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José Guimón* and Pablo Guimón**

Abstract
A simple invention can at times prove extremely useful. This is the case with Plumpy'nut, a variety of ready-to-use therapeutic food (RUTF) conceived in 1999 that is shaping a new regime for emergency interventions to alleviate child malnutrition. This paper applies concepts from the innovation systems literature into the analysis of Plumpy'nut with the aim of identifying the forces driving its successful diffusion as an innovation. Special attention is paid to three features that define the diffusion process: 1) shifting from inpatient to outpatient treatment, 2) building networks through licences, franchises and partnerships, and 3) exploring further varieties of application. We combine the theoretical discussion with insights from field research in Ethiopia, including personal interviews with relevant parties and direct observation of how Plumpy'nut works in practice. The ultimate objectives of this technology assessment exercise are to better understand the innovation journey of Plumpy'nut and to identify possible opportunities for policy intervention.

Keywords: food crises; malnutrition; therapeutic food; technology diffusion; technological regimes; Ethiopia

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1 Introduction

The United Nations Millennium Development Goals set forth the objective of cutting malnutrition in half by 2015. But the Food and Agriculture Organization (FAO) of the United Nations estimates that the number of hungry people will reach 1,020 million in 2009 (or almost one sixth of humanity), which represents an increase of around 200 million since the 1990 baseline period (FAO 2009). Africa and Asia are the most affected regions; and children living in rural areas the most vulnerable. Children under the age of five are particularly at risk from malnutrition, among other reasons because of their more demanding dietary requirements. According to Médecins Sans Frontières, nine children under the age of five die every minute of causes related to malnutrition (MSF 2008). Thus most emergency interventions to alleviate the effects of hunger tend to focus on children.

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. The paradox is that hunger increases despite the fact that there is enough food available for all. Reasons explaining this paradox include institutional shortcomings, lack of sufficient political will, natural catastrophes and armed conflicts (Sen 1982). In recent times new barriers have emerged, including climate change, rise of food prices, increased use of bio-fuels and the global economic crisis that started in mid-2007 (Morris et al. 2008; Oya 2009; Piessea and Thirtle 2009; Sheeran 2008). Innovation in the fight against hunger has become essential to balance out the negative impact of these trends.

The fight against hunger comprises two complementary strategies. The first is to provide technical and financial assistance to the least developed countries to help them achieve *food security*, a broad concept that includes critical attributes of food necessary for healthy populations such as sufficiency, reliability, quality, safety and timeliness (Juma 2007). The attainment of food security requires rural development, political stability and peace, infrastructure development and sustained economic growth. The second strategy is to deploy emergency interventions to provide food and therapeutic components to address malnutrition in the event of a crisis. Even if we accept that the best approach is the pursuit of the first strategy, it is also imperative to consider emergency solutions, and any kind of inflexibility in the strategy employed to fight malnutrition would be grossly unrealistic. Thus, both the governments of the least developed countries and the international community should combine both routes of action.

In this endeavour, innovation in the fight against hunger may manifest itself through different channels. Within the first strategy, the focus is to facilitate the development and transfer of agricultural technology and know-how more appropriate for the least developed countries, including irrigation techniques, fertilizers and transgenic crops (Spielman 2007; Thomas 2005; Naylor et al. 2004). A recent example of success on this front is Nerica, a new rice variety developed for Africa in the mid-1990s (Somado et al. 2008). Within the second strategy, the focus is to develop new types of therapeutic food and delivery practices that raise the efficiency of emergency interventions. A recent example is Plumpy'nut, a new variety of RUTF that is driving a new approach for emergency interventions to alleviate child malnutrition, as we shall argue in this paper.

Plumpy'nut is the commercial name of a protein-packed, nutrient-dense paste that requires neither refrigeration nor preparation. It was developed by a public-private partnership of Nutriset, a French private firm specializing in therapeutic food, and the Institute of Research for Development, a French public research institute based in Paris. The invention was patented and Nutriset's factory launched production in 2001. The aim of this paper is to analyze how Plumpy'nut was invented and further employed in the fight against hunger throughout the world, drawing attention to the factors that explain its diffusion and the features that define the new technological regime.

2 Methodology and sources

The theoretical contribution of this paper consists in applying concepts from the innovation systems framework to the analysis of Plumpy'nut as a new solution to fight hunger. Many studies (some of which will be cited throughout the text) have analyzed Plumpy'nut from the perspectives of nutrition science or development assistance; but none to the best of our knowledge has done so from an innovation systems perspective.

The empirical contribution is based on field research in Ethiopia. This field research was conducted in September 2008, comprising 11 personal interviews with experts and direct observation of how Plumpy'nut works in practice. The interviewees were field representatives from international organizations and NGOs, social workers and local manufacturers of Plumpy'nut. Throughout the paper we will provide testimonies from some of the interviewees, while the full list is available from the authors upon request.

The triangulation of sources, and the fact that earlier drafts of the paper were circulated for comments among some of the interviewees and other experts, both increase the validity of our case study research (Yin, 2003). Other sources besides direct observation and interviews include:

- An analysis of policy documents and white papers from international organizations and NGOs.
- Information provided by Nutriset through its website (www.nutriset.fr).
- An analysis of the patent of Plumpy'nut in the European and U.S. patent offices.
- A multidisciplinary literature review.

The rest of the paper is organized as follows. Section 3 introduces a set of concepts and theories from the innovation systems literature that bring insight to the study of Plumpy'nut. Section 4 describes the 'innovation journey' of Plumpy'nut building on those theoretical concepts and the abovementioned sources. Section 5 completes the paper with some conclusions and suggestions for the development of policy platforms.

3 Theoretical concepts to analyse Plumpy'nut from an innovation systems framework

We describe Plumpy'nut as an innovation, following its dynamic trajectory from invention to experimentation and to full application in multiple contexts. In its most broadly accepted definition (OECD 2006, "Oslo Manual"), innovation implies the introduction of new products or services into the market (product innovation), the use of new production processes (process innovation) or the implementation of new organizational or commercial practices (organizational and marketing innovations). As opposed to invention, in order to innovate it is not sufficient to discover something new

since innovation is associated with the commercialization of a new product/service or to the efficient application of a new process. Evolutionary economics and the innovation systems framework characterize innovation as an interactive process, where both formal and informal interactions between the different agents play a critical role in the diffusion process, which in turn is influenced by policies, incremental learning and tacit knowledge (Edquist 1997; Freeman 1987; Kline and Rosenberg 1986; Lundvall 1992; Nelson and Winter 1982). Thus, the diffusion of innovations occurs within *techno-economic networks*; a set of heterogeneous actors (laboratories, technical research centres, industrial companies, financial organisations, users, and public authorities) which via many interactions organise the relationships between scientific and technical research and the marketplace (Callon et al. 1992).

The vast literature on *technology diffusion* spans different disciplines and focuses on the reasons behind the S-curve that characterizes the rate of adoption of a new technology over time (see Geroski 2000 for a review). Rogers (1995) defines diffusion as the process by which an innovation is 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. This social system is inhabited by actors that can be categorized in relation to their readiness to adopt innovations and in relation to their influence over other actors in the system. *Early adopters, opinion leaders* and *change agents* exert a critical role in the process of diffusion. Diffusion depends on the perceived characteristics of the innovation, in particular its *relative advantage* vis à vis competing technologies, as well as on its *compatibility* with other technologies and values or beliefs. *Flexibility* in the process of adoption may reduce mistakes and encourage *customization* of the innovation to fit more appropriately into local contexts or changing conditions. On the opposite side, many different factors might raise *switching costs*, such as *complexity*, lack of *trialibility* or lack of *observability* of the consequences of the innovation (Rogers 1995; Geroski 2000).

A frequent critique to Rogers's theory is that the 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. The argument is that 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" (Attewell 1992, p. 3). This is a relevant theoretical perspective in the study of Plumpy'nut, which exhibits a market structure where supply is quasi-monopolistic thanks to intellectual property rights while demand is an oligopoly dominated by a few NGOs and international organizations. In this market, it would be unethical for the supplier to abuse the market power granted by its patent because new knowledge that helps reduce malnutrition can be conceptualized as a global public good, as it addresses a fundamental human right[1].

Our analysis also builds upon the concept of *innovation journeys* developed by Rip and Schot (2002) within their study of the co-evolution of science, technology and society.

[1] The right to adequate food is covered in the United Nations Charter, the Universal Declaration of Human Rights and subsequent international conventions on human rights derived from these (Eide, 2002). Archibugi and Bizzarri (2005) define the characteristics of global public goods in their analysis of vaccines for communicable diseases.

At an early stage of the innovation journey, the *new socio-technical option* is open-ended and its applications are still fairly uncertain. Over time, the options become articulated and link up with the social environment, which changes itself to adapt to the possibilities offered by new options. The embedding of technology in society includes *mutual adaptation* with other products, processes, institutions and actors. The diffusion of innovations not only requires improvement and mastery of the technology in a narrow mechanical sense, but also shifts in organizational procedures and practices. Patterns emerge through *linkages*, *alignments* and *networks*, within a trajectory characterized by non-linearity and complexity: "there is no path given in advance, the actors create a path by walking (sometimes stumbling along)" (Rip and Schot 2002, p. 158). That said, according to these authors successful innovation journeys always comprise three distinct phases: Building up a protected space, stepping into the real world, and sector-level changes.

The ultimate outcome of innovation journeys may be the advent of a new *technological regime* or *technological paradigm*, which Dosi (1982) defines as a stabilized model or a pattern of solution of technological problems. Technological regime transformations involve shifts in underlying technological knowledge but also managerial, organizational and social changes. The formation of a new regime means that the innovation shapes new actions and interactions of the different actors in a social system, by imprinting formal and informal rule-sets (Dosi 1982; Georghiou et al. 1986; Nelson and Winter 1982). In turn, technological regime transitions are influenced by governance and agency issues, such as regime membership, resource interdependencies, actor expectations and the ability to coordinate responses (Smith et al. 2005).

The concept of *intermediate* or *appropriate technology* is also important for the study of the diffusion of an innovation such as Plumpy'nut. In "Small is Beautiful" (1973), Schumacher calls for intermediate technologies tailored to the needs and capabilities of developing countries. This author defined intermediate technologies as those 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 materials and is aimed mainly for local use. Building on Schumacher's work, appropriate technology was later suggested as a better term than intermediate technology, since the latter was thought to be suggestive of inferior or second-rate (Akubue 2000; Jequier and Blanc 1983). Appropriate technology is characterized by any or several of the following:

- Low capital investment per unit of output and per employee.
- Organizational simplicity.
- High adaptability to a peculiar social and cultural environment.
- Use of local natural resources.
- Low cost of final product.
- High potential for employment.

As we shall show, judged against these criteria Plumpy'nut is clearly a more appropriate technology for the least developed countries than the previous solutions in place to respond to malnutrition crises. And this is precisely the central reason behind its successful diffusion as an innovation.

4 The innovation journey of Plumpy'nut

Building on Rip and Schot (2002) we distinguish three phases in the innovation journey of Plumpy'nut. The first consists in the gestation of the product and in building up a protected space. In the second phase, the invention steps into the real world through testing and pilot applications. Finally, in the third phase, the innovation experiences a wider diffusion and (possibly) leads to a change of technological regime.

4.1 Gestation

In this first phase of innovation journeys, an actor or group of actors envisage a new product or process with the potential to address more efficiently a market or societal need. In this endeavour, new combinations of existing knowledge are important, as are suggestions from users. The inventor then makes specific promises to sponsors in order to mobilise resources to be able to transform the technological opportunity into a *semblance of functionality*, in a process of *proof of principle* (Rip and Schot 2002, p. 162). Networking and resource mobilization lead to the emergence of a protected space for developing the technological opportunity through R&D. In a subsequent stage, research work within a protected space might lead to intellectual property rights.

Before Plumpy'nut was invented, the standard treatment for severe malnutrition was F100, a milk powder fortified with vitamins and minerals developed in the 1980s. F100 needs to be reconstituted with clean drinking water and consumed almost immediately. This 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 where children need to stay for around one month, usually with their mothers. The problem is that hospital capacities are limited and that, in addition, a mother leaving home and work inevitably puts her other children at risk. Crowded hospitals also multiply the risk of epidemics caused by infectious diseases.

Inpatient treatment will always 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 ready-to-use food supplement that overcame the limitations of F100. In 1997, the French scientist André Briend (then at the Institute of Research for Development and now at the World Health Organization, WHO) teamed up with Michel Lescanne, the director of Nutriset, a French private company founded in 1986 specializing in therapeutic foods. They developed and tested ready-to-use food in the form of chocolate bars with a similar composition as F100. The problem was that they melted easily and tasted worse when vitamins and proteins were added.

But in 1999 Briend envisaged an idea while having breakfast with his children that caused a shift in their line of research. He found his inspiration while spreading Nutella on his toast, which led him to realize that a paste would work better than a bar[2]. The formula was gradually improved in partnership with Nutriset and eventually baptized as Plumpy'nut – a combination of the words "plump" and "peanut".

[2] International Herald Tribune, "In Niger, 'Plumpy'nut' becomes a life-saver", By Michael Wines, August 9, 2005

Plumpy'nut is made of peanuts mixed with a sophisticated vitamin complex that provides 500 kilocalories in each packet. 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 does not spoil even after the package is opened. 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 water demands on poor households are minimized.

Another of Plumpy'nut's virtues is that it takes the treatment of severe malnutrition out of hospitals into homes (Collins et al. 2006). Outpatient treatment allows the mother to carry on with her usual tasks and frees hospital resources to take care of patients who are more seriously ill. 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 addition, Plumpy'nut can be produced locally without the need to develop advanced technological skills and relying mainly on local materials, which was not that easy with previous therapeutic food such as F100. Finally, but also important, the evidence so far is that treatment of malnutrition through Plumpy'nut can be achieved at lower costs per patient than former approaches, although cost comparisons are not straight-forward (Collins 2004).

Using Rogers's terminology, the success of Plumpy'nut can be attributed to its perceived relative advantage, to its compatibility with other processes and values in place, and to its simplicity, trialibility and observability. Moreover, Plumpy'nut can be seen as a more appropriate technology than former solutions since its production is more simple 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.

Once the product had been further developed, the invention was first registered in the French patent office in 2000 (patent number 00/13731) and 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 patents obtained for Plumpy'nut 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 (Source: Nutriset).

4.2 Stepping into the real world

Typical activities in this second phase of the innovation journey include the development of a prototype, testing, trouble shooting, implementation, learning about usage, and preliminary market testing (Rip and Schot 2002). Initial inventions formed in protected laboratory conditions may not necessarily remain relevant in the more unpredictable world outside the laboratory (Nightingale 2004), hence the ability to adjust ideas to implementation conditions becomes critical for technology diffusion, which requires not only improvement and mastery of the technology in a narrow mechanical sense, but also shifts in organizational procedures and practices. The introduction of the new product or process often takes place with a few lead users. The visibility of the product increases, and new potential opportunities appear.

In the case of Plumpy'nut, after further developing the product and setting up the manufacturing process, the production started in 2001 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.

According to Enserink (2008) Mark Manary, a nutrition scientist at Washington University in St. Louis, Missouri, was the first to test the product in clinical trials, in Malawi in 2002. Subsequently, it was used widely on the ground for the first time during the humanitarian crises in Darfur, western Sudan, in 2003. In both cases, the introduction of Plumpy'nut was very successful.

4.3 Wider diffusion

Once an innovation proves its value through testing and pilot applications, the third phase of the innovation journey involves wider adoption and diffusion. This requires sector transformations and new socio-technical linkages, as suppliers orient themselves to the new technology and exploit economies of scale and scope, while users recognize further varieties of application (Rip and Schot 2002, p. 165). It may also lead, as discussed in Section 3, to the stabilization of a new technological regime.

In the case of Plumpy'nut, after testing in Malawi and the success of its pilot application in Sudan, since 2005 it has gradually become the most widely used therapeutic solution to fight child malnutrition across Africa. For example, recent successful experiences have been reported in Ethiopia (Eklund and Girma 2008), Kenya (Dibari et al. 2008), Malawi (Sadler et al. 2008; Linneman et al. 2007), Niger (Defourny et al. 2007; Gaboulaud et al. 2007), Sudan (Enserink 2008) and Sierra Leone (Navarro-Colorado and Laquière 2005). The record of achievements demonstrates that Plumpy'nut is more efficient than the previous solutions in place (Briend et al. 2006).

Demand and production have greatly expanded. Nutriset (the biggest producer by far) produced more than 15,000 tons in 2008 and UNICEF (the biggest buyer) purchased around 8,000 tons in 2008 and expects global production to grow to at least 50,000 tons by 2011 (Enserink 2008). This growth estimate suggests that, despite its rapid diffusion in recent years, Plumpy'nut is still in an intermediate phase of its S-curve of diffusion. The diffusion process has been supported by some NGOs such as MSF, the Bill Clinton Foundation or Valid International, which recognized the virtues of Plumpy'nut and acted as early adopters.

In the rest of this section we elaborate further on three specific dimensions of the innovation journey of Plumpy'nut which have been critical drivers of its successful diffusion in the past and which we sustain are keys features of the new technological regime that is emerging. First, the change in the therapeutic care regime, from inpatient to outpatient. Second, the expansion of the supply network through franchises, licenses and partnerships. And third, the development of new varieties of application. We will

illustrate the discussion with some examples and testimonies from field research in Ethiopia and through information provided by Nutriset.

4.3.1 Shifting from inpatient to outpatient care

Traditional approaches to malnutrition crises rely on inpatient therapeutic feeding centers (TFC) as their primary mode of intervention, which provide intensive, high-quality care for severely malnourished patients. As discussed in Briend et al. (2006) and Collins (2004), this approach has several drawbacks:

- 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.
- They 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 number 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 the care of other children.
- Partly as a result of the previous issues, they are often unpopular with the target population, which causes people to present for treatment late, often after major complications have occurred.

Yet the advent of Plumpy'nut has enabled 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. Indeed, as we argued in Section 4.1, one of the main virtues of Plumpy'nut is that it enables outpatient treatment of malnutrition through a system of community-based therapeutic care (CTC). CTC is organized around networks of local workers or volunteers who visit household to detect cases of malnutrition using simple protocols, and encourage patients to visit nearby outpatient medical centers where Plumpy'nut is provided and patients are monitored. Sensitisation and mobilisation of the population initially 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 (Collins 2004). 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. CTC programs evolve over time and also adapt to differing contexts.

Admission criteria for TFCs normally followed the Standard Weight-for-Height (WFH) protocol recommended by WHO, which requires numeracy and the ability to perform height/length measurements, use complex tables and perform arithmetic calculations using decimal numbers. These requirements have proved problematic when trying to mobilise community members as volunteers. But CTC allows for simpler admission criteria, using MUAC (mid upper arm circumference) assessment to screen for cases, which does not require the user to be numerate or literate (Briend and Zimick 1986).

While CTC have proved to be highly efficient for patients suffering from severe acute malnutrition *without* complications, it needs to be stressed that TFC are still necessary for those suffering from severe acute malnutrition *with* complications, especially when

appetite is poor, since these kinds of patients do not respond well and still require inpatient treatment including liquid diets (Briend et al. 2006; Gaboulaud 2007).

Box 1. Health extension networks: the case of Ethiopia

Despite strong economic growth in recent years, the WHO estimates that 42% of children in Ethiopia are underweight. The causes include primitive farming, years of poor political management and an uncontrolled birth rate in one of Africa's most highly populated countries (over 75 million inhabitants). The average rural family has six or seven members who live in a 30 square-meter house and farm less than one hectare without machinery. "They call them famine plots", explains Marc Rubin, Unicef's head of operations and emergencies in Ethiopia. "The households are too large and rely on plots that are too small". For a family of six that relies on subsistence farming with hardly any profit and without the capacity to store surplus, the loss of a harvest due to meteorological or other reasons can prove fatal. The population in Ethiopia is mostly rural and geographically dispersed throughout a very large country with poor infrastructures, hence the invention of Plumpy'nut in itself is not sufficient to combat malnutrition; it also has to reach the target population.

Against this background, the Government, advised by Unicef, created an outpatient network to ensure that Plumpy'nut arrives where it is needed. "In Ethiopia the first huge demand for this product coincided with the health extension program that started in 2004", explains Van Steirteghem, the Unicef representative in the country. "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 24,000 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. Bedria Tadele is one of these health extension workers. She is 22 years old and started in this job two years ago after a recruitment process. She feels lucky with her job and states that "you have to compete for the post". She trained in the city for one year and now earns a Government wage and is responsible, with two colleagues, for a community of 3,188 people in 708 households, the same community in which Bedria 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 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 Plumpy'nut 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 an effective health network that starts in households.

The ultimate aim of CTC 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 (Collins 2004).

In conclusion, throughout the diffusion of Plumpy'nut, a key success factor present in all experiences was the community-based management of its provision (Collins et al. 2006; Eklund and Girma 2008). In some cases, new networks were created almost from scratch whereas in others existing community networks were utilized. In fact, an advantage of CTC as a form of intervention to fight malnutrition crises are the synergies that can be built with other programs, including general hygiene and HIV prevention and treatment. In a way, Plumpy'nut benefited from a wider trend towards local participation in health and development assistance programs, while at the same time it helped reinforce this trend.

4.3.2 Building a network of franchises, licences and partnerships

Another driver of Plumpy'nut's diffusion has been the increasing willingness of Nutriset to share its knowledge and allow manufacturing in the field through franchises, licenses and partnership agreements. 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 and since then the so-called "Plumpy'nut in the field" program has expanded to five countries (Ethiopia, Malawi, Niger, Democratic Republic of Congo and Dominican Republic). The franchising system is based on the transfer of Nutriset's know-how (production, management and distribution) to a local, independent producer known as the "Franchisee". Nutriset aims at ensuring homogeneity in quality standards and requires the franchisee to adhere to the following principles (Source: Nutriset):

- 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.

The general benefits of local manufacturing through this franchise system are wide-reaching. In addition to the transfer of knowledge and the licence to use the patent and registered brand name, franchisees benefit from continuous training; assistance and quality control; and access to R&D projects and to technological management or nutritional improvements (Source: Nutriset). Local production in the field allows for significant cost reductions[3]. It also stimulates the local economy by creating jobs and transferring technology, while representing an advance towards achieving self-sufficiency to address malnutrition crises. Indeed, Plumpy'nut can be manufactured easily using basic technology that is readily available in developing countries (Fellows 2003). The equipment required –a peanut roaster and grinder, and a mixing and filling machine– is relatively inexpensive and easy to use and maintain. The production process relies mainly on local materials and is intended for local use. The technology exhibits low capital investment per employee; organizational simplicity; high

[3] According to Collins et al. (2006), the production cost in Nutriset's French factory was around US$3,500 per ton, while local manufacturing allows for a price reduction of US$1,000 per ton, without taking into account the savings of transport costs. Similarly, Sandige et al. (2004) report cost savings of around 50% thanks to local production.

adaptability to the local social environment; high potential for employment; and low demands for high skills, not only in the production process itself but also in matters of organization and raw material supply. These are the main criteria to define a technology as intermediate or appropriate to the specificities of the least developed countries, as discussed in Section 3.

Box 2. Local manufacturing through franchises: the case of Ethiopia

We visited the headquarters of Hilina Enriched Food Processing Center in Legetafo, a few kilometres north of Ethiopia's capital city. This is one of the African franchisees that produce Plumpy'nut in situ. The director, Belete Beyene, proudly shows us around the factory that he built from scratch. Capacity will be doubled soon when the new 1,500-square-metre plant under construction next door is finished. 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 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 new plant is at full capacity, production is expected to reach 600 tons per month, around half of the French factory's current production.

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% 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". (Source: personal interview)

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%). 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", he assures us. "This is not just any industrial production process. If you're not careful you can kill a child".

Following the success of the franchise scheme, more recently Nutriset has also offered to grant licences to new producers with the purpose of avoiding the risks of monopoly, thus making healthy competition possible, and of helping developing countries build their own capacity (Source: Nutriset). This proposal was made during (and possibly influenced by) Nutriset's meeting in Rome in March 2007 with humanitarian stakeholders regarding intellectual property rights. The main principles of the licence agreement are phrased by Nutriset in the following terms:

"Nutriset may grant an intuitu personae, non-exclusive and non-transferable license to any public or private company or non-governmental organisation, real and serious, with headquarters and main shareholders based in a Developing Country, to manufacture and market products using the Patent owned by Nutriset/IRD, in

Developing Countries. In this kind of agreement, whose aim is to stimulate new product design and application development, the producer:
- Develops its own brand name and distinctive signs.
- Uses its own quality system.
Companies without a license are not authorized to produce or market products using Nutriset Patents in any way. Nutriset may consider this as an infringement and may choose to sue such companies."(Source: www.nutriset.fr)

In 2008 Nutriset further embraced an open innovation network by signing a strategic partnership agreement with Industrial Revelation Initiative, a U.S.-based NGO active in nutrition advocacy and in East Africa. This partnership comprises a joint venture called Edesia, established in the U.S. in 2009. Edesia's mandate comprises the following strategic objectives (Source: Nutriset):

- To set up and subsequently operate a new Plumpy'nut production site located in the US (Providence, Rhode Island), which expects to start production by the beginning of 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 U.S. partner into the scene also holds geo-political relevance. For example, 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.

4.3.3 Exploring further varieties of application

Post-innovation improvements and adaptation to new niches or "further varieties of application" (Rip and Schot 2002, p. 165) can exert a critical role in the diffusion of innovations and influence technological trajectories in other disciplines or spheres of society. Along these lines, it is worth exploring the new varieties of application which have emerged for Plumpy'nut in recent years.

After the introduction of Plumpy'nut, Nutriset has expanded its product range incorporating new packaging and formulation options for RUTF in response to specific market niches, such as Plumpy'doz and Nutributter. Furthermore, both within and outside Nutriset, there is a growing interest in the development of new formulae of RUTF with different kinds of locally-available grains and legumes, without the addition of milk powder or peanuts[4]. 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. (2006) this approach requires further research to determine its effectiveness.

[4] For example, Henry and Seyoum (2004) report on the development of new recipes by Valid International in conjunction with Oxford Brookes University.

Other varieties of application include treatment of malnutrition in adults and the use of Plumpy'nut not only for alleviation but also for prevention purposes. In the first case, Dibari et al. (2008) report experiences in Kenya with malnourished HIV+ adults but call for a different approach in the use of Plumpy'nut since they find a high proportion of the patients could not comply with the full prescription due to "dietary boredom" and clinical conditions associated with HIV such as lack of appetite and nausea. With regard to the use of Plumpy'nut for prevention purposes, MSF has experimented with mass distribution of the product in Niger and is advocating the wider extension of this practice. However, as discussed in Enserink (2008), nutrition experts are divided on whether this is an efficient approach for prevention.

5 Conclusions and policy implications

The diffusion of Plumpy'nut is shaping a new technological regime in the deployment of emergency interventions to alleviate the effects of malnutrition. The combination of RUTF and its feasible provision through outpatient networks is gradually transforming the way severe malnutrition is managed. Indeed, the introduction of Plumpy'nut has been accompanied by a shift towards a new treatment regime, with new clinical protocols, new professional interactions and, in general, a change in the organisational structures that control service delivery. In this sense, the case of Plumpy'nut is a clear example of how the diffusion of a new technology often requires modifications in organizational practices and procedures. It is also an example of the difficulty of making the difference in practice between product, service, process, organizational and marketing innovations, despite the clear taxonomy defined in the OECD Oslo Manual.

International organizations can play a critical role in promoting the application of science, technology and innovation in the fight against hunger. A recent example is the International Assessment of Agricultural Science and Technology for Development, an international panel which after a 4-year process involving over 400 international experts issued a statement in 2008 officially calling for a shift of agricultural science and technology towards more holistic approaches (www.agassessment.org). This panel has already been compared to the Intergovernmental Panel on Climate Change for the quality of its governance and the relevance of its recommendations (Vanloqueren and Baret 2009).

In the case of RUTF, four international organizations within the United Nations system issued a joint statement in 2007 advocating home treatment with RUTF for severely malnourished children[5]. By acting as opinion leaders and change agents, they contribute to the formation of the emerging technological regime.

Public policies may influence technological regimes in many different ways, including research funding orientations, public-private partnerships, and intellectual property regulations. As explained by Kuhlmann (2009), 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

[5] "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.

deliberation among key stakeholders from different levels and policy domains, with the aim of defining joint policies related to sustainable development.

Along those lines, it would be advisable to further institutionalize a technology assessment committee to perform targeted foresight of innovations to fight hunger (including ethical, legal and social aspects) and, in particular, of Plumpy'nut and other types of RUTF, bringing together international organizations, NGOs, local governments, industry representatives (including Nutriset) and other civil society stakeholders. The policy approach should strive for a balance between the public funding of basic research (for example to develop new formulae for RUTF using different crops) and the support of implementation institutions and guidelines (for example through the development of protocols and training programs for efficient community-based therapeutic care). The foresight and advisory processes should be accountable to the public and aim at gauging the opinion of the countries that suffer most from malnutrition.

The patent of Plumpy'nut is a particular issue worth the attention of such policy platforms. Despite the emergence of franchise and licence arrangements described in Section 4.3.2, the debate around the patent is still controversial (Enserink 2008). Some argue there should be no patents on key humanitarian nutrition products and that, 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 so far provided a rational and well organized process of technology transfer. Moreover, the private sector is an increasingly important actor in R&D which tends to focus on innovations that can be protected by patents, so limiting intellectual property protection for innovations such as Plumpy'nut could have the adverse effect of reducing incentives for private firms to engage in much needed R&D. Beyond encouraging Nutriset to expand its network of franchises, licences and partnerships, a more aggressive policy response could be to include new provisions in international intellectual property agreements that promote knowledge-sharing with developing countries. Another role of policy makers is to prepare the transition for 2018, when the patent rights of Nutriset expire.

Based on our study, policy platforms should also encourage R&D efforts aimed at the development of new formulae of RUTF using different kinds of grains and legumes other than peanuts, and without the need to add milk-powder, as discussed in Section 4.3.3. This would accelerate the international diffusion process and enable a higher degree of self sufficiency for affected countries. This is an example of how a new technological regime shapes further technological trajectories (Dosi 1982). 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.

Finally, our analysis of Plumpy'nut may offer some lessons for other innovations in the fight against hunger and for other domains such as the treatment of aids or the development and provision of vaccines for communicable diseases. These kinds of synergies and interdisciplinary learning opportunities should be further explored in forthcoming international fora and technology assessment groups.

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ANNEX 1. Photos from Ethiopia

A malnourished child taking Plumpy'nut.

Bedria Talede, a health extension worker who visits families to diagnose cases of malnutrition and prescribe Plumpy'nut based treatment.

A medical post where Plumpy'nut is distributed and malnourished children are monitored using simple protocols.

Local manufacturing of Plumpy'nut at Hilina Enriched Food Processing Center.

*** All photos by Alfredo Cáliz**