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Nutritional Quality of Weaning Foods Formulated from Yam (*Dioscorea alata* and *Dioscorea cayenensis*) Composite Flours

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Abstract: Some potential weaning diets formulated from yam species *Dioscorea alata* variety *Bètè bètè* and *Dioscorea cayenensis* variety *Lokpa*, soybean and cassava have previously been evaluated. In this study, four different diets (unfermented flour made of *Dioscorea alata*, fermented flour made of *Dioscorea alata*, unfermented flour made of *Dioscorea cayenensis*, fermented flour made of *Dioscorea cayenensis*) were prepared and fed to weaning rats for a period of 28 days. The study aimed to find out the *in vivo* impact of these yam composite flours. The performance characteristics of the developed products were investigated and compared with those of *Cérélac* (a commercial weaning food).The body weight change (BWC) of rats fed the different diets was highest in the rats fed *Cérélac* (3.39 g) followed by rats fed the fermented composite flours (FBBF and FLOF; 1.97 and 2.00 g, respectively) and casein-based diets (2.48 g) and least in rats fed the unfermented composite flour diets (FBBNF and FLONF; 1.60 and 1.51 g, respectively). A similar trend was observed in the total feed and protein intakes of the experimental animals. Moreover, the rat fed fermented composite flours showed high Protein Efficiency Ratio (2.25 – 2.37), Biological Value (78.94 – 79.46), True Digestibility (80.11 – 92.28) and Net Protein Utilization (60.91 – 76.34), comparable to those obtained with the casein-fed rats. The present study have shown that the values obtained with the test diet, especially for the fermented composite flours compared favourably with the reference diets (*Cérélac* and casein) in all the parameters investigated and should be considered a good weaning diet from a nutritional point of view.

Keywords: Yam, *Dioscorea alata*, *Dioscorea cayenensis*, Composite Flours, Weaning Food

1. Introduction

Yam is one of the major food crops in many part of world e.g. West Africa, the Caribbean, Asia and Brazil [1]. Belonging to the *Dioscoreaceae* family, Yam tubers are the most important staple food in West Africa, after cereals [2, 3]. West Africa is the leading producer of yam and grows over 90% of the worldwide production (40 tonnes fresh tuber/year) followed by the West Indians where Jamaica is the leading producer [4]. Thus, Nigeria is the world's largest producer of yams followed by Ghana, Côte d'Ivoire and Togo [5].

In Côte d'Ivoire, there are many cultivars of yam distributed within two large species that are *Dioscorea alata* and *Dioscorea cayenensis-rotundata* [6, 7]. As a function of the country area, yam is consumed in different forms such as *foutou* (yam boiled in water and crushed), *foufou* (yam boiled in water and crushed in mixture with palm oil), yam mush (*ngbô*), roasted yam, yam stew (yam cooked in a sauce accompanied by vegetables), fried, *baca* (yam crushed after cooking and moistened) and yam couscous (*wassawassa*) [8, 9].

Due to its appreciable content of essential dietary nutrients, yam has been reported to have nutritional superiority than other tropical root crops [10, 3]. Yam is also known for its high starch content of about 84 %. However, Yam is relatively poor in protein (2.1%) and other essential nutrients.Yam as well as cassava roots are among the crops available throughout the year [11]. As recommended by Glover-Amengor et al. [12], other crops like cowpea (25% protein), soybean (40% protein) and groundnut (25% protein) richer in protein and minerals can be added to yam to improve nutritional value of its flour. The composite flours obtained could constitute good food formulas for infants and young children, pregnant and lactating women which are among the most vulnerable people in developing countries [13]. Thus, Digbeu et al. [13] have made composite flours with yam (*Dioscorea alata* variety *Bètè bètè* and *Dioscorea cayenensis* variety *Lokpa*), soybean and cassava in respectively 60, 30 and 10% proportions. These composite flours exhibited good biochemical and hygienic characteristics, making them suitable for human consumption. In addition, flours could be stored over longer periods and thus reduce the post-harvest losses in yam production [13]. As regards Soybean, it has been widely used in human and animal nutrition because of its favourable agronomic characteristics, relatively low price, and high content and quality of proteins and fats [14]. It is largely used to improve the protein content of weaning foods in developing countries. Cassava (*Manihotesculenta* Crantz)is alsoamply used for human and animal consumption, as well as raw material for several industrial products; the most important are the cassava flour and the cassava starch [15].

This research was conducted on Wistar rats to find out the *in vivo* impact of yam composite flours made by Digbeu et al. [13] and highlight their potential usage as potential weaning diets.

2. Materials and Methods

2.1. Experimental Diets

The test diets for the study were formulated in accordance with AOAC [16] procedure. Two varieties of yam were used: *Dioscorea alata* (variety *Bètè bètè*) and *Dioscorea cayenensis* (variety *Lokpa*). The four composite flours used for Wistar rats diet and designatedFBBF (Yam *Bètèbètè* Flour Fermented), FLOF (Yam *Lopka* Flour Fermented), FBBNF (Yam *Bètèbètè* Flour Unfermented), FLONF (Yam *Lopka* Flour Unfermented) originated from the diet formulation of Laboratoire de Nutrition et Sécurité Alimentaire, UFR Sciences et Technologies des Aliments, Université Nangui Abrogoua (Abidjan, Côte d'Ivoire). These flours were formulated as described previously byDigbeu et al. [13]. Casein (designated RCC) served as a reference protein while *Cérélac* (a commercial weaning food designated RTC) served as a control.

2.2. Animal Experiment

For the study, forty two albino young rats of the Wistar strain at 3 weeks of age weighing 60 ± 2 g at the beginning of the experiment were obtained from the Institut Pasteur de Côte d'Ivoire (Abidjan, Côte d'Ivoire). They were randomly distributed in metabolic cages and fed on normal (pellet) diets for a period of 7 days for acclimatization to the environment before the commencement of the experiments. After this period the animals were re-weighed and re-grouped so that the average weight per group was approximately the same (± 2 g) and divided into seven groups of six rats per group. The rats were individually housed in separate cubicles in a metabolic cage with facilities for separate collection of urine and faecal matter. The groups of animals were fed with the food samples (diets) and water *ad libitum* for 28 days. Each animal group was assigned one of the seven diets, the composition of which is given in Table 1. During this period dietary intake was weighed at three-day intervals and growth of the animals was recorded. The total faeces and urine voided during the last 7 days of the experiment were collected, weighed and preserved. The urine collected was preserved by adding a few drops of dilute sulphuric acid to prevent any loss of ammonia and was kept in a frozen condition while the corresponding feed consumed was also recorded for nitrogen determination. Pooled samples of faeces were dried in an oven at 800°C for 12 h, cooled and weighed. Nitrogen in the urine and faeces were determined by Kjeldahl method [16].

Table 1. *Composition of diets.*

Diets	Ingredients						Total dry matter (%)
	Casein (%)	Corresponding flour weighed (%)	Vitamin and mineral mixture (%)	Sugar (%)	Corn starch (%)	Corn oil (%)	
RCC	13.11	00.00	3.00	10	65.00	8.88	100
FBBF	00.00	65.85	3.00	10	11.82	9.32	100
FBBNF	00.00	67.74	3.00	10	10.43	8.83	100
FLOF	00.00	67.36	3.00	10	11.47	8.17	100
FLONF	00.00	75.31	3.00	10	04.55	8.14	100
RPP	00.00	00.00	3.00	10	78.11	8.88	100

RCC (Control Diet Casein), FBBF (Yam *Bètèbètè* Flour Fermented), FLOF (Yam *Lopka* Flour Fermented), FBBNF (Yam *Bètèbètè* Flour Unfermented), FLONF (Yam *Lopka* Flour Unfermented), RPP (protein-free diet).

2.3. Nutritional Parameters

Protein quality parameters used as indices for the performance of the diets during feeding trials were determinedusingOnyeike and Morris [17] methods. The total food intake of the rats was determined by recording the food left after dailyintake. Mean daily feed intake (MDFI) was then calculated as:

MDFI = Total quantity consumed / Number of days of feeding

Daily weight gain was obtained by weighing all the rats individually on a sensitive top loading weighing balance (Metra, model TL 600). Mean daily weight gain (MDWG) was then calculated as:

MDWG = Total weight gain / No. of days of feeding

Using the mean daily weight gain values obtained, the protein efficiency ratio (PER), Net protein retention (NPU) and feed efficiency ratio (FER) were estimated by the method of Pellet and Young [18].

FER = Weight gain / Total feed intake

PER = Weight gain / Total protein intake

NPU = (Weight gain +Loss by 0% Protein group) / Weight of protein consumed

True digestibility (TD) and the biological value were estimated using the method described by Ibironke *et al.* [19].

$$TD(\%) =(N_i - N_f - N_{ef} \times 100) / N_i$$

$$BV = [N_i - (N_f - N_{ef}) - (N_u - N_{eu})] \times 100 / N_i - N_f$$

Where: N_i is nitrogen intake, N_f faecal nitrogen, N_{ef} endogenous faecal nitrogen (from rats fed the protein-free diet), N_u urine nitrogen and N_{eu} endogenous urine nitrogen.

2.4. Statistical Analysis

Data were collected as means of three separate determinations and subjected to one-way analysis of variance using Statistical Package for Social Sciences (SPSS 15.0). The significant differences (p≤0.05) between the mean values were determined using Duncan's Multiple Range Test.

3. Results and Discussion

The feed intakes (g) per day of the albino rats are as shown in Table 2. Feed intakes of animals fed with RTC (*Cérélac*) and RCC (casein-base) diet was significantly (p≤0.05) higher than those of animals fed with yam composite flour diets. As regards these formulated diets, Yam *Bètèbètè* Flour Fermented shows highest feed intake per day followed by both FLOF (Yam *Lopka* Flour Fermented) and FBBNF (Yam *Bètèbètè* Flour Unfermented). A similar trend was observed in the protein intake of the experimental animals. The observed high feed intake of rats on *Cérélac* could be due to the presence of milk, sucrose and aroma in the product thus making it more palatable. Food intake can be influenced by palatability, source of nitrogen and essential amino acid profile [20].

Table 2. *Mean daily feed and protein intakes.*

Diets	Feed intake (g/day)	Protein intake (g/day)
RTC	13.65 ± 1.06[a]	1.59 ± 0.02[a]
RCC	12.88 ± 1.31[b]	1.29 ± 0.01[ab]
FBBF	12.22 ± 1.72[c]	1.22 ± 0.05[bc]
FLOF	11.68 ± 1.72[d]	1.17 ± 0.06[bcd]
FBBNF	11.48 ± 2.11[d]	1.15 ±0.13[cd]
FLONF	10.54 ± 2.13[e]	1.05 ± 0.12[d]
RPP	08.81 ± 1.96[f]	0

Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (p≤0.05). RTC (Control Diet *Cérélac*), RCC (Control Diet Casein), FBBF (Yam *Bètèbètè* Flour Fermented), FLOF (Yam *Lopka* Flour Fermented), FBBNF (Yam *Bètèbètè* Flour Unfermented), FLONF (Yam *Lopka* Flour Unfermented), RPP (protein-free diet).

Table 3 shows that the body weight change (BWC) was highest in rats fed the reference diet (*Cérélac*). The result showed that there wasn't significant differences in the body weight gain of the rats fed the fermentedcomposite flours (FBBF and FLOF)and casein-based diets. Similar observations had been earlier reported for weaning foods formulated from maize gruel 'ogi' and crayfish using combined traditional processing technology [21]. The lower body weight gain of the rats fed formulated flour diets agreedwith their feed intakes. Animals are known to eat more food when it has good organoleptic appeal [22]. Nevertheless, body weight change depends on the amount of feed consumed and the ability to utilize the food [23]. The two unfermented composite flour diets (FBBNF and FLONF) showed similar daily weight gain which is lower than those of fermented flours (FBBF and FLOF).

Table 3. *Body weight change (BWC) of rats (g) fed the diets.*

Diets	Initial body weight (g)	Final body weight (g)	Daily weight gain (g/day)
RTC	62.68± 9.32[a]	160.90 ± 10.24[a]	3.39 ± 0.04[a]
RCC	62.64 ± 8.12[a]	134.44 ± 18.17[b]	2.48 ± 0.90[b]
FBBF	60.88 ± 12.76[a]	117.87± 14.76[b]	1.97 ± 0,25[b]
FLOF	61.58 ± 12.45[a]	120.68 ± 11.84[b]	2.00 ± 0.27[b]
FBBNF	61.83 ± 13.42[a]	108.13± 11.04[b]	1.60 ± 0.20[c]
FLONF	59.84 ± 12.88[a]	103.53± 14.46[b]	1.51 ± 0.18[c]
RPP	62.14 ± 13.35[a]	39.87 ± 10.65[c]	-0,77 ± 0.35[d]

Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (p≤0.05). RTC (Control Diet *Cérélac*), RCC (Control Diet Casein), FBBF (Yam *Bètèbètè* Flour Fermented), FLOF (Yam *Lopka* Flour Fermented), FBBNF (Yam *Bètèbètè* Flour Unfermented), FLONF (Yam *Lopka* Flour Unfermented), RPP (protein-free diet).

The results of feed efficiency ratio (FER) of the experimental animals are shown in Figure1. The feed efficiency ratio (FER) of different diets varied from 0.13 g (FBBNF) to 0.21 g (casein diet). The FER of rats fed with casein and *Cérélac* were not significantly different (p≤0.05) between them, but they were higher than those of rats fed with the two fermented composite flour diets. The unfermented composite flours (FBBNF and FLONF) showed the lowest FER (0.13).

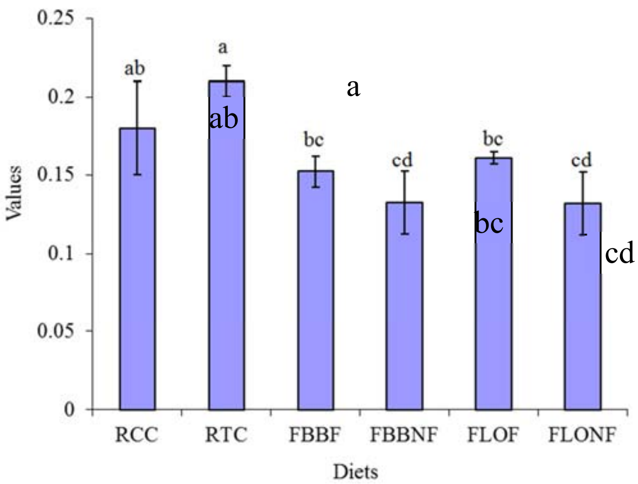

Figure 1. *Feed efficiency ratio of different diets.*

Bars represent ± SE. Values followed by different superscript on the same column are significantly different (p≤0.05). RTC (Control Diet *Cérélac*), RCC (Control Diet Casein), FBBF (Yam *Bètèbètè* Flour Fermented), FLOF (Yam *Lopka* Flour Fermented), FBBNF (Yam *Bètèbètè* Flour Unfermented), FLONF (Yam *Lopka* Flour Unfermented), RPP (protein-free diet).

As shown in Table 4, the corrected protein efficiency ratio (PERc) was highest in the rats fed *Cérélac* (3.01) followed by rats fed both casein (2.5) and fermented composite flour diets (FBBF and FLOF) which didn't showed significant differences (p≤0.05). PER is an index of protein quality. It indicates the relationship between weight gain in the test animals and the corresponding protein intake. As suggested by the Protein Advisory Group (PAG) and U.S. Department of Agriculture guidelines, the PER obtained for our fermented composite flour diets (FBBF and FLOF) are greater than 2.1 as recommended for weaning food [24, 25]. Indeed, a PER value below 1.5 indicates a protein of poor quality; between 1.5 and 2.0 an intermediate quality and above 2.0 good quality proteins [26]. Hence, the proteins of unfermented composite floursFBBNFand FLONF (PER value of 1.85) may be considered a diet with intermediate quality protein, whereas the fermented composite floursFBBF (PER value of 2.25) and FLOF (PER value of 2.37) as protein of good quality.

The true digestibility (TD) of the rats fed *Cérélac*, casein and FLOF did not show any significant difference (p≤0.05) although, they were significantly (p≤0.05) higher than the values obtained for test diets (FBBF, FBBNF and FLONF) (Table 4). TD values give information on the percentage of nitrogen absorbed by the body. TD values of FLOF as well as casein and Cérélac diets were higher than 85 % recommended for children.

The biological value (BV) of the *Cérélac*-fed rats (93.82 %) was significantly higher than those of the casein and formulates diet though within casein and FLOF showed significantly higher BV than others composite flour diets. Biological value gives information on how much of the absorbed nitrogen is actually retained or utilized by the body. The high BV obtained with *Cérélac*, casein and FLOF may suggest that rats fed on these diets had higher nitrogen retention than those on other diets. This also indicated that the essential amino acids in the products were present in sufficient quantity to meet the needs for growth. The nutritional composition of the foods indicates their suitability for young children. The results obtained in the present study are higher than those observed by Onwuka [27], who reported BV value of 59.90 and NPU values of 59.92 for the germinated African yam bean (*Sphenostylis stenocarpa*) seed meals.

Net protein utilization is similar to the biological value except that it involves a direct measure of retention of absorbed nitrogen. Net protein utilization and biological value both measure the same parameter of nitrogen retention; however, the difference lies in that the biological value is calculated from nitrogen absorbed whereas net protein utilization is from nitrogen ingested [28]. The NPU mean value (85.08%) of *Cérélac* diet was significantly higher (p≤0.05) than all other values (Table 4). Experimental diet FLOF (76.34%) and casein (70.22%) showed statistically similar NPU mean value (p≤0.05). As regards other experimental diets, the NPU mean values varied from 56.25 (FLONF) to 60.91% (FBBF) although, there was no significant difference (p≤0.05) between them. The higher NPU value for the rats fed the *Cérélac* and FLOF Diets could be due to higher Nitrogen retention, which implies that they has better quality protein sources compared to other formulated diets.

Table 4. *Protein quality of formulated diets.*

Diets	PERc	True Digestibility (%)	Net Protein Utilization	Biological Value
RTC	3.01 ± 0.25^{a}	94.42 ± 0.34^{a}	85.08 ± 3.13^{a}	93.82 ± 0.31^{a}
RCC	2.5 ± 0.72^{ab}	95.79 ± 0.53^{a}	70.22 ± 1.83^{b}	79.46 ± 0.23^{b}
FBBF	2.25 ± 0.15^{b}	80.11 ± 2.80^{b}	60.91 ± 1.83^{c}	78.94 ± 0.43^{b}
FLOF	2.37 ± 0.43^{b}	92.28 ± 6.01^{a}	76.34 ± 4.71^{b}	79.90 ± 0.14^{b}
FBBNF	1.86 ± 0.40^{c}	77.87 ± 4.00^{b}	57.24 ± 1.27^{c}	73.51 ± 0.22^{d}
FLONF	1.85 ± 0.10^{c}	79.12 ± 4.00^{b}	56.25 ± 1.66^{c}	71.09 ± 0.24^{e}

Values given are the averages of at least three experiments ±SE. Values followed by different superscript on the same column are significantly different (p≤0.05). RTC (Control Diet *Cérélac*), RCC (Control Diet Casein), FBBF (Yam *Bètèbètè* Flour Fermented), FLOF (Yam *Lopka* Flour Fermented), FBBNF (Yam *Bètèbètè* Flour Unfermented), FLONF (Yam *Lopka* Flour Unfermented), RPP (protein-free diet).

4. Conclusion

Based on the present study, it appears that the yam-based composite flours can be useful as weaning food. Especially, the fermented yam composite flours compared favourably with the reference diets (*Cérélac* and casein) in all the parameters investigated. They showed good Protein Efficiency Ratio, Biological Value, True Digestibility and Net protein Utilization. Thus, these flours could be considered as new valuable diets for vulnerable people especially children in poor regions that produce large quantities of yam.

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