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Research Article

Preparation of Ready-to-use Therapeutic Foods Based on Soy, Millet, Rice, Corn, and Sugar for the Management of infant with Moderate Acute Malnutrition

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Abstract

The prevalent number of children in developing countries from suffering MAM is increasing daily and this has significant cost implications for their treatment. Therefore, the management of MAM should be a public health priority. 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. In our study, we aim to enhance the value of ready-to-use foods prepared from local products, namely soya, millet, rice, maize and sugar ($SOMRIS_{10\text{-}16}$). 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 for the treatment of moderate acute malnutrition. It has allowed to develop a ready-to-use therapeutic food using the linear programming technique, then produced according to traditional methods. The nutritional and microbiological qualities have been determined and confirm that the formula based on soy, millet, rice, corn, and sugar ($SOMRIS_{10\text{-}16}$), meets the nutritional and microbiological needs recommended for children with moderate acute malnutrition. It will be subjected to the clinical trial processes in force in order to use it with complete peace of mind.

Keywords

Therapeutic Foods, Moderate Acute Malnutrition, Local Product

1. Introduction

According to the World Health Organization, child malnutrition is a deficiency or excess in a child's energy and nutritional intake [1]. It stems from a host of factors, both pathological and socioeconomic. However, the nutritional factor positions itself de facto as the main cause of this scourge by creating a pathological context favorable to the onset of child malnutrition [1]. Moderate acute malnutrition (MAM) affects many children in developing countries. The prevalent number of children in developing countries from suffering MAM is increasing daily and this has significant cost implications for their treatment. Therefore, the management of MAM should be a public health priority. Nowadays, supplementary feeding

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programs have been established in some African countries [2]. the prevalence of malnutrition in children aged 0 to 5, in 2011, in Côte d'Ivoire, was over 5% and thus deemed "precarious". 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. In our study, we aim to enhance the value of ready-to-use foods prepared from local products, namely soya, millet, rice, maize and sugar ($SOMRIS_{10-16}$). Thus, we formulated a ready-to-use food based on soya, millet, rice, maize and sugar ($SOMRIS_{10-16}$); we determined its physico-chemical composition and its microbiological quality.

2. Material and Methods

2.1. Raw Materials

Taking into consideration of the locally available food in our study areas, the following raw materials used for supplementary food formulation were procured; soya, millet, rice, maize and sugar. As protein foods, soy, egg, and milk were used. Sugar was used for its contribution to the final taste of the product. Also, refined palm oil and olive oil was used for energy density and texture. Spirulina was also selected to cover the mineral salt and vitamin components.

2.2. Treatments of Ingredients

The rice, millet and corn flours were obtained from grains grown in Côte Ivory. After cleaning (sorting, winnowing and washing with water), the grains were moistened with water (5%) and then roasted in a pan between 120 and 130 ℃ 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. Soy flour was obtained using the same process. Cane sugar was ground in a mill and then sieved to obtain a finer powder (150 µm in diameter) with a particle size close to 1000 µm. This process produced icing sugar.

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 be used for the treatment of moderate acute malnourished children. The food formula obtained is composed of; millet flour, corn, rice, soybean, sugar and palm oil; olive oil, dried egg white powder and spirulina. The quantities are as follows; corn 20 g/100 g, millet (17 g/100 g), soybean (18 g/100 g), egg white powder (4 g/100 g), palm oil (20 g/100 g), olive oil (5 g/100 g) and sugar (10 g/100 g). Spirulina (5 g), vitamin C (50 mg/100 g) and emulsifier (950 mg/100 g) were added. The particle size of the retained powdered ingredients was ≤ 300 µm [3].

2.4. Preparation

The $SOMRIS_{10-16}$ formula based on local ingredients was prepared by combining the ingredients. The formulated recipe was standardized as follows:

1. Palm oil was first mixed with soybean powder in a multifunctional mixer (SOKANY®, KF-103S) and then heated to a temperature between 50 and 56 ℃ using a SEVERIN® brand dryer, HT0104 for 15 min. The temperature control was carried out via the infrared thermometer. The sugar glaze was then added to the mixture of corn flour, rice, soybeans previously roasted over low heat for 2 to 5 minutes until a homogeneous paste was obtained constituting mixture 1.
2. To mixture 1 were added egg white powder, olive oil and then heated to 50 ℃ for 5 min to obtain mixture 2. To this mixture 2, spirulina and vitamin C were added and 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 $SOMRIS_{10-16}$. It was stored between 45 and 50 ℃ in 100 ml polypropylene plastic containers.

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

The determination of moisture and dry matter content of the sample was carried out by the AOAC (2000) method [4]. The ash content was determined by ashing in a muffle furnace at 550 ℃ according to the AOAC (2000) method [4]. The samples obtained 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 [5]. The total lipid content was determined according to the AOAC (2000) SOXHLET method [4]. The fiber content was determined according to the AOAC (2000) method [4]. 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 (2015) [6]. The calculation of the energy value (EV) (kcal/100g) was carried out according to the relationship given by the conversion coefficient of metabolized energy also called Atwater factors [6-8].

2.6. 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 [8]. 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).

2.7. 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 international recommendations. Thus, an analysis of variance (ANOVA) followed by a Newman-Keuls test at the 5% threshold was then performed.

3. Results

3.1. Nutritional Composition of the Formulation

The nutritional composition of SOMRIS$_{10\text{-}16}$ is presented in Tables 1, 2. The energy value of the formula is 486.82 kcal per 100g of matter. The fat content is 32.8 ± 0.22 g/100g. The protein composition of the formula is 11.10 ± 0.15 g/100g. The carbohydrate content is 39.30 ± 0.19 g per 100 g. The moisture content is 2.49 ± 0.2 per 100 grams of matter. The SOMRIS$_{10\text{-}16}$ formula has a dry matter content of 96.1 ± 0.1. The fiber content is 2.81 ± 0.19g/100g and is less than 5g/100g. The mineral composition of the food is made of Potassium (1301 mg), Calcium (436 mg), Sodium (215 mg) (Phosphorus 383.15) Magnesium (136), Zinc (13.1) and Copper (1.1). After a one-way analysis of variance (ANOVA), the comparison of means is carried out by the Newman-Keuls test at the 5% threshold. The means on the same line, assigned different letters in superscript are not significantly different between the local formula and the international recommendations ($p < 0.05$) according to the parameter studied.

Table 1. *Biochemical composition of the local formula.*

Parameters	Recommendation*		*SOMRIS$_{10\text{-}16}$*
	Min	Max	
Moisture (%)	2,5	5	2,49 ± 0,2 ^{b}
MS (%)	_	_	96,1 ± 0,1^{b}
Protein (g/100g)	11	16	11,10 ± 0,15 ^{b}
Fat (g/100g)	26	36	29,80 ± 0,21 ^{b}
Ash (g/100g)	_	_	3,19 ± 0,08 ^{b}
Fiber (g/100g)	_	5	2,81 ± 0,19 ^{a}
Carbohydrate	_	_	39,30 ± 0,19 ^{a}
VE (kcal/100g)	520	550	486,82 ab

Each value represents the mean ± standard error (n = 3 replicates). MS: Dry Matter; VE: Energy Value; SOMRIS$_{10\text{-}16}$: Local Formula

Table 2. *Mineral composition of the local formula.*

Minérals (MG/100G)		Recommendation		MIERYS
		MAX	MIN	
Micro-elements	Na	290	-	215
	K	1400	1100	1301
	Ca	600	300	436
	P	600	300	383,15
	Mg	140	80	136
trace Elements	Fe	14	10	12,2
	Zn	14	11	13,1
	Cu	1,8	1,4	1,1

3.2. Microbiological Quality of "SOMRIS$_{10\text{-}16}$"

The value obtained for total aerobic mesophilic germs of local formula is lower than the standard (46 CFU/g). Yeasts were observed but in quantities lower than the pre-established standards. On the other hand, total and faecal coliforms, moulds, salmonella, Escherichia coli and staphylococci were not detected in this study. Thus, the fungal and bacteriological loads detected in the local formula correspond to the microbiological criteria applicable to ready-to-use therapeutic foods intended for children under five years of age with moderate acute malnutrition [9]. The microbiological analyses are presented in Table 3.

Table 3. *Microbiological quality of the local formula.*

MICROORGANISMS	SOMRIS$_{10\text{-}16}$	STANDARDS*
Total mesophilic aerobic germs	46	< 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; UFC: Colony Forming Unit; SOMRIS10-16: Local Formula

4. Discussion

The objective of this study is to formulate a ready-to-use therapeutic food based on local food products for the management of moderate malnutrition cases. The ingredients were selected based on the recommendations of Collins., *et al.* (2006) [10]. These are corn, rice, millet, egg white, palm oil, olive oil, and cane sugar. Spirulina 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 "$SOMRIS_{10\text{-}16}$". Its nutritional composition was studied and compared to international standards. In terms of macronutrients, the energy density of $SOMRIS_{10\text{-}16}$ is 486.82 Kcal per 100g of material. This is an important quality of RUTF intended for the rehabilitation of children with moderate acute malnutrition due to their high energy requirement. This result is the same as that of the Amegovu *et al* study in 2014 [11].

According to international experts, malnourished children need a diet rich in fat [12, 13]. The local formula $SOMRIS_{10\text{-}16}$ has a lipid level of (29.80 ± 0.21 /100g) statistically adequate because its value remains within the limits set from 28 to 36g / 100g [14, 15]. These lipids are necessary for the absorption of vitamins A and E according to the work of Michaelsen in 2009 [16]. 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 (11.10 ± 0.15 g/100g) is superimposable to the recommended standards [8, 17, 18]. These proteins are essential for the rehabilitation of lean mass in malnourished people. Indeed, they are involved in many biological functions such as the formation of muscle tissue, the production of enzymes and hormones as well as growth [20].

Concerning carbohydrates, the carbohydrate content of $SOMRIS_{10\text{-}16}$ (39.30 ± 0.19) is adequate according to the work of Amegovu *et al* (2014) [11]. These carbohydrates contribute to protein synthesis and are involved in thermoregulation in malnourished people [19].

The mineral profile of $SOMRIS_{10\text{-}16}$ has also been studied. It is satisfactory according to the work of Adjou., *et al.* (2012) [21]. 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 organism [15].

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 [16, 22]. They also help control glucose absorption and improve normal protein retention during growth [23]. 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 [19, 20, 24, 25]. The Na/K ratios of the formula obtained are less than 1. The results of the "$SOMRIS_{10\text{-}16}$" mineral profile have values that globally represent 80% of the recommended minimum requirements [5]. At the end of this analysis, it appears that the nutritional composition of $SOMRIS_{10\text{-}16}$ is superimposable to that suggested by experts for the management of children with severe acute malnutrition without complications [15]. 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 [9, 26, 27]. The moisture content of the formula is statistically included in the levels set for ready-to-use foods according to the work of Santini., *et al.* (2013) [28]. This moisture content is due to the different cooking, drying and roasting treatments applied to the different inputs including millet, 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 [23].

Other authors such as Tarhouni., *et al.* (2015) [18], showed that pre-cooking and drying of flours reduce total mesophilic aerobic germs. The absence of hygiene control germs (fecal 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. This work has shown its nutritional and microbiological qualities which are superimposable to international standards. The "$SOMRIS_{10\text{-}16}$" could for this purpose be used for the management of cases of moderate acute malnutrition. It will follow the ongoing clinical trial process in order to be safely prescribed to children.

Abbreviations

MAM	Moderate Acute Malnutrition
INSP	National Institute of Public Health
ANOVA	Analysis of Variance
UNA	University of Nangui Abrogoua
AOAC	Association of Official Analytical Chemists

FAO	Food and Agriculture Organisation
RUTF	Ready-to-Use Therapeutic Foods
$SOMRIS_{10-16}$	Nutritional Food Based on Soy, Millet, Rice, Corn, and Sugar
TMAG	Microbiological Analysis of Total Mesophilic Aerobic Germs

Conflicts of Interest

The authors declare no conflicts of interest.

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