AgriHealth
Journal of Agri-food, Nutrition and Public Health
ISSN 2722-0656 (Print) 2722-0648 (Online)

AgriHealth: Journal of Agri-food, Nutrition and Public Health. 5(1), 10-20, 2024
URL: https://jurnal.uns.ac.id/agrihealth/article/view/79364
DOI: http://dx.doi.org/10.20961/agrihealth.v5i1.79364

Nutritional Compositions and Sensory Evaluation of Fermented Maize and Millet Fortified with Crayfish and Soybeans for the Production of Infant Food

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Received: October 6, 2023; **Accepted**: January 28, 2024

Abstract

Despite the reported improvement in the nutrient status of fermented cereal-based diets in Sub-Saharan Africa, the nutrient needs of infants are still not being met. Hence, this study evaluated the nutritional compositions of fermented protein-fortified cereals. The proteins used in fortifying maize and millet were crayfish (30%), soybeans (30%) and a combination of both protein sources in a ratio of 70:15:15 for cereals, crayfish and soybeans, respectively. Fermentation of protein-fortified cereals was carried out using submerged fermentation for 5 days. Results revealed that fortifying maize and millet with crayfish and soybeans increased the protein content (11.1 to 19.1%). The fortification led to a reduction in crude fiber and carbohydrate contents of raw maize and millet. Fermentation also significantly reduced the carbohydrate content, with the lowest carbohydrate value observed on the last day of fermentation. Fortification with crayfish and fermentation increased all the minerals (potassium, magnesium and calcium) of raw maize and millet, but no significant effect at $p < 0.05$ on the iron content. All the samples that were fortified had better sensory acceptability than those that were not fortified. This study revealed that fermentation and fortification of maize and millet meal (cereal) with soybeans and crayfish can alleviate protein energy malnutrition (PEM) problems.

Keywords: cereals; fermentation; fortification; nutritional-composition; protein

INTRODUCTION

The agricultural sector, which is concerned with cultivating the soil for growing crops and raising livestock, has been described as having an important role in human health as it is believed that agriculture can be linked with poor health (Hawkes and Ruel, 2007). It is also to be noted that the agricultural sector of any economy does provide strength to the health sector in terms of nutrition (Tenriawaru et al., 2022). Meanwhile, cereals are essential sources of the world's food supply, as their role in the human diet worldwide is vital. In light of this, the significant cereals contributing to the diet are rice, barley, maize, wheat, sorghum, oat and millet (Mridula and Sharma, 2015). Millets and maize are important sources of nutrients and indispensable food for millions of people in developing countries such as Africa (Goredema-Matongera et al., 2021; Hassan et al., 2021). These cereals are important ecological food security crops known for their nutritional quality (Akplo et al., 2023; Novotny et al., 2023) and they can be used for dual purposes (feeding man and animals). This group of cereal crops has significant potential to widen the genetic diversity in the food basket to ensure improved food and nutrition security (Filli et al.,

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Cite this as: Ilemobayo, A. M., & Kone, K. J. (2024). Nutritional Compositions and Sensory Evaluation of Fermented Maize and Millet Fortified with Crayfish and Soybeans for the Production of Infant Food. *AgriHealth: Journal of Agri-food, Nutrition and Public Health*, *5*(1), 10-20. doi: http://dx.doi.org/10.20961/agrihealth.v5i1.79364

2010). Maize has been described as one of the leading cereals in production volume and is set to become the most widely grown and traded crop in the next decade (Erenstein et al., 2022). These cereals have been processed into other food products to increase their nutritional, palatability, aesthetic value, acceptability and sensory attributes using several methods, such as fermentation and fortification.

Meanwhile, fermentation is an old processing technique used to diversify and transform maize and millet. Reports from Senanayake et al. (2023) maintained that the fermentation process prolongs the shelf-life of foods, increases protein content and digestibility, availability of minerals, functional properties, prolongs relative nutritional value, and enhances sensory and imparts antimicrobial properties on the food product. Despite the reported improvement in the nutrient status of fermented cereal-based diets in Sub-Saharan Africa, the nutrient needs of infants are still not met. Evidence indicates that it is possible to improve these cereal foods' nutrient quality and acceptability and exploit the possibility of converting them to infant foods by adopting a newer scientific processing method (Anumudu et al., 2018). There have been cases of fermentation of maize singly or mixed with millet for feeding infants (Adeoye et al., 2018; Omenna et al., 2018). Meanwhile, there have been earlier studies that recommended the need for fortification of traditional fermented cereals with protein-source food (Jay et al., 2005) because the intake of ordinary cereals without rich protein-source food could lead to malnutrition and hamper the growth of babies. According to International Food Policy Research Institute (2014), good nutrition is the foundation of healthy living and improved economies.

Mundagowa et al. (2019) affirmed that most African mothers usually breastfeed beyond 12 months, though it is generally complemented with solid food. Wallenborn et al. (2021) reported the disparity in the percentages of women who breastfeed their babies in urban and rural settings in the Lao People's Democratic Republic. Also, Bhattacharjee (2019) reported that only 18 out of 49 African countries (36.7%) met the conditions for exclusive breastfeeding. These reports indicated early supplementation with solid foods or early weaning. Although some women start weaning their infants at three to four months, a few begin within the first two months of life. The first solid food and the most popular weaning food is a thin cereal gruel known by different names depending on the West African country.

Traditional weaning foods (like gruels from maize, millet and guinea corn) in West Africa are known to be low in protein and other nutritive values (Adeyemo and Onilude, 2018). Maize gruel has been traced to protein-energy malnutrition in children during the weaning period (Magala et al., 2017). For adults and older children, a balanced protein-energy intake is usually possible by an upward review of the daily intake of starchy foods of low nutrient density (Abeshu et al., 2016). For infants, however, the volume of the traditional diets may be too large to allow the child to ingest all the food necessary to cover their energy needs. A baby aged four to six months would need 920 g of corn gruel to meet daily needs of energy (740 kcal) and protein (13 g) (Layrisse et al., 1998). Considering the size of an infant's stomach, this situation is difficult to achieve. However, the use of foods of high nutrient density can help to overcome the problem of malnutrition, occasioned by feeding on food with inadequate nutrients (Troesch et al., 2015), with a report from UNICEF (2019) documented that only 42% of the children under six months that enjoyed exclusive breastfeeding. Hence, this study focuses on the protein fortification of fermented maize and millet to bring about weaning food that is rich and adequate in nutrients for the growth and development of children.

MATERIALS AND METHOD

Sample materials

The cereals (maize-*Zea mays* and millet-*Pennisetum glaucum*) and protein foods (soybeans-*Glycine max* and crayfish-*Cambarus batchi*) used for this study were purchased from a local market in Akure, Ondo State, Nigeria. They were transported to the laboratory in clean and sterile black opaque polythene bags sealed and kept at refrigerated temperature (4 °C) in the laboratory. The crops were identified at the Crop, Soil and Pest Management Department, Federal University of Technology, Akure.

Pre-treatment of protein source foods

The protein source foods (soybeans and crayfish) were cleaned thoroughly, after which the cleaned soybeans were boiled in water separately at a temperature of 100 °C for 20 minutes, and the seed coat was removed. The dehulled seeds were sun-dried for 3 days. The dried seeds and cleaned crayfish were dry-milled into flour separately. They were sieved through a fine mesh sieve to obtain protein-based food flour.

Preparation of cereals

About 100 g of cleaned cereals (maize and millet) were soaked, each in a plastic bucket containing 1000 ml of sterile distilled water for 72 hours at 27±2 °C. Afterward, they were washed, wet milled and sieved through a fine mesh. The sieved cereals were allowed to settle at the bottom of the bucket and the water was decanted.

Supplementation of milled cereals with protein-based foods flour

The supplementation of milled cereals and protein sources was carried out in batches: group 1, called the control group, contained milled maize and millet separately, and group 2 had milled cereals mixed with protein in the ratio of 70:30 (w/w), i.e., 70 g of each milled cereal was mixed with 30 g of each of the protein source separately. Furthermore, group 3 consisted of each of the milled cereals with protein sources in a ratio of 70:15:15. In contrast, group 4 accommodated mixed milled cereals with each of the protein sources separately in the ratio of 35:35:30, that is, 35 g each of the milled cereals were mixed with 30 g of protein-source flour. Group 5 contained the mixed cereals and protein sources in the ratio 35:35:15:15. That is, 35 g of each milled cereal was mixed with 15 g of each protein-source flour.

Fermentation of fortified cereals

About 100 g of each fortified and unfortified cereal was mixed with 100 ml of distilled water. The mixture was allowed to ferment naturally at room temperature 27±2 °C for 96 hours. Water was decanted, and the fermented cereal slurry was dried for 2 to 3 days in an oven at 60 °C. The dried fermented cereals were sieved to fine particles and packed in different nylon packaging for further studies.

Proximate and mineral analyses

All samples were analyzed for moisture, ash, fat, protein, crude fiber and carbohydrates using the method described by the Association of Official Analytical Chemists (AOAC) (2012). The mineral composition of each sample, including calcium, potassium, magnesium and iron, was determined using the wet ashing method followed by acid digestion and then spectrophotometric reading (AOAC, 2012).

Sensory evaluation

Sensory characteristics of the fortified fermented maize and millet dough products were assessed by 10 semi-trained members of the Department of Microbiology, Federal University of Technology, Akure (Heymann et al., 2012). Fresh samples of cooked porridge prepared by boiling the dough slurry at 10% (w/v) for 15 minutes were assessed for color, texture, flavor (aroma), taste and overall acceptability. The panelists were instructed to sip water before and after determining each product. The judge recorded the sensory characteristics of each sample using 8-point hedonic scale as described by Mbata et al. (2009), where: 8 = like extremely, 7 = like very much, 6 = like moderately, 5 = like slightly, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely. Each treatment was evaluated three times by each panelist.

Statistical analysis

The data obtained was entered into a Microsoft Excel spreadsheet version 2010 and later exported into Statistical Package for Social Science (SPSS) version 22 for analysis. One-way analysis of variance (ANOVA) and the treatment mean was separated using Duncan's New Multiple Table.

RESULTS AND DISCUSSION

Effect of fortification on the proximate composition of fermented samples

Fortification with crayfish and soybeans increased the protein content of raw maize and millet (Figure 1). The highest increase in protein (11.1 to 19.1%) was recorded in millet+crayfish+soybeans and fermented maize had the lowest protein (10.0%) on the third day of fermentation. However, fortification with crayfish and soybeans reduced raw maize and millet's crude fiber and carbohydrate contents (Figure 2 and 3, respectively). The highest reduction (1.91 to 0.62%) was recorded in raw millet+crayfish+soybeans for crude fiber and the highest reduction (50 to 39.5%) in carbohydrate was recorded in raw maize+millet+crayfish+ soybeans. The increase in the protein content of raw maize and millet after fortification with crayfish and soybeans was corroborated by the research conducted by Adegbusi et al. (2023). This attested to the fact that crayfish and soybeans are sources of protein that cannot be ignored. The reduction in carbohydrate content of the fortified cereals agrees with the report of Mohammed et al. (2021), who found that the addition of soybeans and fish meal caused a significant reduction in the carbohydrate content of yellow maize.

Effect of fermentation on the proximate composition of fermented samples

Fermentation significantly ($p < 0.05$) reduced the carbohydrate content (Figure 3) of the fermented samples. The lowest carbohydrate content was observed on the last day of fermentation, with fermented maize taking the lead (37.5%). Fermentation increased the crude fiber (Figure 2) and ash (Figure 4) content of fermented samples, with the highest crude fiber and ash content observed on the last day of fermentation, with fermented millet and fermented maize+millet+crayfish having the most increased crude fiber (2.50%) and ash content (2.43%), respectively. However, fermented maize and millet+crayfish+soybeans had the lowest ash and crude fiber values on the last day of fermentation.

Fermentation was seen to increase the protein content of the fermented samples significantly,

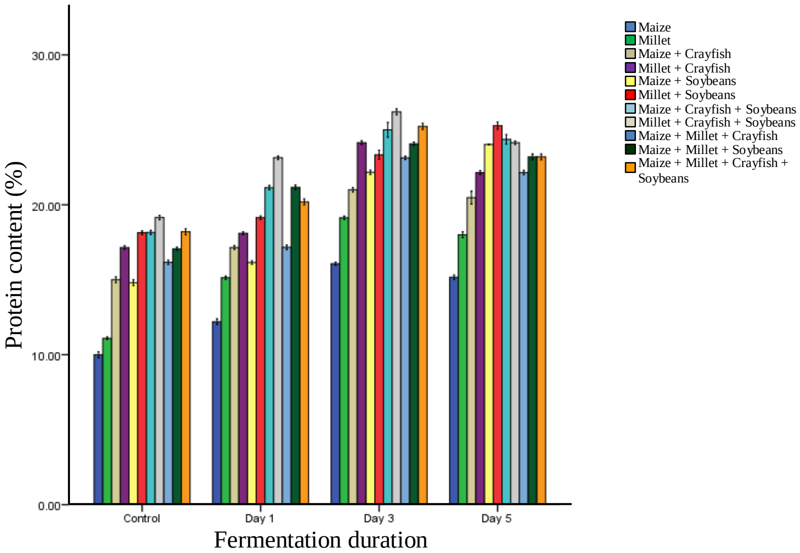

Figure 1. The effect of fermentation on the protein content of fermented samples

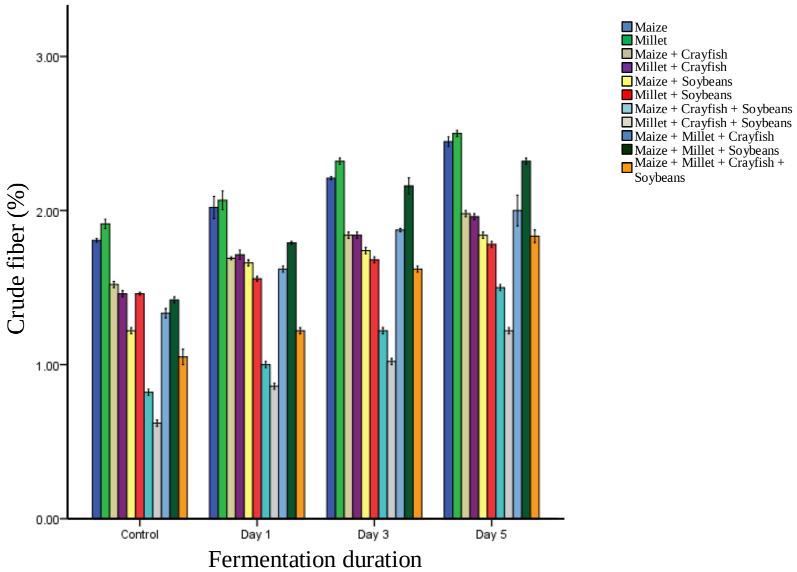

Figure 2. The effect of fermentation on the crude fiber content of fermented samples

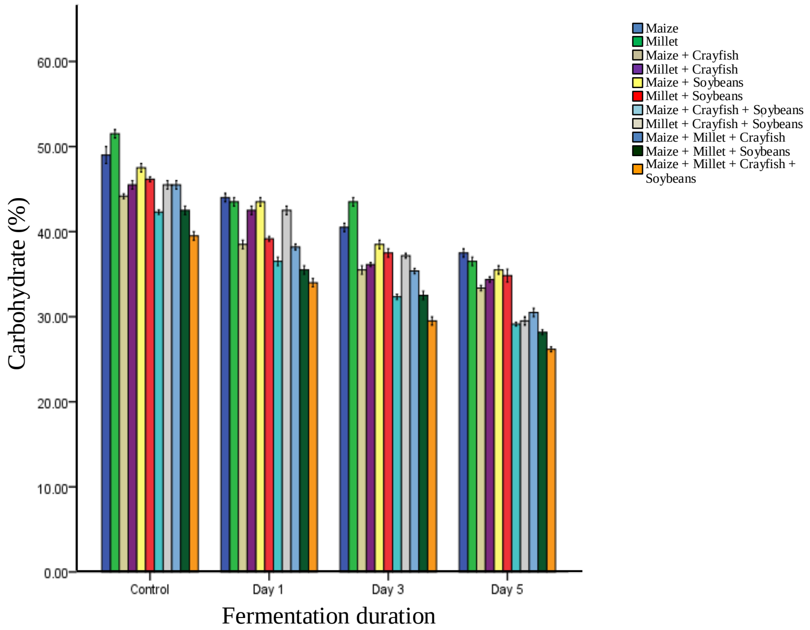

Figure 3. The effect of fermentation on the carbohydrate content of fermented samples

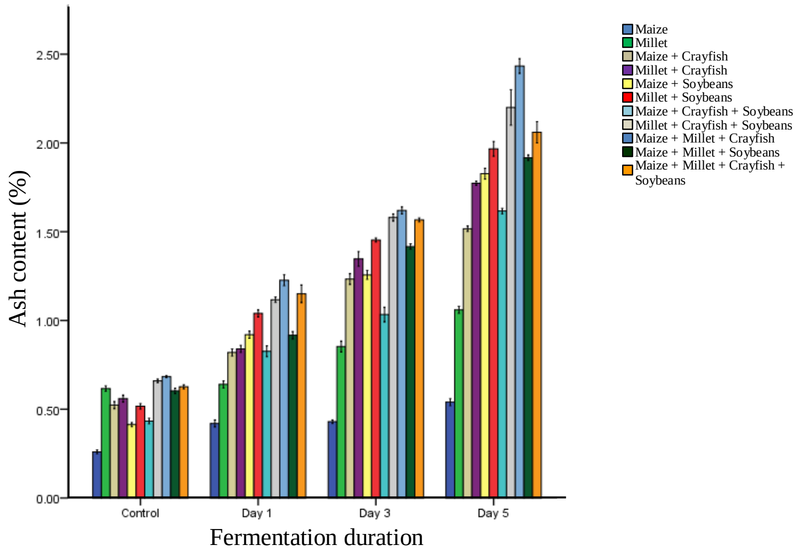

Figure 4. The effect of fermentation on the ash content of fermented samples

agreeing with the report of Sharma et al. (2020), who reported that the length of fermentation during processing is an essential factor in fermentation. This could be attributed to increased microbial load during fermentation, causing extensive hydrolysis of the protein molecule to amino acid and other simple peptides (Modupe et al., 2016). The highest protein content was observed on the third day of fermentation for most of the samples, with fermented millet+crayfish+soybeans having the most elevated protein. A subsequent reduction in protein content in some of the samples was observed after the third day of fermentation, which could be a result of the shift in the nutrient utilization of the microorganisms from carbohydrate to protein and it could be that the fermentation condition from the third day favored more proteolytic organisms to grow. A similar observation was reported by Modupe et al. (2016) on the third day of fermentation of *Parkia biglobosa*.

Fermentation of cereals was reported by Sharma et al. (2020) as a method that generally decreases the level of carbohydrates. The fermentation process may have caused a reduction in the fermented samples' carbohydrate content, which could be due to the microorganisms present during fermentation, which might have utilized the carbohydrate as a source of energy. The reviewed work of Adebo et al. (2022) that established that fermentation, though an old method of food processing, remains a foremost means for increasing the level of nutrients in cereals and legumes lends credence to this point. A similar observation was reported by Tamang et al. (2016) that most species of microorganisms produce several enzymes during fermentation, including amylase, proteinase, mannanase, cellulase and catalase, capable of degrading carbohydrates into simple sugars. In turn, the microorganism has used these as energy sources and for metabolic activities. It is evident from the result generated from this research that the fortified foods were nutritious since the products provided one-third of the recommended dietary allowance (RDA) concerning protein (10 to 12%) as recommended by the Food

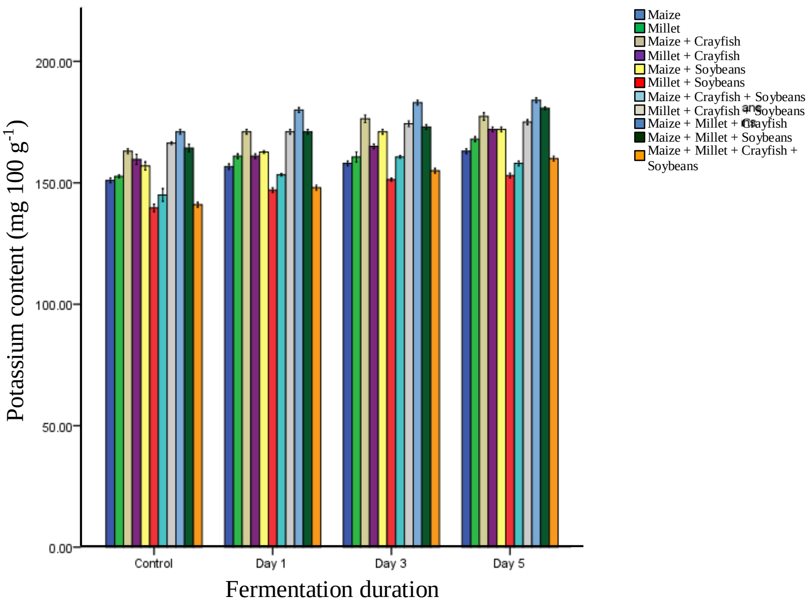

Figure 5. The effect of fermentation on the potassium content of fermented samples

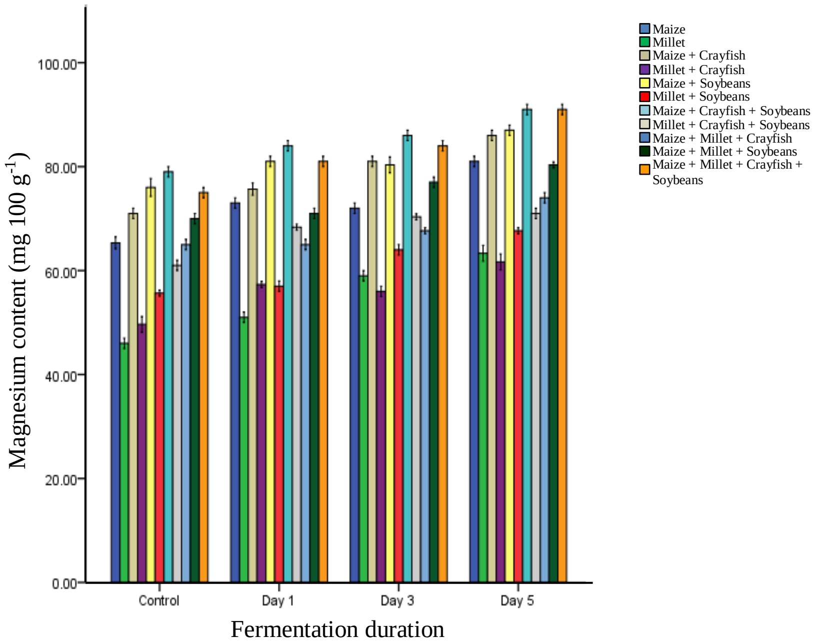

Figure 6. The effect of fermentation on the magnesium content of fermented samples

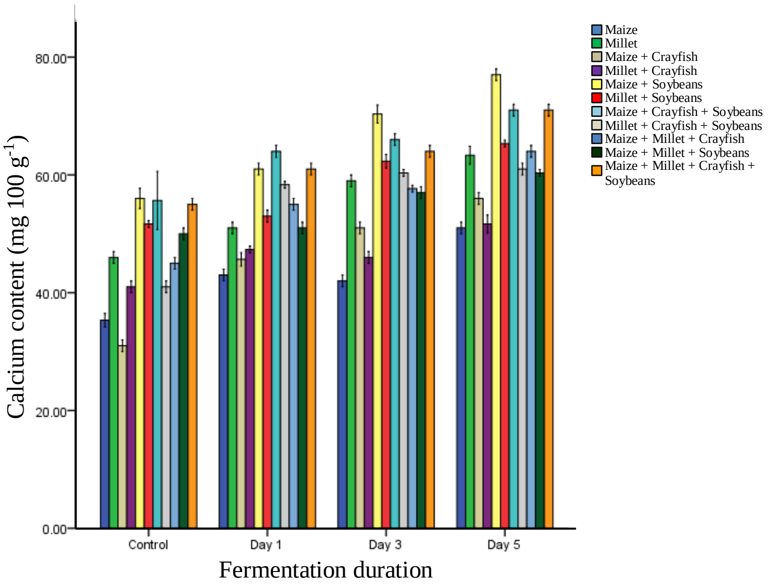

Figure 7. The effect of fermentation on the calcium content of fermented samples

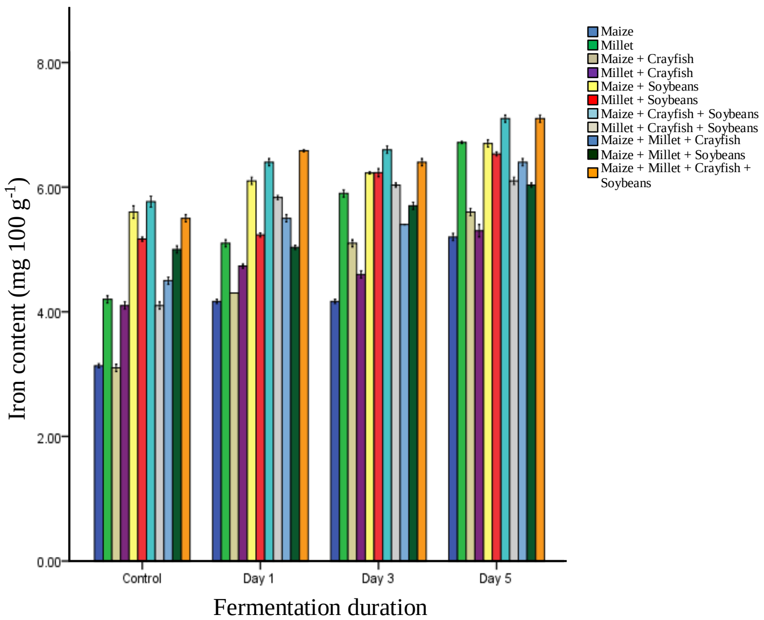

Figure 8. The effect of fermentation on the iron content of fermented samples

and Agriculture Organization (FAO, 1985) for children and rural mothers. The proximate characteristics of the fortified food were within the range reported for weaning and supplementary foods.

Effect of fortification on the mineral composition of fermented samples

Fortification with crayfish increased raw maize and millet's potassium and magnesium contents. The natural potassium in maize and millet increased from 65 and 46 mg g^{-1} to 71 and 49 mg g^{-1} in maize+crayfish and millet+crayfish, respectively, while the magnesium content in maize and millet increased from 151 and 152 mg g^{-1} to 163 and 159 mg g^{-1} in maize+crayfish and millet+crayfish, respectively. However, fortifying maize and millet with crayfish had no significant effect at $p < 0.05$ on the iron content but increased all the minerals determined when fortified with soybeans (Figures 5 to 8).

This increase in all the mineral compositions after adding the protein sources conformed with the report of Okoye and Ene (2018), in which black beans and crayfish were used to fortify

Table 1. Sensory acceptability of fermented samples

Samples	Color	Flavor	Texture	Taste	Overall
M	6.0^{a}	5.6^{a}	5.3^{b}	6.0^{a}	6.0^{b}
ML	6.0^{a}	6.0^{b}	5.1^{a}	6.0^{a}	5.6^{a}
MC	6.6^{c}	6.6^{de}	7.0^{f}	6.6^{c}	6.1^{b}
MLC	6.5^{c}	6.5^{d}	7.0^{f}	6.6^{c}	7.0^{e}
MS	6.3^{b}	6.5^{d}	6.6^{d}	6.6^{c}	6.5^{d}
MLS	6.3^{b}	6.3^{c}	6.0^{c}	6.3^{b}	6.1^{b}
MCS	6.1^{a}	6.1^{bc}	6.5^{c}	6.3^{b}	6.3^{c}
MLCS	7.0^{d}	6.5^{d}	6.5^{c}	6.5^{c}	6.8^{e}
MMLC	6.6^{c}	6.5^{d}	6.8^{e}	6.3^{b}	6.5^{d}
MMLS	6.3^{b}	6.5^{d}	6.6^{d}	6.3^{b}	6.1^{b}
MMLCS	6.6^{c}	6.6^{de}	6.5^{c}	6.6^{c}	6.8^{e}

Note: M = maize, ML = millet, MC = maize+crayfish, MLC = millet+crayfish, MS = maize+soybeans, MLS = millet+soybeans, MCS = maize+crayfish+soybeans, MLCS = millet+crayfish+soybeans, MMLC = maize+millet+crayfish, MMLS = maize+millet+soybeans, MMLCS = maize+millet+crayfish+soybeans

maize. Completing cereals to generate more critical micronutrients is necessary, as reported by UNICEF (2019), which reports that an estimated 51% of preschool children suffer from one or several micronutrient deficiencies.

Effect of fermentation on the mineral composition of fermented samples

Fermentation increased all the minerals determined (Figures 5 to 8), with the lowest mineral contents observed on the first fermentation and the highest on the last day. Fermented maize+millet+crayfish had the highest potassium content (184 mg g^{-1}), increasing from 180 mg g^{-1} on the first day of fermentation. The lowest potassium value (153 mg g^{-1}) was observed in fermented millet+soybeans on the last fermentation day, increasing from 139 mg g^{-1}. The highest and lowest values for magnesium were observed in fermented maize+crayfish+soybeans (91 mg g^{-1}) and millet+crayfish (61 mg g^{-1}) on the last day of fermentation, having increased from 79 and 49 mg g^{-1}, respectively on the first day of fermentation. Lastly, the lowest values for calcium (51 mg g^{-1}) and iron (5.2 mg g^{-1}) were recorded in fermented maize. In contrast, the highest was recorded in fermented maize+soybeans for calcium and the highest in fermented maize+millet+crayfish+soybeans for iron.

Furthermore, fermentation increased all the minerals determined, with the lowest mineral content observed on the first fermentation and the highest on the last day. This fact was supported by the review of Samtiya et al. (2021), who reported that fermentation can improve plant foods' nutrient and mineral bioavailability. This could be attributed to the fact that during fermentation, microorganisms liberate nutrients locked in plant structures and cells by indigestible materials and to the fact that microorganisms are not only catabolic, breaking down more complex compounds, but they also are anabolic, synthesizing several complex growth factors during fermentation.

Sensory acceptability of fermented samples

The overall acceptability scores of the various sensory attributes are shown in Table 1. All the samples that were fortified had better sensory acceptability than those that were not fortified. The organoleptic evaluation, as reported in Table 1, showed that the combinations of cereals (maize and millet), legumes (soybeans) and animal protein (crayfish) to prepare the food mixtures were enjoyed by the panelists. This point was corroborated by Sharma et al. (2020), who affirmed that fermentation enhances the organoleptic properties of food. The acceptability of the fortified cereals could be due to different volatile compounds produced during fermentation that eventually generated a mixture of complex flavors in the products (Erkmen and Bozoglu, 2016). None of the panelists developed any side effects like diarrhea and vomiting after the sensory evaluation.

Limitation and recommendation

The limitation of this research was that starter culture was not used for the fermentation. Still, the organisms that brought about fermentation were present in the food material used. Therefore, it is recommended that starter culture should be used for further study.

CONCLUSIONS

Weaning food made solely from cereal has poor biological value; thus, children weaned entirely on cereal suffer from protein-energy malnutrition (PEM). An excellent supplemental relationship exists between cereal food and protein-based food. Fortified cereal-based food with soybeans and crayfish improves the nutritional content of cereal and, hence, can alleviate problems of PEM. The fortified foods prepared were nutritious and conformed to specifications recommended by the National Institute of Nutrition and Food and Agriculture Organization (FAO) to combat malnutrition, especially in low-income groups.

ACKNOWLEDGEMENTS

This research received no external funding, but the efforts of people like Mr. Caleb Obajaja, Solomon Shina, and Tolu Akinniyi of the Department of Biological Science, University of Medical Sciences Ondo, during the fermentation of the cereals are well appreciated.

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