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Baby Food Made from Cassava Flour (*Manihot esculanta* Crantz) with Yellow Flesh

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Abstract- *The purpose of this study is to manufacture infant food from starchy plants widely available in Madagascar to fight against child malnutrition. Begins at six months of birth, breast milk is not enough to cover the nutritional need of the infant. Thus, the use of complementary foods with nutrient-rich products is essential. Its specific objectives are to produce cassava flour, sesame paste and powdered Moringa oleifera leaves and to characterize the products thus obtained. The results of the analysis show that the cassava bean is very rich in carbohydrates but very low in proteins and fats. On the other hand, sesame paste is rich in fat and protein and that Moringa oleifera powder is high in protein and mineral elements. The combination of these three products, amounting to 27.15g of sesame paste, 44.00g of cassava flour and 28.85g of Moringa oleifera powder, makes it possible to obtain a very good infant food, energy value 390.12 kcal. These three products meet the quality standards of complementary foods with regard to energy intake. The infant flour made contains sufficient mineral salts (Magnesium, calcium, potassium, manganese, copper, zinc, sodium, iron and phosphorus). This infant food is easy to prepare and low preparation cost. The raw materials used are widely available in farmers.*

Keywords- *complementary food, deficiency, energy needs, infant flour, malnutrition.*

I. Introduction

In Madagascar, malnutrition is a major problem, both public health and socioeconomic, which affects a large part of the population including children, pregnant and lactating women. Malnutrition, a physiological condition that can become pathological, is due to a deficiency or excessive consumption of one or more nutrients. Thus, the subject is at risk of suffering from malnutrition when the caloric intake and the nutritional balance do not meet his needs and affect all age groups, but it is particularly common among the poor. The poor nutritional characteristic or the qualitative and quantitative insufficiency of nutrients in food is recognized as the main factor of malnutrition and micronutrient deficiencies in young children [1].

The main objective of this study is to produce moderately priced infant food, permanently available in appropriate places, easy to prepare by their mothers and culturally and organoleptic acceptable (its appearance, texture, smell and his taste). Three vegetable raw materials were used such as cassava roots (*Manihot esculanta* Crantz) with yellow flesh, sesame seeds (*Sesamum indicum*) and *Moringa oleifera* leaves. These three raw materials have high nutritional potentials such as: the cassava root is rich in starch, the sesame rich in fats and proteins and the leaves of *Moringa oleifera* rich in proteins and mineral elements. The specific objective is to transform the fresh cassava root into flour, the sesame seeds into a paste, the *Moringa oleifera* leaves into powder. The characterizations of these products were carried out in order to determine their mass proportions according to the specific energy intakes used (10% of proteins, 30% for lipids and 60% from carbohydrates). The mass of the three raw materials was determined using the system resolution of three equations with three unknowns.

II. Materials and Methods

A. Plant Material

In this study, we will use cassava flour (*Manihot esculanta* Crantz) with yellow flesh, powdered leaves of *Moringa oleifera* and sesame paste (*Sesamum indicum*). The three products are obtained by artisanal processing method. The choice of these three products is justified by their availability, easy to process and prepare and at a lower price.

1) Processing of cassava root into flour

The transformation of cassava roots into flour was the combination of several stages such as sorting, hulling, peeling, washing, grating, wringing, drying, grinding, sieving and finally the storage pending use. This transformation method makes it possible to reduce a large part of the cyanogenic potential in flour [2].

2) Processing of fresh Moringa oleifera leaves into powder

The transformation of fresh *Moringa oleifera* leaves into powder was started by drying in the shade with free air circulation followed by grinding and then sieving. Thus powders obtained were stored in a tightly closed box.

3) Processing of Sesamum indicum seeds into paste

The transformation of sesame seeds into paste was started by drying. The dry seeds were ground into a fine paste. The paste thus obtained was stored in a very opaque box to stop the penetration of light into the box.

B. Characterizations of the Three Products Used

The pH and the acidity were determined according to the method of Vasconcelos *et al*. [3] and Oyewole [4]. The two parameters were determined using the pH meter and the metric. The water content and the dry matter content were determined according to the method described by the AOAC "Association Official Analytical Chemists" [5]. The principle of this method is to eliminate the water by evaporation until the constant mass. The rate of crude ash was determined according to the AOAC method in [6]. A few grams of the sample were incinerated at temperature 550 ^{0}C until white, light gray or reddish ash, apparently free of carbonaceous particles. The total protein content was determined according to the Kjeldahl method. This method quantifies the total proteins in a sample. The fat content was determined according to the methods of the AOAC [6] and Joslyn [7]. The fats in the product were extracted using hexane. The total carbohydrate content was assessed by the difference method. According to Bertrand and Thomas [8] and AOAC [9], it was calculated by subtracting from 100 the sum of humidity, fat, proteins and ashes contained in the sample. Minerals such as calcium, potassium, sodium, magnesium, iron, copper, manganese, Zinc were determined using the atomic absorption spectrophotometer and phosphorus using the UV spectrophotometer. The value of the metabolized energy of the samples was calculated using the calorific coefficients of Atwater and by summing the metabolized energies provided by each nutrient (Proteins, fats and carbohydrates) energy contained in the sample.

C. Determination of the Energy Nutrient Intakes of Products

For the preparation of infant food on the basis of cassava flour with yellow flesh, it is necessary that two other raw materials must be combined in order to establish good nutrients to cover the nutritional needs of children. Sesame and *Moringa oleifera* leaves have been widely available in Madagascar. *Moringa oleifera* leaves are rich in protein and sesame being high in fat and protein. This is why the sesame and *Moringa oleifera* leaves were chosen to cover these food needs.

Based on the protein, lipid and total carbohydrate contents of the three products used and the recommended energy requirements according to the age and sex of the children, formulas for determining the respective masses of these three products are established. The masses, in grams, of the products considered are obtained using the established formulas. During this work, to determine the mass of the three products necessary for the manufacture of infantile flour, we used a system of three equations with three unknowns. We know that the energy needed to cover a child's energy needs comes from these three products. In addition, each type of product provides an amount of energy from three energy principles, such as proteins, fats and carbohydrates. However, according to OMS [10], the reasonable margins concerning the coverage of caloric needs by a mixed intake of proteins, lipids and carbohydrates are the following: 10 to 12% of protein energy; 15 to 35% lipid energy; 55 to 75% carbohydrate energy. To have a system of three equations with three unknowns, we have chosen an inclusive value from each of these intervals and the sum of the three chosen values must be equal to 100%. To do this, the proportions proposed by Pamplona Roger [11] were used to determine the masses of the three products used. These proposals used are as follows: 10%, total energy intake provided by proteins; 30%, total energy intake provided by lipids; 60%, total energy intake provided by carbohydrates.

Generally, the metabolism energies provided by these three energy principles are obtained by summing the metabolism energies of the energy principles (proteins, fats and carbohydrates). The energy supplied by an energy principle is obtained by multiplying its content with its specific calorific coefficient (CCS). Taking into account the protein, lipid and carbohydrate contents of the three products used and after diversification of the total energy intake recommended for its three products, equations number 1 in relation to these two data, according to the unknowns (m_1, m_2 and m_3) have been obtained [12].

$$\begin{cases} E_{P1} + E_{P2} + E_{P3} = E_P \\ E_{L1} + E_{L2} + E_{L3} = E_L \\ E_{G1} + E_{G2} + E_{G3} = E_G \end{cases} \quad (1)$$

With: E_P, corresponds to 10% of the total energy supply provided by proteins; E_L, corresponds to 30% of the total energy intake provided by fat; E_G, corresponds to 60% of the total energy intake provided by carbohydrates,

$$E_P + E_L + E_G = E_{Total} = 100\%,$$

$$E_{P_1} = \frac{CCS_{P_1} \times t_{P_1} \times m_1}{100};\ E_{L_1} = \frac{CCS_{P_2} \times t_{P_2} \times m_1}{100};\ E_{G_1} = \frac{CCS_{P_3} \times t_{P_3} \times m_1}{100};$$

$$E_{P_2} = \frac{CCS_{L_1} \times t_{L_1} \times m_2}{100};\ E_{L_2} = \frac{CCS_{L_2} \times t_{L_2} \times m_2}{100};\ E_{G_2} = \frac{CCS_{L_3} \times t_{L_3} \times m_2}{100};$$

$$E_{P_3} = \frac{CCS_{G_1} \times t_{G_1} \times m_3}{100};\ E_{L_3} = \frac{CCS_{G_2} \times t_{G_2} \times m_3}{100};\ E_{G_3} = \frac{CCS_{G_3} \times t_{G_3} \times m_3}{100}$$

m_1, m_2 and m_3 are respectively the mass, in grams, of cassava flour, sesame paste and powdered leaves of *Moringa oleifera*. CCSP, CCSL and CCSG are the specific calorific coefficients of proteins, fats and carbohydrates of these three products respectively (CCS_{P1}=2.78kcal/g; CCS_{P2}=3.47kcal/g; CCS_{P3}=2.44kcal/g; CCS_{L1}=8.37kcal/g; CCS_{L2}=8.37 kcal/g; CCS_{L3}=8.37kcal/g; CCS_{G1}=4.03kcal/g; CCS_{G2}=4.07kcal/g and CCS_{G3}=3.57kcal/g. t_P, t_L and t_G are respectively the protein and fat content and carbohydrates from these three products [12].

III. Results

The results of the characterizations of the three products are presented in the table I below.

TABLE I: Characterizations of cassava flour, sesame paste and Moringa oleifera leaf powder

Parameters	**Cassava flour**	**Sesame paste**	***Moringa oleifera* leaf powder**
Energy (kcal)	351.59	574.29	270.62
Moisture (g/100g)	10.98	0.53	10.50
Dry matter (g/100g)	89.02	99.47	89.50
Proteins (g/100g)	2.53±1.02	15.70±2.05	30.01±1.30
Fat (g/100g)	0.51±0.85	48.34±0.58	2.20±0.30
Total carbohydrates	84.44	29.57	50.17

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(g/100g)			
Starch (g/100g)	72.43±0.75	-	-
Amylose (%)	11.95±1.25	-	-
Amylopectin (%)	88.05±1.25	-	-
Crude ash (g/100g)	1.54±1.85	5.86±0.75	7.12±0.20
Magnesium (mg/100g)	40.83±0.45	312.00±1.45	596.91±0.15
Calcium (mg/100g)	42.28±1.12	1323.42±0.26	1375.10±0.95
Zinc (mg/100g)	1.92±1.45	3.92±1.32	1.41±1.05
Manganese (mg/100g)	1.23±0.25	1.90±2.40	4.13±1.15
Potassium (mg/100g)	562.45±0.75	437.70±1.25	1542.12±0.45
Copper (mg/100g)	0.17±1.13	1.18±0.72	0.71±1.40
Sodium (mg/100g)	16.11±1.34	3.19±1.24	36.87±0.84
Iron (mg/100g)	36.32±0.25	6.69±2.15	15.91±1.45
Phosphorus (mg/100g)	67.63±1.85	574.70±0.75	210.89±1.16

Each result represents the mean ± standard deviation of 3 independent determinations (n = 3).

The results of the analysis show that cassava flour with yellow pulp is rich in carbohydrates (84.44g/100g) but very low in fat (0.51g/100g) and protein (2.53g/100g). To supplement the nutritional need, it is important to add other products rich in protein and fat. In this study we will use the sesame paste of carbohydrate 29.57g/100g, fat 48.34g/100g, protein 15.70g/100g and powder of *Moringa oleifera* of carbohydrate 50.17g/100g, fat 2.20g/100g and protein 30.01g/100g. According to the system resolution of three equations with three unknowns, the value of the mass m_1, mass of the cassava flour, mass m_2, mass of the sesame paste and m_3, mass of powder of the leaves of *Moringa oleifera* are presented on table II.

TABLE II: Amount of cassava flour, sesame paste and Moringa oleifera leaf powder used in 100g of infant flour

Parameters	Quantities (in g)
Cassava flour	44.00
Sesame paste	27.15
Moringa oleifera leaf powder	25.85

Energy requirements vary depending on the gender and age of the children. Thus, the amount of infant flour used increases with age and gender. According to the bibliographic reading, energy needs are the sum of the energy provided by breast milk and the energy obtained from complementary foods [13], [14]. 0.60g of iodized salt was added to each 100 g of the compound flour [15]. Iodine is an essential element during the growth of the human body. Table III shows the amount of infant flour (Sesame dough, cassava flour and powdered *Moringa oleifera* leaves) to supplement the energy requirements from the complementary food.

TABLE III: Mass of sesame paste, cassava flour and Moringa oleifera leaf powder to be used by age group to provide the recommended energy

Age range (months)	Sex	E (in kcal)	m (in g)	m_S (in g)	m_{Ma} (in g)	m_{Mo} (in g)
6 to 7	Boy	439.33	109.11	29.62	48.01	31.48
	Girl	402.67	100.00	27.15	44.00	28.85
7 to 8	Boy	453.33	112.58	30.57	49.54	32.48
	Girl	419.33	104.14	28.27	45.82	30.04
8 to 9	Boy	468.00	116.22	31.55	51.14	33.53
	Girl	434.67	107.95	29.31	47.50	31.14
9 to 10	Boy	487.33	121.03	32.86	53.25	34.92
	Girl	450.67	111.92	30.39	49.24	32.29
10 to 11	Boy	501.33	124.50	33.80	54.78	35.92
	Girl	462.67	114.90	31.20	50.56	33.15
11 to 12	Boy	516.67	128.31	34.84	56.46	37.02
	Girl	474.67	117.88	32.00	51.87	34.01
12 to 24	Boy	633.33	152.28	42.70	69.20	45.38
	Girl	566.67	140.73	38.21	61.92	40.00

E: Energy to be supplied using manufactured infant flour; m: Mass of manufactured infant flour to use; m_S: Mass of sesame dough to use; m_{Ma}: Mass of cassava flour to use; m_{Mo}: Mass of *Moringa oleifera* leaf powder to use.

From birth to the age of 6 months, breast milk covers all the nutritional needs of the child. However, from the age of six months, it becomes difficult for breastfed children to meet their nutritional needs from breast milk alone. So the acceptance is that six months is the right age to introduce complementary foods [16].

The energies in column 3 of Table 3 are the recommended energies provided by complementary food by age group and sex. To obtain these values, the quantities of infant flour in column 4 in table 3 must be used. Columns 5, 6 and 7 respectively represent the mass of the sesame paste, the mass of the cassava flour and the *Moringa oleifera* powder used to obtain the mass of column 4 and to supply energies in column 3. Nutrient requirements are increased by sex and age. Boys need more food than girls.

IV. Discussion

Our infant flour composed of the three products is very energetic compared to traditional corn-based porridge with a very low energy density of around 36 to 60cal/100ml, for millet and sorghum-based porridge around 44 to 64cal/100ml in Gabon and 60cal/100ml in Congo [17]. Infant flour made from cassava and soybeans, whose nutrient (13 to 14% protein, 10% fat) and energy (390 to 394kcal) content [18] is less than our infant flour of the nutrients and energy provided. The differences can be explained by the use of the three carbohydrate-rich products, cassava; rich in fat, sesame and rich in important proteins, the leaves of *Moringa oleifera*. According to the bibliographic reading, the leaves of *Moringa oleifera* contain a significant amount of important animate acids such as: Histidine, Isoleucine, Leucine, Lysine, Valine, Methionine, Phenylaline, Threonine, Tryptophan, Cysteine, Aspartic Acid, Arginine, Proline, Serine, Glutamic acid, Glutamine, Glycine, Alanine, Arginine [19]. Sesame seeds contain important fats such as palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid, behenic acid, saturated fatty acids, monounsaturated fatty acids, polyunsaturated fatty acid [20]. Reading the literature also indicates that it also contains omega-3 fatty acid [21].

By also comparable to the Codex Food Standard (CAC/GL 08-1991, rev.2013) [22] for children between 6 and 23 months, our infant flour has higher fat and protein content than the Codex standard. Their energy values are close to 400kcal/100g according to this standard.

V. Conclusion

In conclusion, the three raw materials used are local products with the wide availability and lower production prices. All of these three products provide a good nutritional source and cover the baby's energy needs in addition to breast milk. The leaves of *Moringa oleifera* are known for their richness in proteins, certain mineral elements and vitamins. This explains their essential protein intake in a food. Whole sesame seeds have high nutritional potential and especially provide lipids and proteins. The flour from cassava roots with yellow flesh provides high nutritional potential in carbohydrates. It therefore provides the necessary carbohydrate intake. By taking into account the energy needs of children from 6 to 24months, and from the system resolution of three equations with three unknowns, we were able to use a formula meeting the standards required in nutritional quality. The infant food obtained after mixing these three products has a high energy value; that means, it meets the standards recommended for covering the daily energy needs of infants, by a mixed supply of proteins, lipids and carbohydrates. The products obtained can therefore be used in the production of infant food of good nutritional quality in order to combat malnutrition in Madagascar.

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