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QUALITY CHARACTERIZATION OF BREAD RETAILED IN NAIROBI COUNTY, KENYA: PHYSICO-CHEMICAL AND MICROBIAL PROFILES

Aftin HA[1,2]*, Abong GO[1] and MW Okoth[1]

Abdirizack Aftin Hussein

*Corresponding author email: abdirizackaftin@gmail.com

[1]Department of Food Science, Nutrition and Technology, University of Nairobi, P.O. Box 29053-00625, Nairobi, Kenya

[2]Kenya Bureau of Standards, P.O. Box 54974-00200, Nairobi, Kenya

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ABSTRACT

With the ever-increasing intake and diversification of bread in sub-Saharan Africa, greater risks of food fraud are posed. The risks are even higher in the urban areas where both the formal and informal retail exist. Product diversification induced by incorporation of different ingredients in bread processing aggravates the risk of malpractices in processing that is evidenced in product quality. The current study employed a cross-sectional survey of bread retailed in the fourteen supermarkets located in Nairobi County, Kenya to determine their physico-chemical and microbiological characteristics. The study showed that brown bread had significantly ($p<0.001$) higher moisture and water activity, although the fibre and total solids in the brown bread were significantly ($p<0.01$) lower than the white bread. The greatest variability in the physico-chemical attributes was found in the acid insoluble ash, with a coefficient of variation of 82.04%. The highest proportion of the bread, 58.9%, fell short of meeting the regulatory stipulations of the acid insoluble ash. Significantly ($p<0.05$) higher proportion of the brown bread (60.7%) than the white bread (4.4%) had crude fibre contents less optimal than the regulatory stipulations. The greatest adherence to product quality stipulations was found in yeast and mould counts (100%), moisture content (99.1%) and pH aqueous extract (95.5%). Both the brands of bread and retail outlets had quarter of them recording higher moisture, water activity and total acid insoluble ash than the averages of breads traded in supermarkets; whereas the pH, fibre and total solids were lower (kmean clusters=2). Eight principal components maximally explained product variability in the breads, with similar trends of composition between moisture and protein, and fibre and total solids, whereby the latter pair had a negative correlation with the former. In conclusion, the study found that the formal sector still falls short of product quality regulatory stipulations, pointing to greater need to strengthen surveillance component of food control for this sector.

Key words: White, Brown, Bread, Food control, Cluster Analysis, Proximate, Supermarket, Standards

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INTRODUCTION

The cereal product of bread has gained increasing importance in the urban areas of sub-Saharan Africa, SSA [1]. The diet of human population in these areas has shifted to an increasing proportion of bread as one of the preferred foods [2,3]. Bread is favoured due to its convenience in utilization after purchase as it requires no further preparation prior to consumption. The liking of bread among the urban areas of sub-Saharan African countries outdoes that in the rural areas [4,5]. Thus, the former has a higher and increasing consumption as compared to the latter. Moreover, a study by Mason *et al*. [5] reported an increasing affordability of bread in all the major cities in SSA, thereby promoting its utilization. This change has been attributed to many factors key among them being increase in the wage levels. As the consumption trends of this part of the globe changes over time, it is important to ensure the product quality the consumers ascribe to are delivered to them; this places the need to ward off unfair trade practices a priority and key focus. Media reports in Nairobi, Kenya, in the last quarter of 2019 and the first quarter of 2020 showed an increasing trend of food fraud for some of the most consumed foods including meat, fish and vegetables. It is important that scientific evidence of this be generated for less biased discussion on the food control systems in these developing countries.

The physico-chemical and keeping qualities of bread has gained increasing attention with the commercialization of its various types [6]; white, brown, fortified and protein-rich bread. Interventions have been instituted with some developed formulations aiming to improve the physico-chemical and keeping qualities of bread [7, 8]. The two studies reported improvement in the keeping and sensory qualities due to wheat flour substitution in bread. The enhancement of the physical attributes and sensory, nutritional and keeping qualities has been used as a selling point to gain market advantage for various types of breads. Therefore, there is a great diversity of the product attributes for bread traded majorly in the urban settings. To put the argument into perspective, this has created room for unscrupulous practices that pay little attention to improving product attributes but still promote the fraudulent labelling of superior product quality. Even with the introduction of various types of bread the consumption of white bread has still been high due to some additional advantages it presents in its product attributes. Ayele *et al*. [10] and Wanjuu *et al*. [7] reported that the substitution of wheat flour, the move from the pure white bread to composite breads resulted in a decrease in the bread volume. These superior product attributes that remain in white bread have still made it competitive in both the urban and rural markets.

Quality specifications of bread stipulate a maximum moisture and acid insoluble ash contents of 40% and 0.2%, respectively and a pH of 5.3 to 6.0 in breads [11]. On the other hand, differences exist in the specifications of fibre content whereby that of white bread should be a minimum of 0.3 and that of brown bread a maximum of 0.6. The specification stipulates that the whole wheat bread must contain 100% wheat meal, whereas the brown bread must have a minimum of 20% wheat bran or 60% whole wheat in effort to increase the fibre content [12]. Additional labelling of bread as high protein requires that there be a minimum of 22% of protein dry weight basis (dwb). Emerging bread types have also had quality specifications stipulated such as the orange fleshed

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sweet potato (OFSP) bread has a stipulation of a minimum of 20% of OFSP puree or 10% OFSP flour in effort to improve the beta-carotene content [13]. There is need, therefore, to institute appropriate regulatory systems for these emerging and existing types of bread and improving the surveillance component of food control for quality adherence. The present study focuses on one of the weakest links in food control in SSA, with the urban market in Nairobi as a case study, which is surveillance; to ascertain adherence to product quality requirements. The study provides input towards consumer education and the food control system that prevents food fraud.

MATERIALS AND METHODS

Sample collection

A cross-sectional survey of exhaustively sampled fourteen individual retail supermarkets was done in central business district, the commercial epicenter of Nairobi City, Kenya. The fourteen supermarket lines were categorized into four different supermarket chains based on the branding of their retail shops. An exhaustive sampling of all the brands of bread retailed in these supermarkets was done. The sampling of the bread was done in the first week of October, 2019 across all the fourteen supermarkets. In a single supermarket, eight bread samples (four different brands that were for both brown and white breads) were collected. The breads kept in sealed waterproof sterile bags and transported in cooler boxes packed with ice packs, temperature maintained below 5 oC, to the Kenya Bureau of standards laboratories for physio-chemical and microbial analysis. The samples were first analyzed for moisture and yeast and moulds before portions of 50g of the samples, picked from different parts of the bread being dried at 100 degrees Celsius for half an hour and stored in frozen state awaited further physico-chemical analysis.

Analytical methods

Determination of moisture content

Bread's moisture content was determined through moisture loss by oven drying techniques according to AOAC [14]. Drying of the samples was done in duplicates until there was no further change in weight in two successive measurements, then the weight loss was calculated.

Determination of crude fibre

The crude fibre content of the bread samples was determined in duplicate on dry weight basis using standard procedures described in the standard operating procedures of the KEBS [12]. The procedure entailed fat extraction, sequential digestion using 1.25% sulphuric acid and 1.25% sodium hydroxide and ignition using a muffle furnace. The composition of crude fibre was expressed per 100g of sample in dry weight basis (dwb).

Determination of protein content

The protein content was determined in duplicate using Kjeldahl technique as explained in method number 920.87 of AOAC [14]. Protein digestion in the bread samples was done using concentrated sulphuric acid and distilled using 40% sodium hydroxide. Titration of the trapped NH4 was done against0.5 normal HCL. The conversion factor used was 6.25.

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Determination of crude fat content

The crude fat content was determined in duplicate as per method 920.86 of AOAC [14]. Fat extraction was done in a Tecator Soxtec System 1039 from Germany using petroleum ether at 40-60 oC for one hour and twenty four minutes per sample as per KEBS specification (KS 172:2010) [12].

Determination of crude ash content

Crude ash determination of the bread samples was done using the ashing technique in a muffle furnace at 550 oC as described in method number 923.03 of AOAC [14].

Determination of carbohydrate content

Carbohydrate content is determined as per the difference techniques as shown in equation 1.

Equation 1

$$100 - (moisture\ content\ \% + crude\ ash\ \% + crude\ fat\ \% + crude\ protein\ \% + crude\ fibre\ \%)$$

Determination of water activity

The water activity was read in a FTIR pattern DA 7250 near infrared (NIR) Spectroscopy (Perten, Sweden). NIR spectroscopy is a secondary technique that is not a destructive method and enough sample was put in the sample cup. The sample was poured into the sample tray and placed on the sample plate. The auto analyze is tapped to begin the analysis (Pattern instruments DA 7250, Installation and operation manual).

Determination of acid insoluble ash

The total acid insoluble ash was determined as per the standard operating procedures of the KEBS [12]. Ignition of a 5 g sample was done in a muffle furnace at 500°C for 6 hours. The residual ash was covered with dilute hydrochloric acid (water: HCl 2:5 v/v) and filtered by use Whatman filter paper number 150mm, followed by drying in an air oven. Cooling was done in a dessicator. The weight lost was expressed as a % of the total mass of the sample in dwb.

Determination of pH of aqueous extract

The pH of the bread was determined using the standard procedures described by KEBS [12]. Deionized water and ground bread were mixed at the ratio of 10:1 (w/v). The mixture was left to stand for 15 minutes and the pH read using pH meter (Mettler Taledo, USA).

Analysis of Yeast and Moulds

The yeast and mould counts were determined as per the method EAS 217-8 [12], by plating in potato dextrose agar. The microbial counts were transformed into log CFU/g before statistical analysis.

Data analysis

Statistical analysis of the data was done using R Programming Statistical Software [15]. The nutritional contents save for moisture and total solids were first transformed from

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fresh weight basis (fwb) to dry weight basis (dwb) before analysis. The mean and standard deviation of duplicate of samples was generated. Cluster analysis was used to group the variables into clusters of similar statistical trends after normalization of the data. In the clustering, transformed yeast and mould counts (log CFU/g) was eliminated due to the more than 90% of the samples had yeast and mould counts undetected. Analysis of variance was used to evaluate significant differences in the means of individual variables. Tukey's Honest Significant Difference test was used to separate means that are statistically different. Statistical significance was tested at $p<0.05$.

RESULTS AND DISCUSSION

Comparative evaluation of physio-chemical quality of brown and white breads in urban supermarkets

Notwithstanding the supermarket line or the brand, brown bread had significantly ($p<0.05$) higher moisture and water activity (Table 1Table 2). The fibre and total solids in the brown bread was significantly ($p<0.05$) lower than that in the white bread, whereas the crude protein content of the brown bread was significantly ($p<0.01$) higher than that of the white bread. The findings in this study showed that the fibre contents of the brown (0.65 ± 0.17 %) and white breads (0.72 ± 0.19 %) were so high based on the regulatory requirements stipulated in East African Community standards [11]. The regulatory standards in East Africa stipulate that the fibre content of the brown (maximum 0.6% dwb) is higher than that of the white bread (minimum 0.3% dwb) [11-13]. This has been the major selling point of the brown bread; it provides the beneficial fibre to consumers [16]. About a third (32.6%) of the bread samples evaluated had less optimal crude fibre contents (minimum of 0.3% for white bread and maximum of 0.6% for brown bread). The brown bread had higher proportion (60.7%) of its samples exceeding the maximum requirement as compared to white (4.4%) being lower than the minimum requirement stated. A study done on Omani breads established that the crude fibre contents of the retailed white and brown breads were similar thus both laid the health claim of being low glycemix index foods [17]. Another study in Australia also showed that there are instances of white bread with higher fibre contents with no indicated health claim on the label [16], thereby these tend to pass consumers who are interested in the high fibre breads. However, the brown bread in the current study had a lower fibre content than even the white bread. This is contrary to the market selling point for the former whereby the rich fibre content health claim has been utilized as its superior quality to the white. In as much as the white bread has been shown to have high content of indigestible fibre [18], this should be lower than that of the brown bread [19]. The current study did not explore in detail this resulting difference in the crude fibre content, the composition of the digestible fibre compared to the indigestible fibre.

Almost all (99.1% and 95.5%, respectively) of the tested samples had a maximum moisture content of 40% and pH range of 5.3-6.0. Whereas the moisture content and water activity of the brown bread was higher than that of the white bread, a reverse situation was found with the total solids as expected. Studies by Owade *et al.* [8] and Wanjuu *et al.* [7] reported moisture contents of freshly baked white bread as 27-29%, which are lower than the values found in this study. Findings by Wanjuu *et al.* [7] indicate that the moisture content of bread in storage increase with storage time. Additionally,

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moisture content in bread is first determined by the ingredients utilized in the processing [19], and this goes to the greater extent of determining the crumb texture which is a key quality attribute [20]. High moisture content in bread makes the crumb softer, which to a certain extent induces structural degradation [21]. The moisture levels found in the present study met the regulatory requirements of a maximum of 40% set out in the Kenyan standards [12], thus posing less risk of structural degradation and poor acceptability among consumers. On the other hand, more than half (58.9%) of the loaves of bread had a total acid insoluble ash that exceeded 0.2%, which is the regulatory limit both in Kenya and East Africa [11,12]. There was no statistical difference ($p>0.05$) between the white bread and brown bread traded in Nairobi in terms of meeting the minimum amount of 0.2% for the total acid insoluble ash. Variability in the acid insoluble ash was the highest with coefficient of variation (CV) 82.04%. The content of the acid insoluble ash are the non-digestible matter that can be indicative of the foreign indigestible material including soil present in the food [22,23]. For this reason, the regulatory recommendation seeks to have the acid insoluble ash as low as possible for in the case our study, most of the bread had a high composition of inorganic matter, implying a high contamination with impurities.

The study found that the white bread had a higher protein content than the brown bread. The values reported in this study are higher than those of similar white breads evaluated by Owade [24] in Kenya, that had protein content 11.0% dwb. However, the findings of this study are similar to the findings in studies outside of Kenya by Ayele *et al*. [10] and Scheuer *et al*. [25] who reported a protein content of 13-15% dwb in white breads. A study done on retailed brown breads in Ireland found that the brown bread had a comparatively lower protein content of 7-11% dwb [26],values comparatively lower than the earlier values for white bread. Generally, bread is not known to be rich in protein [27], thus the standards in Kenya stipulate protein-rich breads be labelled so, but with a minimum protein content of 22% [13].

Cluster of bread sold in urban supermarkets based on physico-chemical attributes
The kinking in WSSplot (**Error! Reference source not found.**) was at two clusters w hich were then utilized in further partitioning in the Kmeans. In the Kmeans clustering, the yeast and moulds were eliminated as the variable was undetected in the samples. The two chosen components for Kmeans partitioning explained 48.95% of data variability

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displaying an overlap in some variables as shown

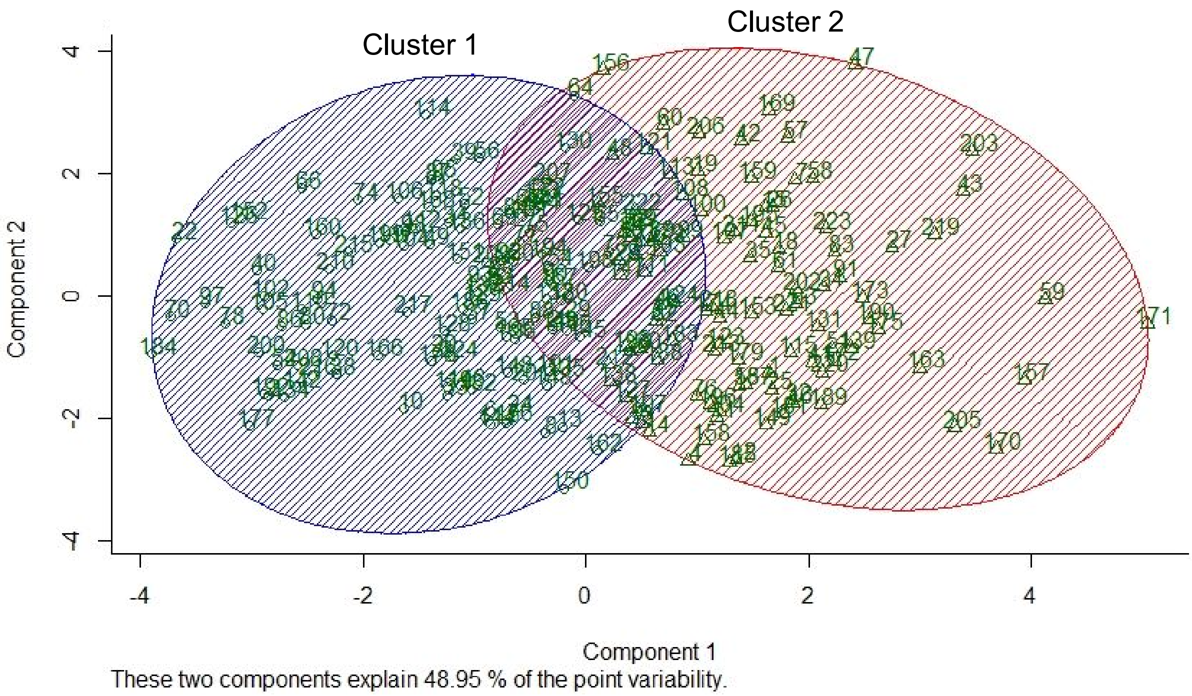

Figure *2*. This implies there was no uniformity in the nutritional and physical attributes of the breads traded in the urban supermarkets in Kenya. The diversity in the production of bread retailed in the urban supermarkets has some set standards they seek to achieve; however, this still has not been optimal for some physical attributes, and nutritional components have higher scores than others based on the place of production and branding. The physico-chemical attributes of bread traded in Nairobi Central Business district (CBD) were in two clusters whereby cluster 1 had higher moisture, ash, pH, crude ash and protein than cluster two, whereas the latter had higher fibre, total solids, water activity and crude fat (Figure 3). The two clusters had equal carbohydrate and acid insoluble ash. Majority of the brands of bread had lower fibre, fat and total solids contents and water activity whereas they had a higher moisture, crude ash and protein contents and pH than the average values of the respective parameters of the breads traded in the retail supermarkets. The moisture levels, pH, water activity and acid insoluble ash of cluster 1 were below the average of all the samples as shown in Figure 3. On the other hand, the fibre and total solids were lower than the averages of all samples. The limited number of clusters implies that product diversification in terms of bread processing, therefore, does not impact greatly to induce diverse product qualities in bread but rather shows a common quality criterion targeted by all the producers. However, loopholes exist with some of the brands and retail stores scoring lower than the average in the market for the product attributes.

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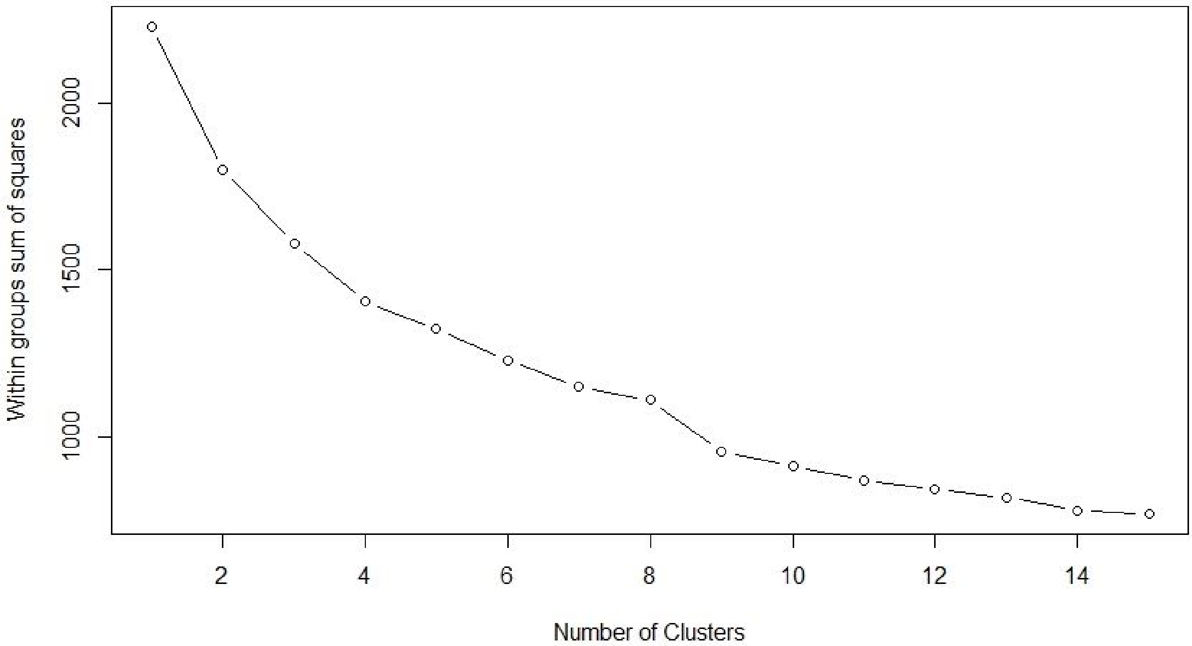

Figure 1: WSS plot for K means clusters for bread sold in Nairobi Kenya

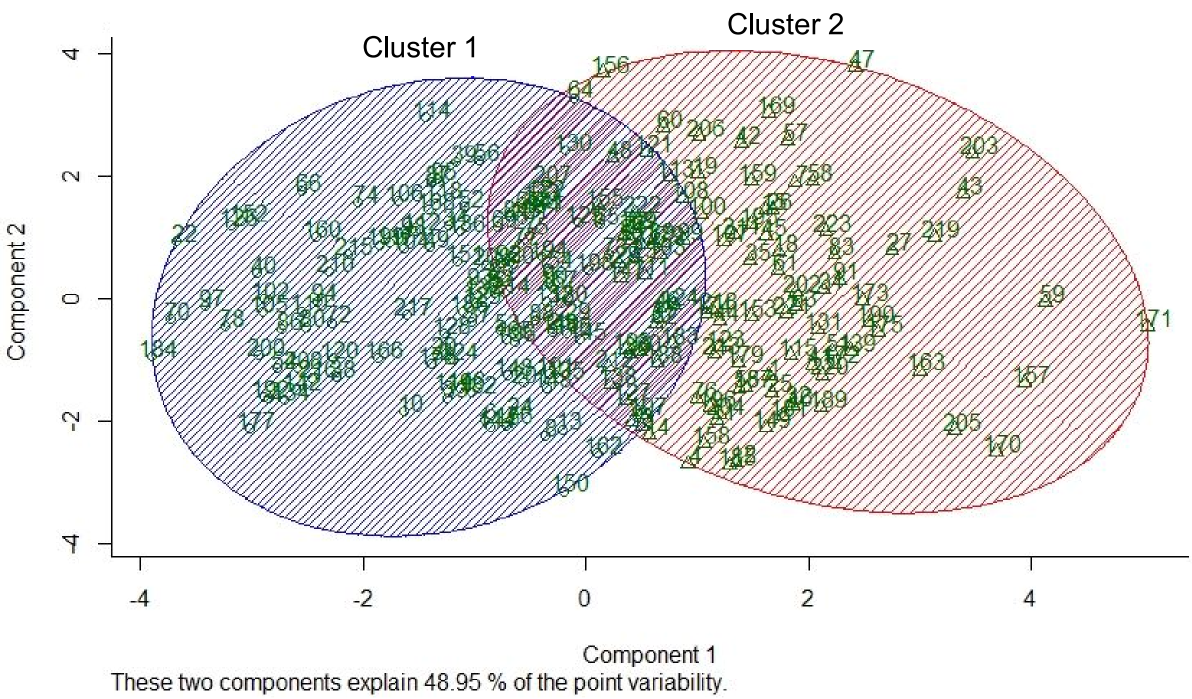

Figure 2: K means clustering of physico-chemical attributes of bread traded in urban supermarkets

The numerical values in the highlighted region represent individual observations in a cluster.

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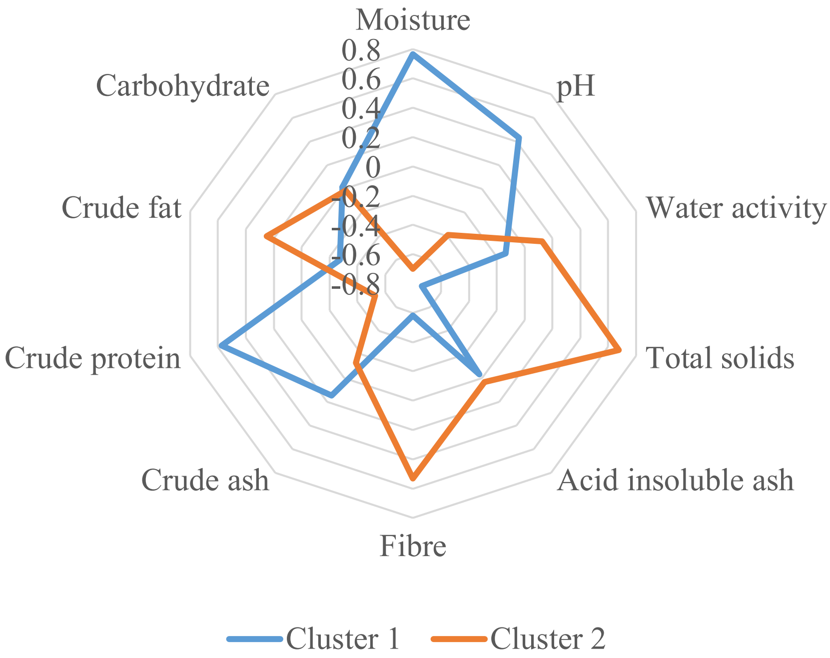

Figure 3: Physico-chemical characterization of bread retailed in the urban county of Nairobi

The values have been normalized to a z-distribution.
Two of the four supermarket chains loaded more in cluster 2 than in cluster 1, whereas only one supermarket chain loaded in cluster 1 more than cluster 2. More than half (8) of the brands of bread loaded in cluster 1 rather than 2. The specific retail supermarkets exhibited less loading in either clusters, but the loading of the specific retail supermarkets was more in cluster 1 (6) as compared to Cluster 2 (4). The diversified loading of these retail outlets in the two clusters are indicative of poor regulation of the retail sector. Poor regulatory mechanisms of the products retailed at the supermarkets put majority of the urban consumers of bread at risk. A study done in South African urban centres found that 94% of the households purchase their breads from supermarkets [28]. The implication of the above findings is that there are gaps in the surveillance components of the food control system. In their study in the urban centres in Nigeria, Olusegun *et al*. [29] reported failure to adhere to the stipulated regulatory standards among a third of the formal enterprises. Another study in the urban capital of Nigeria reported the use of harmful ingredients in amounts beyond the recommended levels that pose risk to the consumers [30], pointing to vulnerability of the quality control of products if effective surveillance systems are not designed and effectively implemented. Surveillance of the sector can help effect producer accountability and promote adherence to product quality to weed out unscrupulous producers.

Eight principal components maximally explained the variability in the data as it explained 99.5% of the trends in physico-chemical quality. With increasing moisture content in bread, the protein content also increased (Figure 4). On the other hand, the fibre contents of the various breads traded in the different supermarkets also increased

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with an increasing content of total solids. Kenya Bureau of Standard (KEBS) [12,13] set the regulatory standards for moisture and fibre levels, although protein is never a concern in white and brown breads for wheat has poor protein quality however, in high protein bread there are stipulations. The setting of a legal stipulation of 40% moisture content by all East African countries [11] sets the limits for the total solids. It is, therefore, imperative to ensure that the stated regulatory stipulations are adhered to in the retailing of bread.

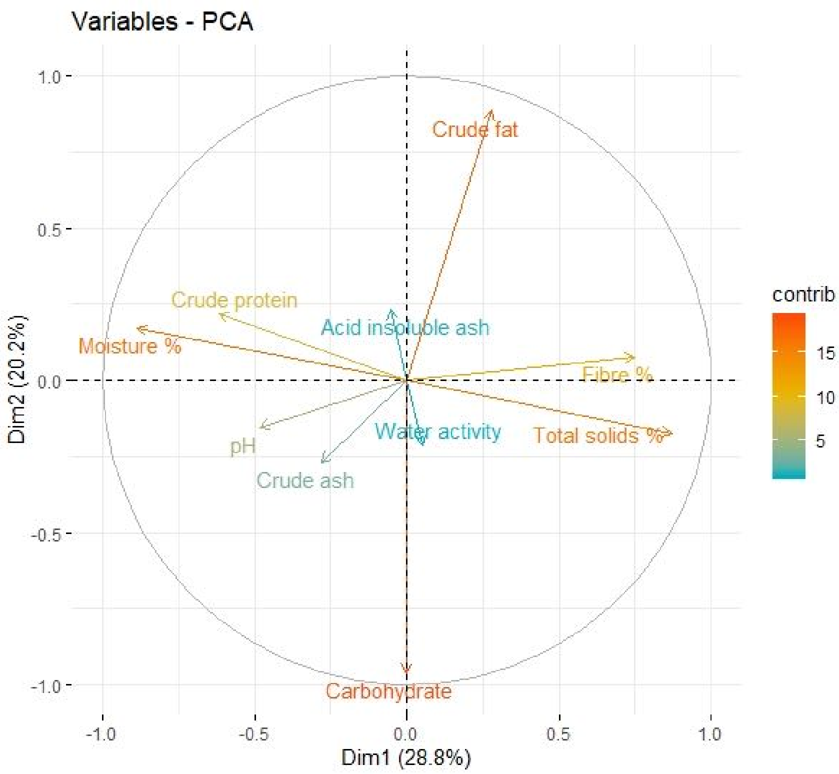

Figure 4: Principle component analysis of physico-chemical attributes of bread retailed in the urban county of Nairobi

Contrib-It is the loading (in percentage) of a variable to the principal components.

CONCLUSION

The crude fibre contents and the total insoluble ash values do not meet the stipulated regulatory requirements. Additionally, clustering of the breads by product attributes found that, in as much as there was no huge deviation of bread to result in many product clusters, instances of products having lower values for attributes than those sold in same supermarket was there. This, therefore, calls for strengthening of the surveillance component of the food control systems even in the formal markets. Restricting the systems just to certification may not be sufficient to reveal the shortfalls in the quality of the products availed to the market especially in the retail stores. The findings of this study point to gaps in the regulation especially the surveillance component of the quality of bread retailed in urban supermarkets.

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Conflict of Interest
The author(s) declares no conflict of interest.

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Table 1: Nutritional quality of bread in urban supermarkets

Type of bread	Moisture (%)	Total solids (%)	Crude protein (%)	Crude fat (%)	Crude fibre (%)	Crude ash (%)	Carbohydrate	Acid insoluble ash (%)
Brown	32.44±2.35a	67.02±2.39b	13.6±1.61a	7.42±3.20a	0.65±0.17b	0.68±0.29a	77.53±3.41a	0.47±0.33a
White	30.34±2.63b	68.95±2.64a	13.1±1.59b	7.53±3.56a	0.72±0.19a	0.69±0.28a	77.83±3.41a	0.36±0.25a
CV %	8.42	3.96	12.1	45.1	22.33	0.94	4.39	82.04
MSD	0.55	0.66	0.42	0.89	0.04	0.07	0.89	0.22
p-value	<0.001	<0.001	0.008	0.808	<0.001	43.1	0.483	0.343

The values are mean ± sd of all the samples analyzed in duplicates. All the variables in dry weight basis except for moisture and total solids. MSD-minimum significant difference

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Table 2: Physical and microbial quality of bread in urban supermarkets

Type	Water activity*	pH	Yeast and moulds log cfu/g
Brown bread	0.87±0.16b	5.66±0.18a	nd
White bread	0.72±0.16a	5.64±0.18a	nd
CV %	13.91	3.26	na
MSD	0.07	0.05	
p-value	<0.001	0.462	na

*Significant at p<0.01. nd-not detected, na-not applicable. The values are mean ± sd of all the 56 samples analyzed in duplicates. MSD-minimum significant difference

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Table 3: Loading of individual observations of variables into clusters

Variables		Cluster 1 (Proportion %)	Cluster 2 (Proportion %)
Supermarket chain	Supermarket chain 1	56 (50.0)	56 (50.0)
	Supermarket chain 2	6 (37.5)	10 (62.5)
	Supermarket chain 3	19 (39.6)	29 (60.4)
	Supermarket chain 4	26 (54.2)	22 (45.8)
Brand	Brand 1	14 (50.0)	14 (50.0)
	Brand 2	20 (71.4)	8 (28.6)
	Brand 3	3 (50.0)	3 (50.0)
	Brand 4	2 (50.0)	2 (50.0)
	Brand 5	2 (100.0)	0 (0.0)
	Brand 6	2 (7.1)	26 (92.9)
	Brand 7	10 (35.7)	18 (64.3)
	Brand 8	1 (100.0)	0 (0.0)
	Brand 9	1 (100.0)	0 (0.0)
	Brand 10	1 (14.3)	6 (85.7)
	Brand 11	4 (57.1)	3 (42.9)
	Brand 12	19 (67.90	9 (32.1)
	Brand 13	24 (85.70	4 (14.3)
	Brand 14	3 (21.4)	11 (78.6)
	Brand 15	11 (78.6)	3 (21.4)
Individual supermarket lines	Supermarket line 1	3 (18.8)	13 (81.3)
	Supermarket line 2	8 (50.0)	8 (50.0)
	Supermarket line 3	8 (50.0)	8 (50.0)
	Supermarket line 4	6 (37.5)	10 (62.5)
	Supermarket line 5	9 (56.3)	7 (43.8)
	Supermarket line 6	8 (50.0)	8 (50.0)
	Supermarket line 7	9 (56.3)	7 (43.8)
	Supermarket line 8	10 (62.5)	6 (37.5)
	Supermarket line 9	11 (68.8)	5 (31.3)
	Supermarket line 10	10 (62.5)	6 (37.5)
	Supermarket line 11	9 (56.3)	7 (43.8)
	Supermarket line 12	4 (25.0)	12 (75.0)
	Supermarket line 13	4 (25.0)	12 (75.0)
	Supermarket line 14	8 (50.0)	8 (50.0)

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