American Journal of Food Science and Technology, 2024, Vol. 12, No. 5, 150-154
Available online at http://pubs.sciepub.com/ajfst/12/5/2
Published by Science and Education Publishing
DOI:10.12691/ajfst-12-5-2

Development of Ready-to-use Maize and Bean Based Therapeutic Foods for the Recovery of Uncomplicated Severe Acute Malnourished Children Aged from 6 to 59 Months

Anon Franck-Donald N'Guessan[1], Adélaïde Marie-Christina Gnonde[1], Kouamé Hermann Yeboue[2,*], Sassor Odile Purifine Ake-Tano[1], Ahoua Yapi[2]

[1]National Institute of public Health, Abidjan, Côte d'Ivoire
[2]Biology and Health Laboratory, Training and Research Unit of Biosciences, Felix Houphouet-Boigny University, Abidjan, Côte d'Ivoire
*Corresponding author: yeboue2@gmail.com

Received August 18, 2024; Revised September 20, 2024; Accepted September 26, 2024

Abstract Ready-to-use therapeutic foods (RUTF) play a fundamental role in the management protocol for severe acute malnutrition in children aged 6 to 59 months. Their availability, , therefore, constitutes a major issue in the fight against infant morbidity and mortality in developing countries. In Côte d'Ivoire, frequent shortages of RUTF are observed in the majority of health structures with repercussions on the level of performance of nutritional programs. Faced with this situation, an Ivorian research team proposed formulating therapeutic foods based on local products. The study was carried out at the National Institute of Public Health and the Nangui Abrogoua University of Côte d'Ivoire. The objective was to develop a formula meeting the recommended nutritional and microbiological requirements in order to use it as a substitute for reference products. It made it possible to develop a ready-to-use therapeutic food using the linear programming technique, then produced using traditional methods. The nutritional and microbiological qualities were determined and confirm that the formula based on corn and beans meets the recommended nutritional and microbiological needs for severely acutely malnourished children without complications. It will be subject to current clinical trial processes in order to use it with complete peace of mind.

Keywords: *Therapeutic foods, Severe acute malnutrition, Local product*

Cite This Article: Anon Franck-Donald N'Guessan, Adélaïde Marie-Christina Gnonde, Kouamé Hermann Yeboue, Sassor Odile Purifine Ake-Tano, and Ahoua Yapi, "Development of Ready-to-use Therapeutic Foods Maize and Bean Based for The Recovery of Uncomplicated Severe Acute Malnourished Children Aged from 6 to 59 Months." *American Journal of Food Science and Technology*, vol. 12, no. 5 (2024): 150-154. doi: 10.12691/ajfst-12-5-2.

1. Introduction

Acute malnutrition among children aged 0 to 5 years is a real public health problem in developing countries and Ivory Coast is not spared. It is the result of an insufficient quantity and/or quality of food provided according to the needs of the individual [1]. This condition can occur in the event of food shortage, recent acute illness, inappropriate diet or a combination of some of these factors [1]. Acute malnutrition can be moderate, severe without complications or severe with complications [2,3].

In its management, ready-to-use therapeutic foods (RUTF) are effective means [4]. They are in the form of spreads, cookies or bars (BP-100) or drinks, composed of ingredients such as cereals, vegetable oil, sugar and vitamin complexes [5].

In Ivory Coast, their unavailability is becoming very frequent and constitutes a major problem in the management of malnutrition. Faced with this challenge, a research team set out to develop ready-to-use therapeutic foods (RUTF) based on local ingredients.

The objective of this work is to formulate one of these nutritional complexes based on corn and beans, meeting nutritional and microbiological recommendations, with a view to use it as substitutes for reference products.

2. Material and Methods

2.1. Type and Location of Study

This is an experimental study over a period of 6 months at the Nutritional Rehabilitation Department of the National Institute of Public Health (NIPH) and the Nutrition Laboratory of the University of Nangui Abrogoua (UNA).

2.2. Production Process

2.2.1. Selection of Ingredients

The major ingredient is the corn. As protein foods, soy, beans, eggs, and milk were used. Sugar was used for its contribution to the final taste of the product. The refined palm oil was, also, used for energy density and texture formation. Spirulina and baobab leaves were selected to cover the mineral salt and vitamin components.

2.2.2. Processing of Ingredients

Corn flour was obtained from corn grains grown in Côte Ivory. After grains cleaning (sorting, winnowing and washing with water), the corn grains were moistened with water (5% per weight) then roasted in a pan between 120 and 130 ° C for 30 to 40 min. The roasted grains were then cooled, pulverized in a grinder (PHILIPS®, RH 2056) and finally sieved using a 300 µm sieve. The bean flour was prepared using the same process. The cane sugar was ground in the mill then sieved to obtain a finer powder (150 µm in diameter) with a particle size close to 1000 µm. This process made it possible to obtain icing sugar.

2.2.3. Formulation

Linear programming was used to carry out the formulation. The model allowed us to have the variables which are the quantities of ingredients to incorporate, the energy values and the nutrient contents which correspond to the quantities to use. The obtained food formula are composed of; corn and bean flour, palm oil and olive oil; dried egg white powder and spirulina. The quantities are as follows; corn (21 g/100 g), bean (27 g/100 g), egg white powder (4 g/100 g), palm oil (20 g/100 g), olive oil (10 g/100 g), and sugar (11 g/100 g). A premix composed of spirulina (4 g) and baobab leaves powder (2 g), vitamin C (50 mg/100 g) and emulsifier (950 mg/100 g) was added. The particle size of the retained powdered ingredients was ≤ 300 µm [6].

2.2.4. Preparation

The RUTF formula based on local ingredients was prepared by combining the ingredients. The formulated recipe was standardized as follows:

- Palm oil was first mixed with soy lecithin powder in a multi-function mixer (SOKANY®, KF-103S) and then heated to a temperature between 50 and 56 ° C using a SEVERIN® brand dryer, HT0104 for 15 min. The temperature control was carried out via the infrared thermometer. The sugar glaze (Very finely powdered sugar) was then added to the previous mixture of corn flour previously roasted over a low heat for 2 to 5 minutes until a homogeneous paste was obtained constituting mixture 1.
- To mixture 1, bean flour previously roasted, egg white powder, olive oil were added, then heated at 50°C for 5 min to obtain mixture 2.
- To this mixture 2, premix was added then homogenized at different speeds (2 to 8) for 3 min/speed degree in order to simulate the silo conditions in the reference RUTF production plants.
- The final mixture is the ready-to-use local food called MAHA. It was stored between 45 and 50°C in 100 ml polypropylene plastic containers.

2.3. Biochemical Analyses of Ready-to-use Therapeutic Food

The determination of moisture and dry matter content of the samples was carried out by the AOAC method (2000) [7]. The ash content was determined by incineration in a muffle furnace at 550 ° C according to the AOAC method (2000) [7]. The obtained samples were used to produce the mineral profile of the samples using the scanning Electron Microscope (SEM). The protein content was determined according to the Kjeldahl method [8]. The total lipid content was determined according to the method using the SOXHLET AOAC (2000) [7]. The fiber content was determined according to the AOAC method (2000) [7]. The calculation of the available carbohydrate content in the samples was obtained by difference and expressed as a percentage according to the relationship given by FAO/INFOODS (2015b) [9]. Total metabolisable energy or Energy Value (EV) (kcal/100g) is calculated from energy-producing food components, according to the conversion coefficient of metabolized energy, also called general Atwater factors, of each component. [9,10,11].

2.4. Microbiological Analyses

Microbiological analysis of total mesophilic aerobic germs (TMAG), Yeasts and Molds, Total and faecal coliforms, Escherichia coli and Staphylococci was performed according to standard procedures for the preparation of culture media and the enumeration of germs [11]. The dosage of each microorganism, 10g of each formula was aseptically removed and added to 90 ml of Buffered Peptone Water (BPE) prepared according to the manufacturer's recommendations (SCHARLAB S. L®, Spain).

2.5. Statistical Analyses

The collected data were processed with Graph Pad Prism software version 7.00. The experimental results are expressed as arithmetic means and accompanied by the standard error (m ± SEM). The nutritional composition was compared to that of the reference product. Thus an analysis of variance (ANOVA) followed by a Newman-Keuls test at the 5% threshold was then carried out.

3. Result

3.1. Nutritional composition of the Formulation

The nutritional composition of MAHA is presented in Table 1 and Table 2. The energy value of the formula is 530.82 kcal per 100g of matter. The lipid content is 32.59 ± 0.18 g/100g. The protein composition of the formula is 13.70 ± 0.75 g/100g. The carbohydrate content is 43.58 ± 0.56 g per 100 g. The moisture content is 2.57 ± 0.1g per 100 g of matter. The MAHA formula has a dry matter content of 98.3 ± 0.1g. The fiber content is 2.77 ± 0.15

g/100g. The mineral composition of the food is made of Potassium (1213mg), Calcium (414mg), Sodium (215), Phosphorus (390), Magnesium (122), Zinc (13.4) and Copper (1.4). The comparison of means is carried out by the Newman-Keuls test at the 5% threshold. The means on the same raw, assigned different letters in superscript are not significantly different between the local formula and *Plumpy'Nut*® ($p < 0.05$) according to the parameter studied.

Table 1. Biochemical composition of the local formula and the reference formula

Parameters	Recommendation		*Plumpy'Nut*®	MAHA
	Min	Max		
Moisture (%)	2,5	5	2,41 ± 0,78 [a]	2,57 ± 0,1 [b]
DM (%)	_	_	97,59 ± 0,35 [c]	98,3 ± 0,1 [b]
Protein (g/100g)	11	16	13,70 ± 0,75 [c]	14,17 ± 0,27 [b]
Fat (g/100g)	26	36	33,84 ± 1,71 [a]	32,59 ± 0,18 [b]
Ash (g/100g)	_	_	3,74 ± 0,91 [a]	3,19 ± 0,08 [b]
Fiber (g/100g)	_	5	1,95 ± 1,41 [b]	2,77 ± 0,15 [a]
Carbohydrate (%)	_	_	44,36 ± 2,35 [a]	43,58 ± 0,56 [a]
VE (kcal/100g)	520	550	536,82 ± 7,17 [a]	53O,29 ± 1,73 [ab]

Each value represents the mean ± standard error (n = 3 replicates).
DM: Dry matter; VE: Energy value; MAHA: Local corn/bean formula
The means on the same raw, assigned different letters in superscript are not significantly different between the local formula and Plumpy'Nut® ($p < 0.05$).

Table 2. Mineral composition of the local formula

Minerals (MG/100G)		Recommendation	MAHA	
		MAX	MIN	
Micro-elements	Na	290	-	215
	K	1400	1100	1213
	Ca	600	300	414
	P	600	300	390
	Mg	140	80	122
Trace elements	Fe	14	10	12,7
	Zn	14	11	13,4
	Cu	1,8	1,4	1,4

3.2. Microbiological Quality of "MAHA"

The obtained value for total aerobic mesophilic germs of local formula is lower than the standard (51 CFU/g). Yeasts were observed but in quantities lower than the pre-established standards. On the other hand, total and faecal coliforms, *molds*, *salmonella*, *Escherichia coli* and *staphylococci* were not detected in this formula. Thus, the fungal and bacteriological loads detected in the MAHA formula correspond to the microbiological criteria applicable to ready-to-use therapeutic foods intended for children under five years of age with severe acute malnutrition without complications [12]. The microbiological analyses are presented in Table 3.

Table 3. Microbiological quality of the local formula

MICRO-ORGANISMS	MAHA	STANDARDS*
Total mesophilic aerobic germs	51	< 104 CFU/g
Total coliforms	Abs	< 10 CFU/g
Faecal coliforms	Abs	Abs/g
Molds	Abs	< 50 CFU/g
Enterobacteriaceae	Abs	< 10 CFU/g
Escherichia coli	Abs	Abs/g
salmonella	Abs	Abs/g
Staphylococci	Abs	Abs/g

Abs: Absent; CFU: Colony Forming Unit; MAHA: Local Corn/Bean Formula.

4. Discussion

The objective of this study is to formulate a ready-to-use therapeutic food based on local nutritional products for the management of severe cases of uncomplicated acute malnutrition. The ingredients were selected based on the recommendations of Collins (2006) [13]. These are corn, bean, egg white, palm oil, olive oil and cane sugar. Spirulina, baobab leaves powder and vitamin C were used as micronutrient supplements. Soy lecithin was used as an emulsifier.

The quantity per food ingredient was defined by linear programming. A formulation work made it possible to obtain a ready-to-use therapeutic food called "MAHA".

Its nutritional composition was studied and compared to international standards. In terms of macronutrients, the energy density of MAHA is 530.29 ± 1.73 Kcal per 100g of material. This is an important quality of RUTF intended for the rehabilitation of severely malnourished children without complications due to their high energy requirement. This result is the same as that of the Amegovu *et al.* study in 2014 [14].

According to international experts, malnourished children need a diet rich in fat [15,16]. The local MAHA formula has a statistically adequate lipid level (32.59 ± 0.18 /100g) because its value remains within the limits set from 28 to 36g / 100g [17,18]. These lipids are necessary for the absorption of vitamins A and E according to FAO/IFAD/UNICEF/WFP/WHO [18]. These vitamins are also important for rapid recovery and reduction of the incidences associated with acute malnutrition. In addition, the protein content of the Formula (14.17 ± 0.27 g/100g) is superimposable to the recommended standards [11], [19,20]. These proteins are essential for the rehabilitation of lean mass in malnourished people.

Indeed, they are involved in many biological functions such as muscle tissue formation, enzyme and hormone production, and growth [21]. Concerning carbohydrates, the carbohydrate content of MAHA is adequate according to the work of Amegovu *et al* (2014) [14].

These carbohydrates contribute to protein synthesis and are involved in thermoregulation in malnourished people [22].

The mineral profile of MAHA has also been studied. It is satisfactory according to the work of Adjou., *et al.* (2012) [23]. These minerals play an important role in the restoration of intracellular and extracellular fluids. They are involved in many biological functions including enzymatic activities as well as the electrolytic balance of the blood flow where certain minerals (Na, K, and Mg) must have a perfect adequacy for the proper functioning of the body [18].

Sodium and potassium are minerals necessary for maintaining the osmotic balance of body fluids as well as body pH by regulating nervous and muscular irritability [24,25]. They also help control glucose absorption and improve normal protein retention during growth [26]. The Na/K ratio of the body is of great interest in the prevention of cardiovascular disorders. A Na/K ratio of less than 1 is therefore recommended [21,22], [27,28]. The Na/K ratio of the formula obtained is less than 1. The results of the "MAHA" mineral profile have values that globally represent 80% of the recommended minimum requirements [8]. At the end of this analysis, it appears that the nutritional composition of MAHA is superimposable to that suggested by experts for the management of children with severe acute malnutrition without complications [18]. The study of the microbiological quality of the local formula indicates that the load of total mesophilic aerobic germs is lower than the microbiological criteria (< 104 CFU/g) indicated by the different organizations involved in the management of acute malnutrition [12], [29,30]. The moisture content of the formula is statistically included in the levels set in ready-to-use foods according to the work of Santini., *et al.* (2013) [31]. This moisture content is due to the different cooking, drying and roasting treatments applied to the different inputs including beans, corn and eggs. The cooking/drying and drying/roasting couplings have allowed a significant reduction in the load of mesophilic aerobic germs. This low moisture content of the local formula is beneficial for better and long-term conservation [26].

Other authors such as Tarhouni *et al.* (2015) [20], also showed that precooking and drying flours reduce total mesophilic aerobic germs. The absence of hygiene control germs (faecal coliforms) and pathogenic germs (S. aureus, Salmonella) in the local formula proves the effectiveness of the cooking conditions (temperature/time). These results could also reflect the compliance with good hygiene practices (GHP) and manufacturing practices (GMP) during the production of local RUTF.

5. Conclusion

The fight against malnutrition in children under five years of age is one of the major areas of public health intervention in the world. The availability of ready-to-use therapeutic foods plays an important role in this process. In Côte d'Ivoire, the frequent shortage of these therapeutic foods motivated the conduct of this study in order to formulate a RUTF based on local ingredients. The work demonstrated its nutritional and microbiological qualities which are superimposable to international standards. The "MAHA" could therefore be used for the management of cases of severe acute malnutrition without complications. It will follow the ongoing clinical trial process in order to be safely prescribed to children.

References

[1] ACF. "L'essentiel des clés pour comprendre la nutrition-santé et le positionnement d'ACF. Département Scientifique et Technique, Secteur Nutrition - Santé, *ACF - International* (2011b).

[2] ACF. "Mettre fin à la malnutrition d'ici à 2030. Faire de la deuxième conférence internationale sur la nutrition une étape décisive. *ACF - International* (2014).

[3] Brixi G. "Innovative optimization of ready to use food for treatment of acute malnutrition". *Maternal and Child Nutrition*; 14(4): e12599 (2018): 1-9.

[4] ACF. "Inventory of definitions commonly used for prevention, diagnosis and treatment of undernutrition". Département Scientifique et Technique, ACF – France. International (2011a).

[5] Brou, K., Kouadio, E. J.P. N., Due, E. A., Kouame, S. K., Tano, K. and Dago, G. "Effects of processing method and blend on some physicochemical properties and digestibility of flours made from selected cereals and legumes". Int. J. Biol. Chem. Sci. 3(5): 1151-1160, October 2009.

[6] Niraula P. 2017. "Preparation of ready –to-use supplementary food (RUSF) for treating moderately acute malnutrition in children aged 6-24 months". Department of Nutrition and Dietetics, Central Campus of Technology Institute of science and Technology Tribhuvan University, Nepal, 78 p., 2017.

[7] AOAC. "Official Methods of Analysis of Association of Official Analytical Chemists. 17th Edition, Gaithersburg, Maryland, USA". Methods 925.10 (2000): 65.17, 974.24, 992.16.

[8] FAO/INFOODS, "Directives FAO/INFOODS relatives à la conversion d'unités, de dénominateurs et d'expressions", version 1.0. FAO, Rome, 2015a.

[9] FAO/INFOODS. "Directives FAO/INFOODS relatives à la vérification des données sur la composition des aliments avant la publication d'une table/base de données utilisateur-Version 1.0. FAO, Rome (2015b).

[10] Callaghan-Gillespie M and Mui M. "Useful Tools for Food Aid: Linear Programming and Protein Quality Tools". *Food and Nutrition Bulletin* 39.S2 (2018): S80-S88.

[11] FAO. "Individual food intake survey methods". Keynote paper, National Institute of Food and Nutrition Research, Rome (2003).

[12] USDA (United States Department of Agriculture), 2013. "National School Lunch Program Fact Sheet". Food and Nutrition Service of the United States Department of Agriculture (2015).

[13] Collins, S., Dent, N., Binns, P., Bahwere, P., Sadler, K. and Hallam, A. "Management of severe acute malnutrition in children". Lancet 368 (9551): 1992-2000.

[14] Amegovu A., Ogwok P., Ochola S., Yiga P., Musalima J., Mandha J., "Sensory acceptability of sorghum peanut blend (SPB) and corn soy blend plus by young chilfren with moderate Acute malnutrition in karamoja Uganda". Journal of Food research 3 (2014): 17-26.

[15] Dibari F. "Design and pre-testing of lipid-based, ready-to-use foods for the prevention and treatment of malnutrition in low resource settings". Doctoral thesis Institute of Global Health, University of College London, England (2015): 353.

[16] *World Food Programme (*WFP). "Technical Specifications for-Ready-to-Use Supplementary Food-RUSF". WFP, Specification reference: MIXRSF000 (2016).

[17] Duclercq MP. "Production des aliments prêts à l'emploi (APE): un aperçu des étapes de leur production « locale » et des défis à relever". Dossier technique du Forum PCMA (2014).

[18] FAO/IFAD/UNICEF/WFP/WHO. "The State of Food Insecurity in the World 2017. Building resilience for peace and food security". Rome (2017).

[19] Ikujenlola AV. "Quality and in vivo assessment of precooked weaning food from quality protein maize, soybean and cashew nut flour blends". Croatian Journal of Food Technology, Biotecnology and Nutrition 11.1-2 (2016): 49-57.

[20] Tarhouni A.. "Mise au point d'un procédé intégré de valorisation des coproduits de la sardinelle aquadocs" (2015).

[21] Ponka R., "Composition nutritionnelle de quelques farines infantiles artisanales du Cameroun". *International Journal of Innovation and Applied Studies* 16.2 (2016): 280-292.

[22] Nieman DC., "Nutrition". WmC. Brown, Dbugye, USA (1992): 237-312.

[23] Adjou ES., Ahoussi-Dahouenon E., Mohamed S., "Investigations on the mycoflora and processing effects on the nutritional quality of peanut (*Arachis hypogea* L. Var. Ts 32-1)". Journal of Microbiology, Biotechnology and Food Sciences 2.3 (2012): 1025-1039.

[24] Kosoko SB., Oluwole O., Sokabi AO., Adepoju M., "Comparative Quality Evaluation of Roasted Cashew Nut Kernel: Effect of Roasting Methods". *Advance Journal of Food Science and Technology* 6.12 (2014): 1362-1371.

[25] Michaelsen KM and Clausen T. "Inadequate supplies of potassium and magnesium in relief food - Implications and countermeasures". Lancet 2 (2009): 1421-1423.

[26] NRC. "Recommended Dietary Allowances. 10th Edition"., Washington DC, National Academy Press, 24 (1989).

[27] Audu SS and Aremu MO. "Effect of processing on chemical composition of red kidney bean (Phaseolus vulgaris L.) flour". *Pakistan Journal of Nutrition* 10.11 (2011): 1069-1075.

[28] OMS. "Note technique: Suppléments alimentaires pour la prise en charge de la malnutrition aiguë aigue chez les nourrissons et les enfants âgés de 6 à 59 mois" (2012).

[29] CAC. "Programme mixte FAO/OMS sur les normes alimentaires". Comité du codex sur la nutrition et les aliments diététiques ou de régime. Document de travail sur une norme pour les aliments prêts à l'emploi. Trente-sixième session. Bali, Indonésie 24-28. CX/NFSDU 14/36/2 Add (2014): 1.

[30] CAC. "Programme mixte FAO/OMS sur les normes alimentaires". Comité du codex sur la nutrition et les aliments diététiques ou de régime. Avant-projet de ligne directrice pour les aliments thérapeutiques prêts à l'emploi (RUTF). Trente-huitième session. Hambourg, Allemagne 5-9 (2016).

[31] Santini A., Novellino E., Armini V., Ritieni A., "State of the art of Ready-to-Use Therapeutic Food: A tool for nutraceuticals addition to foodstuff". *Food Chemistry* 140 (2013): 843-849.