NUTRITIONAL ASSESSMENT OF PRECOOKED FLOUR FORMULATED FROM CORN (*ZEA MAYS*), SOYBEAN (*GLYCINE MAX*) AND GROUNDNUT (*ARACHIS HYPOGAEA*) FLOURS CONSUMED IN CÔTE D'IVOIRE

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ABSTRACT: *The purpose of this study was to enrich corn flour with soybean and peanut flour in order to formulate an enriched feed for children of weaning age. To do this, an enriched corn flour has been formulated by adding to corn flour, soybean and peanut flours. The flour thus composed was characterized physically and biochemically. Then, a growth and biometric study was conducted to evaluate the effect of enriched corn flour on young rats of Wistar strain in growing. The results of the physicochemical and biochemical study give contents in dry matter, protein, fat, ash, carbohydrate and energetic value of 89.44 ± 0.13, 17.85 ± 0.11%, 5.83 ± 1.72%, 1.85 ± 0.03 %, 62.31 ± 0.01% and 442.99 ± 0.05 Kcal / 100g respectively for enriched corn flour. The effect of compound meal on young rats gives the growth level for weight gain, feed efficiency, apparent digestibility, true digestibility, and biological value values of 2.91 ± 0.59 g / j, 0.33 ± 0.07, 86.45 ± 0.31%, 94.28 ± 0.13% 84.27 ± 0.37% respectively. At the level of the biometric study no abnormality was observed at the level of the regulating organs which are the kidneys, the liver, the heart and the spleen compared to the control diet. Nutritional assessment results showing better performance at the 5% threshold for the different nutritional parameters show that enriched corn meal could have a positive impact on children's health and prevent the occurrence of illness such as kwashiorkor due to malnutrition. In addition, the fact that the nutritional parameters comply with the standards required shows that this food could be industrialized to facilitate its accessibility by all layers of society.*

KEYWORDS: Formulation, Enriched Corn Meal, Nutritional Assessment, Soybean, Peanut, Malnutrition.

INTRODUCTION

Maize (*Zea mays L.*) has been the staple food of many populations for thousands of years (FAO, 2014). In Africa in general and West Africa in particularly, it occupies an important place in food consumption (Nago 1997, Adjilé, 2012). In Côte d'Ivoire, maize is the staple diet of rural people. Its production increased from 641610 tons in 2010 to 680800 tons in 2016 (Faostat, 2018). It is used for human food and animal feed (poultry, swine, cattle) and is used as raw material in certain industries such as breweries, soap and oil mills, etc. (Boone et al., 2008). It is the main cereal involved in the diet of populations and especially children of weaning age (Adjanohoun et al., 2012). In the human diet, it is consumed in various forms by all layers of society namely green, cooked, grilled, salad, soup, dry (popcorn, etc.) for adults foods (Escalante et al., 2012). It is also used to make porridges, which are the most common weaning foods for children (Brou et al., 2008, Mbata et al., 2009). In the roasted form, maize flour is used in Côte d'Ivoire and especially in rural areas to make various dishes including couscous, donuts, cakes and tô (Ndjouenkeu et al., 1989). From a nutritional point of view, corn flour is essentially energetic. It is rich in starch, carbohydrates, minerals and vitamins with low protein content and lower nutritional quality than oilseeds and legumes (Adrian et al., 1991, Charcosset and Gallais, 2009, Nuss and Tanumihardjo, 2011). This deficit makes maize an ideal food source for protein enrichment, which is one of the strategies to combat protein-energy malnutrition (Seronie et al., 2004). The enrichment of maize meal by incorporation of resources food rich in protein such as legumes will improve its nutritional balance but especially to put in place a fortified food, enriched to solve the problem of malnutrition at the level of different layers of Ivorian society. In fact, legumes with their high levels of lysine, an essential amino acid, could improve the nutritional quality of roasted corn meal by providing this amino acid which is very limited in cereals in general (Adeniyi et al. 2014). All legumes, soybean is most commonly used for food fortification because of its high protein content about 48 to 50%, minerals, vitamins, protein digestibility around 85 % and its relative low cost compared to animal proteins (Kaur and Ahluwalia, 2003; Mishra et al., 2012). Groundnuts are also widely used because the seeds are high in fat, fiber and protein (Zhang et al., 2011). In addition, peanut contains several antioxidant components necessary for the neutralization of free radicals (Davis et al., 2010). Thus, the objective of this study is to determine the nutritional value of corn flour enriched in soybean and peanut flour in young rats of Wistar strain.

MATERIALS AND METHODS

The grains of corn (*Zea mays*), soybean (*Glycine max*) and groundnut (*Arachis hypogaea*) used in this study were purchased at the Gouro market in Adjamé (wholesale market) in Abidjan, Côte d'Ivoire.

Preparation of different flours

Preparation of roasted corn flour

The corn grain were first cleaned and sorted by hand to remove pieces of pebbles and wood debris. The corn grain were then roasted at 120 ^{o}C for twenty minutes in a Memmert ventilated oven and then ground using a heavy duty speed blender to obtain the flour (Porres et al. 2003). Finally, the flour obtained was successively sieved using a sieve gradient decreasing mesh size of 250 µm, 200 µm and 100 µm in order to obtain a fine flour of roasted corn. The resulting flour was stored at -4 °C in the Electrolux brand freezer in hermetically sealed containers.

Preparation of roasted soybean flour

The soybean grain were first cleaned and sorted by hand to remove pieces of pebbles and wood debris. The corn grain were then roasted at 120 ^{o}C for twenty minutes in a Memmert ventilated oven and then ground using a heavy duty speed blender to obtain the flour (Porres et al. 2003). Finally, the flour obtained was successively sieved using a sieve gradient decreasing mesh size of 250 µm, 200 µm and 100 µm in order to obtain a fine flour of roasted soybean. The resulting flour was stored at -4 °C in the Electrolux brand freezer in hermetically sealed containers.

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Preparation of roasted peanut flour

The peanut grain were first cleaned and sorted by hand to remove pieces of pebbles and wood debris. The corn grain were then roasted at 120 ^{o}C for twenty minutes in a Memmert ventilated oven and then ground using a heavy duty speed blender to obtain the flour (Porres et al. 2003). Finally, the flour obtained was successively sieved using a sieve gradient decreasing mesh size of 250 µm, 200 µm and 100 µm in order to obtain a fine flour of roasted peanut. The resulting flour was stored at -4 ° C in the Electrolux brand freezer in hermetically sealed containers.

Formulation of enriched corn flour and diet preparation

The enriched corn flour was formulated by mixing for 110 g of food composite, 100 g of roasted corn flour about 90%, 5 g of roasted soybean flour about 5% and 5 g of roasted peanut flour about 5%. To the mixture was added 15 mL of distilled water and then the whole was cooked with an Electrolux brand hotplate for 10 minutes.

Proximate Analysis of enriched corn flour

Physicochemical and biochemical characteristics of enriched corn flour were determined in triplicate using AOAC (1990) method for dry matter, ash and fiber content. Raw proteins contents were measured by the Kjeldahl method according to BIPEA (1976) using 6.25 as conversion factor. Lipid content was determined after extraction with hexane in a Soxtherm system during 6 h (AOAC, 1990). As for carbohydrate contents was calculated by the expression described by FAO (1947):

Carbohydrate (%) = 100 - (Protein (%) + Moisture (%) + fat (%) + fiber (%) + Ash (%)).

Nutritional evaluation of enriched corn flour

The nutritional evaluation was conducted with fifteen young Wistar rats from the animals' barn of the UFR Biosciences of Félix Houphouët-Boigny University (Abidjan, Côte d'Ivoire). The young rats which are 50 ±3 day's age were randomly distributed into three (3) groups comprising five (5) rats with average initial weight varied from 45 to 55 g. The experimental room average temperature was 25 °C and the percentage of humidity was 70 %, with 12 hours of daylight and 12 hours of darkness. The young rats were divided in such a way: one (1) group of five (5) young rats was submitted to control diets, one (1) groups of five (5) young rats were submitted to enriched corn flour and one (1) others groups of five (5) young rats were submitted to a diet without protein, proteiprive (PP). The control diet used in this study was made according to the study of Bouafou et al (2011) using herring fish meal as protein source. The rats were acclimatized for five days during which, they were fed with control diet and thereafter fed with the different experimental diets and received water ad libitum. Rats were disposed in individual screened bottomed cages designed separately to feed ad libitum for fifteen (15) days. These animals were used to assess the digestibility of the control diet and different diets of dockounou.

Data statements were done according to Adrian et al., (1991) method. During the experimental period, the feed intake by rats was measured daily; each 3 days between 7h30 and 8h30. Each feed, before offered, was weighed and the following day, the refused feed was also weighed, in order to determine the amount of feed intake. For the dry matter determination, five (5) g of every feed cooked were kept in an oven for 24hours at 70 °C. After weighing it, the dry matter was calculated with the AOAC (1990) method. During the last five-day of experimental period,

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a study of nitrogen (N) balance had consist to collect the faeces of individual rat which were pooled, dried at 85 ºC for 4 h, weighed before groundest into fine powder and stored for faecal N determination. Urine also was collected in sample bottles, preserved in 0.1N HCl to prevent loss of ammonia and stored in a refrigerator until analyzed for urinary nitrogen. The concentration of nitrogen in the diet, faeces and urine was estimated by the Kjeldahl method (AOAC, 1990).

Sampling of animal organs

The last day of nutritional studies, the animals were sacrificed and a longitudinal laparotomy was performed in order to remove liver, spleen, heart and both kidneys. The removed organs were dehumidified on clean toilet paper and then weighed on a Sartorius balance (precision: 0.001 g). The weight of organs was expressed as percentage of live weight of the animal obtained during the last weighing. The relative weight of the organs is determined by the following formula:

$$\text{Organ relatif weight} = \frac{\text{weight of organ (g)}}{\text{live weight of animal (g)}} \times 100$$

Statistical analysis

The experiment was carried out in triplicate for proximate analysis and fivefold for nutritional evaluation. Data obtained were analyzed by Analysis of Variance (ANOVA) using the software IBM SPSS Statistics version 20.0. Differences between means were tested using the Duncan Multiple Range Test with 5% level of significance.

RESULTS

Physicochemical composition of enriched corn flour

Table 1 shows the result of physicochemical and biochemical parameters studies of composite flour. The content of dry matter, ash, moisture, total sugars, total carbohydrate, starch, protein, fat, energy value are respectively 89.44 ±0.13%, 10.56 ±0.13%, 1.85 ±0.03 %, 4.31 ±0.17 g/100g, 62.31 ±0.01 %, 52.19 ±0.2 %, 17.85 ±0.11 %, 5.83 ±1.72 %, 442.99±0.0 (Kcal/100g).

Table 1: Proximate composition of enriched corn flour

Physicochemical parameters	Values
Dry matter (%)	89.44 ±0.13
Moisture (%)	10.56 ±0.13
Ash (%)	1.85 ±0.03
Total sugars (g/100g)	4.31 ±0.17
Total carbohydrate (%)	62.31 ±0.01
Starch (%)	52.19 ±0.2
Protein (%)	17.85 ±0.11
Fat (%)	5.83 ±1.72
Energy Value (Kcal/100g)	442.99±0.05

Effect of different diets on the weight of young rats

Figure 1 shows the weight variation curves of rats fed with different diets. The analysis of the curves reveals two different paces during the experiment: an ascending phase in the rats fed by enriched corn flour and control diet and a descending phase in the rats fed by protein diet. The shape of the growth curves of the rats fed the enriched corn flour and the control diet is identical from day 1 to day 3, whereas from day 3 it is the curve of the rats fed with the enriched corn flour that takes over until on the 15th day.

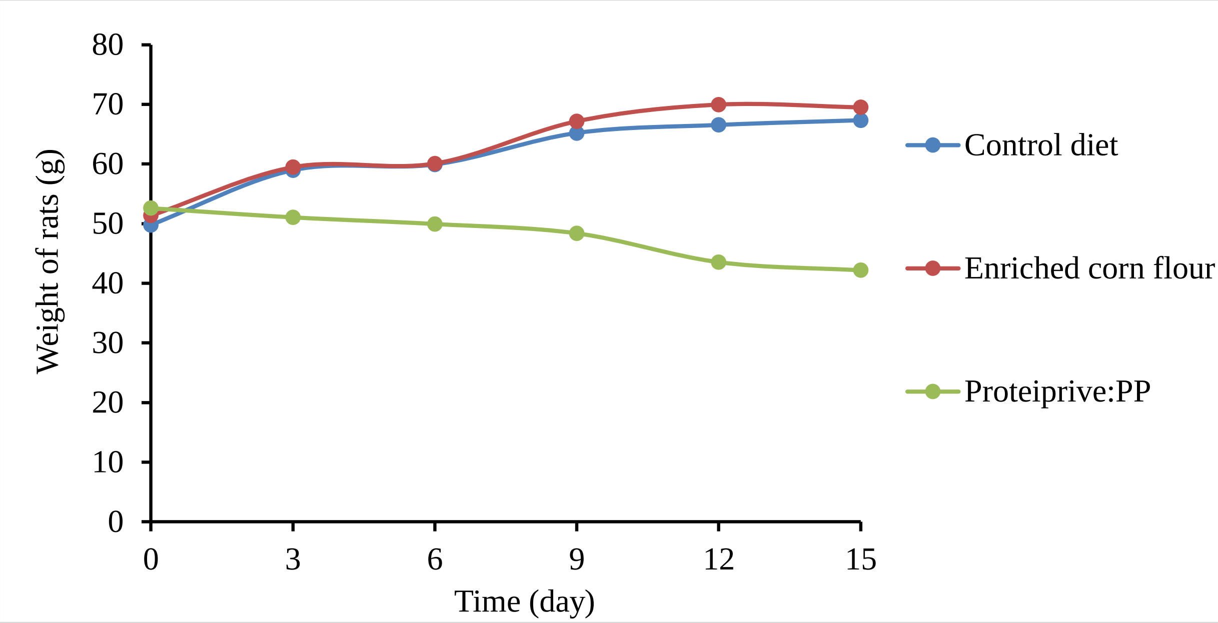

Figure 1: Curve of average weight evolution of rats fed by the different diets

Study of growth parameters

Table 2 shows the growth parameters of young rats fed by control diet and enriched corn flour. Statistical analysis reveals that there is no significant difference in amount of dry matter ingested, weight gain, feed efficiency, amount of total protein intake, and amount of net protein used by rats fed both control diet and enriched corn flour. On the level of amount of dry matter ingested, the values are respectively 9.50 ± 1.54 and 8.87 ± 0.24 for young rats fed by control diet and enriched corn flour. For weight of the young rats, they are respectively 2.89 ± 0.35 and 2.91 ± 0.59 for control diet and enriched corn flour. The food efficiency coefficient obtained is respectively 0.37 ± 0.034 and 0.33 ± 0.07 for control diet and enriched corn flour. As for the amount of total protein ingested, it is respectively 1.37 ± 0.15 and 1.37 ± 0.19 for control diet and enriched corn flour. The amount of net protein used is respectively 79.32 ± 0.001 and 79.46 ± 0.47 for control diet and enriched corn flour. On the other hand, there is a significant difference in food efficiency, apparent and true digestibility, biological value, protein retention of young rats fed by control diet and enriched corn flour. While the coefficient of feed efficiency, apparent digestibility, and biological value are higher in the young rats fed by enriched corn flour, the true digestibility and protein retention are higher in those fed by control diet. The protein efficiency coefficients are respectively 2.11 ± 0.11 and 1.57 ± 0.01 for the control diet and enriched corn flour. As for the apparent digestibility, it is respectively

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84.12 ± 1.31 and 86.45 ± 0.31 for the control diet and enriched corn flour. At the level of the true digestibility, the values obtained are respectively 95.54 ± 0.37 and 94.28 ± 0.13 for the control diet and the enriched corn flour. The biological value obtained is respectively 81.93 ± 1.56 and 84.27 ± 0.37 for the control diet and enriched corn flour. That of protein retention is respectively 4.74 ± 0.50 and 1.89 ± 0.05 for the control diet and enriched corn flour.

Table 2: Growth parameters of rats fed with different diets

Parameters \ Diets	Control diet	Enriched corn flour
Dry matter intake (g/d)	9.50 ±1.54[a]	8.87 ±0.24[a]
Weight gain (g/d)	2.89 ±0.35[a]	2.91 ±0.59[a]
Coefficient of food efficiency	0.37 ±0.034[a]	0.33 ±0.07[a]
Total protein intake (g)	1.37 ±0.15[a]	1.37 ±0.19[a]
Coefficient of Protein efficiency	2.11 ±0.11[b]	1.57 ±0.001[a]
Apparent digestibility	84.12 ±1.31[b]	86.45 ±0.31[a]
True digestibility	95.54 ±0.37[a]	94.28 ±0.13[b]
Biological value	81.93 ±1.56[b]	84.27 ±0.37[a]
Protein retention	4.74 ±0.50[a]	1.89 ±0.05[b]
Net protein used	79.32 ±0.001[a]	79.46 ±0.47[a]

Values are mean ± standard deviation of triplicate determinations. Values with different superscripts are significantly different from each other at the 5% level ($P < 0.05$) on the same line.

Effect of enriched corn flour on vital organs of young rats

Table 3 shows the relative weight of regulatory organs of young rats fed by control diet and enriched corn flour. Statistical analysis reveals that there is no significant difference in relative weight of kidneys, spleen and heart of young rats fed by control diet and enriched corn flour. However, there is a significant difference in relative liver weight of young rats fed both diets. The relative weight values of kidneys are respectively 0.78 ± 0.04 and 0.80 ± 0.05 for control diet and enriched corn flour. That of the liver is respectively 3.01 ± 0.36 and 3.96 ± 0.36 for control diet and enriched corn flour. At the level of the spleen, the relative weight is respectively 0.47 ± 0.20 and 0.31 ± 0.02 for control diet and enriched corn flour. For the heart, the relative weight is 0.51 ± 0.04 and 0.56 ± 0.07 for control diet and enriched corn flour.

Table 3:Organs weight of young rats fed with control diet and enriched corn flour

Organs (%) \ Diets	Kidney	Liver	Spleen	Heart
Diet control	0.78 ±0.04[a]	3.01 ±0.36[b]	0.47 ±0.2[a]	0.51 ±0.04[a]
Enriched corn flour	0.80 ±0.05[a]	3.96 ±0.36[a]	0.31 ±0.02[a]	0.56 ±0.07[a]

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Values are mean ± standard deviation of triplicate determinations. Values with different superscripts are significantly different from each other at the 5% level (P < 0.05) on the same column.

DISCUSSION

The analysis of enriched corn flour reveals very interesting contents. In fact, the moisture content that is inversely correlated with dry matter content is not conducive to proliferation of microorganisms that are responsible of deterioration of nutritional foodstuffs quality (Udensi et al., 2013; Oyarekua, 2013). The levels of total sugars, carbohydrates and starch in enriched corn flour are important and corroborate the energy value of the food, which is consistent with the FAO recommendations (1991) for substitute foods after weaning children. In adition, protein and fat contents of enriched corn flour are also in line with FAO's (1991) recommendation for post-weaning complementary foods. As for the ash content of enriched corn flour, it complies with the standard recommended by FAO (1991) for substitute foods after weaning of children. In fact, the ash content is indicative of the mineral content (Ijarotimi et al., 2013). The fact that the mineral content is in line with the recommendation of FAO (1991) shows that the consumption of enriched corn flour could provide necessary minerals for children's bodies after weaning. In view of the nutritional potential of enriched corn flour, we can deduce that it could be a potential food for children. High nutritional performance of enriched corn flour could be also explained by effect of roasting which has a beneficial effect on food. Indeed Kayodé, 2012 and Hamunyari et al., 2014 showed that heat treatments lead to elimination of antinutritional factors. Which leads according to Kouakou et al. 2016 to improved nutrient concentration of finished product.

At the level of nutritional evaluation, the absence of significant difference observed in nutritional parameters (quantity of dry matter ingested, weight gain, food efficiency coefficient, total amount of protein ingested, amount of net protein used) testifies positive effect of enriched corn flour (roasted corn flour, roasted soy flour and roasted peanut flour) on welfare of young growing rats. In addition, the fact that coefficient of feed efficiency, apparent digestibility and biological value are higher in young rats fed the enriched corn flour compared to those fed the control diet confirms the positive effect of this feed. Comparable observations have been reported by Kouadio et al., (2016) with soybean dockounou (a mixture of senescent plantain and soybean flour) of the 75:25 formulation, which has shown better performance compared to control diet based on granulated. Indeed, biological value measures the efficiency of the use of absorbed nitrogen (Hackler, 1977). According to James et al., (2009), a value of 100% indicates the highest quality of proteins. The net protein used is a measure of the digestibility and biological value of amino acid mixture of the various flours (roasted corn flour, roasted soybean and roasted peanut) (FAO / WHO, 1989). Values obtained are greater than 70%, which is recommended value for a good mixture of dietary and dietary proteins (FNB, 1974). As a result, enriched corn flour could cover the body's protein needs.

The absence of a significant difference between the relative weight of kidneys, spleen and heart of young rats fed with control diet and enriched corn flour reveals that the consumption of enriched corn flour does not have a negative effect on these regulatory organs. In contrast, in the liver, the highest growth was observed in young rats fed with enriched corn flour. Of such observation have been made by Udensi et al., (2013) who indicate that relative liver weight of rats fed by roasted millet and *Mucuna cochinchinesis* diets was higher than that of rats fed with

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control diet. Indeed, this increase in weight of liver can be attributed to an increase in activity imposed by the synthesis, storage and degradation of glycogen and fatty acids. In addition, the liver plays a crucial role in the synthesis and degradation of proteins (Bemeur et al. 2010). As a result, the weight of liver increases without organ being hypertrophied. Consequently, an increase in weight at level of the organ does not always result in an increase in the weight of the viscera.

CONCLUSION

Food fortification is a strategy that improves the nutritional composition of food by its formulation. In this study, addition of soybean and peanut roasted flour improved the nutritional composition of roasted corn flour. This flour does not have a negative impact on health can be made by mothers in rural and urban areas for feeding children and young children to resolve problem of malnutrition and food safety by using local ingredients. The making of enriched corn flour ensures availability and affordability, while helping to alleviate some time-related economic constraints in child feeding practices.

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