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Nutritional Quality Assessment of Complementary Foods Produced from Fermented and Malted Quality Protein Maize Fortified with Soybean Flour

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Malnutrition of varying degrees has been associated with feeding infants with unwholesome and poor quality complementary foods. Therefore, the aim of this study was to produce complementary foods from quality protein maize (QPM) using the processes of malting and fermentation. The resulting flour was blended with processed soy bean flour at a ratio of 70:30 (maize: soybean). The nutritional qualities of the complementary foods were assessed biologically using animal feeding experiment to determine the growth rate, feed intake, protein quality parameters, haematological properties and rehabilitation potentials. The results showed that the protein efficiency ratio (PER) and food efficiency ratio of the malted QPM fortified with soybean were 2.44 and 0.24, respectively, which was the highest among the formulated diets and compared favourably with casein (2.5) and commercial diet (2.3). The QPM-based diets had a better biological value (>60%) and true digestibility (>60%) than the products from normal maize. The packed cell volume of the samples ranged between 23.00 (basal) and 46.00% (soy fermented normal maize). The QPM-based diets enhanced the quick recovery of protein starved/depleted animals better than the NM-based diets. Moreover, the addition of soybean further boosted the ability of the diet to rehabilitate the animals. The best result was seen in the group of rats fed with soy-malted QPM. The use of QPM in complementary food formulation gave better results and could alleviate the problem of protein and energy malnutrition, thereby reducing the mortality rate among infants.

INTRODUCTION

Exclusive breast feeding for the first 6 months is the recommended method of feeding full-term infants by healthy and well-nourished mothers [Kikafunda *et al*., 2003; WHO, 2000]. However, breast milk cannot sustain the nutrient and calories requirements of infant after the age of 6 months; this gives room for the introduction of complementary food that can meet the nutritional requirements of the growing child [Adelekan, 2003; Ikujenlola & Fashakin, 2005]. Complementary food is the food given to infants alongside with breast milk with the bid to supply the necessary nutrients and calories that are hitherto inadequate in the breast milk [Adelekan, 2003]. In Nigeria, like many other developing countries, there are various complementary foods that have been developed and served to infants in various localities [Fashakin *et al*., 1986; Obayanju & Ikujenlola, 2002; Ikujenlola & Fashakin, 2005].

The complementary foods developed based on cereal and starchy root have been associated with the incidence of protein energy malnutrition among the young infants [Inyang & Idoko, 2006]. This accounts for more than 25% death rate in infants in developing countries. Complementary foods produced from cereals are known to be deficient in certain essential amino acids which are required for the adequate growth and healthy living of infant. The essential amino acids; lysine and tryptophan are in short supply in normal maize, however, a new hybrid called Quality Protein Maize (QPM) contains reasonable quantity of these essential amino acids [Prassana *et al*., 2001; Ikujenlola *et al*., 2013]. Apart from the problem of inadequate nutrients plaguing the complementary food produced from cereal, high dietary bulk and high viscosity are factors which affect the quantity of food a child could consume per meal; this invariably affects the quality of the nutrients available to the children. The traditional complementary foods are associated with high viscosity which causes choking and suffocation of infant during feeding. The complementary food that will support growth and maintain good healthy living must contain adequate nutrients and be of low viscosity. Soybean is generally known to be of good nutritional quality in terms of its protein quantity and quality [Iwe, 2003]. The problem of high dietary bulk could be solved using malting and other processes such as extrusion [Hotz & Gibson, 2007]. The infant mortality in Nigeria is one of the highest in Africa. It was 86 deaths per 1000 live births in year 2000 and increased to 111 deaths per 1000 live births in year 2005 [UNFPA, 2005]. Malnutrition seems to be responsible for the highest percentage of all the causes (diarrhea, malaria, measles, pneumonia, malnutrition) of infant mortality. It is widely believed that a well-fed child can guide against diseases and infections [Adelekan,

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2003]. Good measures must be put in place to reduce or stop the increase and one of the good measures would be to adopt malting process in the preparation of infant complementary diets and the use of QPM in place of NM for both infant and family diets. The objective of this study was to produce complementary foods from malted and fermented QPM fortified with soybean and to assess the nutritional quality using animal feeding experiment.

MATERIALS AND METHODS

Materials

The two maize varieties - QPM (Obatampa var.) and NM (TZPB (FARZ 27) were obtained from the Research and Training Farm, Obafemi Awolowo University, Ile-Ife, Nigeria. Soybean was supplied by the International Institute of Tropical Agriculture (I.I.T.A.), Ibadan, Nigeria.

Production of unmalted and malted maize flours

For unmalted maize flour: the maize grains (QPM and NM) were cleaned and washed thoroughly to remove adhering dirts and dust. The washed grains were dried at 60°C for 20 h in a cabinet dryer (Gallenkamp Model ov-160). The dried maize grains were milled (attrition mill), sieved (60 mesh) and packaged (high-density polyethylene) until needed.

For malted flour: cleaned grains (QPM and NM) were steeped in tap water for 8 h at ambient temperature. The steeped grains were washed and spread evenly in a germinating chamber at about 1.5 cm loading depth for a period of 72 h with watering two times daily. The germinated seeds were thereafter thoroughly washed. The malted grains were subsequently dried in the cabinet dryer at 60°C for 20 h and then devegatated, milled, sieved (60 mesh), packaged (high-density polyethylene) and kept until needed [Marero *et al.,* 1988; Sajilata *et al.,* 2002].

Production of fermented maize flour

The maize grains (QPM and NM) were cleaned separately by hand sorting and floatation to remove broken grains and extraneous materials. The grains were washed with tap water. The grains were soaked in water and allowed to ferment for 72 h. The soaked/fermented grains were thoroughly washed, wet milled, sieved, and allowed to settle (3 h), drained, dried (60°C, 12 h), milled, packaged and kept until required [Inyang & Idoko, 2006].

Production of soybean flour

Soybean seeds were cleaned of dirts and extraneous materials. The seeds were soaked in warm water (into which 0.2% $NaHCO_3$ was added) for 3 h. The soaked seeds were decorticated, thoroughly washed and steamed for 1 h. The dehulled seeds were washed and dried in a cabinet dryer (Gallenkamp Model ov-160) at 60°C for 20 h. The dried seeds were milled, sieved (60 mesh), packaged (high-density polyethylene) and stored until needed [Iwe, 2003].

Formulation of complementary diets

The dietary blends were formulated at 0 :100 and 30 :70 (soybean flour : maize flour) in accordance with the recommendation of World Health Organization [FAO/WHO/UNU, 1985].

Biological assessment of the formulated complementary diets

The methods of Dahiya & Kapoor [1993] and Ikujenlola & Fashakin [2005] were adopted. For this study, one hundred and sixty (160) white rats (Wistar strain) between three and four weeks of age were used and adapted to basal diet containing 4% casein for a period of five days to acclimatize to the laboratory condition. After the acclimatization period, the animals were reweighed and grouped into 16 groups of 10 rats per group in a randomized block design and distributed into metabolic cages. The average weight per group was 45.00±2.00 g. One group of animals which served as baseline control was sacrificed at zero day and tissue samples from liver, kidney and the plantaris muscle of the hind leg were collected and weighed. Fourteen groups of rats were fed with formulated diets prepared at 10% protein level (iso-nitrogenous diets) for a period of 28 days and a group was fed with basal diet (non-protein diet). During the feeding experiment, water and food were supplied *ad libitum*, while the dietary intake, disposition and growth changes were monitored regularly. At the completion of the experiment, the animals were anaesthetized and sacrificed. The blood sample was collected for haematological analyses (packed cell volume, white blood cell and platelets) that were conducted at the Department of Haematology (Obafemi Awolowo University, Ile-Ife, Nigeria). The information collected during the feeding experiment were used in determination of growth rate, protein and feed efficiency ratios of the various diets.

For the biological value, true digestibility and net protein utilization determinations the feeding intake was recorded between the fourteenth and twenty-eighth day of the experiment, while the faecal discharge and urine were collected and kept for nitrogen analysis. The data were later used for the various determinations.

$$\text{Biological value} = \frac{(NF_1\text{-}NF_2) + (NU_1\text{-}NU_2) \times 100}{Ni - (NF_1\text{-}NF_2)}$$

where: Ni- nitrogen intake of animal fed test diet, NF1 - nitrogen excreted in feaces of animals fed test diet, NF2 - nitrogen excreted in feaces of animals fed protein free diet, NU1 - nitrogen excreted in urine of animal fed test diet, and NU2 - nitrogen excreted in urine of animal fed protein free diet.

Rehabilitative potentials of the formulated complementary diets

Experimental rats (Wistar strain) (70) of both sexes and of average weight of 62.50±2.00 were starved by feeding the experimental white rats with protein-free diet (protein depletion) for 14 days according to the method of Balogun *et al.* [1994]. The nutritionally-depleted rats were later reweighed, grouped and allotted to rehabilitation diets using the various formulated complementary diets. The formulated complementary diets were fed to the starved rats for a rehabilitation

TABLE 1. Weight gain, food intake of rats and protein efficiency ratio (PER), corrected PER and food efficiency ratio of the formulated complementary diets and controls.

Sample	Food intake (g)	Weight gain (g)	Protein efficiency ratio	Corrected PER	Food efficiency ratio
NM flour	183.03f±8.63	27.11f±4.95	1.48e± 0.15	1.29e	0.15ab± 0.02
QPM flour	166.14g±11.67	34.77e±1.71	2.08cd± 0.15	1.81cd	0.21ab± 0.02
Fermented NM	148.82j±19.73	14.18h± 5.45	0.95g± 0.05	0.83g	0.10b± 0.02
Fermented QPM	161.77h±11.78	19.26g± 2.63	1.19f± 0.10	1.04f	0.12ab± 0.01
Malted NM	160.56h±12.18	26.94f± 5.17	1.68d± 0.10	1.46d	0.17ab± 0.01
Malted QPM	156.67i±15.42	32.45e± 8.08	2.07cd± 0.15	1.80cd	0.21ab± 0.01
Soy NM flour	230.2b±18.87	51.05c± 6.94	2.36bc± 0.25	2.06bc	0.24ab± 0.02
Soy QPM flour	216.71e±14.94	60.83a± 4.78	2.64ab± 0.11	2.30ab	0.26a± 0.01
Soy fermented NM	222.61c±19.27	41.63d ±11.76	1.87de± 0.15	1.63de	0.19ab± 0.01
Soy fermented QPM	237.01a±22.57	55.09b± 4.51	2.32bc± 0.12	2.02bc	0.23a± 0.03
Soy malted NM	215.97e±21.64	50.35c± 3.14	2.36bc± 0.25	2.06bc	0.24a± 0.03
Soy malted QPM	218.76d±14.95	61.35a± 4.54	2.80a± 0.25	2.44a	0.28a± 0.03
Commercial diet	228.66b±25.27	62.56a ±5.39	2.74ab± 0.40	2.39ab	0.27a± 0.04
Casein	219.22d±13.36	63.02a± 5.42	2.87a± 0.35	2.50a	0.29a± 0.04

Means of the same column followed by different letters are significantly different ($p<0.05$). Results are means ± SD of 10 animals per group. Assay period 28 days.

period of 14 days. During this period, the growth performance/weights of the animals were monitored. Compensatory growth rate, number of days required by the starved/depleted rats to gain lost weight during starvation and mortality rate were used as response criteria.

The Animal Ethics Committee of the Obafemi Awolowo University, Ile-Ife, gave the approval for the use of the number of animals, ensured their well-being and prevented unnecessary suffering of the animals during the animal feeding and rehabilitation experiments.

Statistical analysis

Data were analysed using the computer software Matlab. Data obtained from the experiment on food intake, body weight (growth performance), haematological parameters were expressed as mean±SD. The analysis of variance (ANOVA) was performed to determine significant differences between the means. The means were separated using the Fisher's Least Significance Difference (LSD) test and Duncan multiple range test at $p<0.05$.

RESULTS AND DISCUSSION

Food intake and growth performance of the experimental animals during feeding trials

The feeding experiment showed that the mean food intake (Table 1) of experimental animals kept on various formulated diets varied from 148.82 g (fermented normal maize) to 237.01 g (soy fermented QPM). There were significant differences ($p<0.05$) in the food intake of the animals and also in the diets processed from maize varieties.

The growth performance and weight gain/loss of the experimental animals is presented in Figure 1. The mean weight gain of the animals ranged between 14.18 g (fermented NM) and 63.02 g (casein). The weight gain was influenced by the quality of the protein constituents of the diet and the quantity of diet consumed. It was observed that the weight gains of animals placed on QPM diets were higher than those of animals fed with NM diets. The malted QPM diet was better in terms of growth than malted NM. The malted diets improved the growth of the experimental animals better than the fermented diets. Fermented QPM and NM ensured lower weight gain than unfermented QPM and NM. In addition, the inclusion of soy flour to QPM and NM showed significant ($p<0.05$) increase in weight. Furthermore, the addition of soybean flour to malted and fermented diets improved the weight of the experimental animals compared to samples containing soybean with unmalted and unfermented diets. Protein is required for good growth, healthy living, maintenance and production of tissues and cells of the body. Soy malted QPM supported best weight gain among the formulated complementary diets while fermented NM supported the least weight gain. There was a significant difference ($p<0.05$) in the weight gain of rats fed with diets containing soybean and those without soybean. The improved weight gain in soy-fortified diets is due to the fact that soybean contains essential amino acids which are not present in maize [Iwe, 2003]. However, the QPM has reasonable quantity of the essential amino acids lacking in normal maize [Prassana *et al*., 2001; Ikujenlola, 2010; Ikujenlola *et al*., 2013].

The fermented NM and QPM did not support growth as much as the other formulations. This might be due to the loss

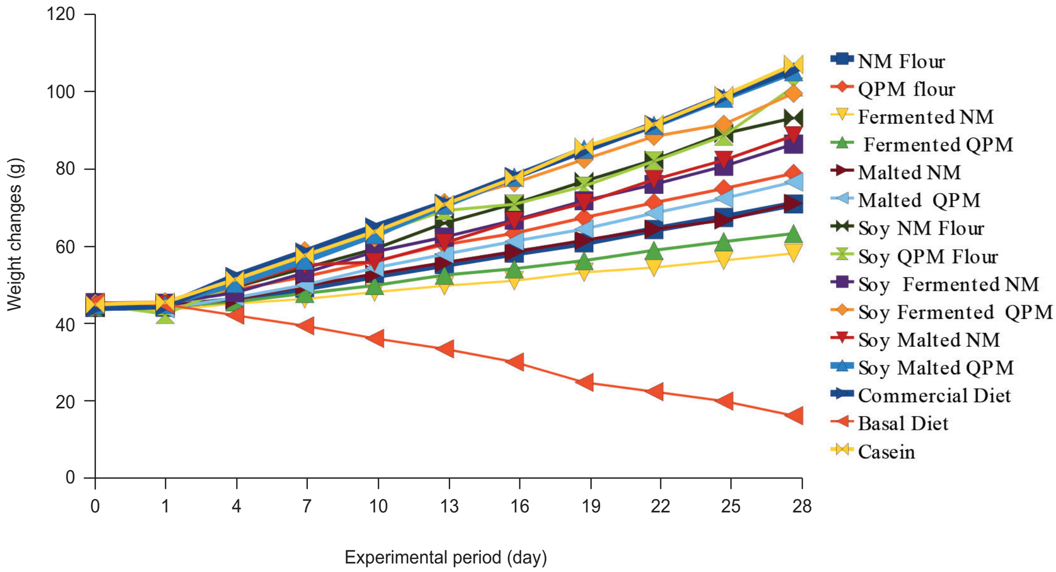

FIGURE 1. Growth performance of the experimental animals fed with various tested diets (mean values of 10 animals per group).

of protein during processing. According to Adeyemi [1989], between 5–40% of protein is lost during ogi production. However, Ojofeitimi & Abiose [1996] reported that unsieved fermented maize gruel (ogi) contained higher protein, mineral and fat contents. The results of the growth performance showed that QPM-based diets supported better growth and this is in agreement with the report of Akumoa-Boateng [2002] that QPM-based diet promotes good and healthy living among children in Ghana.

Protein efficiency ratio (PER) and feed efficiency ratio (FER)

The PER ranged between 0.83 (fermented NM) and 2.50 (casein) (Table 1). The PER of QPM and NM diets were 1.81 and 1.29, respectively. It was observed that the PER and FER of QPM based diets were significantly higher ($p<0.05$) than those of NM based diets. The PER of the fermented diets were lower than those of malted diets from both varieties of maize. Incorporating soybean flour into the blend significantly ($p<0.05$) improved the PER of the processed maize varieties. The PER of soy malted QPM (2.44) compared favourably with the PER of casein (2.50). There was no significant difference ($p>0.05$) between the PER of casein; soy malted QPM and commercial sample (2.39). The PAG (Protein Advisory Group) guidelines recommend a PER of not less than 2.1 and preferably greater than 2.3 for weaning food [PAG, 1971]. A similar recommendation was made by the general U.S. Department of Agriculture guidelines for corn-based blends [Annan & Plahar, 1995].

The feed efficiency ratio (FER) of the diets showed similar trend with the PER (Table 1). The result showed significant variation with respect to maize varieties, method of processing and addition of soy bean. The feed efficiency of soy-enriched malted QPM diet was significantly higher ($p<0.05$) than any other formulated diets from maize varieties, but was not significantly different from the commercial diet.

True digestibility, biological value and net protein utilization

The true digestibility (TD) (Table 1) of the formulated diets varied from 62.93% (fermented NM) to 74.56% (casein). The results showed that the TD of the QPM-based diets were higher than these of the NM-based diets. It was also observed that the TD of malted diets were significantly higher than the TD of fermented diets. The TD of soy-fortified diets were higher than those without soy flour. The cooking process, to which soybean was subjected to, could have destroyed the anti-nutritional factors in the raw soybean; which if present might interfere with the digestibility of the diets. Soaking, heating, dehulling and steam cooking are measures for reducing the level of anti-nutritional factors [Iwe, 2003; Hotz & Gibson, 2007].

The improved digestibility in soy-fortified diets accounted for the good growth performance of the animals during the feeding trials. Apart from the fact that the presence of anti-nutritional factors reduces the protein digestibility, large intakes of dietary fibre, especially hemicelluloses and cereal brans, increase the excretion of nitrogen in the feaces, reducing the apparent protein digestibility by about 10% [Paul & Southgate, 1978; FAO/WHO/UNU, 1991].

The biological value (BV) (Table 2) of the diets ranged from 56.16 (fermented NM) to 89.92% (casein). The results showed that QPM-based diets gave better BV than NM-based diets. Malted diets recorded a higher level of BV than fermented diets. Moreover, the soy-fortified diets showed better BV than the diets which contained no soybean flour. The soy-fortified diets had BV of comparable values with those of casein and commercial diets. BV is directly related to the efficiency of protein utilization; however, it ignores the importance of factors that influence digestion of the protein and interaction of protein with other dietary factors before absorption [Srikantia, 1981].

The values of the net protein utilization (NPU) of the diets varied between 35.34% (fermented NM) and 67.04 % (ca-

TABLE 2. Food intake (g), protein intake (%), nitrogen intake (%), nitrogen retained (%), true digestibility (TD) (%), biological value (BV) (%) and net protein utilization (NPU) (%) of the formulated complementary diets and controls.

Sample	Food intake (g)	Protein intake (%)	Nitrogen intake (%)	Nitrogen retained (%)	TD (%)	BV (%)	NPU (%)
NM flour	$88.85^{f}\pm2.61$	$8.89^{e}\pm0.41$	$1.42^{b}\pm0.12$	$0.32^{b}\pm0.09$	$69.01^{d}\pm4.10$	$65.31^{h}\pm2.44$	$45.07^{h}\pm2.82$
QPM flour	$79.23^{g}\pm1.28$	$7.92^{f}\pm0.15$	$1.26^{b}\pm0.14$	$0.32^{b}\pm0.08$	$72.22^{b}\pm3.24$	$70.32^{f}\pm2.44$	$50.78^{f}\pm2.46$
Fermented NM	$72.36^{h}\pm1.32$	$7.24^{f}\pm0.12$	$1.16^{b}\pm0.16$	$0.09^{b}\pm0.08$	$62.93^{f}\pm4.20$	$56.16^{i}\pm2.44$	$35.34^{i}\pm3.44$
Fermented QPM	$76.23^{g}\pm2.36$	$7.62^{f}\pm 0.16$	$1.22^{b}\pm 0.20$	$0.26^{b}\pm0.02$	$69.66^{c}\pm2.65$	$68.23^{g}\pm4.22$	$47.54^{g}\pm2.64$
Malted NM	$76.13^{g}\pm2.45$	$7.61^{f}\pm0.10$	$1.22^{b}\pm0.14$	$0.19^{b}\pm0.02$	$63.11^{f}\pm2.46$	$57.74^{i}\pm2.40$	$36.44^{i}\pm3.86$
Malted QPM	$71.94^{h}\pm2.33$	$7.19^{c}\pm0.42$	$1.15^{b}\pm0.15$	$0.25^{b}\pm0.04$	$70.43^{c}\pm4.00$	$70.37^{f}\pm3.20$	$49.56^{f}\pm3.20$
Soy NM flour	$103.66^{e}\pm4.45$	$10.37^{cd}\pm0.12$	$1.66^{a}\pm0.11$	$0.57^{ab}\pm0.02$	$69.28^{d}\pm4.02$	$77.39^{e}\pm2.84$	$53.62^{e}\pm3.20$
Soy QPM flour	$121.46^{a}\pm2.48$	$12.15^{a}\pm0.22$	$1.94^{a}\pm0.10$	$0.82^{a}\pm0.06$	$72.10^{b}\pm3.80$	$81.42^{d}\pm2.32$	$58.75^{d}\pm2.10$
Soy fermented NM	$112.32^{c}\pm 3.25$	$11.23^{b}\pm0.30$	$1.80^{a}\pm0.12$	$0.55^{ab}\pm0.04$	$67.22^{e}\pm1.98$	$71.96^{f}\pm4.32$	$48.33^{g}\pm2.88$
Soy fermented QPM	$115.91^{b}\pm4.50$	$11.59^{ab}\pm0.22$	$1.85^{a}\pm0.15$	$0.68^{a}\pm0.01$	$69.10^{d}\pm2.46$	$78.25^{e}\pm4.64$	$54.14^{e}\pm1.80$
Soy malted NM	$102.43^{e}\pm3.48$	$10.24^{d}\pm0.24$	$1.64^{a}\pm0.12$	$0.63^{ab}\pm0.03$	$70.73^{c}\pm3.46$	$82.61^{d}\pm4.20$	$58.43^{d}\pm2.10$
Soy malted QPM	$107.01^{d}\pm3.45$	$10.70^{c}\pm0.12$	$1.71^{a}\pm0.13$	$0.78^{a}\pm0.09$	$73.10^{b}\pm3.46$	$88.00^{b}\pm3.04$	$64.33^{b}\pm2.22$
Commercial diet	$110.62^{c}\pm4.50$	$11.06^{b}\pm0.12$	$1.77^{a}\pm0.09$	$0.79^{a}\pm0.06$	$72.88^{b}\pm4.32$	$86.05^{c}\pm2.34$	$62.71^{c}\pm2.48$
Casein	$107.98^{cd}\pm3.80$	$10.79^{ab}\pm0.21$	$1.73^{a}\pm0.12$	$0.84^{a}\pm0.06$	$74.56^{a}\pm3.52$	$89.92^{a}\pm3.21$	$67.04^{a}\pm2.46$

Means of the same column followed by different letters are significantly different ($p<0.05$). Results are means ± SD of 10 animals per group. Assay period 14 days.

sein) (Table 2). The values of the NPU varied with the maize varieties and the processing methods. The results showed that the values of NPU were directly proportional to the products of biological value and true digestibility. The values reported for NPU in these results were lower than the NPU (74%) reported by Obatolu *et al.* [2000] who worked on malted maize fortified with cowpea. The improvement made by rats fed with the blend containing malted maize could be attributed to the partial hydrolysis of the protein reserve during malting of the grains to amino acid by proteolytic enzymes [Abbey & Mark-Balm, 1988].

The malted diets have better growth promoting quality than the fermented diets. Also the QPM-based diets gave better growth performance than the NM-based diets. The superiority of QPM over NM agrees with the reports of Prassana *et al*. [2001], Akumoa-Boateng [2002], Bai [2007] and Ikujenlola [2010].

Packed cell volume (PCV), white blood cells (WBC) and platelets of the experimental animals

The PCV ranged from 23.00 ± 0.86 (basal) to 46.00 ± 0.29 (soy NM fermented) (Table 3). The PCV of the experimental animals fed on formulated diets was significantly higher ($p<0.05$) than the PCV of the experimental animal fed with basal (protein-free diet). According to Probst *et al*. [2006], the percentage of packed cell volume (% PCV) of rat ranges from 34% to 57%, with the mean at 45%. All the diets had PCV lower than the mean PCV of rat except soy fermented NM diet.

The PCV measures the ratio of the volume occupied by red cells to the volume of whole blood. It is a convenient and rapid measure of the degree of anaemia, and from a nutritional standpoint provides information comparable to the haemoglobin concentration. The PCV levels of the diets were lower than the PCV reported by Annan & Plahar [1995] who worked on similar products. The WBC of the diets varied from $3{,}300\times10^{3}$/L (NM fermented) to $8{,}200\times10^{3}$/L (commercial diet). The WBC of the protein--free diet is lower than the WBC of all other diets. There was significant difference ($P<0.05$) among the WBC of QPM flour, casein and commercial diet and the other formulated diets. WBC are disease fighting cells circulating in the blood. Low WBC count is due to several factors which include malnutrition, viral infections and drugs that destroy white blood cells. The platelets value ranged from 120×10^{9}/L (basal) to 218×10^{9}/L (malted QPM). The value of platelets of the protein-free diet was significantly ($P<0.05$) lower than the values of the platelets of other diets. Platelets help to maintain blood circulation by controlling hemorrhage after an injury to the blood-vessel wall that causes physical or biochemical disruption of the endothelium [Nachman *et al*., 2008]. Low platelets count may be as a result of low nutrient intake, especially protein.

In the developing countries, iron deficiency anaemia is an important nutritional problem. It was estimated that 45% of the children under 5 years suffer from nutritional anaemia [UNICEF, 1999]. Mothers are requested to feed well on diets rich in iron in order to prevent the occurrence of infantile anaemia. Since an infant cannot continue to feed on breast milk alone after the age of 6 months there is a need to prepare complementary diet that will take care of the baby's nutritional need without any deficiency.

TABLE 3. Packed cell volume (PCV), white blood cell (WBC) and blood platelet number of experimental rats fed with formulated diets and controls.

Sample	Packed cell volume	White blood cell (x 10^3 /L)	Blood platelet number (x 10^9/L)
NM flour	31.00±0.28^{f}	5,500.00±111.14^{bc}	140.00±1697.67^{bc}
QPM flour	40.00±1.15^{b}	7,333.00±167.57^{a}	205.00±288.67^{ab}
Fermented NM	32.66±0.58^{e}	3,300.00±104.20^{cd}	188.33±1732.05^{ab}
Fermented QPM	29.66±0.35^{g}	4,266.67±86.11$_{c}$	200.00±1732.05^{ab}
Malted NM	33.33±0.57^{e}	3,800.00±50.17^{cd}	196.00±961.86^{ab}
Malted QPM	27.00±0.19^{h}	4,500.00±101.79^{c}	218.33±288.67^{a}
Soy NM flour	35.00±0.76^{d}	5,566.67±88.09^{bc}	201.67±1443.37^{ab}
Soy QPM flour	32.67±0.36^{e}	4,266.67±83.09^{c}	185.00±577.35^{ab}
Soy fermented NM	46.00±0.29^{a}	4,533.33±42.58^{c}	210.00±192.25^{a}
Soy fermented QPM	30.67±0.17^{fg}	3,506.00±120.32^{c}	173.33±577.35^{b}
Soy malted NM	34.33±0.58^{de}	5,300.00±111.14^{b}	180.00±577.35^{ab}
Soy malted QPM	37.00±0.29^{c}	6,200.00±104.20^{b}	180.00±230.94^{ab}
Commercial diet	30.67±0.58^{fg}	8,200.00±83.09^{a}	192.00±577.35^{ab}
Casein	33.00±0.82^{e}	7,000.00±110.24^{a}	170.00±577.35^{b}
Basal diet	23.00±0.86^{i}	3,000.00±46.24^{d}	120.00±961.86^{c}

Means of the same column followed by different letters are significantly different ($p<0.05$). Results are means ± SD of 10 animals per group. Assay period 28 days.

TABLE 4. Rehabilitation potential of the formulated complementary diets and basal diet.

Sample	Initial weight (g) (A)	Final weight after depletion(g) (B)	Final weight after rehabilitation (g) (C)	Total weight gain(g)(D) (C – A = D)	Mortality rate (%) (E)	Average weight gain during rehabilitation (g)
NM flour	60.02^{d}±4.92	47.72^{e}±2.60	57.30^{d}±1.88	-2.72^{h}±1.88	No death	0.68^{bc}±0.17
QPM flour	61.72^{b}±3.40	50.13^{b}±3.00	62.29^{bc}±2.32	0.57^{f}±0.66	No death	0.86^{bc}±0.12
Fermented NM	62.27^{a}±4.82	50.67^{ab}±2.46	57.86^{d}±4.00	-4.41^{i}±0.22	20.00^{b}	0.51^{d}±0.14
Fermented QPM	59.92^{e}±3.24	48.16^{e}±3.65	57.75^{d}±3.24	-2.17^{h}±1.02	10.00^{c}	0.69^{bc}±0.16
Malted NM	62.68^{a}±2.88	51.06^{a}±3.12	61.11^{c}±3.44	-1.57^{g}±0.88	No death	0.72^{bc}±0.12
Malted QPM	62.74^{a}±2.78	50.25^{b}±2.32	63.65^{b}±2.30	0.91^{e}±0.89	No death	0.96^{ab}±0.14
Soy NM flour	61.88^{bc}±4.65	49.16^{d}±2.65	63.02^{b}±3.46	1.14^{d}±0.24	No death	0.99^{ab}±0.10
Soy QPM flour	62.12^{ab}±2.98	50.89^{a}±3.65	65.16^{a}±2.68	3.04^{b}±1.02	No death	1.02^{ab}±0.09
Soy fermented NM	61.74^{b}±3.45	49.48^{cd}±4.56	62.33^{bc}±2.40	0.59^{f}±0.24	No death	0.92^{ab}±0.12
Soy fermented QPM	61.05^{d}±3.44	49.14^{d}±4.50	61.92^{c}±2.60	0.87^{e}±0.76	No death	0.91^{ab}±0.14
Soy malted NM	62.36^{ac}±3.24	50.51^{ab}±4.90	64.41^{a}±1.80	2.05^{c}±1.06	No death	0.99^{ab}±0.08
Soy malted QPM	60.01^{d}±2.64	48.27^{e}±3.66	64.37^{a}±2.40	4.36^{a}±1.12	No death	1.15^{a}±0.23
Basal diet	61.91^{bc}±2.44	49.78^{c}±3.42	38.02^{e}±2.22	-23.89^{j}±3.45	30.00^{a}	-0.84^{e}±0.14
Commercial diet	59.19^{e}±2.40	48.20^{e}±2.80	64.89^{a}±1.80	5.70^{a}±1.44	No death	1.19^{a}±0.14

Means of the same column followed by different letters are significantly different ($p<0.05$). Results are means ± SD of 5 animals per group. Assay period 28 days.

Rehabilitation potentials of the complementary foods

The starving/depletion period of the experimental animals was accompanied with an average weight loss (Table 4) ranging between 17.96% (fermented QPM) and 20.49% (fermented NM). Some of the animals dropped fur and emaciated. The food intakes during depletion reduced gradually and the faeces discharge was watery and the urine was turbid and dark. Some of the animals were weak and sluggish, while some were anxious to get out of the metabolic cage.

During rehabilitation period (this referred to period when the experimental animals were fed with complementary diets) there were remarkable changes in terms of the rate of feeding, agility, fur development and weight increase. All the groups except the basal group increased in weight at varying degrees throughout the 14 days of rehabilitation. At the end of the rehabilitation period the animals had gained weight ranging between 14.19% and 34.53%. QPM-based diets were better than NM-based diets in terms of recovery and tendency to restore lost weight. Also the malted diets showed better rehabilitation potential than fermented diets. While the diets with soybean enhanced the rehabilitation of the animals significantly better than diets without soybean. The least weight gain was recorded in the group kept on fermented normal maize while the highest weight gain was observed in animals kept on the soy fortified malted QPM. There was no significant difference ($p>0.05$) in the weight gained by the groups kept on soy-fortified malted QPM and commercial diet.

Apart from the fermented QPM diet, all other QPM--based diets restored the original weight of the starved animals before the end of the rehabilitation period however, only soyfortified NM-based diets restored the original weight while at the end of the rehabilitation period other NM diets failed to restore the original weight of the animals.

The study showed that QPM-based diets encouraged quick recovery of the animal from starved and malnourished status. The inclusion of soy flour to QPM further boosted the recovery process since the lysine lacking in normal maize is sufficiently available in QPM and its addition to soybean further increased availability of the indispensable amino acids. At the end of the rehabilitation test, the mortality rate ranged between 10.00% and 30.00% (Table 4). The basal group had the highest mortality rate.

CONCLUSION

The study showed the impact of the QPM on the growth rate of the experimental animals and the potential of the QPM--based complementary diets to effect rehabilitation on nutritional depleted animals. It could be concluded that QPM promotes better growth pattern than normal maize. The addition of soybean further helps the capacity of the diets from QPM to support good growth. The inclusion of soybean to malted maize varieties improved the growth of the experimental animals significantly. The processes of malting and fermentation boosted the nutritional status of the formulated diets. Malting is however found to be better than fermentation.

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