

Article

Quality and Safety of Folded Vermicelli Produced by the Small-scale Processors in Tanga City, Tanzania

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Abstract: Tanga City is the region with several micro-and small-scale pasta processing companies in the country. Therefore, the purpose of this study was to assess the quality and safety of folded vermicelli produced by the small-scale processors in Tanzania. Samples of 1 kg folded vermicelli were collected from 14 processing companies, by the intentional cluster sampling technique. The samples were analysed for aflatoxin and microbiological (*Escherichia coli*, *Aspergillus flavus*, and *Aspergillus parasiticus*) quality. Moreover, physico-chemical quality was assessed in terms of diameter by using a digital calliper, moisture content by oven-drying method at 110°C± 5°C, breaking strength by the texture analyzer, and colour by colourimeter (Chroma Meter CR-400) of the collected samples were determined. In terms of microbial quality, the results indicated contamination by *E. coli* (1.25-3.00 Log CFU.g⁻¹ in 8/14 samples), *A. flavus* (2.23-2.83 Log CFU.g⁻¹ in 12/14 samples), and *A. parasiticus* (1.22-2.75 Log CFU.g⁻¹ in 2/14 samples) as they are beyond the set limits. The diameter varied between 0.90 mm to 1.73 mm in 9/14 samples and moisture content were 10.61% to 12.65% in 13/14 samples, being within the established parameters. The samples indicated low breaking strength with levels between 6.79x10⁵ N.m⁻² to 3.75x10⁶ N.m⁻² in 11/14 samples. The result of brightness (L*) were between 53.03 to 72.14 and yellowness (b*) between 13.68 to 19.48 indices, indicating that there was no significant difference at the 5% level, respectively, although 2/14 samples had red (a*) colour values (-1.32 – +0.56). However, 4/14 samples were detected with aflatoxin B₁ (0.60-0.70 µg.kg⁻¹), they are within the recommended level (5 µg.kg⁻¹). The study underscores the need for concerted efforts to enhance production and hygiene practices to ensure consistent compliance with quality and safety standards.

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1. Introduction

Pasta is an increasingly popular food worldwide and holds a significant place in the culinary landscape due to its convenience, inexpensive, deliciousness, versatility, and nutritional value [11, 23, 30]. Pasta processing and consumption are on the rise in Tanzania [16]. According to recent data, 18,100 metric tons (MT) of pasta was produced in Tanzania in 2019, an increase of roughly 7 percent compared to the previous year, which produced 16,900 MT [19]. Large-scale processing companies like Wilmar Pasta Tanzania Ltd., process quality pasta of different shapes as they have resources (financial and human), facilities, and equipment [29]. On the other hand, micro- and small-scale processors in country have limited resources and facilities to produce consistent product quality [1]. They use rudimentary equipment to process pasta and mainly produce folded

vermicelli. The production requires wheat flour (hard wheat flour) from local companies like Azam, Azania, and Safi Company limited, and water as the main raw materials. They exhibit certain characteristics which distinguish them from their large-scale counter parts. They usually make their business as a single proprietor, not organized as a family business, and operate under a simple organizational structure, consisting of the manager-owner assisted by a few workers. Their products are generally relatively cheap and of rather low quality. This is caused by a lack of facilities and equipment to process and handle the products hygienically [37]. However, the quality and safety of pasta, particularly folded vermicelli, can vary depending on various factors, especially when produced by micro- and small-scale processors. The conditions like low temperature, high humidity, and long drying time, encourage the growth of microorganisms including aflatoxigenic moulds [45]. The processors produce folded vermicelli mainly during the whole month of Ramadan. They lack knowledge on proper handling of food [37]. Besides, drying of the product is done in open sun, often on the rooftops, which are potentially contaminated with various health hazards.

Small-scale folded vermicelli processors in Tanzania face insurmountable challenges to ensure the quality and safety of the product taking into account the nature of their companies. They lack the resources and food safety culture to employ qualified personnel or engage consultants to improve their processing conditions. Moreover, inadequate demands from consumers on quality and safety restrict the improvement of such processing units [37]. Monitoring and controlling their production process is highly recommended to comply with food safety regulations and protect consumers from potential health risks like pathogens and mycotoxin contamination [35]. Among the important quality tests are assessment of microbiological quality. *E. coli*, a common indicator of faecal contamination, poses a risk to consumers' health if present in folded vermicelli [14]. Additionally, the moulds *A. flavus* and *A. parasiticus* are known producers of secondary metabolites, aflatoxins which are group 1 carcinogens. Therefore, the prevention of microbiological contamination and assessing the quality of the folded vermicelli are critical for product safety [32].

Beyond microbiological considerations, the physico-chemical characteristics of folded vermicelli play a vital role in determining the quality. Parameters such as diameter, moisture content, breaking strength, and colour are key indicators of the final pasta quality, and cooking behaviour, which is determined by the drying conditions used [11,39]. Maintaining safe storage moisture levels is essential to prevent mould growth and extend the shelf life of the product [47]. Small-scale processors must navigate the delicate balance between traditional production methods and meeting standardized quality parameters to ensure consumer satisfaction.

Although pasta quality monitoring is common in large-scale processing companies [11,13], it is not the case in micro- and small-scale processors. Such small-scale units are scattered across the country, they process on a seasonal basis and barely receive control and monitoring from food control authorities. This situation creates possibility of contracting various food safety hazards in the product. However, very little has been done to establish the current quality and safety status of vermicelli from micro- and small-scale companies in Tanzania.

Therefore, this study aimed to evaluate the quality and safety of folded vermicelli produced by small-scale processors. The study examined the microbiological landscape, physico-chemical quality and aflatoxin B₁ (AFB₁) contamination of folded vermicelli. The information collected from this study will be used by regulatory authorities and companies to improve their current processing conditions.

2. Materials and Methods

2.1. Study location

The study was conducted in Tanga District Council, Tanga City (Figure 1). Tanga District Council is one of eleven administrative districts of the Tanga Region. It is located below the equator between latitude 06°57" south and longitude 37°32" east. Nine administrative wards (Chumbageni, Duga, Mabawa, Ngamiani Kaskazini, Makorora, Msambweni, Central, Ngamiani Kusini and Ngamiani Kati) out of 27 wards from three divisions (Chumbageni, Ngamiani Kaskazini and Ngamiani Kati) were involved in this study. The wards selected were those with at least one folded vermicelli processing unit [37].

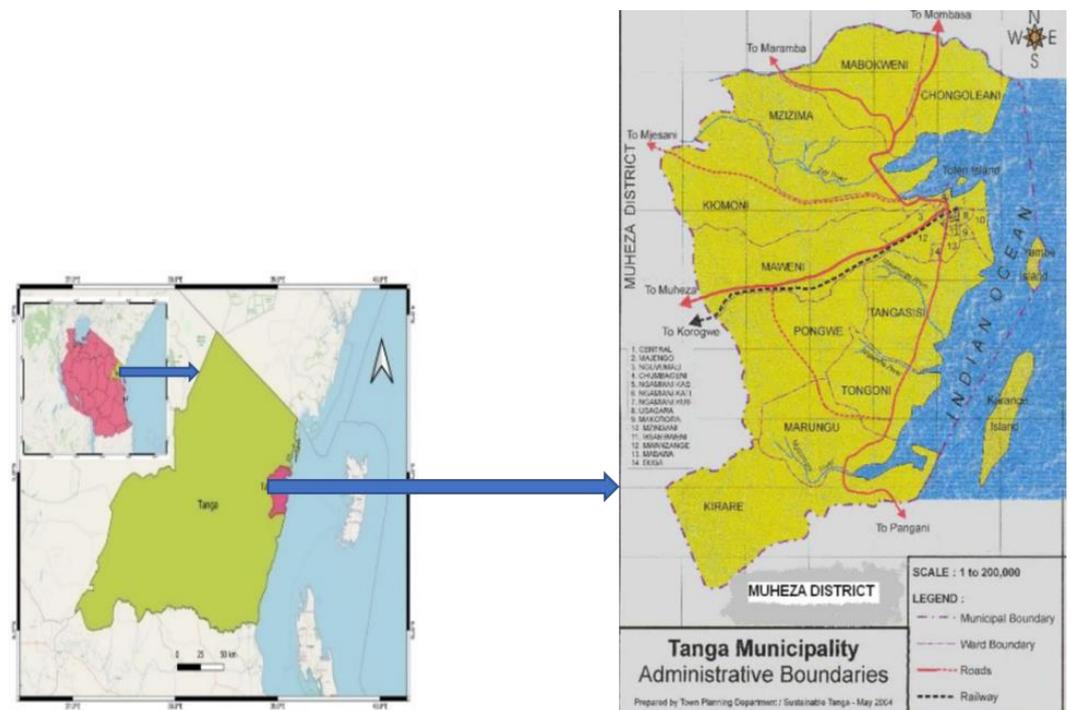


Figure 1. Map of Tanga City showing the study sites where data collected in Tanga District (Source: Authors)

2.2. Sampling procedures

The small-scale processors in the city of Tanga had almost similar processing technical characteristics, since they used a common drying technique, so the study was conducted by analysing the characteristics of the data collection sites. A purposive cluster sampling technique was used by dividing the streets into processing unit(s) groups and subsequently taking random samples from these groups, since it was decided that one sample would be taken from group (1-3), two from group (4-6), three from group (7-9) and four from group (≥ 10), as indicated in the sampling plan (Figure 2). Finally, 14 samples of 1kg each were obtained from the selected processing plants. The samples were hygienically placed in plastic bags and transported to the Food Science and Agro-processing Laboratory at Sokoine University of Agriculture (SUA), and frozen (Daewoo Electronics Co., Ltd. Korea) until they were analysed.

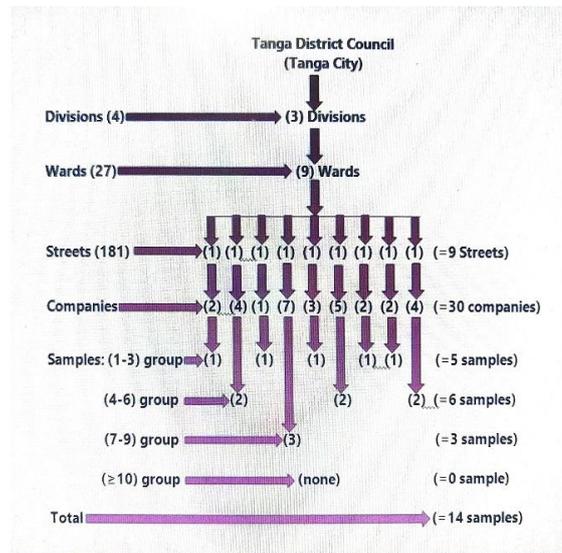


Figure 2. A sampling plan which was used to obtain the final samples from selected folded vermicelli processing units (Source: Authors)

2.3. Assessment of microbiological quality of the products

The product samples were sub-divided into two subsamples, and from each subsample an aliquot of 10 g sample was weighed using analytical balance (COTECH Instruments Ltd, Navi Mumbai, India), and homogenized with 90 ml of peptone water (PW) (Techno Pharmchem, India) for 1 min using a laboratory vortex mixer (Barnstead Thermolyne, 2556 Kerper Boulevard Dubuque, Iowa 52001 USA) to prepare a 10^{-1} dilution. Thereafter from each sample, three serial dilutions were made by taking 1 ml of 10^{-1} into 9 ml of PW to prepare 10^{-2} dilution, then 1 ml from 10^{-2} into 9 ml of PW to make 10^{-3} dilution. From each dilution, 1 ml was taken in duplicate and inoculated onto a sterile petri dish (Axiom GmbH, Germany) containing 15–20 ml of molten MacConkey agar (MCA, for *E. coli*) (Titan Biotech Ltd. Bhiwadi-301019, Rajasthan, India) and Potato Dextrose agar (PDA, for *A. flavus* and *A. parasiticus*) (Techno Pharmchem, India). After inoculation, petri dishes were incubated upright in an incubator (ADVANTEC, Toyo Seisakusho Co., Ltd. Japan) at 37°C for 24 hours for *E. coli* as per ISO 16649-2:2018, and at 30°C for 5 days for *A. flavus* and *A. parasiticus* as per ISO 21527-2:2017. Convincing colonies were counted using the colony counter (Kastech, Korea), expressed as colony-forming units per one gram ($\text{CFU}\cdot\text{g}^{-1}$) of the sample [5, 27, 28, 34, 38].

2.4. Physico-chemical characteristics of the products

2.4.1. Determination of the diameter of the products

Diameters of 14 dry-folded vermicelli samples were measured and recorded using a Digital calliper 150 mm (6") device (RS PRO Digital Vernier Calliper, Oslo, Norway). The device was calibrated (tiled) at zero-millimetre reading before the measurements. The measurements were performed in triplicate for each sample where a piece of a solid folded vermicelli rod was placed between the measuring jaws of the device and adjusted with the fine adjustment roller, then the readings (in mm) were taken on a large LED display screen and the data were recorded. The averaging data were calculated for stable results.

2.4.2. Determination of moisture content of the products

The moisture content of the samples was determined by oven-drying method as per the Association of Official Analytical Chemists (AOAC) – Official method No. 925.10:2000 [3]. About 5 g for each sample were weighed into a petri dish using analytical balance in

duplicate, and placed into oven (Wagtech, Britain) set at $110^{\circ}\text{C} \pm 5^{\circ}\text{C}$ for 24 hours until constant weight. The dried samples were cooled in a desiccator prior to moisture analysis. The moisture content (%) of the folded vermicelli was determined as indicated in equation 1 [25].

$$\% \text{ Moisture Content} = \frac{\text{Sample weight after drying}}{\text{Sample weight before drying}} \times 100 \quad (1)$$

2.4.3. Determination of breaking strength of the products

The Brookfield CT3 Texture Analyser (Brookfield Engineering Laboratories, 11 Commerce Blvd, Middleboro, MA 02346, USA), equipped with a 5-kg load cell, tensile grip, and a sensor/probe (No. 11-TA41 Cylinder 6 mm D, 35 mm L) was used to determine the breaking strength of vermicelli samples. Texture parameters included test speed (1.0 mm.s^{-1}) and rupture distance (9 mm). The testing took place in a temperature-controlled room (26°C). Fourteen dry vermicelli sample strands (each 75 mm long) were placed, held on a tensile grip, and compressed. The peak load/force (g-force) and the distance (mm) of the samples were measured in triplicate. The breaking strength (N.m^{-2}) of the folded vermicelli was calculated using the equation 2.

$$\text{Breaking Strength} = \frac{\text{Force}}{\text{Cross-sectional Area}} \quad (2)$$

2.4.4. Determination of the colour of the products

The colour of the products was measured in duplicate by using a colourimeter 'Chroma Meter CR-400' (Konica Minolta, Inc., Japan). Two different parts of the samples were measured (on the right- and left-hand sides). The following parameters were recorded: L^* , a^* , and b^* . The L^* component quantifies brightness from dark ($L^* = 0$) to bright ($L^* = 100$), a^* redness, from red ($+a^*$) to green ($-a^*$), and b^* yellowness, from yellow ($+b^*$) to blue ($-b^*$) [42].

2.5. Analysis of aflatoxin B_1 contamination of the products

2.5.1. Extraction methods and preparation

Aflatoxin B_1 analysis was carried out by High-Performance Liquid Chromatography (HPLC) with a fluorescence detector as per ISO 16050:2011 [20]. Briefly, the samples were grounded into powder using a high-speed multi-functional crusher (LFGS Company, China), and 5 g of each representative sample were weighed by using analytical balance (COTECH Instruments Ltd, Navi Mumbai, India) and transferred into sample tube (7ITE, Japan) and extracted with 100 ml of 70% methanol solution (1:20 w/v) (PS PARK Scientific Limited, Northampton, U.K), then shaken vigorously in an electric shaker (Baird and Tatlock, Multi Shaker, Greenfield. Oldham, England) for 30 min. Methanol was used as a solvent because aflatoxin dissolves easily in methanol compared with other solvents like ethanol, and acetone [21]. The mixture was filtered through a Whatman No. 1 filter paper (Whatman International Ltd. Maidstone, England), and about 25 ml of the filtrate was obtained and used for analysis.

2.5.2. Preparation of AFB₁ standard

Aflatoxin B_1 standard (98.8%) was obtained from Romer Labs, Tulln, Austria. A stock solution was prepared by dissolving the standard solution in methanol (Finar, India, 99.8%), making $294 \mu\text{g.ml}^{-1}$, and was stored at 4°C . Individual working standards and mixtures were prepared by diluting the stock solutions with the initial composition of the mobile phase (65:35, A: B, v/v). The stock solution was diluted with methanol to 29.4, 3 and $0.1 \mu\text{g.ml}^{-1}$ intermediate solutions for preparing the calibration standard. The

calibration standards, $n=3$ of 0.001, 0.003, 0.005, 0.01, 0.03, 0.05, 0.1, 0.3, and 0.5 $\mu\text{g}\cdot\text{ml}^{-1}$ were prepared.

2.5.3. HPLC-MS/MS conditions

HPLC-MS/MS analysis was performed using an Agilent 1100 HPLC system coupled to a Quattro micro-API tandem quadrupole mass spectrometer (Waters, Manchester, UK). MassLynx4.1 software equipped with Quanlynx software (Waters, Manchester, UK) was used to control the instruments and to process the data. The HPLC consisting of a binary pump, an auto-sampler, and a column heater was used. Chromatographic separation was carried out on a C18 column: (2.6 μm , 2.1 \times 75 mm) and a 10 mm guard column (Phenomenex, USA). Solvent A was 10 mM ammonium formate in water and solvent B was 0.1% formic acid (Finar, India, 98%) in acetonitrile (Finar, India, 99.9%). The flow rate was set at 0.250 $\text{ml}\cdot\text{min}^{-1}$ and the column temperature was 30°C. An auto-sampler was used to inject 10 μl . The retention time was 2.16 min. A Quattro micro-API tandem quadrupole mass spectrometer was operated in positive mode with the electrospray-ionization (ESI) source. The operating parameters were optimized under the following conditions: capillary voltage, 3.5 kV (positive mode); ion source temperature, 150°C; desolvation temperature, 450°C; cone gas flow, 100 $\text{l}\cdot\text{h}^{-1}$; desolvation gas flow, 650 $\text{l}\cdot\text{h}^{-1}$ (both gases were nitrogen); and collision gas was argon.

2.5.4. Method validation parameters

A calibration graph was constructed using peak area against a concentration of AFB₁. The limit of detection (LOD) (0.12 $\mu\text{g}\cdot\text{ml}^{-1}$) was determined from the calibration curve as three times the ratio of the residual standard deviation of the linear regression divided by the slope while the limit of quantification (LOQ) (0.39 $\mu\text{g}\cdot\text{ml}^{-1}$) was determined as ten times the same ratio.

2.6. Statistical Data Analysis

The data were statistically evaluated with a one-way Analysis of Variance (ANOVA) test using Statistical Package for Social Sciences (IBM SPSS Version 25, Chicago, IL, USA). Descriptive statistics were carried out to summarize the microbiological and physico-chemical data. The microbiological, physico-chemical, and aflatoxin B₁ results were compared against the East African Standards (EAS 173:2023) for pasta product-specification and scientific literature. Means were compared using Tukey's Honest Significant Different (HSD) test at a 5% level of significance. Results were expressed as mean \pm standard deviation (SD).

3. Results and Discussion

3.1. Microbiological quality of the products

Table 1 shows the findings regarding microbial contamination of folded vermicelli samples, which highlights issues related to food safety and production practices, where (8/14) samples detected with *E. coli* (ranging from 1.3-3.0 Log CFU.g⁻¹), exceeding the set limits (1 Log CFU.g⁻¹), and *Aspergillus* species, like *A. flavus* detected in 12/14 samples ranged from 2.23 – 2.83 Log CFU.g⁻¹, and *A. parasiticus* in only 2/14 samples, both exceeded the set limits (2 Log CFU.g⁻¹). The presence of *E. coli* in samples indicating inadequate hygiene practices during processing where processors did not wash their hands properly after attending the toilet. Moreover, the use of contaminated or untreated water in washing operations, coupled with potential contamination from birds and pests during open sun-drying, further exacerbates the risk of microbial contamination, posing serious threats to consumer health. Similar studies, such as one conducted in Shaanxi, China reported high levels of 98% of *E. coli* in cold noodle samples [4]. Likewise, the contamination with this mould type occurred most likely during inadequate drying, and

poor storage of pasta, and/or, indirectly, from raw materials themselves. Studies like the one by Halt *et al.* [24] in Osijek, Croatia revealed that there is a 39.40% occurrence of *A. flavus* observed in pasta samples.

Figure 3 shows the microbial presence detected in folded vermicelli from various processing units whereby the highest average concentration for *E. coli* was in samples from Company 3, while Company 5 had the lowest. The values were statistically significant within this group. The presence of *Aspergillus* species varied among companies; for *A. flavus* the highest concentration was found in Company 2, and the data showed *A. parasiticus* values for only a few companies (Company 8 and 13), as they were not available for the majority of the companies. The data suggested that Company 13 had a significantly higher concentration of *A. parasiticus* compared to Company 8, based on the statistical analysis. Companies with higher values might have been at risk for contamination and should have considered implementing improved hygiene or processing controls like proper drying and storage conditions to minimize the risks associated with *E. coli* and fungal growth, including toxigenic fungi that produce aflatoxins.

Table 1. Microbiological findings of the productsamples in Log CFU.g⁻¹ (Mean±SD)

Company No.	<i>Escherichia coli</i>	<i>Aspergillus flavus</i>	<i>Aspergillus parasiticus</i>
1	2.25±0.10 ^a	2.23±0.04 ^e	*
2	*	2.70±0.21 ^{abc}	*
3	3.00±0.02 ^a	2.83±0.01 ^a	*
4	*	2.49±0.00 ^{bcde}	*
5	1.25±1.77 ^{ab}	2.55±0.03 ^{abcde}	*
6	2.97±0.15 ^a	2.59±0.13 ^{abcd}	*
7	2.36±0.26 ^a	2.79±0.08 ^{ab}	*
8	2.63±0.04 ^a	2.78±0.00 ^{ab}	1.22±1.72 ^{ab}
9	2.80±0.02 ^a	2.68±0.08 ^{abc}	*
10	*	*	*
11	*	2.40±0.13 ^{cde}	*
12	*	2.31±0.05 ^{de}	*
13	2.42±0.20 ^a	*	2.75±0.05 ^a
14	*	2.69±0.05 ^{abc}	*

Values are given as means ± standard deviation (SD) of the duplicate determinations. Values in the same column having the same superscripted letters are not statistically significant differences ($p>0.05$) according to Tukey's Honest Significant Different (HSD).

* - indicating the samples were below the detection limit (<0.04 CFU.g⁻¹).

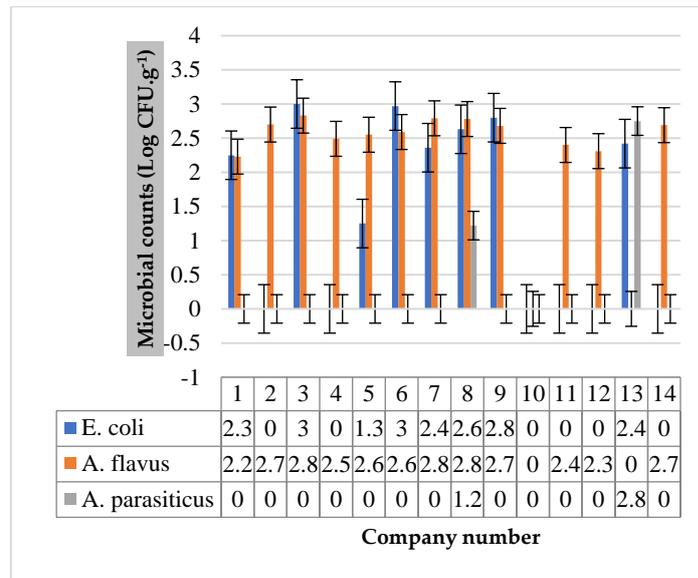


Figure 3. Shows the microbial presence detected in folded vermicelli samples from processing units

3.2. Physico-chemical characteristics of the products

3.2.1. Diameter of the products

The diameter of 14 samples ranged from 0.90 mm to 1.73 mm is shown in [Table 2](#). Nine of those samples were found to be within the acceptable range of 0.50 mm to 1.25 mm, as per the set EAS limits. These products were qualified with the overall quality and consumer acceptability. This resulted due to well-controlling of the manufacturing process, especially in the extrusion process (use of the right die/model size), consistency of raw materials composition, and controlled folding and/or drying processes of vermicelli. Variations in die size change the diameter of pasta and affect its quality and stability [17]. Larger dies produced thicker pasta, leading to a denser texture and potentially uneven cooking, while smaller dies created finer pasta that could be more delicate and prone to breaking. These changes impacted both the texture and the overall stability of the pasta during cooking and handling. Processors required maintaining and improving their production processes to ensure consistency with the set standards across all batches within the recommended diameter range.

3.2.2. Moisture content of the products

The majority (13/14) of samples had moisture content (ranging from 10.61% to 12.65%) below the set limits (12%w/w, [Table 2](#)). This was due to proper drying techniques achieved to have a desired moisture content of vermicelli samples, as excessive moisture can lead to mould growth and product spoilage, while insufficient drying affect shelf stability and texture. The process also believed to improve the food stability, reduce microbiological activity and minimizes physical and chemical changes during the food storage [36]. Likewise studies from various countries including Guelma and Algeria [10] as well as France [6,9] reported the moisture content of the pasta below the legal limits (2.5%). The processors should correlate the relationship between diameter and moisture content that highlights the importance of controlled drying processes to maintain consistent product quality and compliance with standards.

3.2.3. Breaking strength of the products

The study findings revealed that the breaking strength of vermicelli ranged from 6.79×10^5 N.m⁻² to 3.75×10^6 N.m⁻² (Table 2). The majority (11/14) of samples appeared more fragile: statistically ($p < 0.05$) lower forces were, required for breaking the samples (Figure 4), with variations attributed to differences in raw material composition and processing conditions like poor wheat flour-water mixing and binding efficiency during the dough making. A study by Lucisano *et al.* [33] in Milan, Italy showed a 20-30% reduction in the breaking strength influenced by the size distribution of semolina and the drying cycle. Also, Jayasena and Nasar-Abbas [30] in Australia indicated a decrease in breaking strength with the increase in lupin flour concentration at $\geq 20\%$ level.

The breaking strength of dry pasta plays a crucial role in packaging, transport, and storage processes. It directly impacts the pasta's ability to withstand handling and mechanical stresses throughout its journey from production to consumption [30]. Manufacturers should consider the relationship between breaking strength and diameter to ensure uniformity in pasta dimensions to enhance mechanical strength and minimize product loss. This attribute is particularly important for ensuring product quality and customer satisfaction, as intact pasta retains its shape, texture, and overall appeal.

Table 2. Findings of determined physico-chemical characteristics of the products (Mean \pm SD)

Company No.	Diameter (mm)	Moisture content (%w/w)	Breaking strength (N.m ⁻²)
1	0.90 \pm 0.03 ^c	11.43 \pm 0.28 ^{cdef}	3.75 $\times 10^6$ \pm 2.05 $\times 10^6$ ^a
2	1.21 \pm 0.05 ^b	11.80 \pm 0.05 ^{abcde}	1.03 $\times 10^6$ \pm 2.98 $\times 10^5$ ^b
3	1.17 \pm 0.05 ^{bc}	12.65 \pm 0.18 ^a	1.02 $\times 10^6$ \pm 2.29 $\times 10^5$ ^b
4	1.19 \pm 0.06 ^b	12.06 \pm 0.20 ^{abc}	1.25 $\times 10^6$ \pm 6.60 $\times 10^4$ ^b
5	0.98 \pm 0.04 ^{bc}	10.68 \pm 0.02 ^f	2.12 $\times 10^6$ \pm 5.36 $\times 10^4$ ^{ab}
6	0.93 \pm 0.06 ^c	11.84 \pm 0.04 ^{abcde}	2.16 $\times 10^6$ \pm 1.36 $\times 10^6$ ^{ab}
7	1.14 \pm 0.07 ^{bc}	12.49 \pm 0.33 ^{ab}	1.61 $\times 10^6$ \pm 4.06 $\times 10^5$ ^b
8	1.21 \pm 0.05 ^b	11.80 \pm 0.04 ^{abcde}	9.04 $\times 10^5$ \pm 2.04 $\times 10^5$ ^b
9	1.19 \pm 0.19 ^b	11.92 \pm 0.24 ^{abcd}	1.49 $\times 10^6$ \pm 2.44 $\times 10^5$ ^b
10	1.73 \pm 0.09 ^a	11.00 \pm 0.35 ^{ef}	6.79 $\times 10^5$ \pm 2.27 $\times 10^5$ ^b
11	1.55 \pm 0.15 ^a	11.09 \pm 0.33 ^{def}	1.44 $\times 10^6$ \pm 3.96 $\times 10^5$ ^b
12	1.67 \pm 0.13 ^a	11.71 \pm 0.25 ^{bcde}	1.25 $\times 10^6$ \pm 2.89 $\times 10^5$ ^b
13	1.62 \pm 0.08 ^a	11.05 \pm 0.04 ^{def}	7.52 $\times 10^5$ \pm 4.93 $\times 10^4$ ^b
14	1.57 \pm 0.05 ^a	10.61 \pm 0.24 ^f	8.86 $\times 10^5$ \pm 1.53 $\times 10^5$ ^b
Mean	1.29	11.58	1.45 $\times 10^6$
SD	0.29	0.64	9.80 $\times 10^5$

Values are given as means \pm standard deviation (SD) of the duplicate (moisture content) and triplicate (diameter and breaking strength) determinations. Values in the same column having the same superscripted letters are not statistically significant differences ($p > 0.05$) according to Tukey's Honest Significant Different (HSD).

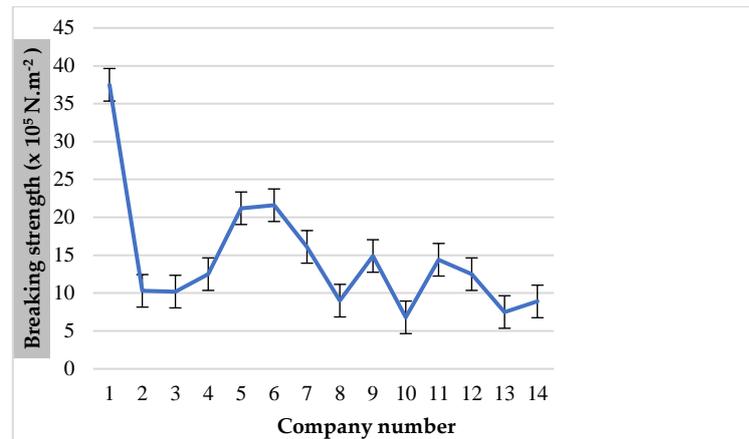


Figure 4. Shows the variation of breaking strength determined in vermicelli samples from processing units

3.2.4. Colour of the products

Colour of dry-folded vermicelli samples is shown in [Table 3](#). The resulting colour of folded vermicelli made from the different processing units was not significantly different (ANOVA, $p > 0.05$) for colour parameters L^* (brightness) and b^* (yellowness) (ranged from 53.03-72.14 and 13.68-19.48, respectively), and a^* (redness) values of samples ranging between -1.32 to 0.56, were recorded in only 2/14 samples from company number 8 and 11.

In respect to the brightness and yellowness, it was found that vermicelli samples presented almost the same profile of values, probably due to wheat flour used in production that was not supplemented with any other ingredients, also influenced with dryness through similar sun-drying method. This was ensured to maintain consistent product quality and ensure that the folded vermicelli met established colour standards. The findings by [Desai *et al.* \[18\]](#) and [Mercier *et al.* \[39\]](#) revealed that there is a decrease in the brightness of pasta incorporated with fish.

A different situation was found for a a^* value of samples, where two appeared red in colour compared to others. This result could mean that the appearance of red colour may be due to non-enzymatic browning related to Maillard reaction (MR) developed in processing (steaming), and/or during vermicelli drying, especially at high temperatures. A slight change in redness could affect the perceived colour, and processors may need to monitor and control factors influencing colour to maintain consistency and enhance product visual appeal.

Colour is a crucial factor in assessing pasta quality [\[8,42\]](#) and consumer preference [\[15, 41, 43, 48\]](#). A bright yellow hue, determined by colorimetric colours; brightness and yellowness, reflects pigment concentration, while the redness is linked to the Maillard reaction's (MR) development [\[2, 7, 12\]](#).

Table 3. Findings of the assessed colour parameters of the vermicelli samples (Mean±SD)

Company No.	Brightness (L*)	Redness (a*)	Yellowness (b*)
1	67.65±4.20 ^a	-0.68±0.01 ^{bc}	19.42±1.74 ^a
2	55.39±12.78 ^a	-0.43±0.04 ^{abc}	15.64±4.43 ^a
3	61.54±2.52 ^a	-1.32±0.18 ^c	14.31±0.25 ^a
4	68.89±1.90 ^a	-0.16±0.21 ^{abc}	19.20±0.35 ^a
5	57.79±1.87 ^a	-0.67±0.39 ^{bc}	15.82±0.57 ^a
6	53.03±5.88 ^a	-0.77±0.33 ^{bc}	13.68±0.83 ^a
7	54.68±7.47 ^a	-0.25±0.13 ^{abc}	14.85±1.01 ^a
8	62.06±1.65 ^a	0.04±0.02 ^{ab}	18.12±0.22 ^a
9	72.14±0.71 ^a	-0.16±0.36 ^{abc}	19.48±1.14 ^a
10	69.83±5.05 ^a	-0.47±0.46 ^{abc}	16.57±1.80 ^a
11	60.79±10.95 ^a	0.56±0.72 ^a	17.72±2.12 ^a
12	61.63±1.39 ^a	-0.19±0.01 ^{abc}	15.47±1.02 ^a
13	53.96±2.27 ^a	-0.26±0.11 ^{abc}	14.11±0.71 ^a
14	64.47±3.91 ^a	-0.42±0.05 ^{abc}	17.31±2.01 ^a
Mean	61.70	-0.37	16.55
SD	7.40	0.48	2.32

Values are given as means ± standard deviation (SD) of the duplicate determinations. Values in the same column having the same superscripted letters are not statistically significant differences ($p>0.05$) according to Tukey's Honest Significant Different (HSD).

3.3. Aflatoxin B₁ contamination of the products

A few samples (4/14) detected with the AFB₁ levels (0.6-0.7 µg.kg⁻¹) were far below the set limits for AFB₁ (5 µg.kg⁻¹) as per EAS for pasta (Table 4). In general, all folded vermicelli samples were complied with such EAS; this was due to the fact that the samples were thoroughly dried, stored in good condition (under wooden pallets), and adequate cleanliness of storage area/room and well property arrangement. Taking into account the drying and handling condition of samples done in open sun drying for two days, which is a potential risk to toxigenic fungi growth [37], where these results are unexpected. Low AFB₁ contamination levels in pasta have been reported in several studies in Ghana (ranging from 0.930-0.935 µg.kg⁻¹) [31], Morocco (0.01-0.25 µg.kg⁻¹) [9], and in Nigeria [macaroni (1.1 µg.kg⁻¹), noodles (2.2 µg.kg⁻¹), and spaghetti (1.2 µg.kg⁻¹)] [22].

In other words, the results obtained by this study did not investigate the presence of mycotoxin in the samples; it seems to be very unlikely that fungi, including mycotoxigenic species, could grow in the final products under proper storage conditions. The presence of moulds, though, does not inevitably mean that the stored pasta is contaminated with mycotoxins. Certain mould species which are mycotoxin producers can be identified without the presence of mycotoxin. That is well known that mycotoxin synthesis occurs only when the moulds are found under favourable conditions [24].

Table 4. The findings of aflatoxin B₁ of the vermicelli samples in $\mu\text{g}\cdot\text{kg}^{-1}$ (Mean \pm SD)

Company No.	AFB ₁ concentration
1	0.60 \pm 0.00 ^a
2	*
3	*
4	*
5	*
6	0.70 \pm 0.14 ^a
7	*
8	*
9	*
10	*
11	*
12	*
13	0.60 \pm 0.00 ^a
14	0.60 \pm 0.00 ^a

Values are given as means \pm standard deviation (SD) of the duplicate determinations. Values in the same column having the same superscripted letters are not statistically significant differences ($p>0.05$) according to Tukey's Honest Significant Different (HSD).

* - indicating that the samples were below the detection limit ($<0.12\mu\text{g}\cdot\text{ml}^{-1}$).

4. Conclusions

The results from this study indicate that the quality and safety of dry-folded vermicelli produced by small-scale processors in Tanzania vary through microbiological, physico-chemical, and aflatoxin B₁ parameters. While compliance with East African Standards was observed in some aspects, inconsistent adherence in microbial safety, particularly *Aspergillus* species, raises concerns. Detection of aflatoxin B₁ in a subset of samples, though within acceptable limits, underscores the importance of continuous monitoring to alleviate potential health risks. Most of the physico-chemical parameters indicated a satisfactory overall quality. Generally, concerted efforts are needed to improve production practices and ensure consistent compliance with quality and safety standards, safeguarding consumer health in the context of aflatoxin exposure.

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