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How ready-to-use therapeutic food shapes a new technological regime to treat child malnutrition

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A b s t r a c t

Since the turn of the 21st century ready-to-use therapeutic food (RUTF) has emerged as the preferred solution to treat acute malnutrition without complications. RUTF is a more appropriate technology than formerly prevalent powdered milk solutions because it enables outpatient care, simpler treatment protocols and production in the field. In this paper we analyze the forces driving the diffusion of RUTF as an innovation to treat child malnutrition and discuss the main features characterizing the new technological regime that results from its wide adoption. We combine the theoretical discussion and the review of secondary sources with insights from field research in Ethiopia, encompassing personal interviews with relevant parties and direct observation of how RUTF works in practice. This technology assessment exercise enables us to suggest some opportunities for policy intervention.

Keywords: Appropriate technology Innovation Malnutrition Therapeutic food Technology diffusion Technological regimes Ethiopia Haiti

1. Introduction

Despite the objective of cutting malnutrition in half by 2015 set forth in the Millennium Development Goals, nearly one sixth of humanity still suffers from malnutrition [12]. Eradicating hunger is one of the most pressing societal challenges of our times, and the lack of progress a shameful failure of the international governance system. But a reason for hope is that in the coming years a higher emphasis on pro-poor innovation might contribute to the reduction of malnutrition. In particular, progress in the development and transfer of agricultural technology and know-how more appropriate for developing countries (including irrigation techniques, fertilizers and transgenic crops) should help address malnutrition by increasing agricultural productivity and enabling greater food security and autonomy [35–37]. However, in this article we focus on a different mode of innovation to fight hunger: the generation and diffusion of new types of therapeutic food and delivery practices that raise the efficiency of emergency interventions once a malnutrition crisis has unfolded.

Children under the age of five are particularly at risk from malnutrition among other reasons because of their more demanding dietary requirements. Thus they are generally the main target of emergency interventions. Until just a few years ago the standard treatment to child malnutrition comprised powdered milk solutions fortified with vitamins and minerals, which are still being used in different contexts. The problem is that powdered milk needs to be reconstituted with clean drinking water and consumed almost immediately, implying that treatment generally needs to be administered through inpatient nutrition centers in hospitals. While inpatient treatment would remain necessary for the most complicated cases of malnutrition, the need for an outpatient approach to acute malnutrition without complications soon became clear. The scientific community and aid organizations started looking for alternatives to powdered milk, searching for some type of ready-to-use therapeutic food (RUTF) that, combined with

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simpler diagnosis and monitoring protocols, could enable outpatient treatment. By the end of the 1990s a viable solution of RUTF was developed by a public–private partnership in France. After testing, the invention was patented and the product was commercialized under the name of Plumpy'nut. It has since been widely used by local governments and international donors across different countries, mainly in Africa but also in Asia and Latin America. Subsequently new producers have entered the market and new formulas with different components have been tested.

Many studies – some of which will be cited in this article – have analyzed RUTF from the perspectives of nutrition science or development assistance. But none to the best of our knowledge has done so from the perspective of the diffusion of innovations, even though this approach has produced significant results in the broader field of medical innovation [20,38]. Our aim is to contribute to filling this gap by analyzing RUTF as an innovation in the fight against hunger, drawing attention to the factors behind its diffusion and to the features that define the emerging technological regime resulting from its wide adoption.

Rogers [30] defines the diffusion of innovations as the process by which they are communicated through different channels over a period of time among the members of a social system, drawing attention to the conditions which increase (or decrease) the likelihood that a new idea, product or practice will be adopted by members of a given community. However, Roger's view of adoption as the outcome of a communication process among users overemphasizes the demand side of innovation and does not pay sufficient attention to the supply side. In the words of Attewell [1: 3], studies on diffusion "should go beyond the individualistic perspective which stresses the innovativeness of potential adopters, and should examine instead the institutional and market structures that channel new technologies to users". In our study we build on Rogers' framework but also aim at explicitly incorporating the supply side to the diffusion story.

The successful diffusion of innovations may ultimately result in the advent of a new technological paradigm or technological regime. Following the pioneering work of Khun [23], Dosi [10] develops a model to analyze technical change based on the notions of technological paradigms and technological trajectories. This model accounts for continuous changes (progress along a technological trajectory within a technological paradigm) as well as discontinuous changes (related to the emergence of a new technological paradigm). The emergence of technological paradigms can be explained by "the interplay between scientific advances, economic factors, institutional variables, and unsolved difficulties on established technological paths" [10: 147].

The formation of a new technological paradigm or regime means that innovation shapes new actions and interactions of the different actors in a social system, thereby imprinting new formal and informal rule-sets. Pérez [27] discusses further the different interconnected processes of change and adaptation underlying the diffusion of technology, including the development of surrounding services, the emergence of institutional facilitators and the cultural adaptation to the logic of the technologies involved. Indeed, technological regime transitions involve not only shifts in underlying knowledge but also changes in the social dimension, such as user and managerial practices, organizational structures, industrial networks and regulations [17]. This explains why some scholars prefer to speak of socio-technical transitions rather than just technological transitions [33,39].

The empirical contribution of our study is based on field research in Ethiopia in September 2008, comprising 11 personal interviews with experts and direct observation of how RUTF works in practice. In addition the study builds upon secondary sources including policy documents and white papers from international organizations and NGOs; websites of RUTF producers; patent documents; and a multidisciplinary literature review. The interviewees were field representatives from international organizations and NGOs, social workers and local manufacturers of RUTF, providing for some extent of triangulation to increase the validity of this case study's results [40]. The purpose of this research was not to provide evidence to test any specific hypothesis, thus it should be taken only as exploratory. However, it should be stressed that exploratory studies may also use theory-building structures with the aim of "debating the value of further investigating various hypotheses or propositions" [40: 154].

The case study of RUTF is reported here using a linear-analytic structure [40]. Following the review of the theoretical background and methods used presented above, Section 2 provides a chronological overview of the development of RUTF from 1997 to present, analyzing the diffusion process from invention, to testing, and to large scale dissemination. Building on the hypothesis that RUTF is leading to a transition in the technological regime to treat child malnutrition, the following sections adopt a more theory-building structure by examining the main features characterizing the new technological regime and the key implications that follow. Section 3 describes how RUTF enables a much needed shift from inpatient to outpatient treatment. Section 4 focuses on the supply side by analyzing the emergence and expansion of production networks in developing countries. Section 5 examines the post-innovation improvements and new contexts of application that followed. Finally, Section 6 discusses further the main findings and Section 7 completes the paper suggesting a set of policy implications.

2. The invention and diffusion of ready-to-use therapeutic food

Before a viable RUTF was developed, the standard treatment for severe malnutrition was F100, a milk powder fortified with vitamins and minerals developed in the 1980s. But F100 needs to be reconstituted with clean drinking water and consumed almost immediately, which has significant drawbacks. It requires potable water, energy to heat it, clean utensils and a highly precise mix which, once made, only retains its properties for a few hours. If left unrefrigerated the solution spoils and may absorb bacteria that cause infectious diseases. This implies that it generally needs to be administered only through inpatient nutrition centers, the downsides of which are that hospital capacities are limited and that crowded hospitals multiply the risk of epidemics. Inpatient treatment (using powdered milk solutions, oral re-hydratation therapy, etc.) would remain necessary for the most complicated cases of malnutrition, but the need for an outpatient approach to acute malnutrition without complications was clear. The scientific community started looking for alternatives in the 1990s. The aim was to develop a more appropriate

technology than F100, in the form of a ready-to-use food supplement. In the mid 1990s, the French scientist André Briend (then at the Institute of Research for Development and now at the WHO) teamed up with Michel Lescanne, the director of Nutriset, a French private company founded in 1986 specializing in therapeutic foods. They tried several forms of RUTF – enriched pancakes, doughnuts, biscuits – but these tests were not conclusive. They tested RUTF in the form of chocolate bars with a similar composition as F100, but the problem was that they melted easily and tasted worse when vitamins and proteins were added.

Finally, they came up with a viable option based on peanut butter mixed with dried skimmed milk, vitamins and minerals. The product was to be distributed under the commercial name of Plumpy'nut — a combination of the words “plumpy” and “peanut”. The first trials were conducted in Chad by Action Contre la Faim in cooperation with the Chad Ministry for Health. A first article was published in The Lancet [2] showing that this variety of RUTF is well accepted compared to F100. The product was further tested in other countries, and in 1998 Médecins Sans Frontières coordinated the first successful large-scale application in Southern Sudan [14].

Large-scale production of Plumpy'nut started in the late 1990s at Nutriset's factory in Malaunay, France. The production process was easy to set up given the existing assets and know-how of Nutriset. The company was already active in the therapeutic food business and had strong connections in the market. It was not too hard to convince some major donors of the virtues of Plumpy'nut. They were eager to participate in this kind of innovation and were particularly sensitive to its advantages in terms of easier on the ground delivery. Following initial trials, the invention was first registered in the French patent office in 2000 (patent number 00/13731) then in the US Patent and Trademark Office also in 2000 (patent number 6,346,284) and in the European Patent Office in 2001 (patent number AP/1647). The patent rights last until 2018 and cover not only the product itself but also the production process. Although both the Institute of Research for Development (IRD) and Nutriset appear as owners, after initial registration IRD granted Nutriset an exclusive exploitation licence for the patents and brand name co-owned, subject to certain conditions of appropriate use.

Plumpy'nut is made of peanuts mixed with a sophisticated vitamin complex that provides sufficient nutrient intake for recovery. Each packet contains one dose and is wrapped in aluminium. It can be stored without refrigeration for up to two years without losing its properties, and up to 24 h after opening. The low density of water makes it a hostile environment for microbes and its fat suspension makes vitamins and minerals very stable. Because it does not need cooking or preparation, the labour, fuel and clean water demands on poor households are minimized. Estimates suggest that treatment of malnutrition through Plumpy'nut can be achieved at lower costs per patient than former approaches, although cost comparisons are not straightforward [5]. Using Rogers's terminology, the successful diffusion of this type of RUTF can be attributed to its perceived relative advantage, t o i t s compatibility with other processes and values in place, and to its simplicity, trialibility and observability [30].

The main advantage of RUTF is that it allows taking the treatment of severe malnutrition out of hospitals into homes. Normally, the mother just has to pick up the packets from a health center once a week, make sure that her child eats two a day at home (the child will eat it with pleasure) and watch as the child puts on weight. In Section 3 we examine in greater detail the shift to outpatient treatment. Another major advantage is that RUTF can be produced locally without the need for advanced technological capabilities and relying on local crops. Compared to other solutions, the production process is simpler and requires lower investments, it is highly adaptable to the specific environment of poor countries, and it uses peanuts which are often available or easy to cultivate in the least developed countries. Section 4 discusses further the advantages of local production, as well as recent initiatives to promote it.

The diffusion process of RUTF was initially supported by NGOs like Action Contre la Faim, MSF, the Bill Clinton Foundation and Valid International, which recognized its advantages and acted as what Rogers [30] calls early adopters. Moreover, in 2007 four international organizations within the United Nations system released a joint statement advocating home treatment with RUTF for severely malnourished children (“Community-Based Management of Severe Acute Malnutrition”, A Joint Statement by the World Health Organization, the World Food Programme, the United Nations System Standing Committee on Nutrition and the United Nations Children's Fund, May 2007, Geneva). According to this document, 80% of children suffering from severe acute malnutrition can be treated at home with RUTF. Through their role as opinion leaders and change agents [30], these international organizations contributed to the expansion of demand and to the formation of a new technological regime. According to Nutrition Articulation Project [26] demand for RUTF more than doubled in the year following this joint statement.

In recent years RUTF has gradually become the most widely used therapeutic solution to fight child malnutrition. Successful experiences have been reported in Ethiopia [13], Kenya [9], Malawi [24,31], Niger [8,16], Sudan [14] and Sierra Leone [25], among others. As a result, demand and production of RUTF have greatly expanded. Nutriset (the biggest manufacturer by far) produced more than 15 000 tons in 2008 and UNICEF (the biggest buyer) purchased around 8000 tons in 2008 and expects global production to grow to at least 50 000 tons by 2011 [14]. According to Nutriset one million children suffering from severe acute malnutrition were treated with Plumpy'nut in 2009 and 1.5 million in 2010.

However, there are also several barriers to a faster diffusion of RUTF. Besides the need for a higher commitment of international donors, the biggest obstacle is the difficulty of reaching the target population in contexts of precarious infrastructures, political instability and conflict which characterize many of the most needed countries. For example, in one of the most recent episodes of famine in Somalia the first flight with aid arrived in July 2011 carrying 10 tons of Plumpy'nut, but its delivery was patchy among other issues because a militia controlling the Southern part of the country bans food aid, branding aid agencies as anti-Muslim and having killed 14 employees of the World Food Program since 2008 [11]. Improving the supply chain to reach the target population in partnership with local governments is a critical condition for success. In fact, despite the fast diffusion of RUTF, much progress remains to be done as only around 10 to 15% of children with severe acute malnutrition are currently being adequately treated, according to Nutriset's estimations (Source: www.nutriset.fr). Other

obstacles to the diffusion of RUTF include those associated with ensuring the compliance of carers and with overcoming the dietary boredom of patients.

3. The shift from inpatient to outpatient treatment

Traditional approaches to malnutrition crises rely on inpatient therapeutic feeding centers (TFC) as their primary mode of intervention. These provide intensive, high-quality care for severely malnourished patients. But this approach has several drawbacks [3,5]:

- TFCs require substantial infrastructure and experienced staff, are expensive, difficult to set up, and heavily dependent on external support.
- Inpatient care prioritizes quality of care at the expense of quantity of care.
- TFCs are centralized and in rural environments patients often have to travel long distances to reach them, especially in settings where the rural population is very geographically dispersed.
- Large numbers of patients are put in proximity, increasing risks of cross-infection.
- Mothers have to stay with their malnourished children for around one month, undermining family life, in particular care of other children.
- As a result of these problems, TFCs are often unpopular with the target population, which causes people to present for treatment late, often after major complications have occurred.

RUTF enables a shift to an outpatient treatment regime, which overcomes these drawbacks and provides for a stronger participation of local communities in the diagnosis and treatment of malnutrition. These community-based, outpatient systems are organized around networks of local workers or volunteers who visit household to detect cases of malnutrition using simple protocols (Box 1 illustrates how this worked in the case of Ethiopia). Primary screening for nutritional status is conducted by community members using a simple armband that associates arm circumference with level of malnutrition. This so-called mid-upper-arm circumference test does not require the user to be numerate or literate, and thus becomes more appropriate to the local context than the standard weight-for-height protocol used under the inpatient regime, which requires the ability to perform height/length measurements, use complex tables and perform arithmetic calculations using decimal numbers [4].

Children classified with severe acute malnutrition are prescribed to visit a nearby health facility where RUTF is provided and patients are monitored. A caretaker, typically the mother, is given one or two weeks' worth of RUTF to bring home, along with other medicines such the antibiotic Amoxicillin if required. The caretaker is responsible for giving children the product every day and returns to the health center for a weekly visit to check weight gain, make sure that the child has not become sick and obtain further supplies of RUTF. This follow-up lasts 6 to 10 weeks, until children reach a target weight. Only patients with severe acute

Box 1
Health extension workers in Ethiopia.

Despite strong economic growth in recent years, the WHO estimates that around 40% of all children in Ethiopia are underweight. The population in Ethiopia is mostly rural and geographically dispersed throughout a very large country with poor infrastructures, hence RUTF in itself is not sufficient to combat malnutrition; the biggest challenge is to reach the target population. Against this background, the Government, advised by UNICEF, created an outpatient network to fight against child malnutrition. According to Mr. Van Steirteghem, the UNICEF representative in the country, “in Ethiopia the first huge demand for Plumpy'nut coincided with the health extension program that started in 2004. At that time we had the product and a mechanism to reach the village level. One is useless without the other. Thanks to the convergence of both factors, we are managing to respond better to this crisis.

The cornerstone of the program are its “health extension workers”: some 24000 young people, mostly women from rural areas, who receive training and then visit families in their community in order to identify malnourished children and advise their families to take part in the program. We interviewed Bedria Tadele, one of these health extension workers, and followed her at work. She is 22 years old and started in this job in 2006 after a competitive recruitment process. She trained in the city for one year and now earns a Government wage and is responsible, with two colleagues, for a community of 3188 people in 708 households; the same community in which she grew up. She walks miles every day to visit between six and ten households. During her home visits, Bedria talks to the mothers, observes the children, measures their arm circumference and looks for signs of illness. When she detects signs of malnutrition, she explains the situation to the mother and gives her an appointment at the closest medical post. These precarious outpatient centres, which require no more equipment than a scale to weigh the children, a board to measure them, stocks of RUTF and a few medicines, have grown in number to the point that almost all inhabitants of the region can walk to the nearest one. Children needing more sophisticated treatment on arrival are transferred to a better equipped hospital. This is a very effective health network that starts in households. Source: Field research, October 2008. For more information about the program see www.unicef.org.

malnutrition with complications (respiratory infection, diarrhoea, loss of appetite, etc.) are referred to hospitals for inpatient treatment including liquid diets [3,16].

Initially, sensitisation and mobilisation of the population focus on key community figures (such as political and tribal leaders, traditional healers, religious leaders, representatives of women's groups, etc.), who are informed about the program and asked for help in mobilising the wider population [5]. As the program evolves, resources are put into selecting volunteers from the community, who are supported by outreach workers employed by the program and are responsible for following up malnourished children at their homes, tracing defaulters and finding new cases. The ultimate aim of community-based outpatient programs is to hand over control in order to help equip local communities to deal with future malnutrition crises without the need for external support. This evolution is critical because malnutrition crises are evolving from sporadic events to which international donors can respond massively and then leave when the problem is solved, towards cyclical crises which reflect structural problems, without a clearly defined start or end [5].

In sum, the success of community-based outpatient networks constitutes a key factor behind the diffusion of RUTF [6,13]. I n some cases, new networks were created almost from scratch whereas in other instances existing community networks were utilized. In fact, an advantage of outpatient care as a form of intervention to fight malnutrition crises are the synergies that can be built with other programs, including general hygiene, vaccination, and HIV prevention and treatment. RUTF has benefited from a wider trend towards local participation in health and development assistance programs, while at the same time it helped reinforce this trend.

4. **The expansion of supply networks**

RUTF can be manufactured using basic technology that is readily available in developing countries [15]. The equipment required –a peanut roaster and grinder, and a mixing and filling machine– is relatively inexpensive and easy to use and maintain. Initially, the only source of Plumpy'nut was Nutriset's factory in France. But, as demand increased, in 2005 the company set up a franchising scheme enabling the local production and commercialization of the product in developing countries using the Plumpy'nut brand and protected know-how. The first local factory was opened in Malawi in 2005 and since that time the so-called PlumpyField network has expanded to ten countries: Ethiopia (see Box 2), Democratic Republic of Congo, Dominican Republic, India, Haiti, Madagascar, Malawi, Mozambique, Niger and Tanzania. Production capacity of the PlumpyField network is expanding rapidly and, according to Nutriset, out of a total of 22 500 tons of Plumpy'nut produced worldwide in 2010 around 8000 were made in developing countries (i.e. 36% of total production).

The franchising system is based on the transfer of Nutriset's know-how (production, management and distribution) to an independent producer based in a country suffering from malnutrition, which may be a public or a private company or NGO, but should not be part of a multinational corporation. According to Nutriset their aim is to ensure homogeneity in quality standards and they require the franchisee to adhere to the following principles:

- Assurance of the quality of the local product.
- Professional ethics of the local partner in his dealings with the humanitarian world.
- Awareness and adherence to the good use of locally available product.
- Producer's strong commitment to making the product available.

Box 2
Manufacturing in Ethiopia.

Hilina Enriched Food Processing Center in Legetafo, a few kilometres north of Ethiopia's capital city, is one of the African franchisees that produce RUTF in situ. The director, Belete Beyene, proudly shows us around the factory that he built from scratch. The plant operates around the clock in three eight-hour shifts, employing a total of 104 workers, all young Ethiopians, 60% women, who earn around 55 US dollars a month (20 dollars above the minimum wage). When the plant opened in 2007, 100 tons of Plumpy'nut were produced each month and production has now almost tripled. In 2010, when the plant expansion is completed, production is expected to reach 600 tons per month. Belete explains how he embarked on this adventure: “Due to the fast growth in demand, UNICEF studied the possibility of encouraging the transfer of a part of production here, where the product is needed. I had a small factory producing a different type of therapeutic food. They contacted me and I said I could do it but I needed money. They found a sponsor, the American Amy Robbins, who donated 300,000 dollars to UNICEF. In Ethiopia we have good peanuts, soya oil and cane sugar. We have 80 per cent of the necessary materials. We only need to import powdered milk from India and the mix of vitamins and minerals that we buy from Nutriset, which also audits process quality”. They now sell their entire production. The main customer is UNICEF, which buys 50%, and the other 50% is distributed among other NGOs, including MSF (10%) and the Bill Clinton Foundation (10%). Mr. Belete supports the franchise scheme and the existence of a patent because he considers that it guarantees control over the activities. “A lot of quality controls are needed (…) this is not just any industrial production process. If you're not careful you can kill a child”, h e argues.

Sources: Field research, October 2008. For more information about local manufacturing see www.nutriset.fr.

The general benefits of local manufacturing through this franchise system are wide-reaching. In addition to the operating licence, franchisees benefit from training; ongoing technical assistance and quality control; and access to R&D projects and to technological management or nutritional improvements. This enables the transfer of technology and contributes to competence building. Production in the field may also allow for significant cost reductions [6,41]. It improves the response to nutritional emergencies, making it easier to tackle chronic malnutrition outside emergency periods. Furthermore, it stimulates the local economy by creating jobs (according to Nutriset 280 direct jobs were created through on the field production up to 2010) and via the local procurement of raw materials. However, the potential benefits of local procurement have not been fully exploited, as only a few of the producers in the field are sourcing peanuts locally. This calls for stronger efforts by Nutriset and international donors to build local supply chains of peanuts in tandem with RUTF manufacturing facilities.

The latest member to join the PlumpyField network was MFK, an NGO operating in Haiti (http://mfkhaiti.org). They set up the production facility during the summer of 2010 and since then have been taking the necessary steps to meet the strict quality standards and packaging requirements to be able to start production. James Rhoads from MFK explained to us in November 2011 that the up-front costs and time needed to complete the audits and quality controls were much higher than expected. He emphasised the often underestimated difficulties associated with the quality of institutions and infrastructures in developing countries (including precarious transport and shipping infrastructure, unreliable electricity networks, lack of water, bureaucracy, barriers to imports, etc.), which raise the costs associated with local production.

Following the success of the franchise scheme, more recently Nutriset has also offered to grant royalty-free licences to not-for-profit producers based in developing countries. The licensee then uses its own product formulations, trademarks, and quality systems. This licence scheme reduces further the risk of monopoly, in particular by stimulating the development of improved products and new applications. But despite the increased willingness of Nutriset to license its patent for the benefit of developing countries, a remaining barrier is that potential producers from developed countries remain unauthorized in principle to use the patent, which might have adverse effects on competition, prices and production capacities [21].

In 2008 Nutriset further embraced an open innovation model by signing a strategic partnership agreement with Industrial Revelation Initiative, a US-based NGO active in nutrition advocacy mainly in East Africa. This partnership comprises a joint venture called Edesia, established in the US in 2009. According to Nutriset's website, Edesia's mandate comprises the following strategic objectives:

- To set up and subsequently operate a new Plumpy'nut production site located in the US (Providence, Rhode Island), which launched production in 2010.
- To create a platform of research and development for new nutrition solutions.
- To forge a closer cooperation with American initiatives acting in developing countries.
- To enable Industrial Revelation Initiative to be an extra support tool for the Plumpy'nut producers network in the developing world (in terms of training, quality control, etc.).

Thus this joint venture goes beyond franchising and licensing by representing a stronger integration of the partners, with higher involvement of both in strategic activities and risk sharing. Besides being an additional sign of Nutriset's open model of innovation, integrating a partner from the US into the scene also holds geo-political relevance. For instance, one can hypothesise that official development assistance programs are influenced by lobbies of national NGOs, which may be locked-in to pre-existing knowledge or may want to protect their specific competencies.

In addition to the Plumpy'nut network, other enterprises have started producing and commercializing similar formulations of RUTF, such as Compact, a private firm based in Norway which also produces peanut-based RUTF and commercializes it under the name of eeZeePaste. In 2009 Compact launched production in India, using local products and labour. According to the company, one of its main strengths lies in logistics: “Compact offers customised service by being ready for dispatch within a few hours from incoming orders thanks to the back-up stocks kept in Norway, Denmark and other strategic places in Africa, Asia and the Middle-East. This has secured a reliable network of freight forwarders and airlines that are geared for quick actions (…) the innovative packaging of our products have been developed to facilitate logistics and to preserve the nutritional value of the food under any conditions” (Source: www.compactforlife.com). Other recent examples of emerging autonomous producers of RUTF that are not licensing Nutriset's patent are the US-based companies Tabatchnick Fine Foods and Challenge Dairy.

5. **New formulations and varieties of application**

Post-innovation improvements and adaptation to new varieties of application exert an important role in the diffusion of innovations and can influence technological trajectories in other disciplines or spheres of society [29]. Beyond the new packaging options that have emerged in recent years, an important effort is being made towards the development of new formulae of RUTF with different kinds of locally-available grains and legumes other than peanuts, both within and outside Nutriset [18]. This is an important development because it would allow tailoring RUTF to specific agricultural contexts. Addition of adapted mineral and vitamin supplement to the local diet seems also to increase the efficacy of programs based on the use of locally available nutrient rich foods, but according to Briend et al. [3] this approach requires further research to determine its effectiveness.

Another promising variety of application consists in the use of RUTF not only for alleviation but also for prevention purposes. MSF has experimented with mass distribution of the product in Niger and is advocating the wider extension of this practice but nutrition experts are divided on whether this is an efficient approach for prevention [14]. To advance further in this direction, in 2010 Nutriset helped establish an international R&D project aimed at developing and testing new solutions to help prevent

malnutrition and to share knowledge and experience. This is an international public–private research collaboration co-chaired by researchers from the University of California Davis and the University of Tampere, Finland, with Nutriset acting as the private partner that conducts product development (source: http://ilins.org).

6. **Discussion**

We have shown how RUTF is shaping a new technological regime in the treatment of child malnutrition. The introduction of RUTF has been accompanied by a shift towards new clinical protocols, new professional interactions and, in general, a change in the organisational structures that control service delivery, a process which can best be characterized as a socio-technical transition [39]. Indeed, the case of RUTF is a clear example of how the diffusion of a new technology requires wider modifications in social structures and organizational practices.

The notion of appropriate technology is useful to understand the diffusion of RUTF and the subsequent formation of a new technological regime. Appropriate technologies are those which better respond to the needs and capabilities of developing countries; technologies where the production methods employed are relatively simple (so that the demands for high skills are minimized, not only in the production process itself but also in matters of organization, raw material supply, financing, marketing, etc.) and where the production process relies mainly on local inputs and is aimed mainly for local use [19,32]. Other criteria to characterize appropriate technology include the low cost of the final product, the low capital investment required to start production, the minimal impact on the environment, the adaptability to the social and cultural environment, the easiness of maintenance, etc. As we have shown, judged against these criteria RUTF is a more appropriate technology than alternative solutions to treat child malnutrition, and this is precisely the central reason behind its successful diffusion as an innovation.

Although the product and production process are protected by patent rights until 2018, the patent holders have encouraged local manufacturing in developing countries which brings along significant advantages. It contributes to sustainable development and to nutritional autonomy, leading to a shift from dependence on international aid towards a higher ability of local communities to react to malnutrition. It also involves a shift from a technology transfer mentality to a collaborative approach to innovation focusing on interactive learning and competence building.

RUTF still exhibits a market structure where supply is quasi-monopolistic thanks to intellectual property rights, but in recent years Nutriset has further embraced an open model of knowledge sharing through different modalities of licences, franchises and partnerships, and simultaneously more autonomous producers have emerged. This is a positive trend because expanding the supply network provides opportunities to improve the quality of local agricultural supply chains in developing countries (of peanuts, oil, etc.), thereby promoting nutritional autonomy. In addition, it is important to ensure that an effective and efficient supply chain is developed that is able to keep pace with rising demand for RUTF. Moreover, the expansion of supply mitigates the risks associated with monopoly by providing a healthy competition that is good for innovation, prices and efficiency. On the demand side, demand is dominated by a few NGOs and international organizations, both as direct buyers and through their influence on local programs. These tend to be very well informed and demanding customers, which scrutinize profit generation along their supply chains, thereby mitigating the risk of abusive monopoly rents.

Affected countries should not be mere recipients of technology but rather partners in the interactive process of innovation, providing a better understanding of the opportunities and constraints associated with pro-poor innovation. Along these lines, the literature on innovation for the bottom of the pyramid suggests the need for a local business model that better embodies local behavioral responses to innovation, emphasizing the importance of strategic alliances between multinational companies and local firms, NGOs and governments [28,34]. Cozzens and Kaplinsky [7] also stress that the inclusion of local communities is necessary to ensure that innovation yields a sustainable reduction of poverty and inequality.

7. **Policy implications**

Public policies may influence technological regimes in many different ways, including research funding orientations, public–private partnerships, and intellectual property regulations. According to Kuhlmann [22] research policy for sustainable development requires a balanced portfolio of exploratory and problem-oriented research, underpinned by substantial socio-economic understanding. This author advocates the institutionalization of policy platforms as spaces for interaction and deliberation among key stakeholders from different levels and policy domains, with the aim of defining joint policies related to sustainable development. Along these lines, it would be advisable to further institutionalize technology platforms to perform targeted foresight of innovations to fight hunger, including ethical, legal and social aspects of RUTF, bringing together international organizations, NGOs, local governments, industry representatives and other civil society stakeholders.

An efficient provision of RUTF could be critical in the achievement of the Millennium Development Goals with respect to malnutrition and child mortality. The policy approach should strive for a balance between the public funding of basic research and the support of implementation institutions (for example through the development of protocols and training programs for efficient community-based therapeutic care). Policy platforms should also monitor the supply chain and ensure that RUTF is available when needed. The foresight and advisory processes should be accountable to the public and aim at gauging the knowledge and opinions of countries suffering most from malnutrition. Policy platforms should aim at modulating this technological regime transition to the benefit of malnourished children and developing countries.

The patent of Plumpy'nut is an important issue worth the attention of such policy platforms. Despite the emergence of franchise and licence schemes the debate around the patent is still controversial [14,21]. Some argue there should be no patents

on key humanitarian nutrition products. Indeed, most past inventions in humanitarian nutrition such as F100 or oral rehydration therapy were not patented. For others, the patent has helped in quality assurance and has provided a well organized process of technology transfer and capability building. Moreover, limiting intellectual property protection for innovations to fight hunger could have the adverse effect of reducing incentives for private firms to engage in much needed R&D. In our view, the focus of policy platforms at this stage should be to encourage Nutriset to promote further an open model of franchises and licenses and, at the same time, prepare the transition for 2018 when the patents expire.

Policy platforms should also encourage ongoing R&D efforts aimed at the development of new formulae of RUTF using different kinds of grains and legumes other than peanuts. This would accelerate the international diffusion process and enable a higher degree of self sufficiency for affected countries. Again, the policy approach should include not only targeted R&D funding but also the development of spaces for knowledge-sharing and coordination of research initiatives.

To conclude, it is important to emphasise that RUTF should not be seen as a panacea that will lead to the end of hunger. Rather, it should be taken as only a short term solution to respond to episodes of acute food deprivation often associated with natural catastrophes and war. The virtues of RUTF should never distract attention from the need to better address the structural causes of chronic hunger by promoting improved agriculture and dietary diversity in low-income countries.

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