International Journal of Agriculture and Environmental Research

ISSN: 2455-6939

Volume: 09, Issue: 05 "September-October 2023"

NUTRITIONAL AND MICROBIOLOGICAL EVALUATION OF TAMARIND SEED FORTIFIED CORN FLOUR

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DOI: https://doi.org/10.51193/IJAER.2023.9511

Received: 18 Oct. 2023 / Accepted: 29 Oct. 2023 / Published: 30 Oct. 2023

ABSTRACT

Food fortification involves the addition of micronutrients to foods and is an intervention used for the prevention of micronutrient deficiencies worldwide. This study developed a tamarind seed fortified corn flour and assessed the nutritional and microbial safety properties. Ten samples of de-husked maize flour were randomly selected from five maize millers located within Kongowea in Mombasa County. The seeds were dried at 100°C for 30 minutes in a hot air oven, roasted at 180^{O}c for 20 minutes, de-husked manually, then ground to a fine powder in an electric grinder. The milled maize flour was mixed with inclusions of 10%, 20%, 30%, 40% and 50% of the tamarind powder. Samples were subjected to proximate analysis, minerals assayed by ICP-OES and *aflatoxin* test using ELISA. Data was analyzed using SPSS and mean differences; post ANOVA test was done using the least squares differences (LSD) method. The results for proximate analysis were 12.48% moisture content, 2.26% fiber, 15.36% protein, 0.68% ash, 23.07 ppm iron and 17.66 ppm zinc. The results for aflatoxin in the blended flour samples were 11.28 ppb. Tamarind has the capacity to diversify the livelihood through value addition and product development.

Fortification of corn flour with tamarind seed can provide a sustainable alternative to the current approach of chemical fortification.

Keywords: Fortification, De-husked maize, Tamarind seed.

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1. INTRODUCTION

Tamarind (*Tamarindus indica L*) is a tree that belongs to the family *Leguminosae* (*Fabaceae*) and subfamily *Caesalpinioidae* which is native to the dry Savanna of tropical Africa [25]. It is indigenous to tropical Africa but has become naturalized in North and South America and is also cultivated in subtropical China, India, Pakistan, Philippines and Spain. India is the world's main producer and consumer of tamarind fruits [13]. The tamarind tree has the ability to grow in poor soils and in semi arid conditions because of their nitrogen fixing capability and ability to withstand long periods of drought [7]. Tamarind tree plays a major role in many aspects of life and is used either for nutritional, medicinal or industrial value [27].

In Kenya, tamarind fruit value chain is yet to be developed since the fruit is mainly considered wild. Nevertheless, there is growing interest in the domestic and export markets due to its multiple uses. There is very limited documentation on the production and marketing of tamarind in Kenya and the existing information is only known to a few market actors. The largest market and destination for tamarind trade in Kenya is in Kongowea market, Mombasa County and some specialty super markets [30].

The fruit contains about 55% pulp, 34% seed, 11% shell, and fibre in a pod [18]. Only a small portion of the seed, in the form of tamarind kernel powder is used as a sizing material in the textile and paper industries. Therefore, tamarind seed is an underutilized by-product during the processing of tamarind. The seeds are hard, shiny and appear red-purple brown in color [11]. Tamarind seeds are a good source of essential fatty acids and minerals particularly Calcium, Phosphorous, Iron, Zinc and Potassium. Tamarind powder has found application in food, cosmetics and pharmaceutical industries [28]. Despite the desirable nutritional features, tamarind seeds are not extensively utilized as food mainly due to the presence of antinutritional compounds such as total phenols, tannins and phytic acids. However, major antinutrients are mostly present in the seed coats and therefore separation of the test a during tamarind processing is vital [13].

Micro nutrient deficiency, or hidden hunger, is regarded a significant contributor to the global burden of disease and it is estimated that over 2 billion people in the world today are micronutrient deficient [21]. In Kenya, more than half of the morbidity and mortality cases among children are as a result of micro nutrient deficiencies. Therefore, food fortification has been considered by the Government of Kenya as a feasible strategy for addressing this condition [26]. Children can consume micronutrients from foods, through food fortification or direct supplementation [17].

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Worldwide, fortification has proven to be effective because it does not require any change in dietary habits. Typical foods fortified around the world are cereal flours (wheat and maize), pasta and noodles, milk, oil and margarines, among others. Grains are the most important sources of all the micronutrients studied and are therefore the leading source of iron and zinc. Maize is one of the world's most important cereal grain. In sub-Saharan Africa, some parts of Southeast Asia and Latin America, where iron deficiency is endemic, maize is a dietary staple for more than 200 million people [10]. It is one of the main staple foods in Kenya and constitutes a significant part of the daily diet. However, concerns on bioavailability and sensory quality resulting from iron fortification have previously been raised [14]. Fortification of wheat flour, maize meal, fats and oils was made mandatory through the amendment of the Food, Drugs and Chemical Substances Act of the Laws of Kenya CAP 254, Notice No 62 of June 2012. This law was amended again in July 2015 through Notice No. 157 to address micronutrient deficiencies among vulnerable groups of the population [12].

In this study, a food diversification approach is applied in which maize flour is fortified using tamarind seed as a substitute to the conventional chemical fortificants. It is anticipated that this approach will be more sustainable since tamarind seed is not only locally available but also the nutritional outcomes are promising. Therefore, this study sought to utilize tamarind seed as a source of iron and zinc for development of fortified corn flour with the aim of reducing micronutrient deficiencies.

2. MATERIALS AND METHODS

2.1 Sampling and sample preparation

The experimental materials (tamarind fruit and corn flour) were obtained from vendors in *Kongowea* market through simple random sampling. A total of 10 samples of tamarind fruit weighing 1 kg each were collected from different vendors. A total of 10 samples of dehulled maize flour (DMF) packaged in 1kg portions were picked across 5 grinding mills within the same area. Blended flour (BF) samples were obtained by mixing the dehulled maize flour (DMF) with tamarind seed in definite ratios. Fortified flour (FF) which is regular flour that contains added micronutrients during milling to improve its nutritional quality was obtained from different millers on the market and was used as a control.

The raw materials (DMF) were aseptically packaged and couriered to Government Chemist and Kenya Marine Fisheries Research Institute (KEMFRI) laboratories in Mombasa for immediate formulation and analysis. The tamarind seeds were inspected for quality aspects such as fruit maturity, presence of fungal, insect and pest infestation as well as absence of sand. The pulp and the seeds were separated by squeezing. The seeds were dried at 100°C for 30 minutes followed

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by cooling to room temperature. Thereafter the seeds were roasted at 180^{O}c for 20 minutes and de-husked manually using pestle and mortar and then ground to fine powder in an electric grinder. The milled maize flour was mixed with inclusions of 10%, 20%, 30%, 40% and 50% of the tamarind seed powder using a commercial electric powered blender.

2.2 Determination of proximate composition

Proximate composition of the raw material and blends were determined as follows: Moisture content was determined by the oven drying method according to AOAC, 2000 [23] method 930.04; Crude protein (N x 6.25) was determined using semi-micro Kjeldal method according to the AOAC, 2000 procedure 978.04; Crude ash was determined according to AOAC, 2000 method 923.05 and crude fibre was determined by the Hennenberg-Stohman according to AOAC 2000 method 920.86. Nutritional analyses were carried out in duplicate for both dehulled maize flour (DMF) and blended flour (BF).

2.2.1 Determination of Moisture Content (AOAC method 930.15)

The test samples were mixed sufficiently and a suitable quantity ground to give sufficient material for replicate determination. Approximately 5 grams of sample was weighed into a previously dried and tarred dish and placed with its lid underneath in the oven for 2 hours at 135°C. The dishes were removed after 2 hours, cooled in the desiccator and weighed. The specification for the size of the dish was also taken into account. The calculation for the moisture content was as follows;

% Moisture content= $(W_1-W_2)*100/W_1–W$

Where, W_1=Weight in grams of the dish with the material before drying

W_2= Weight in grams of the dish with the material after drying

W = Weight in grams of the empty dish

2.2.2 Determination of crude protein (AOAC method 2001.11)

The protein content was determined from the organic nitrogen content using Kjeldahl method where the various nitrogenous compounds were converted into ammonium sulphate by boiling with concentrated Sulphuric acid. The ammonium sulphate formed was decomposed with an alkali (NaOH) and the ammonia liberated absorbed in excess of a standard solution of 0.1M Hydrochloric acid and then back titrated with a standard solution of Sodium hydroxide.

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2 grams of the sample were weighed and transferred into a 500ml Kjeldahl flask taking care to see that no portion of the sample clings to the neck of the flask. To this was added 0.7 grams of Mercuricoxide, 15 grams of Potassium Sulphate and 40ml of concentrated Sulphuric acid (Mercuricoxide is added to increase the rate of organic breakdown during acid digestion). Three glass beads were added and the flask placed in an inclined position on the stand in the digestion chamber. The flask was heated gently at low flame until the initial frothing ceased and the mixture allowed to boil steadily at amoderate rate. The heating was continued until the color of the digest was pale blue. The digest was cooled and 200ml of water added slowly. Sufficient Sodium hydroxide solution (450gm/l) was poured carefully down the side of the flask to make the contents strongly alkaline before mixing the acid and alkaline layer. The flask was connected to a distillation apparatus incorporating an efficient flash head and condenser. To the condenser was fitted a delivery tube to dip just below the surface of the pipetted volume of standard acid contained in a conical flask receiver. Five drops of methyl red indicator were added and the mixture titrated with standardized 0.1 N Sodium Hydroxide solution. A blank titration was carried out simultaneously (1mlof 0.1 N H_2SO_4= 0.0014gmN)

Calculation

% Protein=N x 6.25

Protein on dry wt. basis= Protein content x100 /(100–Moisture content)

2.2.3 Determination of Acid Insoluble Ash (AOAC method 942.05)

To the ash contained in the dish, 25 ml of dilute Hydrochloric acid was added, covered with a watch glass and heated on a water bath for 10 minutes. The mix was allowed to cool and the contents of the dish filtered through a Whatman filter paper No 42. The filter paper was washed with water until the washings were free from acid, returned into the dish and dried in an electricovenfor3 hours. The dried sample was then ignited in a muffle furnace at 600°C until a white to grey ash was obtained.

Calculation

Ash Insoluble ash = $(W_2 – W) * 100/ (W_1 – W)$

Where;

W_2 = weight in grams of dish with the acid in soluble ash

W= Weight in grams of empty dish

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W_1= Weight in grams of the dish with the dried material.

2.2.4 Determination of Crude Fiber (AOAC method 962.09)

Crude fiber is the organic residue that remains after boiling defatted material successively with dilute Sulphuric acid and Sodium hydroxide solution. It is the sum of all the organic compounds and the supporting structure which during analysis remains after removing crude protein, fat and other nitrogen compounds.

The sample was accurately weighed into 2 grams quantity, transferred into a Soxhlet extraction apparatus and extracted with petroleum ether. The extracted sample was then transferred into a dry 1000ml conical flask to which was added 200ml of preheated dilute Sulphuric acid (1.2g of H_2SO_4 per 100ml of water). The mixture was boiled under reflux for exactly 30 minutes, the flask removed and content filtered through fine linen (about 18 threads to a cm) held in a funnel and washed with boiling water until the washings were no longer acid to litmus. A preheated solution of 200ml sodium hydroxide (1.25g NaOH per 100ml distilled carbon free water) was added and boiled for 30 minutes. The contents were removed from the flask and immediately filtered through the filtering cloth. The residue was thoroughly washed, first with hot water and then with 15 ml of ethyl alcohol. The crucible contents were dried at 105±2° Cinanairoven until constant weight achieved then cooled and the weight recorded. The contents were placed in a weighed crucible and incinerated in a muffle furnace until all carbonaceous matter was burnt then cooled in a desiccator and weighed.

Calculation

Crude fiber % by weight= $(W_1 – W_2)$ *100/W

Where;

W_1 = weight in grams of dried residue

W_2= weightin grams of the ash

W= weight in grams of the sample

2.3 Determination of total iron and zinc by ICP-OES

The minerals were determined by inductively coupled plasma optical emission spectrometry (ICP-OES). Sediment samples were treated in closed Teflon vessels with hydrofluoric (HF) acid in combination with nitric acid in order to decompose the samples. The use of HF is essential because it is the only acid that dissolves the silicate lattices to release all the metals. The reagents

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used were nitric acid (65% Suprapur, Merck), hydrofluoric (48% analytical grade), hydrogen peroxide (analytical grade), Boric acid crystals (analytical grade) and Milli-Q-deionized water. Thereafter sample bottles were homogenized for two minutes and allowed to rest a few minutes before opening the bottles. 0.2g of sample was weighed into a labelled Teflon Reactor into which 5 ml of nitric acid and 2ml of hydrofluoric acid were added. 2ml of hydrogen peroxide was added after a period of one hour, the reactor closed and put in a microwave that was set up as follows: Power 1200 W, Ramp time 10 minutes, Pressure 600 Psi, Temperature 190 °C and Holding time 12 minutes.

The samples were allowed to cool at room temperature, the pressure released carefully by opening the valve and the reactor opened. Boric acid (8g) was weighed into a polythene boat, transferred into the reactor and 15 ml of Milli-Q-deionized water added. The reactor was closed and put in a microwave oven that was set up as earlier explained.

The samples were allowed to cool down to room temperature, the pressure released carefully by opening the valve and the reactor opened. The weight of 50ml polyethylene tubes was recorded and labelled. The samples were transferred into 50ml polypropylene graduated tubes and the Teflon reactor rinsed with Milli-Q water 3 times while shaking. The tubes were cooled and diluted to the mark of 50ml with Milli-Q water, weighed and recorded. Two blanks were prepared for each batch of analysis.

2.4 Determination and quantification of total aflatoxinby enzyme linked immunosorbent assay (ELISA) method.

2.4.1 Sample preparation and extraction.

The sample was ground to pass through a 1mm aperture sieve and a fresh extraction solvent of 70:30 analytical grade methanol: deionized water prepared. A sample of 20g was weighed and to it added 100ml of the extraction solvent to make a ratio of 1:5 (w/v). The mix was shaken in a sealed container using a mechanical shaker for 30 minutes. The particulate matter was allowed to settle and then 50ml of the extract filtered through a Whatman number 41 filter paper for analysis.

2.4.2 Assay Procedure

All the kit reagents (conjugate, substrate, stop solution and six standards) were brought to room temperature before use for not more than one hour. One dilution well was placed in a microwell holder for each standard and sample that was tested. An equal number of antibodies coated microtiter wells were placed in another microwell holder and 200 microliters of the conjugate dispensed into each dilution well. Using a new pipette tip for each, 100 microliters of each

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standard and samples were added to appropriate dilution well containing conjugate mix by priming the pipette at least three times. Using a new pipette tip for each, 100 microliters of content were transferred from each dilution well into a corresponding Antibody Coated Microtiter Well and incubated at room temperature for 15 minutes. The contents from the microwells were carefully decanted into a discard basin, the microwells washed by filling each with distilled water and then discarding the water into a discard basin. This wash was repeated five times and the microwells were tapped face down onto a layer of absorbent towels to remove any residual water. The required volume of substrate reagent was transferred in to a clean container to avoid contamination of the kit reagents and 100 microliters of the substrate reagent added to each microwell followed by incubation at room temperature for five minutes. The required volume of the stop solution was transferred to a clean container and 100 microliters of the stop solution from the container added in the same sequence and at the same pace at which the substrate was added. The optical density (OD) of each microwell was recorded with a microtiter plate reader using a 450nm filter. The concentration of each sample was read and recorded in ppb (parts per billion).

There were no ethical considerations to be adopted prior to commencing the study.

2.5 Data analysis

The analyses of the samples were conducted in duplicate. Analysis of variance (ANOVA) and statistical protocol by Least significant difference (LSD) test ($p \leq 0.05$) using SPSS were used in the analyses.

3.0 RESULTS AND DISCUSSION

3.1 Proximate analysis

The nutritional composition of the raw material, formulated blends and the fortified flour are shown in the table below.

Table 1: Proximate composition of dehulled, blended and fortified maize flours (g/100g)

Sample	Moisture content	Fiber	Protein	Ash
DMF	12.011 ± 0.267^{a}	0.808 ± 0.037^{b}	5.737 ± 0.184^{a}	0.838 ± 0.033^{b}
BF	12.481 ± 0.075^{a}	2.264 ± 0.074^{c}	15.357 ± 1.094^{c}	0.685 ± 0.220^{d}
FF	12.185 ± 0.341^{a}	0.629 ± 0.029^{d}	12.574 ± 0.947^{b}	0.500 ± 0.016^{c}
P value	≤ 0.05	≤ 0.05	≤ 0.05	≤ 0.05

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Means within the same column with different superscripts were significantly different at (P≤0.05). Values are presented as means ± standard error, n=10. **DMF** – Dehulled maize flour, **BF** - Blended flour, **FF** – Fortified flour.

3.1.1 Moisture content

There were no significant differences (p=0.05) in the moisture contents of the dehulled maize flour, blended flour and the fortified flour. The moisture contents of the dehulled maize flour, blended flour and fortified flour were found to be 12.01%, 12.48% and 12.19% respectively. The low moisture content of the blended flour observed in this study could be an indicator of a longer shelf life of the product because grain moisture contents below 13% arrest the growth of most molds.

Maize flour is a powder produced from grinding maize for human consumption and it can be contaminated by molds at all phases of the production chain [2]. Flour is a very hygroscopic material and its moisture varies with the changes in temperature and humidity of the storage environment. The moisture content is essential in regard to its shelf life whereby lower the flour moisture is, the better its storage stability [6]. The process of conditioning of maize to increase the moisture content to an appropriate level for milling can increase the counts of microbial contaminants into the flour [5]. A Reduction of grain water content is most frequently realized by residual drying (moisture is less than 15%) and the storage stability is provided at a moisture of 12% [3]. Low grain moisture and suitable storage conditions are the key to ensuring high grain quality. *Asperigillus flavus* usually contaminate food products and synthesize aflatoxins as metabolites in the presence of elevated levels of carbohydrates and low levels of protein. The toxin production is firmly associated with high-carbohydrate and high-fat food [9].

3.1.2 Crude fiber

The results indicate that there were significant differences (p<0.05) in the crude fiber content between the dehulled maize flour, blended flour and the fortified flour. The crude fiber contents for the dehulled maize flour (DMF), blended flour (BF), and fortified flour (FF) were 0.808%, 2.264% and 0.629% respectively. The low fiber content of 0.808% in the dehulled maize flour is attributed to the separation of bran during the milling process. From the results, the crude fiber in the BF (2.26%) was found to be significantly high. However, based on findings of similar studies, the crude fiber content for dehulled maize was found to be 2.0% [1]. A more plausible explanation is because of the combination effect of the flour and tamarind seed, whose crude fiber was 2.20%. These results are in agreement with [11] who reported crude fiber levels of 2.30%. In a similar study, the composition of crude fiber in maize-millet flour blends of 70:30% was found to be 3.03% [4]. Crude fiber largely composed of cellulose and hemicellulose

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provides beneficial effects in humans by increasing water retention capacity during passage of food along the gut. A diet rich in crude fiber is considered healthy [8].

3.1.3 Crude protein

The results indicate that the crude protein contents for the dehulled maize flour, blended flour (80% maize: 20% tamarind) and fortified flour (the standard) were 5.74%, 15.36% and 12.57% respectively. Contrary to the hypothesized association, there was a significant difference ($p<0.05$) in the crude protein contents of the dehulled maize flour, blended flour and the fortified flour. The addition of tamarind seed significantly ($p<0.05$) improved the protein content of the blended maize flour to 15.36%. The study provides a new insight into the relationship between unfortified and fortified maize. The addition of tamarind seed significantly improved the protein content of the de-husked maize flour from 5.74 to 15.36% in the blended flour. Dehulled maize on average has a protein content between 6 - 13% depending on genetic and environmental factors [20]. The data contributes a clear understanding of the combination effect of maize flour and tamarind. The trend was similar in a study by Kamotho, 2019 in which maize fortified with grain amaranth exhibited an increase of up to 15.82%. Maize fortified with defatted pumpkin flour also increased up to 15.86% [15]. Therefore, the use of tamarind seed powder in the blends increases the biological value of the flour.

3.1.4 Ash content

The ash contents for the dehulled maize flour, blended flour and fortified flour were 0.84%, 0.69% and 0.50% respectively. BF had significantly ($p<0.05$) higher ash content (0.69%) than FF (0.50%). The ash content is directly related to the final level of phytic acid in the flour. The higher the ash content the greater the proportion of non-endosperm material. All the samples were within the acceptable range of up to 3 %.

Table 2: Levels of Iron and Zinc A in dehulled, blended and fortified maize flours

Sample	Iron	Zinc
DMF	11.712 ± 0.184^{a}	10.544 ± 0.087^{b}
BF	23.074 ± 1.745^{b}	17.660 ± 0.296^{d}
FF	50.377 ± 4.358^{c}	27.930 ± 1.793^{c}
P	≤0.05	≤0.05

Means within the same column with different superscripts were significantly different at ($P\leq0.05$). Values are presented as means ± standard error, n=10. **DMF** – Dehulled maize flour, **BF** - Blended flour, **FF** – Fortified flour.

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3.2 Micronutrient composition

3.2.1 Iron and zinc

BF was significantly (P<0.05) higher in iron (23.07 ppm) than DMF (11.71 ppm) but lower than FF (50.38 ppm). The iron content increased significantly (p<0.05) in the BF upon addition of tamarind seed up to 23.07 ppm from 11.71 ppm. Iron is a component of hemoglobin that transports oxygen to all body tissues. Additionally, it is a component of proteins and enzymes. Micronutrient deficiencies, especially those related to iodine and iron, are linked to different cognitive impairments, as well as to potential long-term behavioral changes. Among the cognitive impairments caused by iron deficiency, those referring to attention span, intelligence, and sensory perception functions are mainly cited, as well as those associated with emotions and behavior [16]. BF was significantly (P<0.05) higher in Zinc (17.66 ppm) than DMF (10.54 ppm) but lower than FF (27.93 ppm). The addition of tamarind seed improved the zinc content significantly in BF from 10.54 ppm to 17.66 ppm. However, the recommended limit of zinc in fortified flour ranges between 33-65 ppm. The result implies that the BF did not meet the threshold, perhaps due to low content of Zinc in the tamarind seed. Zinc is an essential component of most enzymes in the body, boosts immunity and also helps in the healing of body wounds as well as maintain normal blood glucose levels. Zinc also has a role in improving recall skills, reasoning and attention [17].

3.3 Microbiological properties

Table 3: Relationship between moisture content and aflatoxin in dehulled maize (DM), dehulled maize flour (DMF), Blended flour (BF) and Fortified flour (FF).

Sample	M.C	Aflatoxin
DM	10.91±0.3082^{a}	8.91±10.516^{a}
DMF	12.01±0.2370^{b}	11.28±3.670^{b}
BF	12.01±0.237^{b}	11.28±3.670^{b}
FF	12.18±1.079^{b}	8.16±3.529^{a}

Means within the same column with different superscripts were significantly different at($P \leq 0.05$). Values are presented as means ± standard error, n=10. **DM –** Dehulled maize, **DMF** – Dehulled maize flour, **BF** – Blended flour, **FF** – Fortified flour.

The results indicate that the moisture content of the DM (10.91%) was significantly (P<0.05) lower than that of DMF (12.01%), BF (12.01%) and FF (12.18%). There was no significant difference between the moisture contents of DMF, BF and FF. There was no significant

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difference in the level of total aflatoxin between DM (8.91 ppb) and FF (8.16 ppb), however, the results for DMF and BF (both 11.28 ppb), were significantly ($P<0.05$) higher. The study clearly demonstrates a correlation between moisture content and aflatoxin level. The low moisture content of the DM (10.91%) could be attributed to sufficient drying after the dehulling process. The results seem to suggest an increase in moisture content of DMF (12.01%) which could be attributed to improper packaging after dehulling as well as poor storage conditions. Reduction of grain water content is most frequently realized by residual drying (moisture is less than 15%); the storage stability is provided at the moisture of 12% [3].

Figure 1: Cereals and legumes outlet in Kongowea Market.

Maize, like other stored food products is hygroscopic in nature and tends to absorb or release moisture. Even if properly dried after harvest, exposure to moist and humid conditions during storage will cause the kernel to absorb water from the surroundings, leading to increased maize moisture content [29]. These results build on the existing evidence of a study which reported similar findings of 12.3% moisture content in the storage of dry milled degermed maize products [21].

The results indicated a significantly ($P<0.05$)high level of total aflatoxin in DMF (11.28 ppb) than in DM (8.91 ppb). Similarly, the total aflatoxin in FF (8.16 ppb) was significantly ($P<0.05$) lower than that of BF (11.28 ppb). These results indicate that there was a significant increase in

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the level of aflatoxin in the maize (DM) after milling (DMF) and during blending (BF). The increase in aflatoxin level was attributed to inappropriate packaging and storage at high moisture levels. Removal of testa permits easy entrance of fungi and promotes rapid development of storage deterioration at high moisture and temperature levels. The data contributes a clear understanding that aflatoxin can develop within 24 hours in mold- and fungi-infected corn stored under these conditions, even though the corn previously had a lower level of aflatoxin. The study indeed confirmed that the DM and FF were within the national limits of aflatoxin, however, DMF and BF exceeded the national limit of 10 ppb aflatoxin. Aflatoxin is the main mycotoxin that harms animal and human health due to its carcinogenic nature [19]. Aflatoxin contamination problems can be minimized prior to harvest by thoroughly cleaning out all harvesting, handling and drying equipment and storage bins prior to harvest.

CONCLUSION

The study contributes a clear understanding of the highly nutritious properties of tamarind seed that are of great significance in food fortification. Tamarind seed is a cheap and easily available by product yet underutilized. The study demonstrated that tamarind flour has a good nutritional profile with high levels of protein, lipids and minerals. It can therefore be formulated into different food products as an intervention in mitigating food and nutrition insecurity. Further recommendation is the use of tamarind seed protein as an ingredient in food formulation to supplement the over dependence on conventional protein supplements. The methodological choices were constrained by the ability to effectively separate the test a from the roasted seeds and selectively extract the minerals of interest (iron and zinc) from the tamarind flour matrix.

ACKNOWLEDGEMENT

I wish to express my sincere gratitude and appreciation to Pwani University fraternity and Technical University of Mombasa through the Partnership, Research and Innovation directorate for the support towards the completion of this research work.

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