Development of Cocoyam, Red Kidney Bean, and Mango-Based Complementary Foods: Impact of Fermentation and Malting on Nutritional, Functional, Anti-Nutrient, and Sensory Characteristics

Abstract

Aim: To evaluate the influence of fermentation and malting on the quality of cocoyam, red kidney beans and mango - based complementary foods.

Methodology: Flour was prepared from cocoyam, red kidney beans and mango. It was than blend as follows: 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). This ratio was arrived at, based on their protein content through material balancing to give 16 g protein/100 g. Blends were subjected to proximate, functional and anti-nutrient content analysis. More so, gruels were prepared from blends and sensory attributes determined. NESTLE CERELAC (CS) was used as external control for comparison.

Results: Fermentation and malting improve the nutritional and functional properties; protein varies from 16.01±1.00 (NFNMM) to 16.04±1.00% (FMM), fibre ranged from 3.44±0.05 (NFNMM) to 4.23±0.04 (NFMM), packed bulk density ranged from 0.86±0.02 (NFNMM) to 0.68±0.01 (FMM). Viscosity ranged from 1.32±0.03 (NFNMM) to 1.17±0.02 (FMM), fermentation and malting significantly ($p<0.05$) reduces bulk density and viscosity. Phytate varies from 16.88±0.02 mg/100 g (FMM) to 21.72±0.01 mg/100 g (NFNMM), oxalate varies from 3.23±0.02 mg/100 g (FMM) to 5.71±0.02 mg/100 g (NFNMM), fermentation and malting significantly ($p<0.05$) reduces phytate and oxalate content. In terms of overall acceptability samples FMM and NFMM showed no significantly different ($p > 0.05$) with NESTLE CERELAC,

Conclusion: Fermentation and malting have significant ($P<0.05$) impact on the proximate functional, anti-nutrient and sensory properties of cocoyam-Red kidney beans-Mango based formulated food products.

Key words: Fermentation, Germination, Proximate, Functional, Preference

1.1 Introduction

"It has been proven scientifically that breast milk is the perfect food for the growing infant during the first six months of life" (Oludumila and Enujiugha, 2017). "Beyond this period, the supply of energy and protein and some nutrients from breast milk is no longer adequate to meet an infant's needs" (Foterek et al., 2014). "Thus, complementary feeding is needed to fill the gap between total nutritional needs of the baby and the nutrients provided by breast milk" (Skau et al., 2015). "In developing countries including Nigeria, Cameroon, many families cannot afford commercial weaning foods due to high levels of poverty, and thereby engage in weaning the children on cereal gruels" (Bala et al., 2014). "Cereal gruels are characterized by low energy and protein density due to the large volume of water relative to its solid matter contents during preparation" (Egbujie and Okoye, 2019). "This leads to protein-energy malnutrition and pellagra"(Oludumila and Enujiugha, 2017). "Improved complementary feeding and breastfeeding practices are essential to prevention of protein-energy malnutrition" (Kaur et al., 2020). "To achieve this goal, formulation of nutritious complementary diets from readily available raw food materials using simple technologies have received a lot of attention in developing countries" (Oludumila and Enujiugha, 2017). However, locally available cocoyam, red kidney beans and mango combinations have not been tested for weaning foods. An acceptable, nutritionally-enriched food that can be stored in the home should be produced for consumption in areas where protein intake is low.

"Cocoyam *(Colocasia esculenta*) contributes a significant portion of the carbohydrate content of the diet in many regions especially in developing countries like Nigeria and others. Proximate composition of cocoyam were in the range of 65 – 78% (moisture), 2 – 5 % (ash), 0.2 – 1.10% (fat), 2 – 5% (fiber), 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)" (Matikiti et al., 2017). "Cocoyam have nutritional advantages over root crops and other tuber crops. It has more crude protein than root and other tubers and its starch is highly digestible due to small size of the starch granules (1 - 4 μm), its mineral contents are reasonable" (Tope & Soji, 2013). "All these are lost to nutrition because of low production and utilization" (Charles et al., 2017). "Among the reasons advanced for its under- utilization are presences of toxicants like calcium oxalate, phytate" (Igbabul et al., 2014; Awolu et al., 2017)

"Red kidney bean *(Phaseolus vulgaris)* is a legume. it is a vital source of protein (22.7%), B-vitamins and minerals" (Inyang et al., 2018). "It is used to enhance the protein content in the diet of low and medium income earners in developing countries" (Forwoukeh et al., 2023). "Red kidney bean is rich in unsaturated fatty acids especially linoleic acid. In spite of its high nutritive and health benefits, its content large amount of anti-nutritional factors (phytic acid, tannins and saponin) which affect the absorption of protein and certain minerals. Simple techniques such as soaking, boiling, germination and fermentation are effective in reducing these anti-nutrients" (Inyang et al., 2018; Forwoukeh et al., 2023).

"Mango *(Magnifera indica)* belongs to the genus Angifera. It is a valuable source of vitamins and minerals" (Izidoro et al., 2023). "Mangoes are rich in в-carotene (0.20 mg/100 g) and vitamin C (300 mg/100 g) fresh pulp. The production of mango flour reduces free water, resulting in an increased time-to-market and concentrating health-promoting nutrients" (Gupta et al., 2022).

"Fermentation is a desirable process of biochemical modification of primary food matrix brought about by microorganisms and their enzymes" (Nkhata et al., 2018). "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). Fermentation is used to enhance the bioaccessibility and bioavailability of nutrients from different crops (Hotz, C., & Gibson, 2007) and improves organoleptic properties (Chaves-Lopez et al., 2014).

"Mating is one of the simplest traditional technologies adopted for improving the nutrient composition and functionality of plant foods" (ocheme et al., 2015). "Malting is controlled germination followed by controlled drying of the germinated kernels" (Onwurafor et al., 2020). "Malting promotes the development/activation of hydrolytic enzymes" (Imtiaz & Burhan-Uddin, 2012). "It allows preparation of low-bulk foods through elaboration of amylases resulting in reduced viscosity of the gelled germinated starch" (Onwurafor et al., 2020). "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). Therefore, the objectives of this study were to formulate and evaluate the nutritional, functional, and sensory properties of Cocoyam, Red kidney beans, And Mango based weaning foods using fermentation and/or malting processes.

2. Materials and methods

2.1 Materials

Cocoyam and mango was 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.

2.2 Preparation of raw materials

Cocoyam flour: Cocoyam flour was prepared using the method described by Coronell-tovar et al. (2019). 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 with 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). 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 ^{o}C). 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 ^{o}C 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). 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 ^{o}C for 30 mins. The blanched bean was dehydrated in an air draft dehydrator at 55 ^{o}C 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). 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 were 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 ^{o}c, 30 mins) and dehydrated at 55 ^{o}C 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 mm 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 into 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).

2.3 Complementary food Formulations

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

2.5 Proximate composition of the complementary foods flour

Proximate composition was determined using standard analytical methods as outlined by Ukeyima et al. (2019); Forwoukeh et al. (2023).

2.6 Functional properties complementary foods flour

Water and swelling capacities were determined by methods described by Ojo et al. (2017) while Oil absorption capacities were determined by methods described by ocheme et al. (2015). Loose and packed bulk densities were determined by methods described Forwoukeh et al. (2023) while Viscosities were determined by methods described by Okoronkwo et al. (2023).

2.7 Anti- nutritional properties of the complementary foods flour

Phytate content was determined using the method described by Marolt and Kolar (2021) while Oxalate was determined by the method described by Adeniyi et al. (2009). Tannin was determined by the method described by Nwokenkwo et al. (2020) while Saponin content was determined by the method described by Thenmozhi & Rajan (2015).

2.8 Sensory proper of gruels

Preparation of gruels: Gruels were prepared according to the method described by Okoye et al. 2021. 60 g of each sample were dissolved with 150 mL of potable water to produce the slurry. Then, 180 mL of boiling water was added to each of the slurry with continuous stirring to obtain homogenous gruels. 5 g (WFP 2018 recommendations) of granulated sugar was added to each sample (except control) of the gruel and stirred steadily until uniformly distributed). NESTLE

CERELAC, a commercial cereal based weaning food used as control (CS) following method described by (Onyedika et al., 2019). Organoleptic evaluation of gruels was carried out using a affective testing as described by Hashim et al. (2009). A 9-point hedonic scale where 1 represents "extremely dislike" and 9 represents "extremely like" was used. Twenty (20) semi-trained panelists were used to evaluate appearance, texture, aroma, taste, and overall acceptability.

2.9 Data Analysis

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

3. Results and Discussion

3.1 Proximate composition of the complementary foods

Table 1: Proximate composition (%) of complementary foods from cocoyam, red kidney beans and mango as influenced by fermentation and malting

Complementary foods	Moisture	Ash	Fat	Fiber	Protein	Carbohydrate
FMM	$6.33^{d}\pm1.00$	$2.12^{a}\pm1.00$	$1.88^{c}\pm0.01$	$3.80^{b}\pm1.00$	$16.04^{a}\pm1.00$	$69.92^{b}\pm0.03$
FNMM	$7.10^{b}\pm0.01$	$1.93^{b}\pm0.06$	$1.80^{b}\pm0.04$	$3.67^{b}\pm0.12$	$16.02^{a}\pm1.00$	$69.53^{c}\pm0.01$
NFMM	$6.80^{c}\pm0.02$	$2.26^{a}\pm0.42$	$1.68^{a}\pm1.00$	$4.23^{a}\pm0.04$	$16.03^{a}\pm1.00$	$69.14^{d}\pm0.01$
NFNMM	$7.47^{a}\pm1.00$	$2.24^{a}\pm1.00$	$1.69^{a}\pm0.03$	$3.44^{c}\pm0.05$	$16.01^{a}\pm1.00$	$69.97^{a}\pm0.02$
FAO/WHO Standard	<5	<3	10-25	<5	16	60-75

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 proximate composition of flours as influenced by fermentation and malting. Moisture content of sample NFNMM was significantly ($p<0.05$) higher than that of samples FMM, NFMM, FNMM. This may probably be due to the porous texture of the flour resulting in maximum moisture loss (Samtiya et al., 2020). This observation agrees with Igbabul et al. (2014); Samtiya et al. (2020). The Protein Advisory Group recommended moisture content <10% in order to keep a floury product for a long time (Lohia & Udipi, 2015). The moisture content of flour is important for two reasons. First the higher the amount of moisture content the less the amount of dry solids in the flour. Secondly, flour with moisture content higher than 14-15% is not stable at room temperature as this is prone to microbial spoilage (Adelekan & Alamu, 2021). Ash content is always a rough measure of the inorganic minerals elements in samples (Pranoto et al., 2013). Ash content of the weaning foods shows no significant difference at 5% level. The ash content of the complementary foods was within WHO recommendations (<3%). The high ash content is an indication of high mineral content of the complementary foods (Nwosu, 2013). Minerals, potassium, calcium is integral part of phytate, oxalate molecules where it is covalently bonded rendering it inaccessible by digestive enzymes. The complex matrices in which these minerals are entrapped and **bonded are** largely responsible for their low bioavailability (Onwurafor et al., 2020). Fermentation and malting are processing methods that are applied to free these complexes minerals and make them readily bioavailable (Pranoto *et al.*, The high fat content of fermented and/or malted samples could be due to synthesis of fat during fermentation (Sibian et al., 2017); Combo et al., 2020); Sibian & Riar, 2022). Comparatively, the fat contents of the formulated samples were similar to those reported by Sibian *et al*. (2017); Combo *et al*. (2020); Sibian & Riar (2022).

Low fiber content of the formulated foods would enable children to consume more of the food samples, and give them the opportunity to meet their daily energy and other vital nutrient requirements (Ijarotimi & Keshinro, 2013). NFMM has the highest fiber content indicating that malting increases the fiber content (Sibian & Riar, 2022).

The protein content of the complementary foods shows no significant difference ($p<0.05$). The protein contents of all the formulated blends met the 16 % protein requirement for weaning foods. This was possible because the blending ratios were obtained by material balancing. Comparatively, the protein contents of the complementary foods samples were similar to those reported by Mohammed *et al*. (2021); Samtiya *et al.* (2020). The carbohydrate content of the complementary foods were significantly difference (p<0.05) with sample NFNMM having the highest carbohydrate content. Malting and fermentation have been reported to reduce the carbohydrate content (Igbabul *et al.*, 2014). This is might be due to consumption of carbohydrate by germinating seed and fermentation microorganism (lactic acid bacterial) as source of energy.

3.2 Functional properties of complementary foods

Table 2: Functional properties of complementary foods from cocoyam, red kidney beans and mango as influenced by fermentation and malting

Complementary foods	WAC (ml/g)	OAC (ml/g)	Packed BD(g/ml)	Loose BD(g/ml)	SC(ml/ml)	viscosity (Pa.s)
FMM	$2.06^{b}\pm0.02$	$1.10^{a}\pm0.05$	$0.68^{d}\pm0.01$	$0.60^{d}\pm0.02$	$1.10^{b}\pm0.01$	$1.17^{c}\pm0.02$
FNMM	$2.00^{c}\pm0.01$	$1.01^{b}\pm0.03$	$0.74^{c}\pm0.01$	$0.65^{c}\pm0.03$	$1.07^{c}\pm0.02$	$1.23^{b}\pm0.01$
NFMM	$2.09^{a}\pm0.02$	$1.06^{b}\pm0.02$	$0.78^{b}\pm0.01$	$0.67^{b}\pm0.05$	$1.12^{a}\pm0.04$	$1.21^{b}\pm0.01$
NFNMM	$1.97^{d}\pm0.02$	$0.99^{c}\pm0.01$	$0.86^{a}\pm0.02$	$0.71^{a}\pm0.02$	$1.02^{d}\pm0.01$	$1.32^{a}\pm0.03$

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). **WAC:** Water absorption capacity, **OAC**: Oil absorption capacity, **BD:** Bulk density, **SC**: swelling capacity. **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 impact of fermentation and malting on functional properties of flours. The functional properties explain how food ingredients behave during preparation and cooking. The functional properties impact the finished food products in terms of texture, appearance, structure and taste. “The Water absorption capacity of untreated sample, NFNMM was significantly (<0.05) lower than the treated samples (fermented and/or malted). The water absorption capacity is an index of the maximum amount of water that a food product would absorb and retain" (Eli et al., 2022). "Improvement in the protein quality during malting/fermentation and breakdown of complex carbohydrates led to increment in the water absorption capacity" (Sibian et al., 2020; Sibian & Riar, 2022). "Also high WAC may be attributed to the proportion of hydrophilic and hydrophobic amino acids in the protein and relative amount of carbohydrates" (Adepeju et al., 2014). "The ability of protein in flours to physically bind with water is a determinant of its water absorption capacity. Soybean with a better quality protein tended to absorb more water than groundnut" (Eli et al., 2022). "Fermentation and malting enhanced the protein properties (hydrophilic protein molecules) and therefore increase the water absorption capacity of the complementary foods" (Sibian & Riar, 2022). The increase in water absorption capacity with malting and fermentation could be due to increased solubility as a result of the increase in amount of soluble sugars present in the malted and fermented flours. According to Ocheme et al. (2015), "the increase observed might have been as a result of the production of compounds having good water holding capacity such as soluble sugars". These results agree with reports presented by Gernah et al. (2011); Nitya Sharmaa et al. (2018). "Lower water absorption capacity is desirable for making gruels in which more flour can be added per unit volume of the gruel. This would help to increase the energy density and nutrient content of the infant foods" (Eli et al., 2022).

"Oil absorption capacity of fermented and/or malted samples was significantly ($p<0.05$) higher than NFNMM. The increase might be due to variations in the presence of non-polar side chain, which might bind the hydrocarbon side chain of the oil among the flour" (Chandra et al., 2014). Deepali et al. (2013); Ocheme et al. (2015) stated that "germination-induced increased oil absorption capacity may be due to solubilization and dissociation of proteins leading to exposure of non-polar constituents from within the protein molecule". "Based on this report the lower OAC of NFNMM diet may be due to the fact that the complementary foods (FMM, FNMM, NFMM (with higher OAC) had more available non-polar side chains in their protein molecules than NFNMM. Non-polar amino acid side chains can form hydrophobic interaction with hydrocarbon chains of lipids" (Awuchi et al., 2019). Adepeju et al. (2014) reported that "more hydrophobic proteins show superior binding of lipids, this implies that non- polar amino acids side chains bind the paraffin chains of fats". Similar findings were observed by Kaushal et al. (2012); Suresh and Samsher, (2013); Nitya Sharmaa et al. (2018), who noted flour of high protein (hydrophobic proteins) retain more oil than flour with low protein content. The high OAC makes the flour suitable in facilitating, enhancement in flavour and mouth feel when used in food preparation (Awuchi *et al*., 2019).

"Bulk densities of NFNM were significantly ($p<0.05$) higher than that of treated samples (FMM, FNMM and NFMM). Bulk density is a function of flour wettability which influences packaging design and could be used in determining the required type of packaging material. The lower bulk density implies that less quantity of the food samples would be packaged in constant volume thereby ensuring an economical packaging" (Eli et al.,2022) (Adepeju et al., 2014; Awuchi et al., 2019). "Reduction in bulk densities may be due to the breakdown of complex compounds such as starch and proteins during fermentation and malting" (Ocheme et al., 2015; Onwurafor et al., 2020). According to Eli et al. (2022) "the decrease in bulk density might as result of malting and fermentation which soften the seeds, thus making milling easier, with smaller particle sizes than unmalted grains, hence this bring about reduction in bulk density". "The significance of this is that the less bulky flours will have higher nutrient density, since more flour can be packaged in the same given volume . However, the packed bulk densities would ensure more quantities of the food samples being packaged, but less economical. Nutritionally, loose bulk density promotes easy digestibility of food products, particularly among children with immature digestive system" Eli et al. (2022). The decrease in bulk density with malting and fermentation in the formulated products is in line with report given by Adepeju et al. (2014); Igbabul et al. (2014), Gawande et al. (2018); Onwurafor et al. (2020).

Swelling capacity of untreated sample NFNMM was significantly ($p<0.05$) lower than that of treated samples (FMM, FNMM and NFMM). The swelling capacity is an important factor used in determining the amount of water that food samples would absorb and the degree of swelling within a given time. Ocheme and Chinma (2008) also reported an increase in the swelling power of millet flour as a result of germination. Also similar observation were made by chandra et al. (2014); Moses and Olanrewaju, (2018); Adejuyitan et al. (2020). The increase in swelling power might be due to an increase in soluble solids brought about by the breakdown of lipid, and larger amount of amylose–lipid complex in flour that could inhibit the swelling of starch granules (Nitya Sharmaa et al., 2018). Fats may complex with starch and limit swelling. Phattanakulkaewmorie et al. (2011) reported that swelling power is positively related to the amount of soluble solids. The swelling of starch granules leads to disruption of some of the intermolecular hydrogen bonds, thus allowing more water to enter and enlarge the granules (Eli et al., 2022).

Viscosities at ambient temperature among the formulated food blends were determined. The significant reduction ($p<0.05$) in viscosity with malting and fermentation could be due to breakdown or degradation of starch granules, other macromolecules such as polysaccharides and polypeptides to smaller units, such as dextrins and peptides respectively by the enzymes mobilized during the germination and fermentation process. These observations are in conformity with earlier reports Ariahu et al. (1999); Ariahu et al. (2009); Simwaka et al. (2015); Mohammed et al. (2017); on cereal and legume based gruels. The reduction in viscosity with malting and fermentation could be nutritionally advantageous since for equal volumes, germination and fermentation would permit the addition of higher quantities of food solids to the gruels in comparison to NFNMM formulation. This report is similar to report given by Eli et al. (2022).

3.3 Anti nutrient content of complementary foods

Table 3: Anti nutrient Composition (mg/100 g) of complementary foods from cocoyam, red kidney beans and mango as influenced by fermentation and malting

Complementary foods	Phytates	Oxalate	Tannins	Saponin
FMM	16.88^c±0.02	3.23^d±0.02	0.03^c±0.01	11.71^d±0.01
FNMM	20.33^b± 0.00	5.54^b±0.01	0.05^b±0.01	16.24^c±0.01
NFMM	20.23^b±0.01	5.24^c±0.01	0.06^b±0.01	17.89^b±0.02
NFNMM	21.72^a±0.01	5.71^a±0.02	0.10^a±0.02	23.74^a±0.01
Permissible limit	10-50 mg/100 g	4- 9 mg/100 g	20 mg/g	40 mg/kg

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same column indicate significant difference at ($p<0.05$). **WAC:** Water absorption capacity, **OAC**: Oil absorption capacity, **BD:** Bulk density, **SC**: swelling capacity. **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 change in anti-nutrient content of flours as influenced by fermentation and malting. The phytate, oxalate, tannins and saponin content of NFNMM was significantly higher ($p<0.05$) than the treated (fermented and/or malted) samples. This might be due to fermentation and malting (Igbabul et al., 2014). Fermentation and malting activates phytates enzyme which digests phytate (Sibian & Riar, 2022). Digestion of phytate by enzyme facilitates its leaching from the foods products (Etong *et al*., 2014). These observations are in conformity with earlier reports by Ojokoh, (2006); Ohini et al. (2019); Sibian & Riar, 2022). Phytate are known to form complexes with iron, zinc, calcium and magnesium making them less available (Ohini et al., 2019). Also phytate lowers the bioavailability of minerals and inhibits several proteolytic enzymes and amylases (Etong *et al*., 2014). During fermentation and germination, oxalate oxidase gets activated which breaks down oxalic acid into carbon dioxide. This reduced the oxalate content of flours. The effect of this change was seen correspondingly on calcium content of the complementary foods which increased on sprouting as oxalic acid is known to interfere with calcium absorption. Oxalates affects calcium and magnesium metabolism and react with proteins to form complexes which have an inhibitory effect in peptic digestion (Tope & Soji, 2013). According to Ohini et al., 2019, reported a safe normal range of 4- 9 mg/100 g for oxalates. This report agrees with findings by Adeniyi et al. (2009); Rasha et al. (2011), Sibian & Riar, (2022). The decreae in tannins during fermentation and malting were attributed to the hydrolysis of tannin complexes by enzymes (Pandit and Kaur, 2020; Samtiya et al., 2020). Also transformation of tannins to phenols occurring during fermentation increases phenol content while tannin content reduces (Sripriya et al., 1997; Mohite et al., 2013). 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 (Mahmud et al., 2019). Decreased in saponin content of the flour is due to hydrolysis of saponin complexes by enzymes activated during malting and fermentation (Etukumoh, 2014; Sibian & Riar, 2022). The observed decrease in saponin with fermentation agrees closely with the report by Pandit and Kaur, (2020), Mamiro et al. (2017) and Sibian & Riar, (2022) . The presence of anti-nutritional factors such as phytates and tannins in foods like complementary foods has been reported to constitute an important handicap to the effective utilization of its nutrients in human nutrition. Most cereal-based diets have poor bioavailability of nutrients as a result of the presence of anti-nutritional factors such as phytates and tannins. Phytate (myoinositol hexaphosphate) is an abundant plant constituent, comprising 0.5 to 6% of all cereals, nuts, legumes and oil seeds and normally found in the form of complexes with polyvalent cations, like iron. Anti-nutritional factors are important since they can also be used medically and pharmacologically. Tannic acid, as an astringent and has been known to be used in the treatment of bedsores and minor ulceration (Mahmud *et al*., 2019).

3.4 Sensory scores of gruel samples

Table 4: Sensory scores of complementary foods from cocoyam, red kidney beans and mango complementary foods as influenced by fermentation and malting

Attributes/Samples	FMM	FNMM	NFMM	NFNMM	CS
Appearance	7.62^{a}±1.03	7.60^{a}±0.05	7.65^{a}±1.23	7.59^{a}±1.25	8.42^{a}±1.17
Aroma	6.85^{b}±0.06	6.79^{b}±0.43	6.82^{b}±0.06	6.73^{c}±0.67	8.55^{a}±0.34
Taste	7.63^{a}±1.64	7.26^{c}±1.32	7.70^{a}±1.44	7.21^{c}±0.45	8.01^{a}±0.02
Texture	7.86^{a}±0.02	7.81^{a}±0.56	7.85^{a}±0.06	7.80^{a}±0.65	8.02^{a}±0.02

Overall acceptability	7.95[a]±0.03	7.72[C]±0.57	7.98[a]±1.05	7.67[C]±0.67	8.00[a]±0.04

Values are means of triplicate determinations ± S.D. Means followed by different superscript letters in the same row indicate significant difference at ($p<0.05$). **WAC:** Water absorption capacity, **OAC**: Oil absorption capacity, **BD:** Bulk density, **SC**: swelling capacity. **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 (external control).

The results of sensory evaluation are shown in Table 4. There was no significant difference at 5% level between the test samples and control sample (CS) in terms of appearance or colour. The results show that samples FMM, FNMM, and NFMM are not significantly different from one another in aroma but are significantly different from CS and NFNM fermentation and malting impacted a characteristic flavour (Onyango et al., 2013). FMM and NFMM show no significant difference at 5% level with CS (eternal control) in terms of taste but were significantly different from NFNMM (internal control) fermentation and malting impacted a characteristic sour/sweet taste (Nkhata et al., 2018). The results show that samples are not significantly different ($p>0.05$) from one another in texture. The results show that samples FMM, NFMM and CS are not significantly different ($p>0.05$) from one another in overall acceptability while the values for NESTLE CERELAC were higher than all the food formulations. There were general comments on the slight sourness of the fermented products and the fermented products were acceptable to panelists. This could be due to the fact that fermented (slight sour) gruels are common in local diets. The sour taste in fermented products might be due to the action of lactic acid bacteria which results in hydrolysis of starch to organic acids.

CONCLUSION

Malting and fermentation significantly ($p < 0.05$) affected proximate, functional, anti –nutritional and sensory attributes of cocoyam-Red kidney beans-Mango based formulated food products. Germination and natural fermentation could be used as simple, household adaptable technologies for reducing bulk, viscosity, anti-nutrient and increasing nutrient density of gruels from cocoyam, red kidney beans and mango based food products. Sprouting and fermentation tends to improve the sensory attributes of the formulation. The sensory scores indicate that complementary foods of acceptable sensory quality can be produced from FMM NFMM since they show no significant difference (p>0.05) with NESTLE CERELAC

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