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Research Article

Protein Quality and Haematological Profile of Rats (Albino) Fed with Malted and Fermented Maize Based Complementary Food Supplemented with Soybean and Orange Fleshed Sweet Potato Flour

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ABSTRACT
This study investigated the protein quality and haematological profile in rats fed malted and fermented maize-based complementary food supplemented with soybean and orange-fleshed sweet potato composite flours. Flours were prepared from malted and germinated maize grains and supplemented with soybeans and orange-fleshed sweet potato flour as the complementary foods. The combination of the flours was obtained by material balancing. Four food formulations were obtained and named NMSS, FMSS, MFMSS, and MMSS, NM(control) and Nestle Cerelac (commercial control). Twenty-four Wistar strain of albino rats were grouped into six groups of four rats per cage and were fed the formulated blends and control. The rats were fed for 28 days. Weight changes and haematological parameters of the kidney and liver were examined to assess the suitability of these formulated diets. ANOVA was used for statistical analysis. The results of the total weight gain ranged between 230.67 and 32.67 g in Cerelac and NM, respectively. PER ranges from 2.47 (cerelac) – 0.45 (NM), and FCE ranges from 15.04 (NM) – 2.62 (cerelac). The haematological parameters analysis revealed that PCV ranges between 40.67 (FMSS) and 33.67 % (Cerelac), RBC ranges from 5.50 to 4.60 $X10^3mm^3$, HGB ranges from 12.22 to 11.00 g/dl, WBC ranges from 5.93 to 5.13 $X10^3mm^3$, Lymphocytes ranges from 35.67 to 34.33 %, Neutrophil ranges from 58.00 to 56.00 % and Eosinophil ranges from 3.00 to 2.33 %. The results showed that the formulated blends did not impair any significant organ of the rats, as indicated by the haematological studies.

Keywords: Complementary Foods; Fermentation; Haematological; Maize; Malting; Orange-flesh Sweet potato; Soybeans

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INTRODUCTION

It has been established over time that the greatest nourishment for babies in their first six months of life is breast milk (Oludumai and Enujiugha, 2017). The world's population is impacted by the worldwide issue of baby and child malnutrition. UNICEF reports from 2021 (UNICEF, 2021) show that stunting affects 21.3 percent of children under five, and wasting affects 2.1%. *Ogi* (pap) a fermented cereal grain or porridge produced from millet, sorghum or maize (Gernal *et al*., 2012; Agbor *et al*., 2014) is the most well-known supplemental meal used in infant feeding in Nigeria and many other west African countries. Adults often eat it. The choice of cereal depends on ethnicity and personal desire.

The protein composition of the majority of cereals used to make *ogi* is low, particularly that of amino acids like lysine and methionine (Okoye *et al*., 2021). According to scientific research, the primary

cause of the high prevalence of protein-energy malnutrition in Nigeria and other developing nations is an excessive reliance on traditional complementary foods like ogi and other family diets without sufficient supplementation with high-quality protein sources (Gobana and Geleta 2015, Sule *et al*., 2014).Therefore, employing locally available staple grains and legumes as well as simple/adaptable technologies, it is desirable to research ways and means of creating supplementary foods that are less expensive but equally nutritious and may be accessible to a larger population. Fermentation is the metabolic process that transforms sugar into acids, gases, or alcohol. As in the case of lactic acid fermentation, it happens in bacteria, yeast, and oxygen-starved muscle cells. The natural process of fermentation can improve proteins, vitamins, essential amino acids, anti-nutrients, food appearance, flavours, and scent. Moreover, fermentation produces a safer product and lowers the energy required for cooking (Nkhata *et al*., 2018; Xiang *et al*., 2019). Consequently, the action of microorganisms contributes significantly to food fermentation by causing modifications to the chemical and physical characteristics of the meal to guarantee a specific desired physical and biochemical change within the grain. Malting is the controlled germination of grains, which is subsequently stabilized by grain drying. Malting is primarily used to alter the composition and structure of the grain. Steeping, germination, and drying are the three-unit processes that make up the malting process (Deepika, 2017). The goal of the malting process is to produce malt with a high enzyme and vitamin content from grains.

Corn, often known as maize (*Zea mays L.*), is a significant annual grain crop in the Poaceae family. The Taino word mays mean "life giver," while the ancient Greek term zea means "sustaining life." Because of its nutritional makeup, its grain has a high nutritional value and may be utilized as a raw material to make a wide range of industrial products (Manish *et al*., 2020). Soybean (*Glycine max*) Merrill) is the wonder crop of the twenty-first century. A low-cost source of high-quality proteins with an excellent amino acid balance (Asuk *et al*., 2020). The crop is considered a beneficiary because it has approximately 40% protein, a high concentration of essential amino acids (apart from methionine and cysteine), 20% oil that is rich in polyunsaturated fatty acids, particularly omega-6 and omega-3 fatty acids, 6–7% total minerals, 5–6% crude fiber, and 17–19% carbohydrates (Varo *et al*., 2022; Babarinde *et al*., 2020). It may play a crucial role in functional foods and be employed to improve the quality of the final product (Eke *et al*., 2018). Sweet potato, or *Ipomoea batatas* [L.] Lam., is a dicotyledonous plant belonging to the Convolvulaceae family that thrives in tropical and subtropical regions as well as some temperate regions of the developing world. Vitamin A insufficiency may be alleviated by eating sweet potato cultivars with orange flesh (Fabian *et al*., 2016). This investigation was designed to evaluate the water intake and feed consumed by the rats, weight changes in the rats, protein quality of the complementary food and haematological profile of rats (Albino) fed with malted and fermented maize-based complementary food supplemented with soybean and orange-fleshed sweet potato flour.

MATERIALS AND METHODS

Experimental food samples

The study was carried out using formulations and analysis of maize (cereal), soybean (legumes) and orange - fleshed sweet potato supplementary flour. The foodstuff used are maize grains (*Zea mays* L.), soya beans (*Glycine max*) and orange - flesh sweet potatoes (*Ipomoea batatas* [L.] Lam.). Nestle Cerelac was used as the control.

The orange - flesh sweet potatoes, grains and Cerelac (a maize – soybean based infant food made by Nestle Foods, Nigeria PLC, Lagos) were obtained from markets in Makurdi, Benue State, Nigeria.

Preliminary treatments of grain (maize and soy bean) sample

Before sorting, the raw grains were cleaned individually by removing any unnecessary materials. Once the clean maize and soy bean seeds had been manually sorted and winnowed to eliminate stones, trash, and faulty seeds, they were placed in 10-liter buckets and securely sealed with lids. Before being sun-dried, cleaned maize samples were washed in a sodium chloride solution to disinfect the grains. After drying, the grains were ground and sieved through a 0.2 mm sieve.

The tubers of sweet potatoes were cleaned, peeled, cut into slices, and then rinsed with deionized water. Slices were blanched or immersed in boiling water for five minutes after the water was drained, they were then dried in an oven set to 60 °C for seventy-two hours, the dried chips were then ground and sieved using a 0.2 mm sieve.

Preparation of non-malted and malted maize flours

The procedure outlined by (Eli *et al*., 2022a) was used for malting. The maize grains were disinfected by washing them in a 5% (w/v) sodium chloride (NaCl) solution. They were then placed in a plastic bucket and soaked in water room temperature, for a total of twelve hours, the steep water was change every four hours. The grains were then drained in a plastic basket, spread out in a single layer over a moistened bag, and left to germinate for seventy-

two hours at room temperature, with water sprayed every twelve hours. After 72 hours, both the germinated and non-germinated grains were taken out and dried to constant weight in an air draft oven (Genlab Widnes, U.K., model T12H) set at 60 °C. The testa and rootlets were separated from the cotyledons, which were then winnowed away. Then, using a benchtop electric powder grinder (DE-2000 g), the cotyledons were ground into flour so they could pass through a 0.2 mm particle size sieve. The resulting flours, malted maize (MM) and normal maize (NM), were then used for product formulation and analysis.

Preparation of fermented maize flours

Using the technique outlined by (Eli *et al*., 2022b) fermented maize dough was produced through accelerated spontaneous lactic acid fermentation. This procedure involved mixing 120.0 g of normal maize (NM) and malted maize (MM) flours with 80 mL of distilled water, then letting the mixture naturally ferment for 24 hours at room temperature in a covered 500 mL glass beaker. Half of the fermented mixture was employed as a starting culture for a fresh fermentation cycle at the end of this, the titratable acidity, a measure of the activity of lactic acid bacteria, and pH were tracked throughout this procedure, until the medium's pH normalized and stayed constant. The fermented concentrates were ground in an electric powder grinder (DE 2000 g) to a particle size of 0.2 mm after being dried for 72 hours at 60 °C in a fan-driven electric oven (Gen lab Widnes, UK, model T12 H) to constant weight. Following their packaging in low density polyethylene bags, the fermented maize (FM) and malted fermented maize (MFM) flours were used for product formulation and analysis.

Formulation of the experimental blends

Through material balancing from their separate proximate compositions, four distinct food formulations were created by combining the various maize flours with the orange - fleshed sweet potato and soybean flour to provide 16 g protein (Gernah *et al*., 2012a).

Table 1: Ingredients mix (g/100g) by materials balancing

Samples	Maize	Soybean	Sweet potato
NMSS	59.00	24.00	17.00
FMSS	57.00	28.00	15.00
MFMSS	58.00	27.00	15.00
MMSS	58.00	26.00	16.00

Key:

NMSS - Normal maize, soybeans and sweet potato
FMSS - Fermented maize, soybeans and sweet potato
MFMSS - Malted fermented maize, soybeans and sweet potato
MMSS - Malted maize, soybeans and sweet potato

Animal trials

The animals utilized in this investigation were male Wistar-strain rats weighing 40–60 g, which were acquired from the Animal House of College of Health Sciences Benue State University Makurdi. By getting ethical clearance certified by the College of Health Sciences Ethical Committee with reference number BSUTH/CMAC/HREC/101/V.III/XX, the procedure adhered to all ethical protocols. During feeding, the rats were divided into six (6) groups of four rats each at random. They were confined to cages. The rats were allowed to stabilize on the usual laboratory feed for 7 days and deprived for one day before feeding with the experimental diets begin.

Below are the formulated and control diet used to feed the animals

Diet 1 - Normal maize, soybeans and sweet potato (NMSS)
Diet 2 - Fermented maize, soybeans and sweet potato (FMSS)
Diet 3 - Malted fermented maize, soybeans and sweet potato (MFMSS)
Diet 4 - Malted maize, soybeans and sweet potato (MMSS)
Diet 5 - Normal maize (NM) (control)
Diet 6 - Nestle Cerelac (commercial control)

During the feeding experimentation, rats were apportioned the diets as follows:

Group 1 - Normal maize, soybeans and sweet potato (NMSS)
Group 2 - Fermented maize, soybeans and sweet potato (FMSS)
Group 3 - Malted fermented maize, soybeans and sweet potato (MFMSS)
Group 4 - Malted maize, soybeans and sweet potato (MMSS)
Group 5 - Normal maize (NM) (control)
Group 6 - Nestle Cerelac (commercial control)

Just before every feeding, 40 g of each diet was weighed and administered to the rats which was increased to 60 g after two weeks. For 28 days, the rats were provided with unlimited food and water

ad libitum. To collect the feces, papers were placed beneath the cage. Rat weights, feeds, and water were recorded daily. Rats' daily food intake was calculated by noting the amount of food left over after 9 am. Weighing each rat separately every seven days to determine weight gain.

Animal slaughtering and phlebotomy

Each rat was given chloroform anaesthesia in a desiccator on the twenty-eighth day of the feeding experiment period, and they were then slaughtered. For criteria requiring the use of whole blood, a part of each rat's whole blood was collected and placed into sample bottles along with sample bottles containing EDTA (Eli *et al*., 2022b). Following an instant cap, the bottles were utilised for a variety of haematological investigations after the contents had been gently mixed for approximately a minute by repeated inversion.

Determination of protein quality

Standard techniques were used to calculate protein quality indicators. The usual Kjeldhal method was used to determine the faeces' nitrogen concentration (AOAC, 2012). The Protein Efficiency Ratio (PER) was calculated using the Mean Daily Feed Intake (MFDI) and Mean Daily Weight Gain (MDWG) values. Standard formulas were used to compute Feed Conversion Efficiency (FCE).

$$Mean\ daily\ food\ intake\ (MDFI) = \frac{Total\ Quantity\ Consumed}{Number\ of\ Days\ of\ Feeding} \ldots 1$$

$$Mean\ Daily\ Weight\ Gain\ (MDWG) = \frac{Total\ weight\ Gain}{Number\ of\ Days\ of\ Feeding} \ldots 2$$

$$Protein\ Efficiency\ Ratio\ (PER) = \frac{Weight\ Gain}{Total\ Protein\ Intake} \ldots 3$$

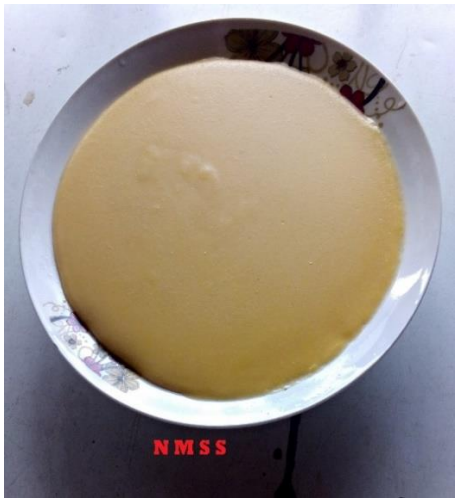
$$Feed\ Conversion\ Efficiency\ (FCE) = \frac{Daily\ Feed\ Intake}{\text{Daily Weight Gain}} \ldots 4$$

Determination of Haematological Parameters

Haematological parameter analysis was done, in the Department of Veterinary Medicine at Joseph Sarwuan Tarkaa University Makurdi, one (1) millilitre of the five millilitres of blood drawn from the Wistar rats was promptly transferred into sterile EDTA-K3 Vacuum tubes, appropriately labelled, and stored for haematological analysis. To combine the serum and plasma, the sample vial containing the blood was put in a mixer. Haematological parameters were determined using a three-part cell counter (Sysmex KX-2N), commonly known as an Automated Blood Cell Count or Differential Cell Counter. White blood cells are divided into three groups by the haematological differential analyser according to their sizes: lymphocytes, which are tiny, Eosinophils are medium-sized cells, while neutrophils are massive cells. Using Coulter's principles, the analyser passes the blood sample cells via an aperture that allows only one cell at a time to pass between two electrodes using hydrodynamic focusing. This creates electrical resistance, which the cell counters record, measure, amp up, and appropriately process before a computer interprets it as logical histograms (Graham, 2022). White blood cells (WBC), lymphocytes, neutrophils, and eosinophils are among the haematological characteristics that were examined in this study. Red blood cells (RBC), haemoglobin (HGB), and packed cell volume (PCV) are further haematological parameters that are assessed.

Data Analysis

All results were subjected to analysis of variance using 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.


NMSS


NMSS
NORMAL MAIZE + SOYBEAN +
SWEET POTATO FLOUR


FMSS


FMSS
FERMENTED MAIZE + SOYBEAN +
SWEET POTATO FLOUR


MFMSS


MFSS
MALTED FERMENTED MAIZE +
SOYBEAN + SWEET POTATO FLOUR

Plate I. Diagram showing diet formulations

RESULTS

Water, feed intake, weight changes and protein quality

The result of water intake, feed consumed, weight changes during feeding trials with the complementary and control diet and are presented in table 2, 3, 4 respectively while the protein quality results are shown in table 5.

Haematological indices

The haematological parameters of animals fed with the control and formulated diets are Packed cell volume (PVC), Red blood cell (RBC) and Haemoglobin (HGB) are presented in table 6 while the White blood cell (WBC), Lymphocytes, Neutrophils, and Eosinophil are presented in Table 7. The statistical difference existed among the formulated foods compared to the controls.

Table 2: Average and total water intake by an animal for 28 days (mL)

Samples	Average water intake	Total water intake
CERELAC	237.13^{a}±2.95	948.52^{a}±0.96
NM	74.36^{f}±1.70	297.44^{f}±1.75
NMSS	195.18^{c}±4.99	780.72^{c}±1.22
FMSS	210.09^{b}±1.98	840.36^{b}±0.82
MFMSS	168.02^{d}±1.56	672.21^{d}±0.41
MMSS	98.87^{e}±1.38	395.47^{e}±1.03

Values are mean ± standard deviation of triplicate results. Means with different superscripts on the same column are significantly different at (P ≤ 0.05)

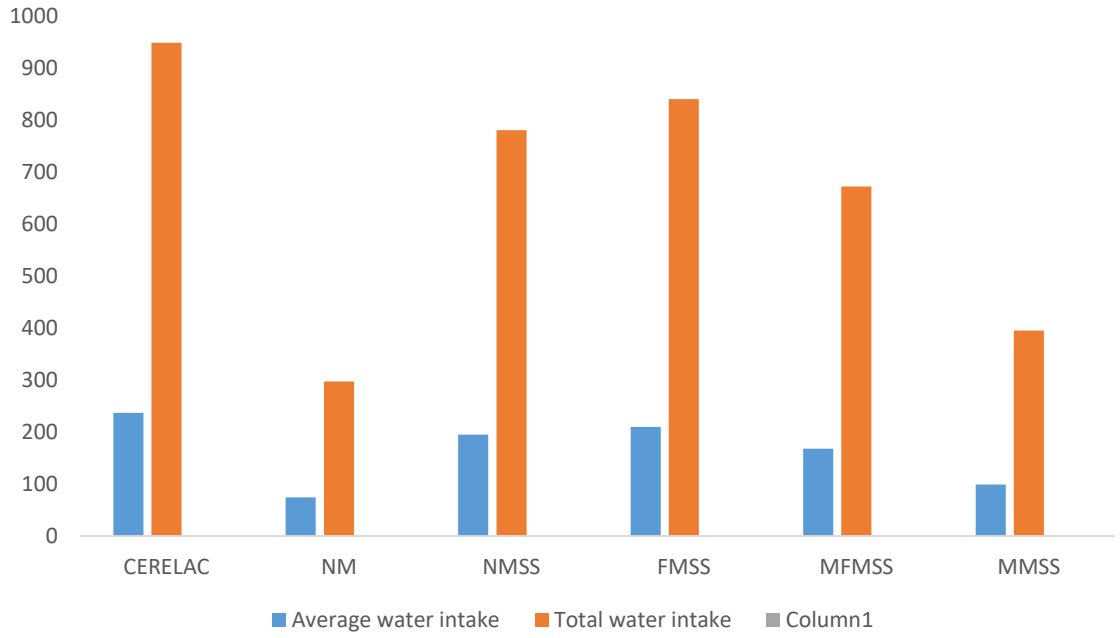


Figure 1: Showing the average and total water intake by an animal for 28 days (mL)

Table 3: Average and total feed consumed by an animal for 28 days (g)

Samples	Average feed consumption	Total feed consumption
CERELAC	149.49^{a}±1.71	597.96^{a}± 0.54
NM	113.97^{c}±1.56	455.88^{c}± 0.62
NMSS	145.55^{b}±1.96	582.20^{b}± 0.51
FMSS	113.96^{c}±1.56	455.84^{c}± 0.44
MFMSS	113.91^{c}±1.54	455.64^{c}± 0.21
MMSS	99.00^{d}±1.65	396.00^{d}± 0.35

Values are mean ± standard deviation of triplicate results

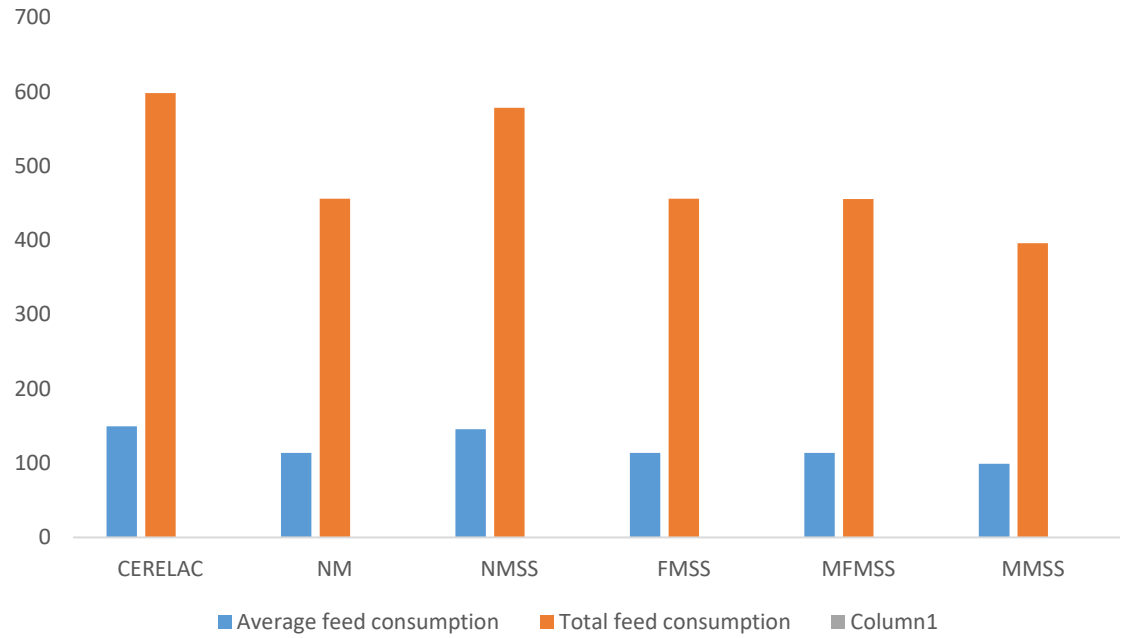


Figure 2: Average and total feed consumed by an animal for 28 days (g)

Table 4: Weight changes in rats during feeding (g)

Samples	Initial weight	Final weight	Differences	Total weight gain
CERELAC	52.17^{a}±1.69	109.83^{a}±0.03	57.67^{a}± 0.03	230.67^{a}±0.04
NM	51.67^{a} ±1.88	59.83^{c}±1.06	8.17^{c}±1.02	32.67^{c}±0.23
NMSS	49.50^{a} ±2.06	69.17^{c}±1.05	19.67^{bc}±1.05	78.67^{bc}±1.05
FMSS	55.69^{a}±0.75	84.33^{b}±0.99	28.67^{b}±0.87	105.67^{bc}±1.06
MFMSS	49.83^{a}±0.61	83.83^{b}±0.05	34.00^{b}±0.64	136.00^{b}±0.94
MMSS	53.33^{a}±2.03	83.67^{b}±0.12	30.33^{b}±0.75	121.33^{b}±0.87

Values are mean ± standard deviation of triplicate results.
Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)

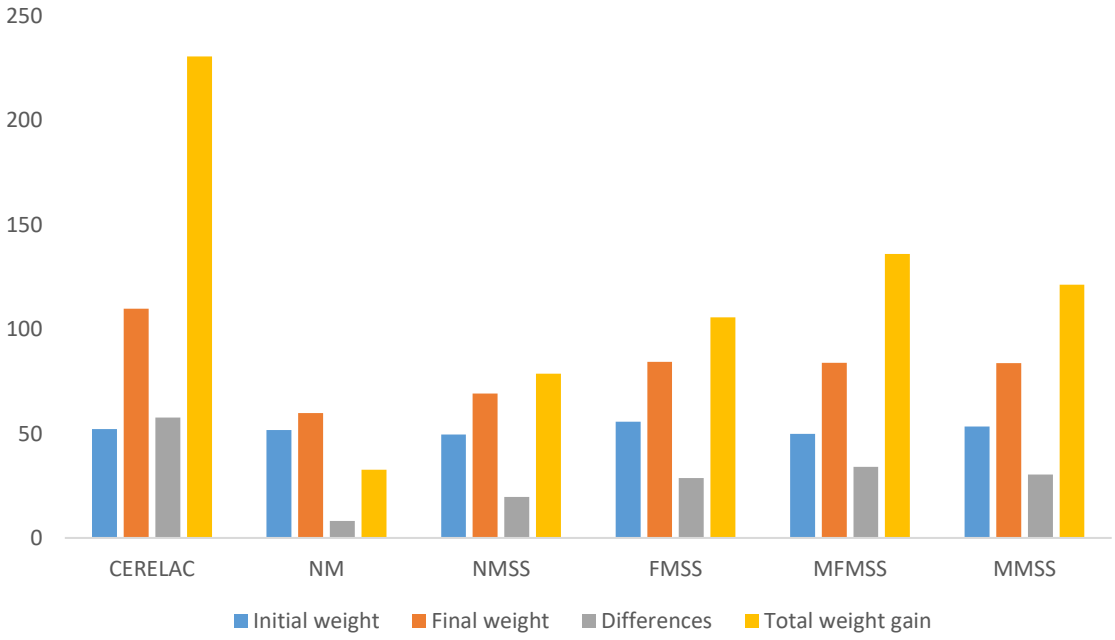


Figure 3: Showing weight changes in rats during feeding

Table 5: Mean daily food intake, mean daily weight gain, protein efficiency ratio and food conversion efficiency of experimental animals per group.

Samples	MDFI (g)	MDWG (g)	PER	FCE
Cerelac	21.36^{a}±0.24	8.24^{a}±1.09	2.47^{a}±0.22	2.62^{c}±0.32
NM	16.28^{c}±0.22	1.17^{c}±0.39	0.45^{c}±0.15	15.04^{a}±1.08
NMSS	20.66^{b}±0.29	2.81^{bc}±0.32	0.86^{bc}±0.10	7.42^{b}±0.88
FMSS	16.28^{c}±0.22	3.77^{bc}±0.77	1.45^{abc}±0.28	3.89^{bc}±0.57
MFMSS	16.27^{c}±0.22	4.86^{b}±0.91	1.86^{ab}±0.32	3.43^{bc}±0.64
MMSS	14.14^{d}±0.23	4.36^{b}±1.23	1.96^{ab}±1.43	4.69^{bc}±0.17

Values are mean ± standard deviation of triplicate results
Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)
KEY: MDFI = Mean daily food intake, MDWG = Mean daily weight gain, PER = Protein efficiency ratio, FCE = Food conversion efficiency.

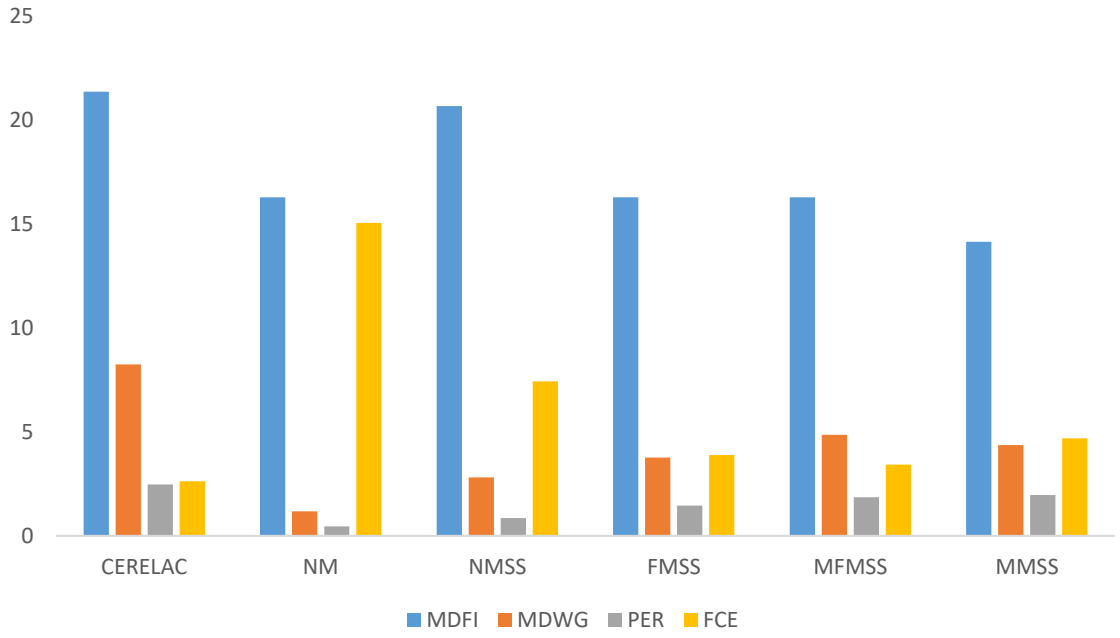


Figure 4: Showing mean daily food intake, mean daily weight gain, protein efficiency ratio and food conversion efficiency of experimental animals per group

Table 6: Some Haematological Parameters of Rats Fed with the Formulated and Control Diets

Samples	PCV%	RBC(X10^{3}mm^{3})	HGB (g/dL)
CERELAC	33.67^{c}±0.57	4.60^{b}±0.26	12.11^{ab}±0.70
NM	39.00^{ab}±0.01	5.50^{a}±0.26	11.78^{ab}±0.19
NMSS	38.33^{b}±0.58	5.23^{a}±0.15	12.22^{a}±0.69
FMSS	40.67^{a}±0.58	5.47^{a}±0.35	11.55^{ab}±0.69
MFMSS	35.33^{c}±0.08	4.60^{b}±0.26	11.00^{b}±0.67
MMSS	39.67^{ab}±0.58	5.50^{a}±0.26	11.22^{ab}±0.39
Ranges	30 – 44	3.50 – 5.50	11- 16

Values are mean ± standard deviation of triplicate results.
Means with different superscripts on the same column are significantly different at ($P \leq 0.05$)
KEY: PCV = Packed cell volume, RBC = Red blood cell, HGB = Haemoglobin.

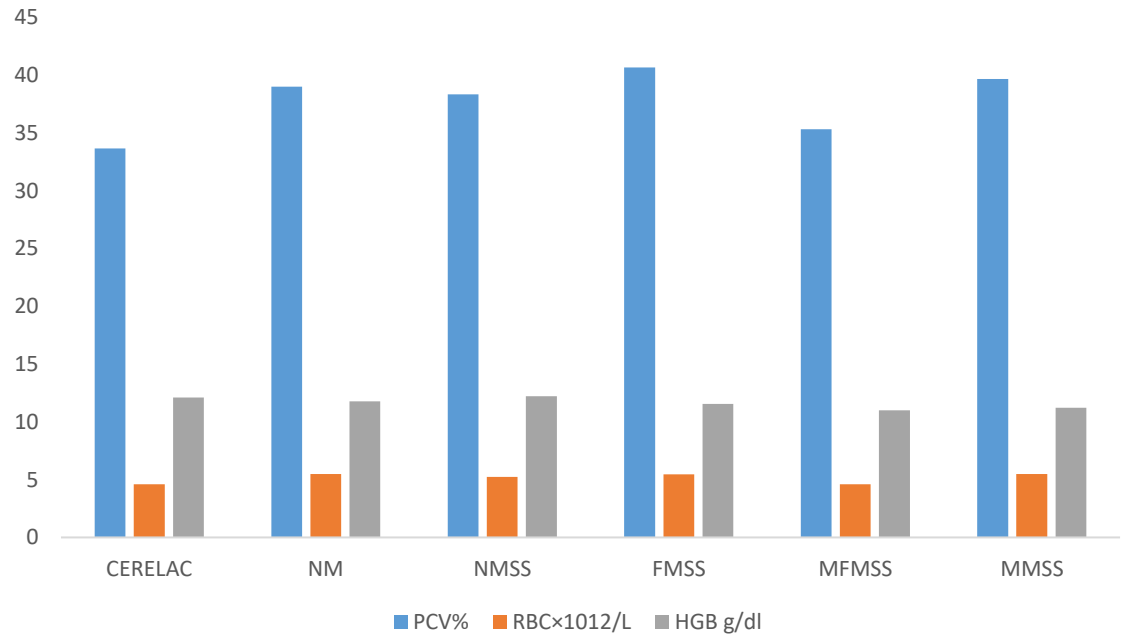


Figure 5: Showing some Haematological Parameters of Rats Fed with the Formulated and Control Diets

Table 7: Some Haematological Parameters of Rats Fed with the Formulated and Control Diets

Samples	WBC(X10^{3}mm^3)	Lymphocytes(%)	Neutrophil(%)	Eosinophil(%)
CERELAC	5.47^a±0.31	34.33^a±2.08	58.00^a±1.00	3.00^a±1.00
NM	5.67^a±0.31	34.67^a±2.08	56.00^a±1.00	2.33^a±0.58
NMSS	5.73^a±0.94	35.67^a±3.21	57.33^a±1.53	2.33^a±0.58
FMSS	5.93^a±0.80	34.33^a±1.53	57.00^a±1.73	2.67^a±1.15
MFMSS	5.13^a±0.41	34.67^a±2.52	57.33^a±1.53	3.00^a±0.01
MMSS	5.80^a±0.72	34.67^a±1.53	57.67^a±1.15	2.33^a±1.15
Ranges	4 -10	20 – 40	50 – 70	0.5 – 5.0

Values are mean ± standard deviation of triplicate results.
Means with different superscripts on the same column are significantly different at P ≤ 0.05
KEY: WBC -White blood cell

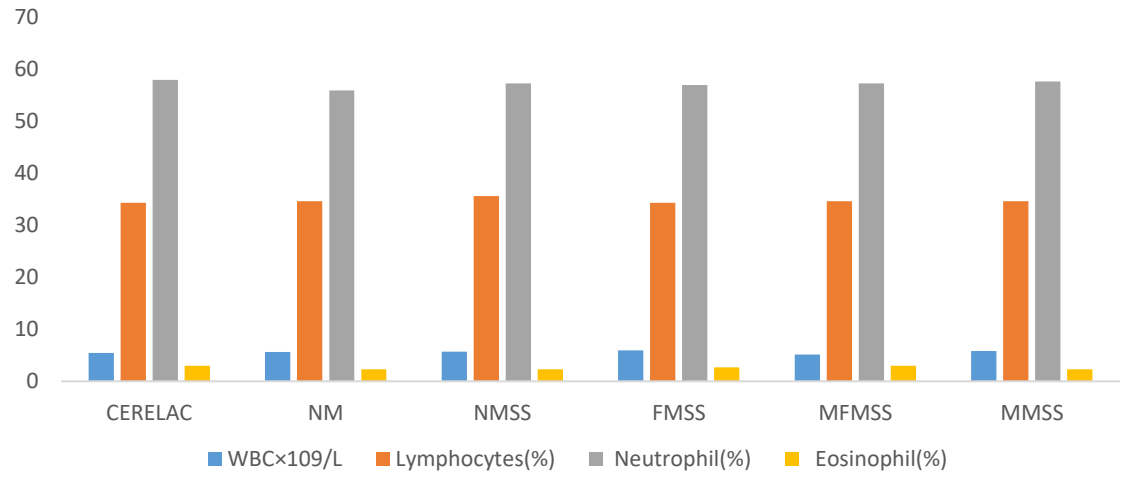


Figure 6: Showing some Haematological Parameters of Rats Fed with the Formulated and Control Diets

DISCUSSION

The water intake by the animals are presented in table 2, the significant difference was obtained at P ≤ 0.05. Difference was observed between the controls in total water intake and total food consumption as compared to the formulated blends. The total water intake ranged between 948.53 mL and 297.44 mL for CERELAC and NM respectively. The water intake in NMSS, MNFSS, MFMSS and FMSS is significantly lower than CERELAC, high when compared to NM (normal maize flour). This can also be seen in the chart (Figure 1) with the control (cerelac) been the highest when compared to the rest. Factors affecting lower intake of water include dry matter content or the physical form of the diets. Therefore, lower intake of water by the experimental animal fed with NM could be due to the physical form of the formulated diet. This agreed with the findings of (Babarinde *et al*., 2020) where the rats feed with cerelac recorded the highest water intake.

The feed consumed during feeding trial were presented in Table 3. The total food consumed by the animals was highest in CERELAC (597.95g) and lowest in MMSS (396.00g) respectively. This might probably be because of its palatability and this is in agreement with (Eli *et al*., 2022b). The food consumed in each group ranges as 597.95g, 578.15g, 455.89g, 455.84g, 455.63g and 396.00g for CERELAC, NMSS, FMSS, NM, MFMSS and MMSS respectively. The rate of food consumption in NMSS, FMSS, NM, MFMSS and MMSS was significantly lower than CERELAC. This result follows an earlier work of (Sengev *et al.,* 2016) where rats feed with complementary food showed highest intake of cerelac (control). It was observed that the malted and fermented food formulations were consumed less in comparison to the nonmalted and nonfermented blends, this can also be seen in the chart (Figure 2), cerelac was found to be the highest in both the average feed consumed and total feed consumed while the least was found in MMSS. This could be related to the sour characteristics of the fermented products which affected their intake by the experimental rats. According to (Gernah *et al*., 2012b), it has been established that rats prefer diet with some sweet taste and may consume higher quantities of such diets. Thus, the nonfermented diet was sweeter and therefore was consumed more; the significant difference was obtained at P ≤ 0.05.

The weight changes of rats recorded during the feeding period of 28 days was presented in table 4 and figure 3. Rats fed with CERELAC (control) diet recorded the highest weight gain/growth rate followed by rats fed with MFMSS, this is because malting and fermentation are known to improve nutrients in food, this is in agreement with the work of (Eli *et al*., 2022b) who notice increased weight gain/growth as a result of malting and fermentation. Rats fed with NM had the lowest growth rate. This was also represented in the chart (Figure 3) with cerelac been the highest when compared with the others. There was no mortality recorded in any group.

The influence of the complementary foods on growth performance of male Wistar rats were presented in table 5. It was observed that animals fed with CERELAC (control sample) had the highest (significant difference (P ≤ 0.05)) food consumption while animals fed NM ate lowest, this was also represented in the chart (Figure 4) where the MDFI, MDWG and PER were found to be highest in cerelac, while the lowest were in NM, this might probably be because of its palatability as stated by (Sengev *et al.,* 2016; Eli *et al*., 2022b).Sour characteristics of the fermented products affected intake by the experimental rats. According to (Gernah *et al*., 2012a; *Eli et al*., 2022b), it has been established that rats prefer a diet with some sweet taste and may consume higher quantities of such diets. Thus, the non-fermented 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. Fermentation and malting increase bioavailability and digestibility of food and these may result to higher growth rate. This is in conformity with the work of (Eli *et al.,* 2022b) where fermented and malted food increased the growth rate of the rats. 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). NM shows PER value which was significantly (P ≤ 0.05) lower than the other test samples. This is in tandem with the work (Nkhata *et al*., 2018) where the control (cerelac) diet shows a higher PER among the formulated diets, fermentation and malting have been reported to improve protein efficiency due to improved bioavailability and digestibility of protein (Nkhata *et al*., 2018). FCE was highest in cerelac and lowest in NM, the lower the value the more effective the conversion efficiency in the body of the animal. The result obtained here is in agreement with the previous work (Eli *et al*., 2022b) where cerelac showed a better feed conversion efficiency (FCE) than the rest of the samples.

Tables 6 and 7 display the haematological results. The parameters pertaining to blood and the organs that create it are known as haematological parameters. One technique that may help identify some changes in health status that might not be noticeable during a physical examination but have

an impact on the animals' fitness is the haematological and serum examination (Eli *et al*., 2024). Furthermore, as alterations in the blood system have a higher predictive value for human toxicity, haematological indices in animals are crucial for assessing the toxicity risk. Rats fed with the designed blends and control diets showed similar levels, indicating that the rats' bodies did not mount an immunological response to the composite flours. From the chart (Figure 6) it can be seen that there is no significant difference in the haematological parameters (WBC, Lymphocytes, Neutrophil and Eosinophil) of the different complementary food product and the values are within the clinical range, this is in agreement with the work of (Adejuwon *et al*., 2021) which showed haematological values being within the medical reference range. The body uses leukocytes, neutrophils, monocytes, eosinophils, basophils, and lymphocytes, which are produced when white blood cells break, to help fight infections (Eli *et al*., 2024). The haematological parameters determined are stated as follows: PCV, RBC, HGB, WBC, Lymphocytes, Neutrophil and Eosinophil. The PCV ranges from 40.67 – 33.67 % respectively, RBC ranges from 5.50 – 4.60 respectively, HGB ranges from 12.22 – 11.00 g/dl % respectively, WBC ranges from 5.93 – 5.13 respectively, Lymphocytes ranges from 35.67 – 34.33 % respectively, Neutrophil ranges from 58.00 – 56.00 % respectively and Eosinophil ranges from 3.00 – 2.33 % respectively.

Since the white blood cells and a few of the previously mentioned indicators were within the clinical reference range and comparable to those of the CERELAC control, it may be concluded that the antinutritional elements in the diet formulation were not significant enough to endanger human health. Physiological measures such packed cell volume (PCV) and hemoglobin (HGB) are used to measure iron intake, metabolism, and deficiency. The rats' feeding experiment results demonstrated that the blends supported normal iron metabolisms because there was no discernible variation in the physiological response to iron intake. Another name for packed cell volume is haematocrit (Ht or Hct), which is the proportion of red blood cells in whole blood. Percentage PCV was found to be highest in FMSS while the least is seen in cerelac as indicated in the chart (Figure 5), while the RBC showed no much difference, the same applied to HGB. Packed cell volume has a role in the movement of nutrients and oxygen. Consequently, a higher packed cell capacity indicates improved transportation, which raises primary and secondary polycythemia. The degree of anemia is indicated by the haemoglobin concentration and haematocrit. (Eli *et al*., 2024). The figures derived from the previously mentioned parameters demonstrated that the diets were not harmful to the red blood cells.

CONCLUSIONS

The results obtained from the protein quality test of the rats was seen to have positive body weight changes, all the rats survived at the end of the experiments. Samples MFMSS and MMSS showed better growth characteristics, which was evident by good PER values. Among the formulated diet MMSS gave the best PER results in the rat's bioassay, while from the haematological analysis it was observed that the absence of toxic substances in the formulated diets indicated that the formulated foods were good and also safe for infant consumption.

This research revealed that the blends formulated from non-malted, malted and fermented maize flour supplemented with soybeans and orange fleshed sweet potato flour were significantly better in all indices when compared to the non-supplemented flour. The formulated blends can be considered as complementary diet suitable for infant growth and development. Among the formulated diet the MFMSS and MMSS are the most preferable and recommended for infant feeding. Conclusively since malted and fermented food are better for diabetic patients due to its low glycaemic index, it is suggested that further studies be carried out on diabetic induced Albino rats. This study can be used as a guide for others in food formulations especially in complementary feeding and guide for policy making, therefore, information obtained is vital and will be made available to Federal Ministry of Agriculture, MDAs and Agricultural Research Council of Nigeria.

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REFERENCES

Adejuwon, K.P., Osundahunsi, O.F., Akinola, S.A., Oluwamukomi, M.O. and Mwanza, M. (2021). Effect of fermentation on nutritional quality,

growth and hematological parameters of rats fed sorghum-soybean-orange flesh sweet potato complementary diet. *Food science and nutrition*. 9(2):639-650.

Agbor, G.A., Vinson., J.A. and Donnelly, P.E. (2014). Folin ciocalteau reagent for polyphenolic assay. International. *Journal of Food Science, Nutrition and Dietetics*. 3:147 – 156.

AOAC (2012). Official Methods of Analysis. 18th edn. Association of Official Analytical Chemists, Washington, D.C., U.S.A.

Asuk, A.A., Ugwu, M.N. and Idole, B. (2020). The effect of different malting periods on the nutritional composition of malted sorghum-soy composite flour. *Journal of Food Science and Nutrition Research*. 3 (3):217-230.

Babarinde, G.O., Ebun, A.A. and Adegbola, P.I. (2020) Hepatotoxicity and Biochemical Evaluation of a novel breakfast food produced from the blend of fonio (Digitaria iburua Stapf) and pigeon pea (Cajanus cajan (L.) Millspaugh) in albino rats. *Bulletin of the National Research Centre*. 44(1):1-10.

Deepika, B. (2017). Malting: An indigenous technology used for improving the nutritional quality of grains. *Journal of Asian Dairy and Food Research.* 12(8):1-5.

Eke-Ejiofor, J., Wordu, G.O. and Bivan, S.K. (2018) Functional and pasting properties of acha, deffated soybean and groundnut flour blends. *American Journal of Food Science and Technology*. 6(5):215-228.

Eli, Z.W., Ahure, D., Obochi, G. O. and Alexander. P.D.(2022b). Physical, electrolytes and lipid profile of rats fed with complementary blends produced from malted and fermented acha flour supplemented with soybeans flour. *Journal of FUW Trends in Science & Technology.* 7(3): 219 – 228.

Eli, Z. W., Obochi, G. O., Ahure, D., Alexander, P. D., Gurumtet, I., Nyango, P. and Akpensuen, M. S. (2024). Effects of Complementary Foods Formulation Produced from Malted and Fermented Acha Flours Supplemented with Soybeans Flour on haematological and Histological Parameters of Albino Rats. *International Journal of Emerging Multidisciplinaries Biomedical and Clinical Research.* 2 (1): 1 – 18.

Eli, Z. W., Obochi, G. O. and Ahure, D.(2022a) Pasting, functional, microbial and sensory evaluation of complementary food blends produced from malted and fermented *acha* flour supplemented with soybeans flour. *International Journal of Food Science and Nutrition.* 7 (4): 23-31.

Fabian, F. D., Mourad, M., Moira, D.A., Imelda, A.A., Atmarita, A., Glen, M. G., Siti, M. and Alicia, C. (2016). Bio fortified β – carotene rice improves vitamin A intake and reduces the prevalence of inadequacy among women and young children in a stimulated analysis in Bangladesh, Indonesia, and the Philippines. *Journal of American Clinical Nutrition.* 104 (3): 769 – 775.

Gernah, D.I., Ariahu, C.C. and Ingbian, E.K. (2012b) Nutritional and sensory evaluation of food formulations from malted and fermented maize (Zea mays L.) fortified with defatted sesame (Sesamun indicum L.) flour. *African journal of food, agriculture, nutrition and development*.12 (6):6614-31.

Gernah, D.I., Ariahu, C.C. and Umeh, E.U. (2012a). Physical and microbiological evaluation of food formulations from malted and fermented maize (Zea mays L.) fortified with defatted sesame (Sesamun indicum L.) flour. *Advance Journal of Food Science and Technology*. 4(3):148- 54.

Gobana, G.M. and Geleta, T.E. (2015). Characterization and Optimization of Soybean Oil from Soybean Seed (Keta and Billo 19) Variety.

Graham, M.D. (2022). The coulter principle: A history. Cytometry. *A Journal of Quantitative Cell Science*. 101(1): 8-11

Manish, K.Y., Arbind, K.R., Mukesh, K.S., Nagendra, K., Ajay, K., Shanker, J. and Abbay, K. (2020). Quantification of plant biochemical from certain genotypes of maize and their effect on different degree of infestation of maize spotted stem borer chilo partellus. *Journal of Entomology and Zoology Studies.* 8 (1):600 – 605.

Minemba, D., Gleeson, D.B., Veneklaas, E. and Ryan, M.H. (2019). Variation in morphological and physiological root traits and organic acid exudation of three sweet potato cultivars under seven phosphorus levels. *Journal of Science Horticulture*. 10: 10 – 21.

Nkhata, S. G., Ayua, E., Kamau, E. H. and Shingiro, J. B. (2018) Fermentation and germination improve nutritional value of cereals and legumes through activation of endogenous enzymes. *Journal of Food Science and Nutrition.* 6:2446–2458.

Ojokoh, A.O. (2006). Roselle (Hibiscus Sabdariffa) Calyx Diet and Histopathological Changes in Liver of Albino Rats. *Journal of Pakistan Nutritio.* 5(2):110–3.

Okoye, J.I., Egbujie, A.E. and Ene, G.I. (2021). Evaluation of complementary foods produced from sorghum, soybean and Irish potato composite flours. *Science World Journal.*16 (3):206-11.

Oludumai, O.R. and Enujiugha, V.N. (2017). Physicochemical and rheological properties of complementary diet from blends of maize, African yam Bean and Pigeon Pea. Scientific. *Journal of Food Science and Nutrition*. 3 (1): 1- 11.

Sengev, I.A., Ariahu, C.C. and Gernah, D.I. (2016). Effect of Natural Fermentation on the Vitamins, Amino Acids and Protein Quality Indices of

Sorghum-Based Complementary Foods. *American Journal of Food and Nutrition.* 6(3): 91–100.

Sule, E. I., Umoh, V. J., Whong, C. M. Z., Abdullahi, I. O. and Alabi, O. (2014). Chemical and nutritional values of maize and maize products obtained from selected markets in Kaduna State, Nigeria. *African Journal of Food Science and Technology.* 5(4): 100-104.

UNICEF. 2021 Edition. 2021. UNICEF/WHO/World Bank Joint Child Malnutrition Estimates. https://data.unicef.org/topic/nutrition/malnutrition/retrived from.Google Scholar

Varo, M.A., Serratosa, M.P., Martín-Gómez, J., Moyano, L. and Mérida, J. (2022) Influence of Fermentation Time on the Phenolic Compounds, Vitamin C, Color and Antioxidant Activity in the Winemaking Process of Blueberry (Vaccinium corymbosum) Wine Obtained by Maceration. *International Journal of Emerging Multidisciplinaries. Molecules. 27(22):7744.*

Xiang, H., Sun-Waterhouse, D., Waterhouse, G. I., Cui, C. and Ruan, Z. (2019) Fermentation enabled wellness foods, a fresh perspective. *Journal of Food Science and Human Wellness.* 8: 203–243.