works? Interventions for maternal and child undernutrition and survival. *Lancet*, *371*(9610), 417-440. https://doi.org/10.1016/S0140-6736(07)61693-6

Das, J. K., Salam, R. A., Saeed, M., Kazmi, F. A., & Bhutta, Z. A. (2020). Effectiveness of Interventions for Managing Acute Malnutrition in Children under Five Years of Age in Low-Income and Middle-Income Countries: A Systematic Review and Meta-Analysis. *Nutrients*, *12*(1). https://doi.org/10.3390/nu12010116

Dibari, F., Bahwere, P., Huerga, H., Irena, A. H., Owino, V., Collins, S., & Seal, A. (2013). Development of a cross-over randomized trial method to determine the acceptability and safety of novel ready-to-use therapeutic foods. *Nutrition*, *29*(1), 107-112. https://doi.org/10.1016/j.nut.2012.04.016

Dibari, F., Diop, e. H., Collins, S., & Seal, A. (2012). Low-cost, ready-to-use therapeutic foods can be designed using locally available commodities with the aid of linear programming. *J Nutr*, *142*(5), 955-961. https://doi.org/10.3945/jn.111.156943

Gaur, S., Lopez, E. C., Ojha, A., & Andrade, J. E. (2018). Functionalization of Lipid-Based Nutrient Supplement with β-Cyclodextrin Inclusions of Oregano Essential Oil. *J Food Sci*, *83*(6), 1748-1756. https://doi.org/10.1111/1750-3841.14178

Gaur, S., Sloffer, E. M., Ojha, A., Patra, F., Shukla, D., Engeseth, N. J., Patel, P. R., & Andrade, J. E. (2017). Omega-3-Fortified Lipid-Based Nutrient Supplement: Development, Characterization, and Consumer Acceptability. *Food Nutr Bull*, *38*(2), 158-171. https://doi.org/10.1177/0379572117701234

Irena, A. H., Bahwere, P., Owino, V. O., Diop, E. I., Bachmann, M. O., Mbwili-Muleya, C., Dibari, F., Sadler, K., & Collins, S. (2015). Comparison of the effectiveness of a milk-free soy-maize-sorghum-based ready-to-use therapeutic food to standard ready-to-use therapeutic food with 25% milk in nutrition management of severely acutely malnourished Zambian children: an equivalence non-blinded cluster randomised controlled trial. *Matern Child Nutr*, *11 Suppl 4*, 105-119. https://doi.org/10.1111/mcn.12054

Manary, M., & Callaghan-Gillespie, M. (2020). Role of Optimized Plant Protein Combinations as a Low-Cost Alternative to Dairy Ingredients in Foods for Prevention and Treatment of Moderate Acute Malnutrition and Severe Acute Malnutrition. *Nestle Nutr Inst Workshop Ser*, *93*, 111-120. https://doi.org/10.1159/000503347

Manary, M. J., & Sandige, H. L. (2008). Management of acute moderate and severe childhood malnutrition. *BMJ*, *337*, a2180. https://doi.org/10.1136/bmj.a2180

Sato, W., Furuta, C., Matsunaga, K., Bahwere, P., Collins, S., Sadler, K., Akomo, P., Banda, C., Maganga, E., Kathumba, S., & Murakami, H. (2018). Amino-acid-enriched cereals ready-to-use therapeutic foods (RUTF) are as effective as milk-based RUTF in recovering essential amino acid during the treatment of severe acute malnutrition in children: An individually randomized control trial in Malawi. *PLoS One*, *13*(8), e0201686. https://doi.org/10.1371/journal.pone.0201686

Sloffer, E. M., Gaur, S., Engeseth, N. J., & Andrade, J. E. (2017). Development and Physico-Chemical Characterization of a Shea Butter-Containing Lipid Nutrition Supplement for Sub-Saharan Africa. *Foods*, *6*(11). https://doi.org/10.3390/foods6110097

UNICEF. (2019). *Ready-to-Use Therapeutic Foods: Market Outlook*.

UNICEF, WHO, & Group, T. W. B. (2020). *Joint child malnutrition estimates:levels and trends in child malnutrition*.

UNICEF, WHO, & WFP. (2007). *Community-based management of severe acute malnutrition: A joint statement*.

Weber, J. M., Ryan, K. N., Tandon, R., Mathur, M., Girma, T., Steiner-Asiedu, M., Saalia, F., Zaidi, S., Soofi, S., Okos, M., Vosti, S. A., & Manary, M. J. (2017). Acceptability of locally produced ready-to-use therapeutic foods in Ethiopia, Ghana, Pakistan and India. *Matern Child Nutr*, *13*(2). https://doi.org/10.1111/mcn.12250

WFP. (2017). *USAID Helps Boost Nutrition, Relief And Livelihood Activities In Pakistan*. Retrieved January 18 from

WFP. (2021). *Specialized Nutritious Foods*. Retrieved January 18 from https://www.wfp.org/specialized-nutritious-food

WFP, & UNHCR. (2011). *Guidelines for Selective Feeding: The Management of Malnutrition in Emergencies*. https://cms.emergency.unhcr.org/documents/11982/32558/Guidelines+for+selective+feeding.+The+management+of+malnutrition+in+emergencies/117faa46-7fa4-446b-8104-10f5a4c763e1