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Nutritional Quality of 1st Generation Quality Protein Maize Diet and its Effect on Some Biological Indices of Albino Wistar Rats

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Abstract: Twenty male albino rats of the Wistar strain were placed in four experimental groups of five rats each. Group A (Reference group) received a standard protein diet, Group B received a basal or protein-free diet, Group C received the F_1-QPM diet, while Group D received common maize (CM) diet. Water and feed were allowed *ad libitum*. Rats were fed for 21 days at the expiration of which indices of protein nutritional quality viz PER, NPU, NPR, TD and BV, were evaluated. The results showed that Group C rats had a higher ($p<0.05$) protein efficiency ratio (PER) value of 0.97±0.06 compared to rats in Group D (0.48±0.28). Similarly, net protein utilization (NPU) value of 80.67±3.21% for group C was significantly ($p<0.05$) higher than for group D (41.83±5.48). The same trend was observed for true digestibility (TD) and biological value (BV). The values were TD (89.27±0.55% for Group C and 81.59±0.11% for Group D) and BV (90.30±2.56% for Group C and 51.00±6.10% for Group D) respectively. Values of net protein ratio (NPR) obtained also followed the same trend (1.85±0.06 for Group C and 1.61±0.39 for Group D) but not significantly different ($p>0.05$). Additionally, the protein contents of the F_1-QPM and CM diets compared showed that though F_1-QPM had a higher level of protein (11.80±2.84%) than CM (10.67±0.31%), the difference was not significant ($p>0.05$). Quality protein maize (QPM) maintained its high nutritional quality in spite of change in environment. Increased cultivation and utilization of QPM is recommended as this could help to alleviate hunger and protein malnutrition in developing countries.

Key words: Maize, quality protein maize (QPM), F_1-generation, nutritional quality

INTRODUCTION

Although animal foods are known to be important for their protein content, some plant foods also supply an appreciable quantity of protein in human diets. This is important to developing countries in trans Sahara Africa particularly Nigeria where about 80% of the population mainly peasants depend on protein derived from plant foods for nutrition since animal foods are often beyond the economic reach of most families. Maize is one of the most popular and widely used cereal crops in the world, ranking third in importance after rice and wheat. In Nigeria, maize ranks fourth after millet, sorghum and rice (Obi, 1991).

Unfortunately, the use of maize as protein food is limited by its deficiency in the two essential amino acids lysine and tryptophan coupled with a low Biological Value (BV) of 40-57% (Bressani, 1992). A genetic approach to improve the nutritional quality or biological utilization of maize protein yielded the Quality Protein Maize (QPM), which combines the high nutritional quality of *opaque-2* gene (high lysine and high tryptophan) with the shiny, transparent kernel structure of common maize

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(Enwere, 1998; Vasal, 2001; Crow and Kermicle, 2002). A number of studies suggest that QPM with its content of *opaque-2* gene is almost as effective as milk protein. Feeding trials with opaque-2 maize showed a significant improvement in protein deficiency malnutrition and stopped pellagra, a disease associated with insufficient intake of nicotinamide or its precursor tryptophan, within 100 days (Enwere, 1998; Nelson, 2001).

Nutritional evaluation of QPM in various locations has proved the superiority of QPM over normal maize in the feeding of various animals (Sullivan *et al*., 1989; Burgoon *et al*., 1992; Osei *et al*., 1999; Gao, 2002; Fufa *et al*., 2003; De Paula *et al*., 2004). Also, the various traditional methods of processing of maize have no significant effect on the protein nutritional quality of QPM (Fufa *et al*., 2003). Toxicity studies have shown that, though a genetically modified food, QPM does not have any health risk on the hepatic tissue of animals (Agiang *et al*., 2006). Therefore increased cultivation and utilization of QPM could go a long way toward alleviating a major food problem.

From the initial eleven developing countries who grew the QPM developed at the International Maize and Wheat Improvement Centre (Centro Internacional de Mejoramiento de Maiz y Trigo: CIMMYT), farmers in many more countries have become interested in cultivating the crop (Future Harvest, 2000). However, it is known that environmental factors affect the grain yield, crude protein content and protein quality of maize (Bhatnagar *et al*., 2004; Eppendorfer *et al*., 2006; Marques da Silva and Silva, 2006). This study was therefore undertaken to determine the protein quality of first generation quality protein maize (F_1-QPM) through assessing its effect on the indices of nutritional quality using Wistar rat models. It was also to evaluate whether environment has any impact on the protein content and quality of QPM.

MATERIALS AND METHODS

Collection of Samples

The Quality Protein Maize (QPM) was obtained from the International Maize and Wheat Improvement Centre (CIMMYT) based in Mexico, South America. The grain was cultivated in an experimental farm at Agoi-Ibami village in Yakurr Local Government Area (LGA) of Cross River State, Nigeria. Agoi-Ibami in Nigeria lies between latitudes 5°32′ and 4°27′ north of the equator and longitudes 7°50′ and 9°28′ east of the meridian and belongs to the Central senatorial district of Cross River State, with an average annual rainfall of 2,369 mm, average maximum temperature of 32.6°C and average maximum relative humidity of 83%. The soil type is loamy. Cultivation took place for 3 months (between January and April, 2007) at the end of which the ripe grains (F_1-QPM) were harvested, sun-dried and dehulled. The white variety of common maize (CM) was purchased from a local market in Agoi-Ibami village, Cross River State of Nigeria.

Treatment of Samples for Analysis

The QPM, F_1-QPM and CM grains were separately cleaned from dust and other foreign particles and ground into powdery form using a standard mill. The samples were then sifted, packed in airtight bags and stored in the refrigerator at -20°C until when used for analyses. The crude protein content of the maize samples was determined according to AOAC (1995) procedure, before they were fed to the animals.

Diet Composition

The composition of the diets (Table 1) were compounded to supply 10% protein on dry matter basis (Pellet and Young, 1980). Casein served as the control. Mineral, vitamin mix, oil and sucrose were added to balance the diets.

Table 1: Composition of experimental diets (g kg^{-1})

Ingredient	A Reference	B Basal	C F1-QPM	D CM
Corn starch	600	700	600	600
Casein	100	-	-	-
Test material	-	-	100	100
Sucrose	150	150	150	150
Groundnut oil	50	50	50	50
Mineral	40	40	40	40
Vitamin	10	10	10	10
Cellulose	50	50	50	50

Animal Feeding Experiment

Twenty male albino rats of the Wistar strain weighing 46-52 g were collected from the stock of the Animal house of Physiology department and taken to the Animal house of Biochemistry department both in the Faculty of Basic Medical Sciences, University of Calabar. The rats were weighed and randomly assigned on the basis of body weight and litter origin into four groups (A, B, C, D) of five rats each. Rats in each experimental animal group were housed singly in well-ventilated stainless metabolic cages and allowed access to one of the four experimental diets (Table 1). Group A (Reference group) received a standard protein diet, Group B received a basal or protein-free diet, Group C received the first generation quality protein maize (F_1-QPM) diet, while group D received common maize (CM) diet. The trial consisted of a 3 day acclimatization period followed by a 21-day total collection period. Water and diets were allowed *ad libitum*. The weight of the animals was taken at the beginning and at the end of the study period (21 days). Food intakes were measured and faecal collections made for the period.

Laboratory Analysis

Diets, faeces and carcass were analysed for nitrogen (N) content by the AOAC (1995) procedure.

Biological Assay

Food intake was calculated as: Food fed to animals-Food spilled. All biological parameters were determined as described by Pellet and Young (1980). Protein efficiency ratio (PER) was obtained by relating the weight gain to the amount of protein consumed using the equation:

$$\text{PER} = \frac{\text{Weight gain (g)}}{\text{Protein intake (g)}}$$

Net Protein utilization (NPU) was calculated by the difference in carcass nitrogen between rats fed the test diets and those fed the protein-free diet, according to the equation:

$$\text{NPU} = \frac{\text{Carcass N of test group-carcass N in basal group}}{\text{N intake of test group}} \text{ or}$$

$$\text{NPU} = \frac{\text{N retained} \times 100}{\text{N intake}}$$

Net protein ratio (NPR) was calculated by the difference in body weight changes between the test group and the basal (protein-free) group through the following equation:

$$\text{NPR} = \frac{\text{Weight gain on test diet + weight loss on basal diet}}{\text{Protein ingested by the test group}}$$

True digestibility (TD) was derived based on nitrogen consumed and faecal nitrogen using the formula:

$$TD = \frac{\text{N intake-(faecal N on test diet-faecal N on basal diet)} \times 100}{\text{N intake}}$$

Biological value (BV) was derived using the following equation:

$$BV = \frac{NPU}{TD} \times 100 \text{ or } BV = \frac{\text{N retained} \times 100}{\text{N absorbed}}$$

Statistical Analysis

All results were submitted to statistical analysis of variance (ANOVA) using the SPSS 2003 (version 13.0).

RESULTS AND DISCUSSION

The crude protein content of the maize samples were different (10.67±0.31% for CM, 11.48±1.57% for QPM and 11.80±2.84 for F_1-QPM) but comparable ($p>0.05$) (Table 2).

The food intake, protein intake, weight changes and faecal nitrogen (N) of animals placed on various experimental diets is summarized in Table 3. Food consumption of the rats varied. The values were: 137.19±0.18 g for reference group, 26.23±0.03 g for basal group, 144.29±0.34 g for F_1-QPM group and 126.38±0.20 g for CM group. It was least in the group fed basal diet. The group fed F_1-QPM diet consumed more ($p<0.05$) than the CM group. The protein intake of the animals also differed. However, although the F_1-QPM group had a higher protein intake (17.07±3.29 g) than the CM group (13.28±1.49 g), the difference was not significant ($p>0.05$). The F_1-QPM-fed group of rats recorded a higher weight gain and less faecal nitrogen excretion (16.27±2.31 and 0.31±0.07 g, respectively) than the CM group (6.37±2.07 and 0.40±0.02 g, respectively).

The protein efficiency ratio (PER), net protein utilization (NPU), true digestibility (TD) and biological value (BV) of F_1-QPM group (0.97±0.06, 80.67±3.21, 89.27±0.55 and 90.30±2.56 respectively) were significantly ($p<0.05$) higher than those of the CM group (0.48±0.28, 41.83±5.48, 81.59±0.11 and 51.00±6.10, respectively). The F_1-QPM group also had higher net protein ratio (NPR) value (1.85±0.06) than the CM group (1.61±0.39). However, the difference was not significant ($p>0.05$) (Table 4).

Table 2: Crude protein contents (%) of the maize samples

Sample	Crude protein (%)
Common maize (CM)	10.67±0.31
Quality protein maize (QPM)	11.48±1.57
1st generation quality protein maize (F_1-QPM)	11.80±2.84

Table 3: Food intake, protein intake, weight gain/loss and faecal nitrogen (n) of animals fed with the different experimental diets

	Experimental diets			
Variable	A Reference	B Basal	C F_1-QPM	D CM
Food intake	137.19±0.18	26.23±0.03[a]	144.29±0.34[a,b,*]	126.38±0.20[a,*]
Protein intake	16.55±1.30	0.00	17.07±3.29	13.28±1.49
Weight gain/loss	23.03±4.14	-15.00±9.64[a]	16.27±2.31*	6.37±2.07[a,*]
Faecal nitrogen (N)	0.19±0.04	0.09±0.04[a]	0.31±0.07[a,b,*]	0.40±0.02[a,*]

a = $p<0.05$ versus Reference, b = $p<0.05$ versus CM, * = $p<0.05$ versus basal

Table 4: Biological evaluation of the experimental diets

Variable	Reference diet	F_1-QPM diet	CM diet
PER	1.40±0.13	0.97±0.06[a,b]	0.48±0.28[a]
NPU	75.83±4.19	80.67±3.21[b]	41.83±5.48[a]
NPR	2.30±0.36	1.85±0.06	1.61±0.39[a]
TD	93.73±0.11	89.27±0.55[a,b]	81.59±0.11[a]
BV	80.78±3.93	90.30±2.56[a,b]	51.00±6.10[a]

a = $p<0.05$ versus Reference, b = $p<0.05$ versus CM

The crude protein content and protein quality of first generation quality protein maize (F_1-QPM) were determined with the view to establish whether the QPM offsprings (F_1-QPM) could retain the nutritional characteristics of their parent maize across environment. The mean±SD crude protein content of the F_1-QPM in this study compared well with the parent CIMMYT (International Maize and Wheat Improvement Centre) QPM from which it was obtained and with CM. This result is in agreement with the report that QPM has about the same amount of protein as common maize (Enwere, 1998). Although the parent QPM was obtained from CIMMYT in Mexico, South America, the protein content of the F_1-QPM obtained from it did not change.

The higher food intake for the F_1-QPM group indicated that the diet was more palatable to the rats. The low food intake for the CM group could be due to poor palatability and biological variations. The more palatable a diet is, the more it is accepted and consumed and vice versa. Food intake is associated with nitrogen (N) source, palatability, flavour and essential amino acid (EAA) profile (Chikwendu and Obizoba, 2003).

There was a higher ($p<0.05$) weight gain in F_1-QPM rats than CM group even though their levels of protein intake were comparable. Similar observations had been recorded by other workers both in rats and in other animal models (Bai, 2002; Zhai, 2002). This is most probably due to the higher lysine and tryptophan contents of the F_1-QPM diet resulting in higher biological utilization of the diet with a resultant better growth performance of rats which received the diet. This is further supported by the fact that the F_1-QPM rats also scored higher values in the other biological indices of protein quality (PER, NPU, TD and BV) utilized in the study. The NPR of F_1-QPM was also higher than that of the CM animals although the difference was not significant ($p>0.05$).

The faecal nitrogen (N) for the groups was influenced by protein quality and N intake. The higher the faecal N excretion, the lower the digestibility of a protein. Thus, the lower faecal N excretion of the F_1-QPM group was due to high protein digestibility and the higher faecal N of the CM group indicates low digestibility due to poor quality of the protein. In conclusion, the results obtained in this study suggest that environment does not affect the protein content and quality of QPM as the protein content and parameters assessed indicative of protein quality did not differ between QPM and that of F_1-QPM. We recommend that more toxicity studies on various body organs should be conducted to ascertain the safety of F_1-QPM.

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