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Production of Cocoyam, Red Kidney Beans, and Mango- based weaning foods: Impact of fermentation and malting on minerals, essential amino acids and protein quality

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Abstract
This work investigated the impact of accelerated natural fermentation and malting on the minerals, amino acid and protein quality of cocoyam, red kidney beans, and mango based complementary foods. Samples were formulated based on 16% protein to satisfy the nutrient requirement of preschool children to obtain fermented cocoyam/ malted red kidney beans/ mango (FMM); Fermented cocoyam/ non- malted red kidney beans/ mango (FNMM); Non- fermented cocoyam/ malted red kidney beans/ mango (NFMM); Non- fermented cocoyam/ Non- malted red kidney beans/ mango (NFNMM).The minerals, amino acids and growth study parameters were examined using standard procedures was used as external control. Potassium (31.03±0.96 (NFNMM) - 35.74±0.95 mg/100 g (FMM), Magnesium (36.39±0.95 - to 32.12±0.36 mg/100 g), Calcium (53.36±1.54 (FMM) to 40.32±0.25 mg/100 g (NFNMM)), increased significantly ($p< 0.05$) with fermentation and malting. Most amino acids (Essential and non-essential) increased significantly with fermentation and malting. NFMM and FMM exhibited higher growth response when fed to rats compared to FNMM and NFNMM. Samples FMM and NFMM gave better protein efficiency ratio (PER) of, 1.47 and 1.46 followed by FNMM and NFNMM. Among all the test samples, FMM gave the best PER result.

Keywords: Red Kidney Beans, natural fermentation, amino acids

Introduction

According to Matikiti *et al*. (2017) cocoyam (Colocasia esculenta) contains 65 – 78% (moisture), 2 – 5 % (ash), 0.2 – 1.10% (fat), 2 – 5% (fibre), 14 – 23% (carbohydrates), 390 – 460 mg/100 g (potassium), 24 – 43 mg/100 g (calcium), 79 – 91 k/cal (energy), 0.3 – 4.8% (protein) and 79 – 110 mg/100 g (magnesium). Studies by Igbabul *et al*. (2014) [18] and Tope & Soji, (2013) [42],
the tubers contain easily digestible starch (small size of the starch granules, 1 - 4 μm) (Charles *et al*., 2017) [8] and are known to contain substantial amounts of protein, fibre, vitamin C, thiamine, riboflavin, potassium, sodium, phosphorus, magnesium, calcium and niacin. It has more crude protein than root and other tubers but very low protein (0.3 -4.8%) compared to red kidney beans (22.7%) (Inyang *et al*., 2018). Red kidney beans is used to enhance the protein, linoleic acid content in the diet of low and medium income earners (Forwoukeh *et al*., 2023) [14]. Therefore, on the basis of complementarity, the combination of cocoyam and red kidney beans in food formulations could adequately provide most nutrients needed in human diets.

Cocoyam is still regarded as less important than other tropical root crops such as yam, cassava and sweet potato and as food for low income people. In Nigeria cocoyam is one of the under exploited tropical root plant that is very nutritious but its utilization is still at the subsistence level and highly neglected crop. Some researchers have decried the extinction of cocoyam in Nigeria despite its numerous nutritious and health benefits (Igbabul *et al*., 2014) [18]. In phytomedicine, (Ilonzo, 1995) reported that consumption of roasted cocoyam with palm oil for a period of three months can cure diabetes. Diabetic patients in Nigeria eat cocoyam to manage the disease (Igbabul *et al*., 2014) [18]. In the case of red kidney beans and mango, there is growing awareness of the food potentials of this legume. Red kidney bean is used in the fortification of low protein diets such as local cereal based weaning foods. Mango is a valuable sources of vitamins and minerals (Izidoro *et al*., 2023).

Among the reasons advanced for under - utilization of cocoyam is presence of toxicants like calcium oxalate, phytate, trypsin inhibitors, cyanide, and its susceptibility to pre and post -harvest diseases, which reduce storage stability and quality of the products (Tope & Soji, (2013) [42].

Malting and natural fermentation are among the simple and locally adaptable technologies for toxicants reduction (Nkhata *et al*., 2018). Also during malting metabolic activity results in the production of primary and secondary metabolites thereby improving the nutritional and functional properties of the grain (Abbas & Mushara, 2008) [1]. The most important processes associated with the fermentation phase is the hydrolysis of some complex organic molecules such as lipids, protein and phytin to fatty acids, lactic acid, acetic acid, amino acids and phosphate (Tope & Soji, 2013) [42]. Fermentation is used to enhance the bioaccessibility and bioavailability of nutrients from different crop (Onwurafor *et al*., 2020) [33]. Therefore the objectives of this work are to evaluate both by chemical analysis and feeding trial experiments on rats, of cocoyam-red kidney beans and mango based weaning foods using fermentation and/or malting processes.

Materials and methods

1. Materials

Cocoyam and mango were purchased from railway market in Makurdi, Benue State, Nigeria. Red kidney bean was purchased from food Market Ndop, North West region Cameroon. Identification of the crops was done in the

Department of biological Science, Benue State University Makurdi, Nigeria. Male wistar rats were purchased from the College of Health Sciences, Benue State University, Makurdi

2. Preparation of raw materials

Cocoyam flour: Cocoyam flour was prepared using the method described by Coronell-tovar *et al*. (2019) [9]. Cocoyam was washed with water to eliminate soil particles and dirt. The corm peel and the pulp was sliced (1cm). The slices were washed, boiled in potable water for 15 mins using a gas cooker. The cooked slices were dehydrated an air draft dehydrator at 55 °C for 15 h. Dried samples were ground, sieved (0.05 mm) and packaged in high density polyethylene bags.

Fermented cocoyam flour: Fermented cocoyam flour was prepared following the method described by Ariahu *et al*. (1999) [5]. One hundred and twenty grams (120 g) of cocoyam flour was mixed with 80 ml of distilled water in a 500 ml beaker which was covered and the concentrate allowed to undergo natural fermentation at room temperature (30 ± 2 ºC). Fermentation was accelerated by adding 50% fermenting (back-slopping) slurry to fresh concentrate at 24 hour intervals over a period of 96 h when the pH stabilized. The fermented concentrates were dehydrated in an air draft dehydrator at 50 ºC for 12 h to obtain fermented cocoyam flour.

Red kidney beans flour: The red kidney bean flour was prepared using the method described by Inyang *et al*. (2018); Ukeyima *et al*. (2019) [43]. The bean was thoroughly cleaned. This was followed by soaking in clean water for 12 hours and the water was changed every 6 hours to prevent fermentation. After this the beans was blanched in hot water at 85 ºC for 30 mins. The blanched bean was dehydrated in an air draft dehydrator at 55 ºC for 20 hours and dehulled by hand rubbing. The dried bean was milled, sieved (0.05 mm) and packaged in high density polyethylene.

Malted red kidney beans flour: The malted red kidney beans flour was prepared according to the method of Okoye *et al*. (2021) [30]. Red kidney beans seeds were thoroughly cleaned and steeped in potable water at room temperature (30±2 ^{0}C) for 12 h with a change of water at intervals of 6 h to prevent fermentation. After steeping, the seeds was drained, rinsed and immersed in 2% sodium hypochlorite solution for 10 min to disinfect the seeds. The seeds were then rinsed for five consecutive times with excess water, spread on the jute bag and allowed to germinate at room temperature (30±2 ^{0}C) for 72 h until the rootless reached a length of 1.5 cm. During this period, the seeds were sprinkled with water at intervals of 6 h to facilitate germination. The germinated seeds were blanched (85 ºc, 30 mins) and dehydrated at 55 ºC for 20 h. The dried malted seeds were cleaned and rubbed in-between palms to remove the roots and shoots along with the hulls. The seeds were milled, sieved (0.05 mn sieve) and packaged in high density polyethylene.

Mango flour: Ripe mature mangoes popularly known as Brockley was washed using potable water. The mango was peeled and the pulp sliced in to 1cm thickness. The sliced mango pulp was blanched at 70 ºC for 5 mins and dehydrated in an air draft dehydrator at 55 ºc for 24 hours to obtain mango flakes. The mango flakes was ground using laboratory grinders (M/S Sujata: New Delhi India), sieved (0.05 mm sieve) and packaged in high density polyethylene (Izidoro *et al*., 2023).

3. Complementary food Formulations

Four samples FMM, FNMM, NFMM, NFNMM, were formulated. This ratio was arrived at, based on their protein content through material balancing to give 16 g protein/100 g.

Ingredients mix (g/100) by materials balancing

Complementary foods	Non- fermented cocoyam flour (g)	Fermented cocoyam flour (g)	Non-malted red kidney beans (g)	Malted red kidney beans (g)	Mango flour (g)
FMM	-	38.00	-	52.00	10
FNMM	-	25.00	65.00	-	10
NFMM	32.00	-	-	58.00	10
NFNMM	20.00	-	70.00	-	10

4. Mineral content of the flour

Minerals analysis was by AACC (Cereals and Grains Association, formerly American Association of Cereal Chemists) official inductively coupled plasma spectroscopy as described by Badawy and Arafa, (2021) [6].

5. Amino acids content of flour

Amino acid analysis was by ion exchange chromatography (IEC) as described by (Sengev *et al*., 2016b) [36]

6. Feeding trials

Daily feed intake, daily weight gain (g/rat/day) was determined following methods described by (Ojokoh, 2006) [29] While Foods conversion efficiency, Apparent Digestibility (AD)**,** Protein efficiency ratio (PER) was determined using methods described by Sengev *et al*. (2016) [36].

7. Data Analysis

Data obtained were analysed using the one-way ANOVA and mean separated using Duncan's Multiple Range Test (DMRT) at 5% limit of significant using Statistical package for social science (SPSS) version 26.

Results and Discussion

1. Mineral content of weaning foods

Table 1: Minerals content (mg/100 g) of complementary foods from cocoyam, red kidney beans and mango as influenced by fermentation and malting

Weaning foods	Na	K	Mg	Fe	Zn	Ca	p
FMM	23.94^d±0.10	35.74^a±0.95	33.83^b±0.97	1.41^c±0.38	3.38^a±0.36	53.36^a±1.54	79.31^a ±0.92
FNMM	26.32^b±0.1	31.23^c±0.10	34.79^b±0.20	2.37^b±0.15	3.36^a±0.01	48.27^b±0.04	58.32^c ±0.47

NFMM	25.88^{c}±0.04	32.08^{b}±0.99	36.39^{a}±0.95	1.53^{c}±0.44	3.37^{a}±0.05	49.47^{b}±0.04	65.14^{b}±0.17
NFNMM	28.34^{a}±0.10	31.03^{d}±0.96	32.12^{c}±0.36	2.82^{a}±0.77	3.35^{a}±0.38	40.32^{c}±0.25	56.38^{d}±0.06
Codex	296	516	32	16	3.2	250	356
WFP	Max 0.4	700-773	54-168	11.6-40	4.2 - 14	260-800	180-550

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same column indicate significant difference at (p<0.05). FMM: Fermented cocoyam/ malted red kidney beans/ mango; FNMM: Fermented cocoyam/ non- malted red kidney beans/ mango; NFMM: Non- fermented cocoyam/ malted red kidney beans/ mango; NFNMM: Non- fermented cocoyam/ Non- malted red kidney beans/ mango

Table 1 shows the change in mineral content of the flours as influenced by fermentation and malting. It was observed that malting and/or fermentation decreased sodium (Na), iron (Fe) content of the weaning foods. The decrease can be ascribed to possible leaching of the minerals during fermenting or malting processes (Igbabul *et al*., 2014 [18]; Gautam & Gupta, 2018 [15]; Onwurafor *et al*., 2020 [33]; Onwurafor *et al*., 2020) [33]. Also according to Ojokoh, (2006) [29] microorganisms might have use some of this minerals for their metabolic activities. The mango flour was added to improves the mineral content of the flours (Izidoro *et al*., 2023). Sodium intake needs to be monitored as it can become major dietary problem where high blood pressure is concerned (Ijarotimi & Keshinro, 2013 [19, 20]; Edima-Nyah *et al*., 2019) [10]. Conversely fermentation and/or malting increased Potassium (K), Magnesium (Mg), Calcium (Ca), phosphorus (p) and zinc (Zn) content of the weaning foods. This can be ascribed to possible leaching of soluble anti - nutritional factors during fermentation and/or malting (Gautam & Gupta, 2018) [15] resulting to increased bioavailability of minerals. Pranoto *et al*. (2013); Luo *et al*. (2014) and Gautam & Gupta, (2018) [15], hypothesized that the remarkable increase in phytase activity during germination and fermentation helps reduce phytic acids, which bind potassium subsequently leading to increased mineral availability. During germination, oxalate oxidase gets activated which breaks down oxalic acid into carbon dioxide and hydrogen peroxide and releases calcium (Gautam & Gupta, 2018) [15]. Oxalic acid is known to interfere with calcium absorption (Gautam & Gupta, 2018) [15]. Calcium deficiency can lead to ricket, osteomalacia and tooth decay (Gautam & Gupta, 2018) [15]. This report agree with report presented by Gautam & Gupta, (2018) [15]; Onwurafor *et al*., (2020) [33] who observed that malting and/or fermentation increase these minerals.

3.2 Mineral ratios of the weaning foods

Table 2: Mineral ratios of the weaning foods

Complementary foods	Na: K	Fe: Zn	Ca: K	Ca: P
FMM	0.67	0.42	1.49	0.67
FNMM	0.83	0.72	1.55	0.83
NFMM	0.81	0.45	1.54	0.76
NFNMM	0.91	0.84	1.30	0.72
Standard	<1	>2	<4	>0.5

FMM: Fermented cocoyam/ malted red kidney beans/ mango; FNMM: Fermented cocoyam/ non- malted red kidney beans/ mango; NFMM: Non- fermented cocoyam/ malted red kidney beans/ mango; NFNMM: Non- fermented cocoyam/ Non- malted red kidney beans/ mango

Table 2 shows the mineral ratio of the flours as influenced by fermentation and malting. The effectiveness of minerals in the diets is influenced by mineral–mineral interactions that may either enhance or reduce the absorption of certain micronutrients in the body (Soetan *et al*., 2010 [41]; Gemede, 2020) [16]. The sodium–potassium (Na:K) ratios (0.67 (FMM) to 0.91 (NFNMM)) of the weaning foods were within the recommended values (<1) (Ijarotimi *et al*., 2013) [19, 20] and Jacob *et al*. (2015). Malting and fermentation reduced the Na:K ratio resulting to products which is more functional to hypertensive persons. The lower sodium and higher potassium intake help to reduce high blood pressure in hypertensive patients (Perez & Chang, 2014 [35]; Gemede, 2020) [16]. The iron–zinc (Fe/Zn) ratios of the weaning foods were not within the recommended values (>2) (Gemede, 2020). This might be due to leaching of iron during fermentation and/or malting. Gemede, (2020) [16] reported that iron did not impair zinc absorption up to an iron: zinc ratio of 2:1; then a dose-dependent effect was observed up to a ratio of 5:1; when the ratio was increased from 5:1 to10:1, no further inhibition of zinc occurred. The iron present in the weaning foods might impair zinc absorption. The calcium–potassium (Ca/K) ratios of the weaning foods were within the recommended values (<4). The Ca/K ratio is called the thyroid ratio because calcium and potassium play a vital role in regulating thyroid activity (Olagbemide *et al*., 2016) [31]. Low Ca/K ratio would indicate an elevation of thyroid expression. Thyroid hormones (thyroxine T3 and triiodothyronine T4) support the rate at which the body uses fats and carbohydrates (Gemede, 2020) [16]. Fermentation and/or malting increased Ca /K ratios. Calcium–phosphorous (Ca:P) ratios of the weaning foods were within recommended values (>0.5) (Jacob *et al*., 2015). Furthermore, food is considered as good if Ca/P ratio is >1 and poor if this ratio is <0.5 (Alinnor & Oze, 2011) [3]. A higher calcium–phosphorous (Ca/P) levels in foods are required for favorable calcium absorption in the intestine for bone formation. The high Ca/P ratio observed in this study is of nutritional benefit, particularly for children and the aged who need higher intakes of calcium and phosphorus for bone formation and maintenance (Oluwole *et al*., 2013) [32].

3.3 Amino acid profile of weaning foods

Table 3: Essential amino acid profile (g/100 g protein) of complementary foods

Amino acids	FMM	FNMM	NFMM	NFNMM
Leucine	7.56^{a}±0.02	7.38^{c}±0.01	7.47^{b}±0.02	7.35^{c}±0.01
Lysine	5.03^{a}±0.02	4.50^{c}±0.06	4.73^{b}±0.02	4.27^{d}± 0.01
Isoleucine	3.98^{a}±0.02	3.88^{b}±0.01	4.07^{a}±0.03	3.60^{c}±1.12
Phenylalanine	3.87^{a}±0.02	3.46^{c} ±0.02	3.76^{b}±0.02	3.16^{d}±0.03
Tryptophan	1.38^{a}±0.01	1.17^{c}±0.02	1.26^{b}±0.02	1.03^{d}±0.02
Valine	5.09^{a}±0.02	5.00^{b}±0.1	4.98^{b}±0.01	4.87^{c}±0.02
Methionine	2.74^{b}±0.04	2.63^{c}±0.02	2.88^{a}±0.01	2.24^{d}±0.03
Proline	3.82^{b}±0.03	4.01^{a}±0.06	4.97^{a}±0.07	2.23^{c}±0.03
Arginine	5.07^{a}±0.03	5.33^{a}±0.02	5.58^{a}±0.02	4.99^{b}±0.03
Tyrosine	2.00^{d}±0.01	3.06^{b}±0.03	2.42^{c}±0.04	3.44^{a}±0.02
Histidine	2.27^{a}±0.02	1.98^{c}± 0.01	2.07^{b}±0.01	1.18^{d}±0.04
Cysteine	1.09^{a}±0.02	0.90^{b}±0.04	0.91^{b}±0.02	0.48^{c}±0.03
Alanine	1.02^{d}±0.05	2.73^{c}±0.01	3.90^{b}±0.02	4.47^{a}±0.02
Glutamic acid	9.70^{a}±0.06	8.24^{b}±0.03	6.11^{c}±0.01	5.96^{d}±0.01
Glycine	5.50^{a}±0.03	4.24^{b}±0.01	4.51^{b}±0.02	4.08^{b}±0.03
Threonine	2.98^{d}±0.02	3.26^{c}±0.02	3.51^{b}±0.06	3.64^{a}±0.02
serine	3.70^{a}±0.01	3.00^{c}±0.02	3.40^{b}±0.01	1.80^{d}±0.04
Aspartic acid	10.21^{b}±0.01	10.41^{b}±0.03	8.96^{c}±0.05	10.85^{a}±0.02

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same row indicate significant difference at ($p<0.05$). FMM: Fermented cocoyam/ malted red kidney beans/ mango; FNMM: Fermented cocoyam/ non- malted red kidney beans/ mango; NFMM: Non- fermented cocoyam/ malted red kidney beans/ mango; NFNMM: Non- fermented cocoyam/ Non-malted red kidney beans/ mango Table 3 shows the amino acids profile of the complementary foods as influenced by fermentation and malting. The essential amino acid contents of non-fermented, Non malted sample were significantly ($p<0.05$) less than the corresponding fermented and/or malted samples. This could be due to the synthesis of some essential amino acids during fermentation (Simwaka *et al.*, 2015 [40]; Bhathal and Kaur, 2015 [7]; Sengev *et al.*, 2016) [36]. The increase in amino acids in the fermented and/or malted product shows that the carbohydrate utilization is closely proportional to protein production during fermentation and malting. Sengev *et al*. (2016) [36] reported that single cell protein produced by Aspergillus niger contained 30.4% crude protein and had an essential amino acid profile featuring a high lysine content and appreciable amounts of methionine and tryptophan. The most important physiological processes associated with the germination phase are the synthesis of amylases, proteases and other endogenous hydrolytic enzymes, for the release of sugars and amino acids from starch and protein, respectively (Baranwal, 2017). Similar observations were found in a study by Mohamed and Huiming (2007); Shalaby & El-shourbagy (2016) [37]; Kaur *et al., (*2020); Sibian & Riar, 2022 [39], who reported increase in essential amino acid content of germinated kidney bean. The quality of protein is mainly a function of its essential amino acids. The essential amino acids are necessary for tissue maintenance and are also required for the growth of infants (Shalaby & El-shourbagy, 2016) [37]

The non-essential amino acids also followed the same pattern as NFNMM had significantly (<0.05) lower values compared to fermented and/or malted samples in most cases. The reduction in amino acids with fermentation may be due to its utilization for growth and production of enzymes and other organic compounds by the microorganisms during fermentation and malting. Reduction in the concentration of some amino acid of the blends during fermentation was in agreement with the findings of sengev *et al*., (2016) [36] who observed a reduction in amino acid content of Sorghum-Based Complementary Foods after fermentation.

3.4 Chemical scores (%) of essential Amino acids of weaning foods

Table 4: Chemical scores (%) of essential Amino acids of complementary foods

	Complementary Foods			
Amino Acid	**FMM**	**FNMM**	**NFMM**	**NFNMM**
Leucine	180.00	175.71	177.86	175.00
Lysine	101.67	112.62	107.14	119.76
Isoleucine	94.76	92.38	96.90	92.38
Phenylalanine	138.21	123.57	134.29	112.86
Tryptophan	98.57	83.57	90.00	73.57
Valine	121.19	119.05	118.57	115.95
Methionine	124.55	119.55	130.91	101.81
Histidine	113.5	99.00	103.5	59.00
Threonine	106.43	116.43	125.36	130.00

Key:

$$\% \text{ chemical score } = \frac{\text{value of amino acid in complemtary food } (\frac{g}{100g}\text{protein})}{\text{FAO Ref. valued}} x100$$

FMM: Fermented cocoyam/ malted red kidney beans/ mango; FNMM: Fermented cocoyam/ non- malted red kidney beans/ mango; NFMM: Non- fermented cocoyam/ malted red kidney beans/ mango; NFNMM: Non- fermented cocoyam/ Non- malted red kidney beans/ mango

Table 4 shows the Chemical scores (%) of essential Amino acids of weaning foods as influenced by fermentation and malting. Amino acid score of complementary foods was observed as per the reference values of FAO (2013) [13]. The detrimental factor for food protein quality greatly depends on the content and availability of amino acids (Sibian & Riar, 2022) [39]. A greater proportion of the essential amino acids in FMM (fermented and malted) shown higher amino acid score and were reported above 100 while NFNMM shown amino acids score below100 in some essential amino acids. Overall amino acid score showed increment as a result of germination and fermentation (Sibian *et al*., 2017) [38]. Amino acid score above 100 indicate high availability of amino acids. This results agree with report presented by Sibian *et al* (2017) [38]; Sengev *et al*. (2016) [36]; Sibian & Riar (2022) [39], who reported fermentation and malting improved the availability of essential amino acid score of red kidney beans and sorghum. The most important physiological processes associated with the germination phase are the synthesis of amylases, proteases and other endogenous hydrolytic enzymes. During malting, the hydrolytic enzymes migrate from the germ into the endosperm where starch and protein are hydrolyzed to sugars and amino acids, respectively (Kaur *et al*., 2020). Fermentation involved hydrolysis (by lactic acid bacteria and yeasts) of some complex organic molecules such as lipids, protein and phytin to fatty acids, lactic acid, acetic acid, amino acids and phosphate (Tope & Soji, 2013) [42].

3.5 Influence of complementary foods on growth performance of male wistar rats

Table 5: Influence of the complementary foods on growth performance of male wistar rats

Weaning foods	MDFI (g/rat/day)	MDWG (g/rat/day)	PER	FCE	AD (%)
FMM	$6.46^{d}\pm0.11$	$1.51^{c}\pm0.14$	$1.47^{b}\pm 0.32$	$4.27^{c}\pm0.21$	$80.01^{b}\pm0.05$
FNMM	$6.42^{e}\pm0.03$	$1.37^{d}\pm0.15$	$1.33^{c}\pm0.12$	$4.68^{b}\pm1.11$	$77.50^{d}\pm$o.11
NFMM	$7.04^{b}\pm 0.12$	$1.66^{b}\pm0.15$	$1.46^{b}\pm0.20$	$4.24^{c}\pm0.02$	$79.75^{c}\pm0.23$
NFNMM	$6.90^{c}\pm 0.22$	$1.23^{e}\pm0.14$	$1.12^{d}\pm0.27$	$5.61^{a}\pm1.04$	$75.25^{e}\pm0.12$
CS	$8.73^{a}\pm0.59$	$2.65^{a}\pm0.21$	$2.21^{a}\pm0.15$	$3.29^{e}\pm0.07$	$82.65^{a}\pm0.45$

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same column indicate significant difference at ($p<0.05$). MDFI= Mean daily food intake, MDWG= Mean daily weight gain, PER= protein efficiency ratio, FCE= Food conversion efficiency, AD= Apparent digestibility, FMM: Fermented cocoyam/ malted red kidney beans/ mango; FNMM: Fermented cocoyam/ non- malted red kidney beans/ mango; NFMM: Non- fermented cocoyam/ malted red kidney beans/ mango; NFNMM: Non- fermented cocoyam/ Non- malted red kidney beans/ mango, **CS:** CERELAC

Table 5 shows the influence of the complementary foods on growth performance of male wistar rats. It was observed that animals fed with CERELAC (control sample) had the highest (significant difference ($p<0.05$)) food consumption while animals fed FNMM ate lowest. This might probably be because of its palatability as stated by Ojokoh, (2006) [29]; Sengev *et al*. (2016) [36]; Eli *et al*. (2022) [11]. Sour characteristics of the fermented products affected intake by the experimental rats. According to Gernah *et al*. (2012) Eli *et al*. (2022) [11] it has been established that rats prefer a diet with some sweet taste and may consume higher quantities of such diets. Thus, the unfermented diet was not sour and therefore was consume more. In the rat bioassay, all rats survived to the end of the observation and gained positive body weight. The weight changes computed shows that group fed with CERELAC is significantly ($p<0.05$) higher than the other groups. Rats fed NFNMM had the lowest growth rate. This might be due to lack of treatments. Fermentation and malting increase bioavailability and digestibility of food and these may result to higher growth rate. This is in conformity with Sengev *et al*. (2016) [36]; Eli *et al*. (2022) [11]. The PER (ability of protein to support growth) indicates the relationship between weight gain in the test animals and the corresponding protein intake (Sengev *et al*., 2016) [36]. NFNMM shows PER value which was significantly ($p<0.05$) lower than the other test samples. Fermentation and malting have been reported to improve protein efficiency due to improved bioavailability and digestibility of protein (Onyango *et al*., 2013 [34]; Nkhata *et al*., 2018).

During these processes, starch and protein are hydrolyzed (hydrolytic enzymes) to sugars and amino acids, respectively thereby improving digestibility (Kaur *et al*., 2020). Sample NFNMM shows FCE value which was significantly ($p<0.05$) lower. This might be due to the lack of fermentation and malting. Fermentation and malting result to reduction in anti -nutrients (for example tannin) thereby reduce the chances of the binding of dietary protein and digestive enzymes into complexes that are not readily digestible (Ojokoh, 2006) [29]. Since tannins are known to reduce the availability of proteins, carbohydrates and minerals through the formation of indigestible complexes, breakdown of such complexes will invariably improve the availability of the nutrients (Tope & Soji, 2013) [42]. FCE is important calculation for growth which can be used to determine if the diets are being used as efficiently as possible (sengev *et al*., 2016) [36]. In this study, the FCE indicated good growth. The lower the value of FCE, indicate higher efficiency. Sample NFNMM shows AD value which was significantly ($p<0.05$) lower. This might be due to the lack of fermentation and malting. This processes lead to reduction in tannins, oxalate, phytic acid, and carbohydrates which can complex with proteins and hence limiting accessibility by digestive enzymes (El-Hag *et al*., 2002 [12]; Osman, 2011; Hassan *et al*., 2015) [17]. As reported by El-Hag *et al*. (2002) [12]; Ali *et al*. (2003); Alka *et al*. (2012) [4];

Pranoto *et al*. (2013) fermentation increases the digestibility of plant proteins. Plant protein has poor digestibility relative to animal protein (CS content animal protein giving it the high digestibility).

Conclusion

Fermentation and malting caused increase mineral as well as the essential amino acid contents of the blends. In the rat bioassay, all rats survived to the end of the observation and gained positive body weight. Samples FMM and NFMM exhibited good growth behaviour, which was evident by good PER values. Among all the test samples, FMM gave the best PER result.

Reference

1. Abbas TEE, Ushara NAM. The effect of germination of low-tannin sorghum grains on its nutrient contents and broiler chicks' performance. Pak J Nutr,2008:7(3):470–4.
2. Ali MAM, El-Tinay AH, Abdalla AH. Effect of fermentation on the *in vitro* protein digestibility of pearl millet. J Food Chem,2003:80:51–4. https://doi.org/10.1016/S0308-8146(02)00234-0.
3. Alinnor IJ, Oze R. Chemical evaluation of the nutritive value of Pentaclethra macrophylla benth (African Oil Bean) seeds. Pak J Nutr,2011:10(4):335–9.
4. Alka S, Neelam Y, Shruti S. Effect of fermentation on physicochemical properties & *in vitro* starch and protein digestibility of selected cereals. Int J Agric Food Sci,2012:2:66–70.
5. Ariahu CC, Ukpabi U, Mbajunwa KO. Production of African breadfruit (Treculia africana) and soybean (Glycine max) seed based food formulations, 2: Effects of germination and fermentation on microbiological and physical properties. Plant Foods Hum Nutr,1999:54(3):207–16. https://doi.org/10.1023/A:1008196725387.
6. Badawy WZ, Arafa SG. Utilization of Marjoram to Improve the Nutritional Value and the Safety of Snacks. Middle East J Appl Sci,2021:11(3):595–602. https://doi.org/10.36632/mejas/2021.11.3.47.
7. Bhathal S, Kaur N. Effect of germination on nutrient composition of gluten-free Quinoa (Chenopodium Quinoa). Int J Sci Res,2015:4:423–5.
8. Charles I, Maxwell OI, Ogechi NP, Chibuzo AA. Physiochemical Properties of Cocoyam Starch Extracted in Two Media. Int Lett Nat Sci,2017:64:32–9. https://doi.org/10.18052/www.scipress.com/ILNS.64.32
9. Coronell-Tovar DC, Chávez-Jáuregui RN, Bosques-Vega Á, López-Moreno ML. Characterization of cocoyam (Xanthosoma spp.) corm flour from the Nazareno cultivar. Food Sci Technol,2019:29(2):349–57. https://doi.org/10.1590/fst.30017.
10. Edima-Nyah AP, Ojimelukwe PC, Nwabueze TU. *In vitro* Nutrient Analysis of High Fibre Snack Bars Produced From Blends of African Breadfruit, Maize and Coconut. IOSR J Environ Sci Toxicol Food Technol,2019:13(10):52–61.
11. Eli ZW, Dinnah A, Godwin OO, Ponan DA. Physical, electrolytes and lipid profile of rats fed with complementary blends produced from malted and fermented acha (Digitaria exilis) flour supplemented with soybeans (Glycine max) flour. FUW Trends Sci Technol J,2022:7(3):219–28.
12. El-Hag ME, El-Tinay AH, Yousif NE. Effect of fermentation and dehulling on starch, total polyphenols, phytic acid content and *in vitro* protein digestibility of pearl millet. J Food Chem,2002:77:193–6. https://doi.org/10.1016/S0308-8146(01)00336-3.
13. FAO. Dietary protein quality evaluation in human nutrition. Report of an FAO Expert Consultation. Auckland, New Zealand. Food and Nutrition Paper,2013:92:27.
14. Forwoukeh HV, Amove J, Yusufu MI. Characteristics of Whole Wheat, Red Kidney Bean and Defatted Coconut Flour Blends and Its Application in Bread Production. Asian Food Sci J,2023:22(9):23–39. https://doi.org/10.9734/AFSJ/2023/v22i9655.
15. Gautam L, Gupta A. Impact of malting on nutrient and antinutrient content of processed composite flour prepared with different grains,2018:7(4):2934–7.
16. Gemede HF. Nutritional and antinutritional evaluation of complementary foods formulated from maize, pea, and anchote flours. Food Sci Nutr,2020:8:2156–64. https://doi.org/10.1002/fsn3.1516.
17. Hassan GF, Yusuf L, Adebolu TT, Onifade AK. Effect of fermentation on mineral and antinutritional composition of cocoyam (Colocasia esculenta linn). Sky J Food Sci,2015:4:042–9.
18. Igbabul BD, Amove J, Twadue I. Effect of fermentation on the proximate composition, antinutritional factors and functional properties of cocoyam (Colocasia esculenta) flour. Afr J Food Sci Technol,2014:5(3):67–74.
19. Ijarotimi OS, Adeoti OA, Ariyo O. Comparative study on nutrient composition, phytochemical, and functional characteristics of raw, germinated, and fermented Moringa oleifera seed flour. Food Sci Nutr,2013:1(6):452–63.
20. Ijarotimi SO, Keshinro OO. Determination of nutrient composition and protein quality of potential complementary foods formulated from the combination of fermented popcorn, African locust and bambara groundnut seed flour. Pol J Food Nutr Sci,2013:63(3):155–66. https://doi.org/10.2478/v10222-012-0079-z.
21. Ilonzo F. You and your health with phytomedicine (healing remedies from plants). The Centre for Psychic and Healing Administration. Nobel Publication, Enugu, Nigeria,1995:26.
22. Inyang UE, Daniel EA, Bello FA. Production and Quality Evaluation of Functional Biscuits from Whole Wheat Flour Supplemented with Acha (Fonio) and Kidney Bean Flours. Asian J Agric Food Sci,2018:06(06):193–201.
23. Izidoro M, Leonel M, Leonel S, Lossoli NAB, Cândido HT, Züge PGU, De Jesus Assis JL. Nutritional and technological properties of pulp and peel flours from different mango cultivars. Food Sci Technol (Brazil),2023:43:1–10. https://doi.org/10.1590/fst.107922.
24. Jacob AG, Etong DI, Tijjani A. Proximate, mineral and antinutritional compositions of melon (Citrullus lanatus) seeds. Br J Res,2015:2(5):142–51.
25. Kaur S, Kaur N, Kaur A. Characterization of malted cereals and legume for development of value-added

supplementary foods to combat malnutrition. Int J Chem Stud,2020:8(4):2549–55. https://doi.org/10.22271/chemi.2020.v8.i4ad.10022.
26. Matikiti A, Allemann J, Kujeke G, Gasura E. Nutritional composition of cocoyam (Colocasia esculenta), grown in Manicaland province in Zimbabwe. Asian J Agric Rural Dev,2017:7(3):48–55. https://doi.org/10.18488/journal.1005/2017.7.3/1005.3.48.55.
27. Mohamed LB, Huiming Z. Formulation and nutritional quality of extruded weaning food supplemented with whole egg powder. Am J Food Technol,2007:2(6):477–89.
28. Nkhata GS, Ayua E, Kamau HE, Shingiro J. Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. Food Sci Nutr,2018:6:2446–58.
29. Ojokoh AO. Roselle (Hibiscus Sabdariffa) Calyx Diet and Histopathological Changes in Liver of Albino Rats. Pak J Nutr,2006:5(2):110–3.
30. Okoye JI, Egbujie AE, Ene GI. Evaluation of complementary foods produced from sorghum, soybean and irish potato composite flours. Sci World J,2021:16(3):206–11.
31. Olagbemide PT, Ojiezeh TI, Adarabioyo MI. Essential vitamins and mineral salts in some extracts used in alternative medicine in Nigeria. Der Pharma Chemica,2016:8(14).
32. Oluwole IS, Adeoti OA, Ariyo O. Comparative study on nutrient composition, phytochemical, and functional characteristics of raw, germinated, and fermented Moringa oleifera seed flour. Food Sci Nutr,2013:1(6):452–63.
33. Onwurafor EU, Uzodinma EO, Uchegbu NN, Ani JC, Umunnakwe IL, Ziegler G. Effect of malting periods on the nutrient composition, antinutrient content and pasting properties of mungbean flour. J Trop Agric Food Environ Ext,2020:19(1):18–24.
34. Onyango CA, Ochanda SO, Mwasaru MA, Ochieng JK, Mathooko FM, Kinyuru JN. Effects of malting and fermentation on antinutrient reduction and protein digestibility of red sorghum, white sorghum and pearl millet. J Food Res,2013:2:41–9. https://doi.org/10.5539/jfr.v2n1p41.
35. Perez V, Chang ET. Sodium-to-potassium ratio and blood pressure, hypertension, and related factors. Adv Nutr,2014:5(6):712–41.
36. Sengev IA, Ariahu CC, Gernah DI. Effect of Natural Fermentation on the Vitamins, Amino Acids and Protein Quality Indices of Sorghum-Based Complementary Foods. Am J Food Nutr,2016:6(3):91–100. https://doi.org/10.5251/ajfn.2016.6.3.91.100.
37. Shalaby HS, El-shourbagy GA. Chemical and Physical Properties of Weaning Food Containing Legumes. J Food Dairy Sci,2016:7(12):511–5.
38. Sibian MS, Saxena DC, Riar CS. Effect of germination on chemical, functional and nutritional characteristics of wheat, brown rice and triticale: A comparative study. J Sci Food Agric,2017:97:4643–51.
39. Sibian MS, Riar CS. Effect of germination on chemical composition, antinutritional factors, functional properties and nutritional value of kidney bean (Phaseolus vulgaris). Carpathian J Food Sci Technol,2022:15(1):208–19.
40. Simwaka JE, Huiming Z, Masamba KG. Amino Acid Profile, Mineral, Pasting, Thermal and Protein Solubility Characteristics of Sorghum-Finger millet based Complementary Food as affected by Fermentation. J Acad Ind Res,2015:3(10):504. http://jairjp.com/MARCH 2015/09 JOYCE.pdf.
41. Soetan KO, Olaiya CO, Oyewole OE. The importance of mineral elements for humans, domestic animals and plants – A review. Afr J Food Sci,2010:4(5):200–22.
42. Tope AK, Soji F. Effect of Fermentation on Nutrient and Antinutrient Contents of Cocoyam Corm. J Pharm Nutr Sci,2013:3:171–7.
43. Ukeyima MT, Dendegh TA, Isusu SE. Quality Characteristics of Bread Produced from Wheat and White Kidney Bean Composite Flour. Eur J Nutr Food Saf,2019:10(4):263–72. https://doi.org/10.9734/EJNFS/2019/v10i430120.