Effect of Malting and fermentation on the physicochemical properties of maize flour

Abstract

The study investigated the effects of malting and fermentation on the physicochemical properties of maize flour. Maize grains were subjected to malting and fermentation to produce malted fermented maize flour (MFM), malted non-fermented maize flour (MNFM), non-malted fermented maize flour (NMFM), and non-malted non-fermented maize flour (NMNFM). Key parameters~~, including pH, total titratable acidity (TTA), proximate composition, and vitamin content, were analyzed using standard methods~~ were analysed using standard methods, including pH, total titratable acidity (TTA), proximate composition, and vitamin content. Results revealed a significant reduction in pH and an increase in TTA during fermentation, with the MFM samples exhibiting the highest acidity levels. Proximate composition showed that malting and fermentation improved crude protein, fat, and fiber ~~content~~ while reducing carbohydrate content. Vitamin analysis indicated that MFM had the highest vitamin C content, attributed to the malting process, while MNFM and NMFM demonstrated superior levels of vitamins A, B1, and B2. These findings highlight the potential of malting and fermentation as complementary methods for enhancing ~~the nutritional and functional properties of maize flour~~ maize flour's nutritional and functional properties for ~~both~~ food applications and ~~nutritional~~ dietary interventions.

Keywords: Malting, Fermentation, Maize flour, Physicochemical properties, Nutritional enhancement

1. Introduction

Maize (Zea mays) is one of the most widely consumed cereal grains globally, serving as a staple food in many regions, particularly ~~in~~ developing countries (Ranum *et al.*, 2014). It is valued for its versatility and ability to provide essential nutrients and dietary energy. However, raw maize has limitations, including low protein quality, reduced ~~bioavailability of certain nutrients, and the presence of~~nutrient bioavailability, and antinutritional factors such as phytates and tannins (Samtiya *et al.*, 2020). These challenges necessitate processing techniques that can enhance the nutritional and functional qualities of maize.

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Malting and fermentation are traditional processing methods that have been extensively used to improve the quality of cereal grains, including maize. Malting, a process involving controlled germination and drying, activates endogenous enzymes that break down complex carbohydrates, proteins, and antinutritional factors, enhancing nutrient bioavailability and functional properties (Guzmán-Ortiz *et al.*, 2019). Fermentation, a biological process driven by microorganisms, improves the nutritional profile, enhances ~~flavor~~flavour, reduces antinutritional factors, and increases the production of beneficial organic acids (Abbaspour, 2024).

This study investigates the effects of malting and fermentation on the physicochemical properties of maize flour, ~~with specific focus~~specifically focusing on parameters such as pH, total titratable acidity (TTA), proximate composition, and vitamin content. These parameters provide critical insights into ~~the quality, nutritional value, and suitability of maize flour~~ maize flour's quality, nutritional value, and suitability for various applications. The findings of this research will contribute to understanding how these processing methods can be ~~optimized~~ optimised to improve the nutritional and functional properties of maize, thereby supporting its role in food security and industrial utilization.

2. Materials and Methods

2.1 Sourcing of raw materials

Maize grains were obtained from a local ~~market in Makurdi, Benue State, Nigeria~~Makurdi, Benue State, Nigeria market. The grains were cleaned prior to use

2.2. Raw material preparation

2.2.1. Preparation of non-malted and malted maize flour

Malting was performed following Eli *et al.* (2022). Maize grains were disinfected with a 5% NaCl solution, soaked in tap water at 30 ± 2 °C for 12 hours (changing the water every 4 hours), and germinated for 72 hours on a moistened bag, with water sprayed every 12 hours. After germination, the grains were dried at 60 °C in an air draft oven for 3 days. The dried seeds were manually split to remove testa and rootlets, which were winnowed off. The cotyledons were milled into flour (0.2 mm particle size). The resulting non-malted (NMM) and malted (MM) maize flours were packaged in airtight polyethylene bags and stored at 30 ± 2 °C for product formulation and analysis.

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Fermented maize dough was prepared using an accelerated natural lactic acid fermentation method. Non-malted (NM) and malted (MM) maize flours (120 g each) were mixed with 80 mL of distilled water and fermented in covered glass beakers at room temperature (30 ± 2 °C) for 24 hours. Half of the fermented mixture was used as a starter culture for subsequent fermentation cycles. The pH and titratable acidity were monitored until the pH stabilized. The fermented mixtures were dried at 60 °C for 3 days, milled to a 0.2 mm particle size, and packaged in low-density polyethylene bags. The flours were stored in airtight containers at ambient conditions prior to product formulation and analysis (Gernah *et al.*, 2012).

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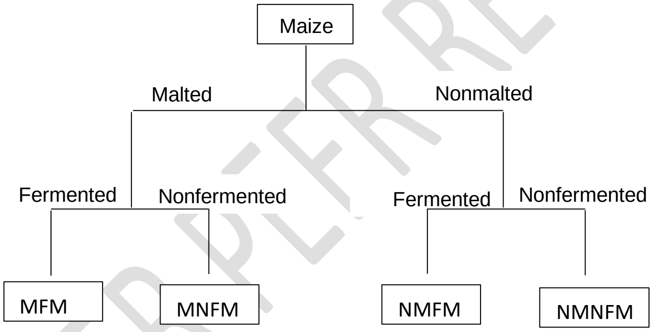

Figure 1: Experimental design

MFM: Malted fermented maize flour, MNFM: Malted ~~non fermented~~non-fermented maize flour, NMNFM: ~~Non malted~~Non-malted non fermented maize flour, NMFM: ~~Non malted~~Non-malted fermented maize flour

2.3 Determination of pH

The pH of the fermented samples was determined by mixing 20 g of the sample with 100 mL of distilled water. The mixture was left at room temperature for 30 min. The pH of the supernatant was then measured with a pH meter (Igbabul *et al.*, 2014).

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2.4 Determination of titratable acidity (TTA)

~~Titratable acidity of the fermented samples was determined by dissolving 20 g of the sample in 100 mL of distilled water and titrating 20 mL aliquot with 0.1 N NaOH to phenolphthalein end point, the~~The titratable acidity of the fermented samples was determined by dissolving 20 g of the sample in 100 mL of distilled water and titrating 20 mL aliquot with 0.1 N NaOH to the phenolphthalein end point; the TTA was then obtained by calculation. (Matela *et al.*, 2019).

$$TTA = \frac{mL\ of\ base \times 0.1N\ NaoH}{Sample\ weight} \times 100 \qquad (1)$$

2.5 Determination of the proximate composition of the maize flour produced

Proximate composition was determined using standard analytical methods (AOAC, 2012).

2.6 Determination of vitamins using UV – Vis Spectrophotometer

2.6.1 Vitamin A

One gram (1 g) of the sample was weighed and macerated with 20 mL of petroleum ether. It was evaporated to dryness, and 0.2 mL of chloroform acetic anhydride was added. 2 mL of TCA chloroform ~~were~~ was added, and the absorbance was measured at 620nm. The concentration of vitamin A was extrapolated from the standard curve (Omoboyowa *et al.*, 2015).

2.6.2 Determination of ~~vitamin~~ Vitamin C

Vitamin C content was determined by the spectrophotometric method. About 10g of the sample was mixed with 50 mL of 5 % metaphosphoric acid acetic acid solution and transferred to the 250 mL conical flask. Then, 50mL of phosphoric acid solution was added into the flask. The solution was filtered using Whatman filter paper~~ and the filtrate was collected for determination of~~, and the filtrate was collected to determine vitamin C. ~~To the filtered sample solution few drop of bromine solution was added and mixed~~A few drops of bromine solution were added and mixed to the filtered sample solution. Then~~ few drops of thiourea solution were added into the~~

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~~sample solution to remove access of~~, a few drops of thiourea solution were added to the sample solution to remove access to the bromine solution. Then 1ml of 2, 4 DNPH (2, 4 Dinitrophenylhydrazine) solution was added to the sample solution and to the entire standard. ~~Coupling~~ A coupling reaction occurs due to 2, 4 DNPH solution. To complete the reaction all the standards and sample solution were kept at 37°C for 3 hours. After 3 hours ~~solutions were cooled on ice bath~~, solutions were cooled in an ice bath, and 5 mL of H_2SO_4 was added. As a result, coloured solutions were obtained whose absorbance was measured at a specific wavelength.

2.6.3 Determination of thiamine

Thiamine content was determined according to the method of Omoboyowa *et al.* (2015). Five grams of the sample was ~~homogenized~~ homogenised with ethanolic sodium hydroxide (50 mL). It was filtered into a 100 mL flask. 10 mL of the filtrate was pipetted ~~and the colour developed by~~ , and the colour developed by the addition of 10 mL potassium dichromate and read from the spectrophotometer at 360 nm. A blank was prepared ~~and the colour also~~, and the colour was developed and read at the same wavelength.

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2.6.4 Determination of riboflavin

Riboflavin content was determined according to the method of Omoboyowa *et al.* (2015). Five grams of the sample was extracted with 100 mL of 50% ethanol solution and shaken for ~~1~~ one h. This was filtered into ~~100 mL flask; 10 mL of the extract was pipetted into~~ a 100 mL flask; 10 mL of the extract was pipetted into a 50 mL volumetric flask. 10 mL of 5% potassium permanganate and 10 mL of 30% H_2O_2 were added and allowed to stand over a hot water bath for about 30 min. 2 mL of 40% sodium sulphate was added. This was made up to 50 mL mark with deionized water ~~and the absorbance~~ , and the absorbance was measured at 510 nm in a spectrophotometer.

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2.7 Data Analysis

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

3. Results and Discussion

3.1 Changes in pH and titratable acidity with fermentation time of malted and fermented ~~maize~~ maize flour

Table 1 showed that the titratable acidity of the malted maize (MM) ranged between 3.92 and 4.56 while that of non-malted maize (NMM) ranged between 4.06 and 5.91. The pH of malted maize (MM) ranged between 3.41 – 5.32, while that of non-malted maize (NMM) ranged between 3.98 – 6.13. During ~~fermentation of maize dough,~~ the fermentation of maize dough, the accumulation of organic acids increased the total titratable acids and caused the pH to drop (Igbabul *et al.*, 2014). There ~~was rapid and significant differences in the changes in TTA and pH ($p \leq 0.05$) from day 0 – 2 in the maize dough, while from day 3 – 4~~were rapid and significant differences in the changes in TTA and pH ($p \leq 0.05$) from day 0 – 2 in the maize dough, while from day 3 – 4, the changes were less rapid but still significant ($p \leq 0.05$). The pH and acidity of the ~~maize~~ maize dough varied among the different treatments with fermentation time. Fermentation time had ~~greater influence on the pH and acidity of the NMM dough than~~ a greater influence on the pH and acidity of the NMM dough than the MM sample. Fermentation to a pH value of 4 and below is recommended in cereal flour products meant for making thin porridge for complementary feeding of children. This pH helps ~~in their preservation during storage due to high acid levels in~~preserve them during storage due to high acid levels, which many microorganisms cannot survive. The drop in pH is expected to make the fermented mix sour and also enhance the keeping quality since microbial inhibition is effective below pH 4 (Ochanda *et al.*, 2010).

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Table 1: Changes in pH and titratable acidity with fermentation time of malted and fermented ~~maize~~ maize flour

Parameters	**Fermentation time (days)**				
	0	**1**	**2**	**3**	**4**
TTA MM	4.56 ± 0.13	4.51 ± 0.06	4.24 ± 0.41	3.96 ± 0.08	3.92 ± 0.11
TTA NMM	5.91 ± 0.32	5.64 ± 0.17	5.33 ± 0.22	4.18 ± 0.03	4.06 ± 0.07
pH MM	5.32	4.58	3.99	3.46	3.41
pH NMM	6.13	5.31	4.97	4.10	3.98

Values are mean ± standard deviation of triplicate replicates.

3.2. Proximate composition of the raw materials (%).

Table 2 shows that soybean is highest in crude protein, crude fat, fibre and crude ash but lowest in carbohydrates (CHO) when compared with the other samples analysed, that is; 41.5 %, 7.32 %, 5.08 %, 3.75 % and 37.30 % respectively. That is ~~in the right blend proportion soybean will adequately fortify these cereals with the aforementioned nutrients (except carbohydrates), thus agreeing the reports by other researchers Ikese et al. (2016);~~ , in the right blend proportion, soybean will adequately fortify these cereals with the aforementioned nutrients (except carbohydrates), thus agreeing on the reports by Solomon (2005) and Ikese *et al.* (2016).

Moisture content is an indicator of flour storability. Moisture content greater than 14.5 % supports microbial growth (AOAC, 2012). Low moisture contents are required for safe and prolonged storage as higher moisture contents can lead to microbial damage and subsequent deterioration in quality. The moisture content of the flours ranged from 5.05 to 9.60 %; NMNFM has the highest moisture content (9.60 %) while~~, SBF has the lowest moisture content (5.05 %), the~~ SBF has the lowest moisture content (5.05 %); the moisture content reported in this work falls within the acceptable limit of less than 14.5 %. This can be used as an index for their storage stability. The higher the moisture content, the shorter the shelf life. Product moisture is significant to shelf life, packaging and general acceptability. ~~There was no significant difference ($p \le 0.05$)~~ No significant difference ($p \le 0.05$) was found in ash content among the NMFM and

NMNFM flours. The ash content of the flours ranged from 1.04 to 3.75 %, and the ash content of OFSP and SBF were found to be 3.44 and 3.75 % respectively, which is higher than the rest of the samples, is an indication that SBF and OFSP samples are rich in mineral elements compared to the rest of the samples in the table. This value is closer to the ash content values of 2.17 %; 2.25 and 2.72 % reported by Gernah *et al.* (2011)

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The fibre content of the flour ranged from 0.46 % - 5.08 %. Food that is rich in fibre keeps the digestive system healthy, aids digestion and prevents constipation. There is ~~significant difference ($p \leq 0.05$) in the fibre content of the flour, SBF and OFSP has the highest fibre content of 5.08 and 3.08 % respectively compared to that of NMFM, NMNFM, MNFM and MFM 1.91 %, 0.96~~ a significant difference ($p \leq 0.05$) in the fibre content of the flour; SBF and OFSP have the highest fibre content of 5.08 and 3.08 %, respectively, compared to that of NMFM, NMNFM, MNFM and MFM, 1.91 %, 0.96, %, 0.46 % and 1.60 % respectively. The values are closer to the fibre content values of 2.12 %~~; 1.82 %,~~ 1.82 %, and 1.78 % reported by Gernah *et al.* (2011).

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The calorific content in MNFM (374.48g) and SBF (371.76 g) were found to be higher than that of OFSP, NMFM, NMNFM and MFM, i.e. 330.11 kcal/g, 346.62 kcal/g, 359.30 kcal/g and 356.42 kcal/g. ~~There were no significant differences ($P \leq 0.05$)~~ No significant differences ($P \leq 0.05$) were found in the calorific content values of NMFM, NMNFM and MFM flours.

Table 2 Proximate composition of the maize flour produced (%)

Samples	Moisture	Crude Ash	Crude Fibre	Crude Fat	Crude Protein	Crude Carbohydrate	Calorific Content (Kcal/100 g)
NMFM	$8.14^{b}\pm0.05$	$1.27^{a}\pm0.09$	$1.91^{a}\pm0.01$	$2.08^{d}\pm0.01$	$12.6^{a}\pm0.01$	$74.00^{b}\pm0.01$	$346.62^{b}\pm0.09$
NMNFM	$9.60^{a}\pm0.33$	$1.19^{a}\pm0.05$	$0.96^{c}\pm0.04$	$5.00^{b}\pm0.01$	$10.7^{c}\pm0.40$	$72.55^{c}\pm3.\ 14$	$359.30^{b}\pm13.3$
MNFM	$6.70^{d}\pm0.02$	$1.04^{b}\pm0.05$	$0.46^{d}\pm0.09$	$5.20^{a}\pm0.01$	$11.7^{b}\pm0.80$	$74.90^{a}\pm2.27$	$374.48^{a}\pm5.33$

MFM	7.08^{c}±0.01	1.31^{a}±0.17	1.60^{b}±0.20	3.01^{c}±0.01	12.3^{ab}±0.20	74.70^{a}±2.34	356.42^{b}±8.80

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

4.2.4 Vitamin composition of the ~~maize~~ maize flour produced (mg/100 g)

From Table 3 ~~Vitamin A ranges between 0.003 – 0.246 mg/100g, vitamin B_1 ranges from 0.0023 – 0.958 mg/100g, vitamin B_2 ranges from 0.0015 – 0.508 mg/100 g~~, Vitamin A ranges between 0.003 – 0.246 mg/100g, vitamin B1 ranges from 0.0023 – 0.958 mg/100g, vitamin B2 ranges from 0.0015 – 0.508 mg/100 g, and vitamin C ranges from 1.300 – 41.10 mg/100 g. It can be seen that the OFSP is highest in vitamins A, B_1 and B_2 (0.246, 0.958 and 0.508 mg/100 g ~~respectively),~~ , respectively), and Beta-carotene is sensitive to light (Mmari, 2017). With this ~~when added to the formulation~~, when added to the formulation, it will improve the vitamin content of the complementary food. While the MFM is highest in vitamin C (41.10 mg/100 g), this could be ~~as a result of the sample been~~a result of the sample being malted.

Table 3: Vitamin composition of non-malted, malted and fermented ~~maize~~maize, soybeans and sweet potato flour used in product formulation (mg /100 g)

Samples	A	B_1	B_2	C
MFM	0.043^{a}±0.008	0.834^{a}±0.003	0.472^{a}±0.005	41.10^{a}±0.050
MNFM	0.205^{b}±0.007	0.562^{c}±0.001	0.224^{d}±0.002	31.10^{c}±0.017
NMFM	0.003^{c}±0.0004	0.746^{b}±0.002	0.292^{c}±0.001	39.80^{b}±0.001
NMNFM	0.042^{a}±0.005	0.128^{d}±0.002	0.339^{b}±0.002	15.30^{d}±0.0001

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

Conclusion

This study demonstrated that malting and fermentation significantly enhance the physicochemical properties of maize flour. The processes ~~resulted in~~ improved proximate composition, particularly in crude protein, fiber, and fat content, while reducing carbohydrate levels. Furthermore, fermentation contributed to increased acidity and reduced pH, ~~which are~~ critical for improving storage stability and microbial safety. The vitamin content analysis confirmed that malting and fermentation ~~are effective in enriching~~effectively enrich the micronutrient profile of ~~maize~~ maize flour, particularly for vitamin C and B-complex vitamins. These findings underscore the value of malting and fermentation as traditional yet effective strategies for improving the nutritional quality of maize-based food products. ~~Optimizing~~ Optimising these processing techniques can contribute to developing nutrient-dense complementary foods and addressing malnutrition challenges in maize-dependent populations.

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