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Research Article

Assessment of Microbiological Quality, Nutrient Composition, and Physical Characteristics in Groundnut Flour (*Nsinjiro*) Sold in Local Markets in Central and Southern Regions of Malawi

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Abstract:

Background of study: Malawi produces groundnuts for consumption, trade, and animal feed. Microbiological quality, nutrient composition, physical properties, in groundnut flour sold in Malawian markets had not been identified and studied extensively. Therefore, their nature and extent of distribution needed to be documented as the basis for intervention programs in Malawi.
Aims and scope of paper: To assess Microbiological Quality, Nutrient composition, and Physical Characteristics in Groundnut Flour sold in Local markets in Central and Southern Regions of Malawi.
Methods: In the Central, 16 samples were purchased of 32 while in the Southern region, 22 samples were purchased of 39 respectively. Samples were stored in a deep freezer at 4 ^{O}C for 26 days pending analysis. Later samples were analyzed using multiple standard methods and the data were analyzed using SPSS.
Result: 18.42% of samples contained *E. coli* ranging from 0 to 30 cfu/g, and 13.16% contained *Salmonella* ranging from 0 to 70 cfu/g, and these exceeded the permissible limits for Malawi and the International Commission on Microbiological Standards for Foods. The limit for Malawi is 10,000 cfu/g, while the ICMSF is 500,000 cfu/g. They contained protein (30.67%), carbohydrate (37.87%), fat (43.90%), and ash (3.43%). They were light in color with L* (49.79-59.88).
Conclusion: The results indicated that the groundnut flour studied was susceptible to microbial contamination, hence, hygienic monitoring before marketing is required. Policy enactment for sanitary practices, and enforcement of standards to reduce the menace of microbes and avoid food-borne diseases among the populace is required.

Keywords: Color Attributes; Groundnut Flour; Marketplace; Microbial Loads; Proximate Analysis.

1. INTRODUCTION

One of the most significant food crops is groundnut (*Arachis hypogaea* L.). In 2019, it was projected that the world would produce 47.09 million metric tons (USDA, 2020). The world's total groundnut production was 39.75 million metric tons, and Sub-Saharan African countries contributed 27.6 %. Around the world (Figure 1), various tropical and subtropical countries, including Malawi, widely cultivate and consume groundnuts and their derived products.

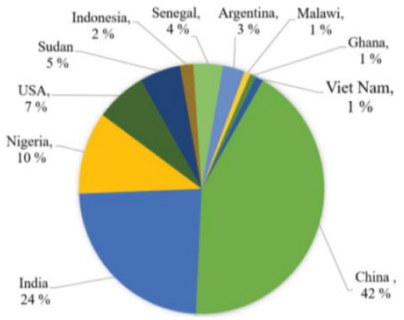

Figure 1. Groundnut Production (Million Metric Tons)

Malawi is one of the top groundnut-producing countries in East and Southern Africa, and it is mostly cultivated by local farmers. (Ngwira Amos *et al.*, 2019). It is produced for human consumption, trade, and animal feed (Ngwira Amos *et al.* 2019). Vendors process some groundnuts into flour for sale in various local markets. (Chisinga & Matita, 2021; Vroegindewey *et al.*, 2019).

Groundnut flour can be consumed daily in various forms in Malawi. (Njoroge *et al.,* 2017; Gama, Adhikari, & Hoisington, 2018). Regular consumption of groundnut flour may lead to foodborne pathogens. Groundnuts are contaminated with *Listeria species*, *Salmonella* species, coliforms, *Escherichia coli* (E. coli), yeasts, and molds in addition to aflatoxins. (Uçkun & Var, 2018). The presence of *Salmonella* and *E. coli* in groundnut flour is a sign of poisoning. The proportion of moisture, protein, fat, ash, crude fiber, carbohydrates, and color determines the physical characteristics of groundnut flour (MBS, 2017).

Therefore, it was from this background that the study was conducted to assess microbiological quality, nutrient composition, and physical characteristics in groundnut flour sold in local markets in the central and Southern Regions of Malawi. Specifically, to determine the microbial loads in groundnut flour (E. coli, Salmonella spp., Coliform, Yeast and molds, and Aerobic plate count) and the physical characteristics of groundnut flour (the amount of moisture, protein, fat, ash, crude fiber, carbohydrates, and Color), respectively.

2. MATERIALS AND METHODS

2.1 Study design

The investigation was conducted on purpose in two specific regions among the most productive groundnut regions in Malawi, where groundnuts are also consumed in substantial quantities. Based on literary sources, the Central Region of Malawi produces more than half of the nation's groundnuts (Vroegindewey *et al.*, 2019). The regions comprised Central and Southern, which also harbor the majority of local markets, such as *Nkhamenya, Chatoloma, Chamama, Kasungu, Nkanda, Mchinji, Kamwendo, Mponela, Nambuma, Dowa, Lumbadzi, Mvera, Mitundu, Lilongwe, Dedza, Salima, Manjawira, Balaka, Ulongwe, Liwonde, Mwanza, Zalewa, Chingale, Zomba, Govara, Lunzu, Mbulumbuzi, Njuri, Chiradzulu, Ndirande, Blantyre, Limbe, Nkando, Goliati, Bvumbwe, Thyolo, Mulanje,* and *Muloza*.

2.2 Study area

A partial map of Malawi showing some locations of markets where groundnut flour samples were purchased is shown in Figure 2.

Malawi is found in the southern part of Africa. It is a landlocked country that borders Tanzania, Zambia, and Mozambique. Both land and water, mostly Lake Malawi, make up its 118,480 sq. km of total land area. It is situated between longitudes 32° and 36° E and latitudes 9° and 18° S. Politically, Malawi is divided into three regions: the North, the Center, and the South. The weather of Malawi is typically tropical, with warm temperatures between November and April, and 90 % of the year's precipitation comes from equatorial rains.

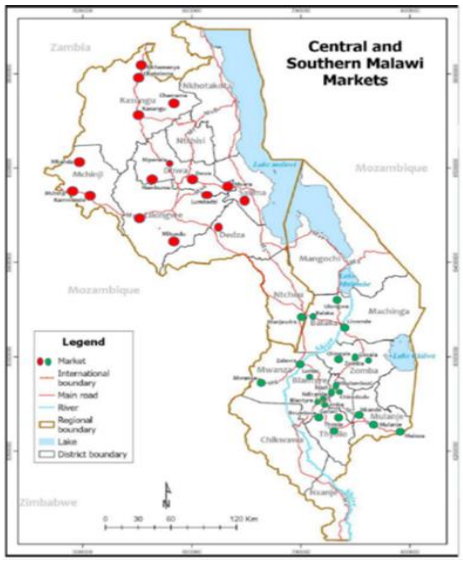

Figure 2. A partial map of Malawi displaying the study markets

From September to April, maximum temperatures in the lower Shire Valley and along the lake average around 27 to 29 °C (80.6 to 80.6 °F) (Moore, 2019). With typical annual temperatures ranging between 22 and 18 degrees Celsius and rainfall varying between 900 and 1,500 mm every year, Malawi's central region is located at an elevation of between 1,300 and 1,700 meters above sea level (Moore, 2019). A rain shadow zone covers most of Malawi's southern area; it experiences minimum and maximum temperatures of 14 and 32°C and receives about 800 mm of rainfall on average every year. The primary food crop is maize, which is occasionally interplanted with groundnuts. (Makate & Mango, 2017).

2.3 Sampling Approach

This was one of the Quantitative types of research conducted on Groundnut Flour samples collected from various local markets. The purposive sampling technique was used for the selection of the local markets in all the regions, respectively. However, the selection of vendors in the markets was done using a simple random sampling technique after the observational survey. Due to their predominance in the production of groundnutsand groundnut flour marketing, 2 of the 3 regions were purposefully selected. From each region, formal local markets from the list of markets obtained from the Ministry of Local Government office were picked based on where groundnut flour marketing takes place. In the last stage, at least 5 and ut most 10 groundnut flour vendors/sellers were selected in each local market. Then, vendors/sellers from whom the groundnut flour was purchased were picked. A total of thirty-eight (n = 38) of 71 local markets were selected for the study. In the Central region, samples were purchased from sixteen (16) local markets of thirty-two (32), while in the Southern region, twenty-two (22) samples were purchased from thirty-nine (39) markets, respectively. Immediately after being granted the Ethical Clearance Approval for the study by the Institutional Review Board of the University of Cape Coast **(**ID (UCCIRB/CANS/2022/53)), primary data

collection from various retail local market outlets in Malawi started (during the daytime) on 9th January and completed on 4th February 2023. Data was collected three times during the study.

2.4 Sample collection procedure

The thirty-eight (n=38) groundnut flour samples (1kg each and well-mixed) were randomly purchased from local markets across the 2 regions in Malawi. The sample was purchased based on the samples that each seller had on hand. Samples were packed in sterile polyethylene plastic Ziplock sachets (made in China), tagged with the market's code name, and kept in an insulated cooler box at a temperature of 10 °C to prevent moisture changes caused by the environment. Later, samples were transported at the same temperature (10 °C) to the University of Cape Coast's Africa Centre of Excellence for Food Fraud and Food Safety (AFriFoodinTegrity Centre) laboratories in Ghana. While awaiting analysis, samples were stored in a deep freezer (4 ºC).

Data collection followed inclusion and exclusion techniques where authenticated local markets by the Ministry of Local Government and where groundnut flour marketing was taking place, including at least 5 and utmost 10 vendors selling the groundnut flour, which was well packaged, and the markets were accessible for sampling, were included in the study.
Again, all unauthenticated (informal) local markets, all markets that had fewer than 5 and zero vendors/sellers, vendors whose *nsinjiro* was unpackaged or not in a container, and markets that could not be accessed due to other factors, such as bad roads, were excluded from the research.

Data collection instruments involved the use of an electronic balance (Adam, Model PW254, UK) to measure the weight of samples during sample collection. Data collection forms were designed in such a way that counter-weighing of the sample mass (confirmatory weighing) was required after purchasing it right from the vendor/seller. The balance was used when portioning the sample into portions for laboratory analysis. All laboratory work required mass measurement before analysis, and an electronic balance was used to collect such data.

There were some limitations in this research, as some markets could not be accessed due to bad weather conditions, as some roads leading to such markets were impassable. Other markets had few vendors/sellers of groundnut flour, and it was also difficult to know whether the groundnut flour was produced and sold in the same locality or not.

2.5 Data statistical analysis

The statistical analysis was performed using the IBM Statistical Program for Social Scientists (SPSS), version 20 (IBM Inc.). Descriptive statistics were used to summarize the data. Mean and Standard Deviation (Mean ± SD) of triplicates, ranges, including percentages, were used to report descriptive statistical analysis. The discrepancies between the sample mean values were compared using analysis of variance (ANOVA).

2.6 Microbiological Quality Analysis of groundnut flour

Escherichia coli

The standard Pour Plate Count Method (Chouhan, 2015) was used to measure the colony-forming units (CFU/g) of *Escherichia coli (E. coli)*. Plate Count Agar (Oxoid, Hampshire, England), Peptone Water (Oxoid), Eosin Methylene Blue agar (Oxoid), Mannitol Salt Agar (Oxoid), and Potato Dextrose agar (Oxoid) were used to develop the culture media according to the manufacturer's instructions. Using Peptone Water (Oxoid) as the recovery diluent, 180 mL of the peptone water was made in triplicate and sterilized using an autoclave for 15 minutes at 121°C and a pressure of 15 psi with all prepared media and Petri dishes. Following an acceptable homogenization of the groundnut flour samples, 20 g of groundnut flour was weighed aseptically into peptone water (the recovery diluent), and it was incubated for 30 minutes at 37°C. In sterile Buffered Peptone Water, the test materials were serially diluted to a concentration of 10^{-3}. Isolated colonies with a diameter of 2 to 3 mm, a greenish metallic sheen from light reflection, and dark purple centers were recognized as colonies of *E. coli* for the presumptive test. To conduct a confirmation test, isolated colonies were injected into OxoidSIM (Sulfite Indole Motility) media by inserting the needle roughly two-thirds of the way into the medium. Until growth was visible, it was cultured for 24 hours at 37 °C. 5 drops of Kovác's reagent were applied to the deep's surface to check for the presence of indole. Within seconds of introducing the reagent to the top layer of agar, a red hue started to appear, which was an indication of a positive indole test.

Salmonella spp.

Salmonella was determined according to Chouhan (2015). Twenty-five (25)g of groundnut flour sample and 225 mL of buffered peptone water were combined for the pre-enrichment, which was then incubated for 18 hours at 37 °C. The Rappaport-Vassiliadis Broth and Muller Kauffmann Tetrathionate Broth were used for the enrichment step, which was carried out and incubated at 41.5 °C for 24 hours. On Bismuth Sulfite Agar and Xylose Lysine Desoxycholate Agar, respectively, the isolates were examined. *Salmonella* colonies were counted and quantified for the sample in colony-forming units per gram.

Total coliform count

Eosin Methylene Blue agar was inoculated with triplicate dilutions of 1 mL of 10^{-1} for each sample. To count the total number of coliforms (CFU/g) in the sample, triplicate dilutions were each cultured for 48 hours at 37 °C. Then, 10 sample colonies were chosen, each put into a tube of Brilliant Green Lactose Bile Broth, and tested to confirm that the colonies were coliform. The tubes were incubated at 35 °C, and after 24 and 48 hours, gas production was checked.

Yeast and mold count

On Potato Dextrose agar that had been treated with ampicillin, triplicate dilutions of 1 mL of 10^{-1} for each sample were plated to test for yeasts and molds.
To check for Yeast and mold counts (CFU/g) in the sample, each duplicate dilution was cultured for 7 days at room temperature.

Aerobic plate count (APC)

Eleven grams of G/nut flour were homogenized in peptone water in an Erlenmeyer flask, and 1 mL of a 10^{-2} dilution of the sample was inoculated in triplicate on plate count agar and incubated at 37 °C for 48 hours. The average number of colonies per gram (CFU/g) for the sample was calculated after counting each colony.

2.7 Physicochemical Characteristics of Groundnut flour *Yeast and mold count*

The groundnut flour samples were analyzed to determine their moisture, ash, crude protein, crude fiber, fat, and carbohydrate contents, respectively, following the procedures outlined by Chouhan (2015).

Moisture content

Porcelain crucibles were washed, heated, and dried at 100ºC in a hot air oven for 60 minutes, cooled in a desiccator, and weighed using an electronic balance, Adam (Model PW254, UK). The G/nut flour samples were placed in clean, oven-dried crucibles, and then 10–12 g of each sample was weighed. The crucibles containing the sample were placed on the oven's base for even distribution of heat. They were vacuum-dried for 48 hours at 105°C in a thermostatically controlled oven to a constant weight. When the time was over, the crucibles and their contents were taken out and weighed after cooling in a desiccator. There were three duplicates of each sample. Samples were analyzed, and mean readings were obtained per sample. The % water loss by each sample was calculated to obtain the moisture content as follows;

$$\text{Moisture Content (\%)} = \frac{M1-M2}{M1-MO} \times 100 \quad (1)$$

Where, M0 = weight of the Porcelain crucible,
M1 = weight of the fresh sample plus the crucible, and
M2 = weight of the dried sample plus the crucible.

Total ash content

The porcelain crucible containing the dried samples was gently preheated in an oven at 105°C for about 1 hour, transferred to a Biobase Muffle Furnace (model MR 417-TP, China), and heated there overnight at 550°C. It took several heating cycles to completely burn out all of the carbon particles. The heating was switched off after the allotted amount of time had elapsed. After being removed from the furnace and allowed to cool in a desiccator, the ash in the crucible was weighed once again using an electronic balance built by Adam (Model PW254, UK). The ash content as a proportion of the original sample was calculated.

$$\text{Ash content (\%)} = \frac{\text{Weight of ash}}{\text{Weight of sample}} \times \frac{100}{1} \quad (2)$$

Crude protein

Crude protein was determined using the Kjeldahl technique described by Famurewa *et al.* (2021). The process involved digesting the sample, distilling it, and titrating the result. A 100 mL Kjeldahl flask was filled with around 0.2 g of the sample. The Kjeldahl flask was filled with 4.4 mL of the concentrated sulfuric acid (H_2SO_4) solution. The flask was heated for 2 hours at 360°C (until frothing stopped) in an angled position on a heating mantle within a fume cabinet. When the content inside the Kjeldahl flask turned green, the heating was stopped, and the flask was left to cool. Immediately after digestion, the digests were quantitatively transferred into 100 mL volumetric flasks and diluted to the necessary volume. A steam distillation system was set up. For roughly 20 minutes, distilled water was used to cleanse the distillation equipment. Following a thorough cleaning of the equipment, 5 milliliters of boric acid indicator solution were poured into a 100-milliliter conical flask, which was placed beneath the condenser with the receiver tube's tip completely submerged beneath the surface of the standard solution of 20 % boric acid. All of the ammonia was distilled into the boric acid solution after the material was heated in a heating mantle. To make the solution alkaline and to start distillation right away, 10 mL of a 50 % NaOH mixture was carefully added, and the distillate was collected. The distillate in the receiver flask was treated with 3 drops of the indicator (wine red), and the solution was titrated with 0.1N HCl solution until the solution's color changed from green to wine red. Using all the reagents in identical amounts but without the sample to be analyzed, a digestion blank determination was performed, and the result was subtracted from the sample's titre value. The resulting titre values were utilized to determine nitrogen concentration and, in turn, the quantity of protein. It was converted using a factor of 6.25 (Udosen *et al.*, 2017). The total nitrogen percentage by weight (on a moisture-free basis) was

$$\text{Total Nitrogen (\% N)} = \frac{(\text{Sample titre value} - \text{Blank titre value}) \times 0.1 \times 0.01401 \times 100}{\text{sample weight} \times 10} \quad (3)$$

$$\text{Wt. (dry basis)} = \frac{0.014\ (V1-V2) \times NA}{(100-M)/100} \times \frac{100}{1} \quad (4)$$

Where Wt. = sample weight, V_1 = test value, V_2 = test value of blank and N_A = acidity normality. M = percentage moisture, 0.014 = 1 g mole of nitrogen, % crude protein = % nitrogen x 6.25. (6.25 was the factor used for the conversion of nitrogen value to protein content of the sample).

Crude fibre content

Sodium hydroxide, 1.25 %, and 12.5 g of NaOH were dissolved in 700 mL of distilled water and then diluted to volume in a 1000 mL volumetric flask. Sulfuric Acid, 1.25 %, Added 12.5 g of concentrated sulfuric acid to a volumetric flask that has been diluted to volume with 400 mL of distilled water. The sample was weighed and placed into a boiling flask along with 100 mL of a 1.25 % sulfuric acid solution. The flask was then allowed to boil for 30 minutes. A numbered sintered glass crucible

was used to filter the acid after it had been boiled. 100 mL of the 1.25 % NaOH solution was added after the residue had been poured back into the boiling flask. The mixture was allowed to boil for 30 minutes after being rinsed three times with hot water and methanol. After the boiling, the filtering continued. The remaining material was poured into a sizable porcelain crucible, dried overnight at 105°C with the sample, and weighed using an electronic balance. For roughly 4 hours, the contents of the crucible were burned at 500°C using a Biobase Muffle Furnace (model MR 417-TP, China). The crucible containing the ash was weighed after cooling it in a desiccator. The following equation was used to compute the percentage content of crude fiber:

$$\text{Crude fiber (\%)} = \frac{\text{Weight of crucible + weight of ash residue}}{\text{Total weight of sample}} \times \frac{100}{1} \quad (5)$$

Crude fat content

The Soxhlet extraction method was used to calculate the fat content of groundnut flour. Using an electronic balance, Adam (Model PW254, UK) weighed a clean, empty 50 X 10 mm thimble and recorded the weight as (W1); it was reweighed after being filled with roughly 10–12 g of the G/nut flour sample and recorded as (W2). The cotton wool-wrapped thimble was put into the extraction barrel of known weight (W3) that contained the solvent. This was transferred to a Soxhlet extractor with a 50 mL capacity. Around 150 mL of petroleum ether (40:60) was put into a 250 mL round-bottom flask that had been well cleaned and dried. The round-bottom flask was attached to the Soxhlet extraction kit and set on the heating mantle as a source of heat, with the condenser securely fastened in place. Gently boiling the solvent caused it to evaporate and reflux into the barrel. The evacuation took 6 hours to complete. The flask was removed and then dried in an oven at a temperature of 60°C for 2 hours until a constant weight was reached and recorded as (W4). This was done shortly after the round-bottom flask was taken out of the oven, left to cool in a desiccator, and then taken out of the apparatus. The following equation was used to compute the proportion of fat or oil:

$$\text{Crude Fat (\%)} = \frac{\text{Weight gain by the flask}}{\text{Weight of sample}} \times \frac{100}{1} \quad (6)$$

$$\text{oilcontent (\%)} = \frac{W4 - W3}{W2 - W1} \times \frac{100}{1} \quad (7)$$

Where W1 = weight of thimble, W2 = weight of thimble + sample, W3 = weight of flask and
W4 = Weight of flask + crude fat.

Nitrogen-free extract (carbohydrates)

The amount of total carbohydrates was calculated by subtracting the sum of the percentages of other components from 100. Content of carbohydrates = 100 - (moisture + protein + fat + ash + fiber).

2.8 Coor attributes of groundnut flour

Using a real-time automatic color difference meter, the color measurements of the groundnut flour (L*, a*, and b*) were analyzed according to Hunter's specifications (Ocean Optics, 77,501, 400 µV) following a method described by Abano, Quayson, Bosompem, and Quarm (2019). The color difference meter was turned on and left in Read mode for 30 minutes to warm up. The color difference meter was then accurately calibrated before analysis. Calibration was done in such a way that the standard black was measured first, and then the white standard tile. After calibration, the groundnut flour sample was put into the petri dish, the meter was placed over the sample, and the "Read sample" button was selected on the menu to get the color measurements. The sample measurement was done in triplicate per sample. From Ocean Optics' Spectra Suite data processor, the processed data was extracted from the Ocean Optics Spectra Suite data processor, and the color readings were displayed as L*, a*, and b* values. L* (white = 100, black = 0), a* (red = positive (+60), green = negative (-60)), and b* (yellow = positive value, blue = negative value). For all other samples, this process was repeated, and color values were noted. The hue angle (h*) was calculated using the equation;

$$h^* = \tan^{-1}\left(\frac{b^*}{a^*}\right) \quad (8)$$

3. RESULTS AND DISCUSSION

3.1 Result

Microbial loads (*E. coli*, *Salmonella*, coliform, yeast, and molds) in groundnut flour collected from Central and Southern regions of Malawi are presented in Tables 1 and 2, respectively.

Table 1. Microbial loads in groundnut flour sourced from the Central Region

	Microbial loads (CFU/g)				
Market	*E. Coli*	*Salmonella*	Total Coliform	Yeast & Molds	TPC
CA	Abs	Abs	20	40	35
CMA	Abs	40	80	20	30
DA	10	Abs	30	15	60
DZ	Abs	Abs	Abs	40	12
KO	26	Abs	13	30	52
KU	20	Abs	60	12	14
LD	Abs	Abs	11	Abs	20
LL	Abs	Abs	24	90	58
MA	Abs	Abs	12	11	56
MC	Abs	Abs	50	60	Abs
MD	Abs	Abs	Abs	80	13
MP	Abs	Abs	20	50	14
MV	Abs	Abs	40	10	112
NA	Abs	Abs	30	16	21
NKA	Abs	Abs	15	20	19
SA	Abs	Abs	Abs	70	28

Abs stand for "absent."
Key: CA = Chamama, CMA = Chatoloma, DA = Dowa, DZ = Dedza, KO = Kamwendo, KU = Kasungu LD = Lumbadzi, LL = Lilongwe, MA = Mkanda, MC = Mchinji, MD = Mitundu, MP = Mponela, MV = Mvera,

NA = Nambuma, NKA = Nkhamenya, and SA =Salima local market.

Table 2. Microbial loads in Groundnut Flour sourced from the Southern Region

Market	Microbial loads (CFU/g)				
	E. Coli	Salmonella	Total Coliform	Yea & Molds	TPC
BA	Abs	10	30	30	45
BE	Abs	Abs	10	50	70
BT	Abs	Abs	10	10	50
CE	Abs	Abs	Abs	11	33
CU	Abs	Abs	60	50	55
GA	Abs	Abs	Abs	10	22
GI	30	Abs	Abs	12	41
LB	Abs	Abs	23	15	37
LE	Abs	70	30	11	12
LU	Abs	Abs	20	50	11
MJ	20	Abs	13	60	35
ML	Abs	Abs	26	50	47
MN	Abs	Abs	60	20	11
MR	20	Abs	37	80	45
MZ	Abs	Abs	31	50	210
NJ	Abs	Abs	15	20	16
NO	Abs	Abs	13	40	35
NX	10	30	40	70	85
TO	Abs	Abs	10	50	102
UL	Abs	20	14	40	56
ZA	Abs	Abs	Abs	10	Abs
ZW	Abs	Abs	60	Abs	60

Abs stand for "Absent"
Key: BA = Balaka, BE =Bvumbwe, BT=Blantyre, CE = Chingale, CU = Chiradzulu, GA = Govala, GI = Goliati, LB= Limbe, LE = Liwonde, LU = Lunzu, MJ = Mulanje, ML = Muloza, MN = Mwanza, MR = Manjawira, MZ = Mbulumbuzi, NJ= Njuri, NO = Nkando, NX = Ndirande, TO = Thyolo, UL = Ulongwe, ZA = Zomba and ZW = Zalewa local market

Table 3. Results of Proximate Analysis of G/Nut Flour (Central Region)

	Proximate composition (%)					
Market	**Moisture**	**Protein**	**Fat**	**Ash**	**Fibre**	**Carbohydrate**
CA	5.98^{a}	25.43^{c}	30.87^{cb}	2.96^{abcde}	6.21^{bc}	34.52^{g}
CMA	6.49^{b}	24.35^{a}	33.56^{d}	3.14^{ef}	6.67^{cdef}	32.29^{f}
DA	7.06^{cde}	26.45^{de}	38.55^{f}	3.16^{ef}	7.16^{fg}	24.68^{b}
DZ	7.69^{fg}	23.63^{a}	37.46^{ef}	3.08^{de}	6.76^{cdef}	29.07^{d}
KO	6.56^{b}	28.30^{f}	42.49^{g}	3.04^{cde}	7.02^{ef}	19.15^{a}
KU	6.58^{bc}	27.42^{f}	31.36^{c}	3.15^{ef}	6.35^{bcde}	31.73^{f}
LD	6.44^{ab}	24.26^{a}	30.61^{bc}	2.75^{abc}	6.95^{def}	35.43^{gh}
LL	7.80^{fg}	24.25^{a}	38.29^{f}	2.96^{abcde}	7.80^{g}	26.70^{c}
MA	7.84^{g}	24.42^{ab}	28.82^{a}	2.99^{bcde}	6.96^{def}	36.81^{h}
MC	6.87^{bcd}	25.35^{bc}	30.61^{bc}	2.89^{abcde}	6.28^{bc}	34.87^{g}
MD	7.34^{def}	24.38^{a}	29.71^{ab}	2.70^{a}	7.24^{fg}	35.96^{gh}

Proximate composition (%)						
Market	**Market**	**Market**	**Market**	**Market**	**Market**	**Market**
MP	6.59^{bc}	30.67^{g}	30.70^{bc}	2.99^{bcde}	6.00^{ab}	29.64^{de}
MV	7.51^{efg}	26.15^{cd}	32.94^{d}	2.71^{ab}	7.13^{f}	31.07^{ef}
NA	6.62^{bc}	27.37^{ef}	36.84^{e}	3.11^{e}	6.14^{abc}	26.54^{c}
NKA	6.54^{b}	26.20^{cd}	30.01^{b}	2.80^{abcd}	5.53^{a}	35.45^{gh}
SA	7.49^{efg}	25.43^{c}	37.90^{ef}	3.41^{f}	6.33^{bcd}	26.93^{c}

Means that are not identical (P < 0.05) are significantly different.
Key: CA = Chamama, CMA = Chatoloma, DA = Dowa, DZ = Dedza, KO = Kamwendo, KU = Kasungu, LD = Lumbadzi, LL = Lilongwe, MA = Mkanda, MC = Mchinji, MD = Mitundu, MP = Mponela, MV = Mvera, NA = Nambuma, NKA = Nkhamenya, and SA = Salima local market.

Table 4. Results of Proximate Analysis of G/nut Flour (Southern Region)

Proximate composition (%)						
Market	Moisture	Protein	Fat	Ash	Fibre	Carbohydrate
BA	6.55^{ab}	24.64^{de}	30.70^{b}	2.93^{abcde}	5.67^{a}	36.06^{ij}
BE	7.44^{def}	23.66^{abc}	43.90^{k}	2.78^{abc}	6.85^{bcde}	22.81^{ab}
BT	6.15^{a}	24.85^{ef}	41.15^{j}	3.43^{f}	5.94^{ab}	24.62^{c}
CE	7.25^{cde}	23.64^{ab}	35.52^{fg}	3.22^{def}	7.06^{cdef}	30.57^{ef}
CU	6.08^{a}	24.39^{bcde}	31.93^{bcd}	3.09^{cdef}	6.15^{abc}	34.44^{hi}
GA	6.78^{bc}	23.76^{bc}	28.71^{a}	2.65^{ab}	7.00^{cdef}	37.87^{k}
GI	6.62^{ab}	24.12^{bcde}	29.03^{a}	3.10^{cdef}	6.78^{bcde}	36.97^{jk}
LB	7.34^{cde}	25.67^{fg}	35.59^{g}	2.97^{abcde}	6.35^{abcd}	29.43^{de}
LE	7.37^{cde}	22.83^{a}	31.62^{bc}	3.17^{cdef}	6.40^{abcde}	35.98^{ij}
LU	6.94^{bcd}	27.34^{h}	38.03^{hi}	2.97^{abcde}	7.27^{efg}	24.40^{bc}
MJ	6.53^{ab}	25.64^{fg}	31.25^{bc}	3.19^{def}	6.61^{bcde}	33.3^{gh}
ML	8.01^{f}	24.49^{cde}	31.74^{bc}	2.95^{abcde}	7.10^{defg}	33.72^{gh}
MN	7.37^{cde}	27.01^{h}	32.64^{cd}	2.84^{abcd}	7.87^{fg}	29.64^{de}
MR	6.86^{bcd}	24.47^{bcde}	33.22^{de}	2.87^{abcd}	6.85^{bcde}	32.59^{g}
MZ	6.60^{ab}	26.95^{h}	34.14^{ef}	2.76^{abc}	6.62^{bcde}	29.53^{de}
NJ	6.61^{ab}	26.89^{h}	31.66^{bc}	3.13^{cdef}	6.34^{abcd}	31.99^{fg}
NO	6.15^{a}	25.59^{fg}	31.02^{b}	3.09^{cdef}	5.95^{ab}	34.35^{hi}
NX	6.62^{ab}	23.91^{bcd}	36.77^{gh}	2.57^{a}	6.18^{abc}	30.56^{ef}
TO	6.40^{ab}	26.62^{h}	38.21^{i}	3.01^{bcde}	6.71^{bcde}	25.45^{c}
UL	7.39^{de}	25.74^{g}	36.43^{g}	3.30^{ef}	5.95^{ab}	28.58^{d}
ZA	7.72^{ef}	24.07^{bcde}	42.67^{k}	2.91^{abcde}	7.97^{g}	22.37^{a}
ZW	6.98^{bcd}	26.77^{h}	40.82^{j}	2.90^{abcde}	6.70^{bcde}	22.81^{ab}

Means that are not identical (P <0.05) are significantly different.
Key: BA = Balaka, BE = Bvumbwe, BT= Blantyre, CE = Chingale, CU = Chiradzulu, GA = Govala, GI = Goliati, LB= Limbe, LE = Liwonde, LU = Lunzu, MJ = Mulanje, ML = Muloza, MN = Mwanza, MR = Manjawira, MZ = Mbulumbuzi, NJ= Njuri, NO = Nkando, NX = Ndirande, TO = Thyolo, UL = Ulongwe, ZA = Zomba and ZW = Zalewa local market.
As illustrated in Figure 3, the study's findings indicated that total Coliform is the second most common contamination after yeast and mold. The least contaminant was a *Salmonella* species. The nutritional composition (Ash, carbohydrates,

fats, proteins, moisture content, including fibre content) of groundnut flour is shown in Figure 4.

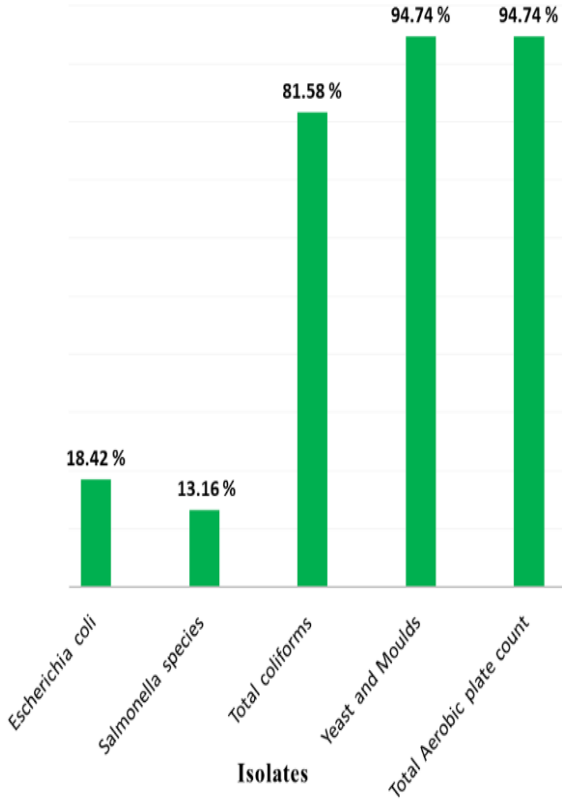

Figure 3. Proportion of microbial isolates found in groundnut flou

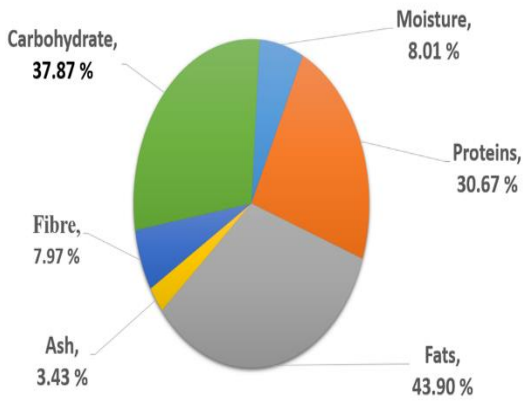

Figure 4. Percentage of the nutritional Composition of groundnut flour

Coor attributes of groundnut flour

One of the crucial aspects of a food product's quality index that influences how customers view it is its color (Hebbar & Kanade, 2017). Tables 5 and 6 show the color values that were found for groundnut flour sourced from the Central and Southern Regions of Malawi, respectively. Furthermore, the standard appearance of groundnut flour is shown in Figure 5.

Table 5. Color properties of Groundnut Flour (Central Region)

Market	L*	a*	b*	Hue
NKA	56.01	3.75	16.87	77.44º
CMA	56.22	4.55	16.47	74.55º
CA	53.99	2.33	17.04	82.19º
KU	57.54	2.64	17.88	81.61º
MA	59.32	4.52	16.13	74.33º
MC	57.15	3.76	18.10	78.26º
KO	58.32	5.78	15.71	69.74º
NA	57.30	4.61	16.33	74.24º
MP	56.54	3.52	6.44	77.93º
DA	55.63	4.50	17.50	75.57º
LD	57.46	3.03	16.14	74.89º
MV	56.66	2.50	15.50	80.82º
MD	53.90	3.54	15.13	76.75º
LL	51.99	4.24	13.12	72.06º
DZ	57.75	5.72	14.94	69.07º
SA	59.15	5.052	17.23	73.64º

Notes: **L*** = black to white; **a*** = green to red; **b*** blue to yellow.
Key: CA = Chamama, CMA = Chatoloma, DA = Dowa, DZ = Dedza, KO = Kamwendo, KU = Kasungu, LD = Lumbadzi, LL = Lilongwe, MA = Mkanda, MC = Mchinji, MD = Mitundu, MP = Morella, MV = Mvera, NA = Nambuma, NKA = Nkhamenya, and SA =Salima local market.

Figure 5. The standard appearance of groundnut flour

3.2 Discussion

Implications

All samples across the 2 regions (100 %) were contaminated by single or multiple microorganisms

(Tables 1 and 2). *Escherichia coli*, *Salmonella* species, and total coliforms showed levels of contamination ranging from 0 to 2.6 x 10^1, 7.0 x 10, and 3.7 x 10^1 CFU/g, while yeast and mold counts and total aerobic plate count (TPC) ranged from 0 to 2.0 x 10^1 and 2.1 x 10^2 CFC/g, respectively. From the perspective of food safety, these results indicate that the groundnut flour studied contained microbial loads. This could be due to weaknesses in the production process. Furthermore, the results might be associated with poor hygienic practice during and after processing, packaging, and or sales in the local markets. The presence of coliform/enteric bacteria such as *E. coli*, is unacceptable because it is an indication of contamination probably either by faecal and or via other means of contamination such as unhygienic environmental conditions, poor personal hygiene during production, waters and utensils used during processing and after, packaging in polythene bags, hawking and so on (Adesakin & Obiekezie, 2020). The levels observed were 13.16%, 18.42%, and 81.58 % for *Salmonella* species, E. *coli*, and total coliforms, and all did not comply with the Malawi groundnut flour specification (DMS 1275:2022) (MBS, 2017). The microbiological permissible limit for groundnut flour is 10^4 CFC/g (MBS, 2017). Yeast and mold count and TPC met acceptable standards because the results were below 10^4 CFC/g. A comparison between groundnut flour and the specification (DMS 1275:2022) helped to assess the samples' level of microbiological quality because the Malawi food laws (MBS, 2017) exclude the groundnut flour microbial requirements.

The results were also compared with the Microbiological Assessment Standards for Safety of Ready-to-Eat Foods and the Compendium of Microbiological Criteria for Food (Kai, 2016). The high bacterial loads were below the recommended standard of the FDA (1.0×10^5) as allowable microbial contamination for food (State et al., 2025). The findings revealed that microbial loads should not exceed 5 x 10^5 CFU/g. However, *E. coli* and *Salmonella* should be absent in all the G/nut flour samples (State et al., 2025). Continuous consumption, especially large quantities, could lead to foodborne illnesses such as diarrhoea, enteric fever, salmonellosis, and others (Anyanwu *et al*., 2016). However, it has already been documented that both microbes are present in groundnut products worldwide (Anyanwu *et al*., 2016). Malawi has a very high incidence of outbreaks of *Salmonellosis* in human beings, with 444 cases per 100,000 persons per year (Teklemariam et al., 2023). This could be attributed to the consumption of contaminated peanuts with *Salmonella*.

The presence of *E. coli* suggested that the groundnut flour had been handled in an unsanitary manner throughout processing, storage, packaging, transportation, and sale. However, the discovery of *E. coli* in the groundnut flour was consistent with research done by Patil *et al.* (2019), who also found *E. coli* in their groundnut paste samples. Furthermore, the presence of *Salmonella* in groundnut flour is potentially hazardous because the data show that microbiological levels are higher than anticipated (Kai, 2016). This may emanate from inadequate processing of G/nut flour or may be due to cross-contamination during processing and handling. Since its discovery, however, *Salmonella* has continued to be a common and ongoing issue in the food supply. Therefore, careful adherence to good manufacturing procedures (GMP) is necessary for *Salmonella* control (Carminati *et al.*, 2016). The study of food contamination by molds is important because there is also a risk to human health due to the probable development of mycotoxins. These results, albeit at first seeming paradoxical, may be a result of some hygienic improvements made to the entire process of obtaining artisanal groundnut flour.

Patil *et al.* (2019) reported that 50 % of the groundnut-derived products sourced from various local markets and shops were contaminated with microbial loads that varied from 1.7×10^2 to 4.9×10^6 cfu/g, respectively. Similar to total aerobic plate count, yeast and mold count range from 2.3×10^2 to 4.8×10^5 CFU/g and 1×10^2 to 1.45×10^6 cfu/g, which is in contrast to the results of the present investigation. Spices and herbs are comparable to groundnut flour in terms of nutrients and microbiological development (Aparecida *et al.*, 2015). *Escherichia coli*, *Salmonella*, total Coliform, Yeast, and molds were found in herbs and spice preparations of ready-to-eat meals, according to Spence, (2016) investigation. Total Aerobic Plate Count (TPC), which is a quality assessment that also includes extended shelf-life meals, is a quality indicator rather than a safety indicator and cannot be used to directly assess the safety of groundnut flour. Groundnut flours are typically exposed to the environment through their direct handling, packaging, and storage conditions, which may be a factor in the varied moisture content levels observed in the study. The mean moisture content (Tables 3 and 4) ranged from 5.98 to 8.01 %. According to Iwe *et al.* (2016) the groundnut flour samples' moisture content obtained in the study was below the threshold for spoilage by microorganisms (< 9%), and this showed good shelf stability of *nsinjiro*. According to Patil *et al.* (2019), processed cereals and legumes should have a moisture content between 3% to 8% on a dry basis. The low moisture level of the groundnut flour was consistent with Ocheme *et al.* (2018) findings for groundnut powders. Odeniyi *et al.* (2019) recorded moisture content ranging from 1.15 ± 0.05 to 9.14 ± 0.03 % in representative ready-to-eat groundnut-derived product samples.

The results of proximate analysis for groundnut flour showed a high overall protein level ranging from 22.83 to 30.67 %, with the highest value found in the sample from the Mponela market, while the lowest values were observed in the sample from the Liwonde local market, respectively. The results indicate nutrient density and digestibility in groundnut flour (Chinma *et al*., 2021). The samples' protein content varied from 22.83 to 30.67%, and this could be due to the processing technique, as proteins normally decrease or are even lost with an increase in drying air and temperature by denaturation, probably because of the release of amino

acids. The study found that the fat content of G/nut flour ranged from 28.71 to 43.90%. Due to the product's moderate susceptibility to fatty acid-mediated rancidity, this is a sign of improved shelf stability (Chinma *et al.*, 2021). The ash and fiber contents ranged from 2.57 to 3.43% and 5.67 to 7.97%, respectively. The results could be attributed to groundnuts' high mineral and fiber contents (Darbe & Tange, 2018). Ash is an indirect indicator of the higher inorganic content and minerals present in groundnut flour. The carbohydrate content ranged from 19.15 to 37.87%, relatively high in the Govala market sample. This suggests that groundnut flour would provide the necessary energy to satisfy consumer demand. Overall, the proximate analysis showed that groundnut flour is rich in nutrients (Figure 4) essential for human health and enough to satisfy the dietary demands for energy and protein of people susceptible to malnutrition (Mupunga *et al.*, 2017). This means that it is consistent with UN Goal No. 2 (United Nations, 2016).

The color of G/nut flour samples (Tables 5 and 6) ranged from L* (49.79 ± 6.731 to 59.88 ± 0.430), a* (2.33 ± 0.297 to 5.78 ± 0.168), and b* (13.12 ± 0.761 to 18.10 ± 0.779), respectively. Luminosity (L*) ranged from being light (high L* value = 59.88 ± 0.430) to less light (lower L* value = 49.79 ± 6.731). These findings have shown that the color is consistent with the standard appearance of the groundnut flour (Figure 5). These results agree with what Ijarotimi *et al.* (2022) reported for processed groundnut flour samples; the color was lighter (high L* = 57.24), while the other was less light (lower L* value = 40.76). According to Ijarotimi *et al.* (2022), groundnut flour typically takes on the hue of the groundnuts, with coloration varying from light brown to dark red. Groundnut flour samples' hue angle is another color quality metric utilized, and the study's results showed a range of values between 69.74 ± 1.489° and 82.19 ± 1.292°; all the values were lower than 90°.

According to Ijarotimi *et al.* (2022), all processed groundnut flour samples had hue angles (H) that were less than 90 degrees, with the greatest value (57.74°) and the lowest value (49.73°). The hue angle measures how much a color deviates from a grey color with a comparable brightness. Food color is a crucial sensory component of food acceptance. It significantly impacts expectations for flavor perception, food preference, pleasantness, and acceptability, which play a crucial part in food choice.

During groundnut flour processing, the Maillard and enzymatic reactions between proteins and reducing sugars are what essentially regulate color formation (Cheng & Bhat, 2016).

Research contribution

The study findings have contributed knowledge on the safety of groundnut flour sold in various local markets of Malawi in relation to levels of microbial loads, particularly in the study regions. The study has also generated baseline information for government sectors and agencies to enact policies aimed at improving food safety regulations. The data produced ought to aid in the creation of policies that would fight malnutrition and enhance the standard of living for those who sell groundnut flour. The research has revealed that groundnut flour sold in various local markets around Malawi's Central and Southern Regions is light in color and nutritious; however, it requires adequate sanitary conditions for its processing and sale.

Limitations

The study used a small sample size. Thirty-eight (38) of 71 local markets were included in the study following the inclusion and exclusion criteria. All markets that had fewer than 5 groundnut flour sellers were not included in the research. There was no specific funding for this research. Aflatoxin levels were not assessed in this research.

Suggestions

Microbial contamination in groundnut flour appears to be an endemic problem in all the local markets across the 2 regions, so it deserves a closer research emphasis, intending to curtail the resultant adverse health effects. Moisture content is utilized as a good quality indicator for groundnut flour. The variation in color of the groundnut flour can be attributed to the whole artisanal flour-obtaining process, genetic background, agronomic practices, and age of the groundnuts, including processing treatments before groundnuts are milled into flour.

4. CONCLUSION

The present findings confirm the general status of microbiological quality, nutritional composition, and physicochemical characteristics in groundnut flour sold from various local marketplaces in Malawi. These results indicate that the groundnut flour studied was susceptible to microbial contamination; hence, hygienic monitoring before marketing is required.

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AUTHOR CONTRIBUTION STATEMENT

The idea to conduct the research and write all aspects of this manuscript was conceptualized by ACB, while DM contributed the study area's partial map showing the location where samples were collected.

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