Evaluation of Fungi Infestation of Stored White and Yellow Cassava Garri in Jos North Metropolis

John W. C.[1*] Ishaya M.[2] Ihum T. A.[3] Joshua V. I.[1] Dinchi P. T.[1] and Sikiru G. K.[1]
1. Federal College of Forestry, Jos, Nigeria
2. Federal College of Forestry Resources Management, Maiduguri, Nigeria.
3. Nigerian Stored Products Research Institute (NSPRI) Ilorin, Kwara State, Nigeria.
* Corresponding author: jowaltee@gmail.com

Abstract: Food security is required national development and for human survival. However, it is important that food security should not be seen only in the perspective of availability but also on safety. This study determined the mycological quality of selected white and yellow Garri sold within Jos North metropolis. The study was conducted at the biology laboratory of Federal College of Forestry, Jos. A total of 24 samples (12 white and 12 yellow) were purchased from Katako, Terminus, Busa buji and New market. The sample were collected in sterile polyethylene nylon. The fungi were isolated using prepared and sterilized Patatose dextrose agar. Identification of fungi was carried using microscopic method. Disk Diffusion Technique on Muller Hilton Agar (MHA) was used to determine fungal sensitivity. Data were statistical analyses using ANOVA and t-test at *p*value ≥ 0.05. The means was separated using Duncan's Multiple Range Test. The result revealed white Garri from Terminus has the highest fungal load of 14.50± 1.26 Sfu/gl. Busa buji showed the lowest value of 5.50±1.53 Sfu/gl. The Fungi isolated were *Aspergillus niger, Curvilaria* sp, *Penicillium* sp, *fusarium oxysparum, Geitricum* sp and Macrophrosis. *Aspergillus* sp had the highest frequency of occurrence (28.95% and 23.68%) in both white and yellow Garri while Macrophrosis had the least frequency occurrence of 2.63%. The pH values of white and yellow Garri ranges between 5 and 6 and moisture content showed that yellow Garri had the highest moisture content of 21.76 ± 1.24. The isolate were more sensitive to keteconarzole than fluconazole and Griseofulvin. The findings revealed that consumers are exposed to the risk of fungal infestation. Therefore renewed vigilance on the efficiency of garri processing condition, handling and storage is required.
Key word: Garri, fungi, pH, moisture content, consumers

INTRODUCTION

Cultivation of cassava (*Manihot esculanta* Crantz) is majorly needed for human consumption. It is an important staple food in Tropical Africa including Nigeria (Chinwe *et al.,* 2016). Worldwide, Nigeria is among major cassava producing countries (Obi et al., 2022). Cassava production is geared towards alleviation of the food crisis in developing regions and is suitable because of its sufficient nutrient, high energy yielding, availability, tolerance and adequate farming methods in Africa (Chinwe *et al.,* 2016; Obi *et al*., 2022).

Garri is a fermented bye product of cassava (*Manihot esculenta* Crantz) tubers and is well known, it is widely consumed in West and Central Africa. Ten million tons of Cassava is estimated to be cultivated in Nigeria alone per annum (Okafor *et al*., 2018). In Nigeria and most West African countries, Garri is one of the commonly consumed and preferred Cassava products due to it affordability, easy to cook and long shelf life (FAO, 2010; Oluwafemi and Udeh, 2016; Awoyale *et al*., 2021). Majority of the cassava harvested from farms in Nigeria are being transformed into Garri (Adebayo *et al*., 2012; Okolo and Makanjuola, 2021).

However, as nutritious and acceptable as Garri can be, the unhygienic methods experienced in processing of the cassava roots into Garri predisposes the product to a lot of microbial contaminations and, this has serious health implications. Microbial contamination of garri could arise due to processing conditions, storage methods, and storage containers (Akindele and Abimbola, 2018). The high carbohydrate content of Garri encourages fungal growth (Aguoru *et al*., 2014). Moulds such as *Penicillium, Aspergillus, Rhizopus, Fusarium, Mucor* and *Cladosporium* have been implicated with processed garri (Aguoru *et al*., 2014; Ezekiel *et al*., 2020; Orpin *et al*., 2020; Tersoo-Abiem *et al*., 2020; Obi *et al*., 2022). Report has suggested that moisture content create suitable condition for mould proliferation and contamination of garri during storage

(Halliday *et al*., 1967). *Aspergillus flavus*, *Aspergillus parasiticus* and *Penicillium* spp presence in garri has been reported in many studies can also produce aflatoxins (Ezekiel *et al*., 2020; Tolulope *et al.,* 2020), which have serious effects on health especially when consume in high dosage.

Garri is largely sold in open market and consume without any form of pre-treatment which may endanger consumer's health (Okafor *et al*., 2018). Development of moulds in Garri may lead to changes in the nutritive quality, organoleptic and microbiological content, finally leading to product spoilage. Based on the negative health effects of post-harvest fungal deterioration of Garri, it becomes important to supply baseline information on the types of fungal flora associated with Garri in Jos and possible management measures. This study was aimed at determining the mycological quality of selected white and yellow Garri sold within Jos North metropolis for consumer's awareness.

MATERIALS AND METHODS

Study area: The study was carried out at Biology Lab of Federal College of Forestry Jos North Local Government Area of Plateau State located at Northern Guinea Savannah at Latitude $9^0$55 and $8^0$55 Longitude. It has an average elevation of 1.250m above sea level and stands at a height of about 600m, above surround plain. The average temperature ranges between 21^0C and 25^0C. The climate of the state is cool due to its high altitude. Rainy season is usually April to September while dry season is October to March. The mean annual rainfall is 1.260mm (Wuyep and Daloeng, 2020).

Sample collection: A total of 24 samples (12 Yellow and 12 White garri 20 gram each) were collected randomly from three major markets within Jos metropolis. Samples were collected in labelled sterile polyethylene bags and transported to Biology laboratory of Federal College of Forestry Jos for analysis after three days.

Sample preparation and isolation of fungi from garri: Ten (10) grams of potato dextrose agar was dissolved in 250mls of distilled water, the dissolved medium was thoroughly mixed using a sterilized glass rod and autoclaved at 121°C for 15minutes. One (1) gram of each sample was suspended in 9 ml of sterilized distilled water in a test tube, the samples were homogenized and a ten (10) fold serial dilution technique was carried out by dispensing 1ml of the suspension into another 9 ml of distilled water up to the 10th test tube. One (1) milliliter of the diluents were collected and dropped on the already solidified Potato Dextrose Agar in a glass plates. Incubation of the inoculated plates were done at 25ºC for 7 days and were examined after 3 days for possible growths.

Cultural characteristics: Macroscopically, the fungal isolates were characterized according to size, growth pattern, colour, pigmentation and texture (Tolulope *et al*., 2020).

Microscopy identification of fungi from garri: The fungal isolates were identified by picking small portion of the subculture fungi. The picked culture were teased and placed on a grease free clean glass slide containing Lactophenol cotton blue stain, and covered with a cover slip. The slide was observed under microscope with 10x and 40x objective lens. The presence of conidial heads, conidiosphores, philiades and rhizoids were recorded (John *et al*., 2016).

***Antibiogram assay of isolated fungi*:** The method described by Olabode *et al*. (2016) was adopted. This was carried out by disk diffusion technique on Muller Hilton Agar (MHA). Methylene blue was added to the surface of the agar and allowed to air dry prior to the inoculation of the fungal isolates. The fungi were inoculated by dipping a sterile swab into the standardized inoculums suspension (0.5 McFarland standards, 10^6 cells/ ml) and streaked over the agar surface. The plates were allowed to dry for 15mins at ambient temperature and the prepared antifungal drugs in 10 mg/ml was applied. The zones of inhibitions of the isolates were

taken using meter ruler after 72 hours of incubation to determine sensitivity.

Determination of moisture content of garri sample: This was done by a modification of method describe by Aguoru *et al*. (2014). The moisture content of each of the garri samples was determined immediately after collection. This was carried out by weighing 5.0g of the garri and drying in an oven maintained at 60°C for 10 h to obtain a constant weight. This was followed by placing the sample in a desiccator to cool before re-weighted. The difference in weight of the garri was taken to determine the moisture content.

pH determination of garri sample: The pH of the different samples of yellow and white garri was examined following method described by Ogiehor and Ikenebomah (2010). Ten grams of each sample was homogeneous in 10 ml of distilled water and the pH of the suspension determined using a glass electrode pH meter (Hach pH 1500).

Analysis of data collected: The various data obtained from this study was subjected to statistical analyses: ANOVA and t-test was used to compare significant difference between the treatments at *p*value ≥ 0.05. The means was separated using Duncan Multiple Range Test (DMRT).

RESULTS

Total viable fungal counts of white and yellow garri obtained from different markets in Jos North

The findings in Table 1 showed the Total Viable Fungal counts of white and yellow garri from the different markets. White garri collected from Terminus market gave the highest fungal load of 14.50 ± 1.26 sfu while Busabuji market showed the lowest value of 5.50 ± 1.53 sfu. The findings of the White garri indicated significant difference between the various markets at $p \leq$ value 0.05 while the findings of the Yellow garri indicated no significant difference between the various markets at *p*-value 0.05. The results in Table 1 also indicated that Yellow garri has the highest fungi load of 19.31 ± 0.51 compare to White garri with 9.23 ± 0.96. The result of the t-test indicated significant difference at p value $\leq$ 0.01.

Macroscopic and microscopic features of the fungi isolates from Yellow and White garri

Plate 1 demonstrated the fungi identification (Macroscopic and Microscopic features) from yellow and white garri collected from the various markets. The probable fungi isolate identified include *Aspergillus niger, Cuvurlaria lunata*, *Penicillum* sp, *Fusarium oxysporum* and *Geotricum* sp.

Frequency Distribution and Percentage of Fungal Isolates from Garri

Table 2 revealed Frequency Distribution and Percentage of Fungal Isolates from Garri. A total of 7 fungi genera were isolated from garri obtained from the various markets. Penicillum species with 28.95% gave the most frequently occurring mould compared to other species. *Microsphaerosis*sp showed the least occurring with 2.63%.

Changes in pH content of white and yellow garri at ambient temperature.

Table 3 indicated the results of Changes in pH content of white and yellow garri at ambient temperature. Results showed white garri from Katako market with the highest pH value of 6.15 ± 0.04 but statistically, the findings showed there was no significant different in pH among the various markets. Also the comparative study indicated no significant different existed in pH values between yellow and white garri.

Changes in moisture content of white and yellow garri at ambient temperature.

Table 4 indicated the changes in moisture content of white and yellow garri at ambient temperature. Fingings showed yellow garri from Terminus market with the highest moisture value of 21.76 ± 1.24 but statistically, the findings showed there was no significant different in moisture among the various markets. White garri obtained from Terminus market indicated lowest moisture value of 11.79 ± 0.87 but statistically, the findings showed there was no significant different in moisture among the various markets. The comparative study indicated significant different existed in

Moisture values between yellow and white garri from Terminus and Busabuji market.

Antifungal sensitivity (Zone of Inhibitions (mm) At Day 3 Incubation.

The findings in Table 5 indicated the Antifungal sensitivity of the various fungal isolates after 3 days of incubation. *Geotrichum* sp and *Microsphearosis* sp showed the highest sensitivity by zone of inhibition of 4.07 ± 0.09, 4.13 ± 0.03 and 4.23 ± 0.09 mm to Ketoconazole, Fluconazole and Griseofulvin respectively. *Aspergillus niger* and *Fusarium oxysporum* were resistant to Griseofulvin showing 0.00 ± 0.00 mm zone of inhibition. The lowest zone of inhibition to Ketoconazole and Fluconazole of 1.20 ± 0.06 and 0.47 ± 0.07 mm were exhibited by *Aspergillus niger* and *Penicillum* sp respectively. The findings revealed there was significant difference between the isolates at *p* value ≤ 0.01.

Antifungal sensitivity (Zone of Inhibitions (mm) At Day 4 Incubation

Table 6 revealed the Antifungal sensitivity of the various fungal isolates after 4 days of exposure. *Microsphaerosis* sp gave the highest sensitivity with zone of inhibition of 4.33 ± 0.03, 4.17 ± 0.07 and 4.10 ± 0.00 mm to Ketoconazole, Fluconazole and Griseofulvin respectively. *Asperrgillus niger* was resistant to Griseofulvin with 0.00 ± 0.00 mm zone of inhibition after 4 days of exposure. The lowest zone of inhibition to Ketoconazole and Fluconazole of 1.43 ± 0.03 and 0.40 ± 0.10 mm were exhibited by *Asperrgillusniger*. This study in revealed that there was significant difference between the isolates at *p* value ≤ 0.01.

Antifungal sensitivity (Zone of Inhibitions (mm) At Day 5 Incubation

Table 7 showed the Antifungal sensitivity of the various fungal isolates after 5 days of exposure. The findings indicated *Asperrgillus niger* was resistant to Griseofulvin showing 0.00 ± 0.00 mm zone of inhibition after 5 days of exposure. *Microsphaerosis* sp gave the highest sensitivity with zone of inhibition of 4.30 ± 0.12, 4.13 ± 0.03 and 4.17 ± 0.07 mm to Ketoconazole, Fluconazole and Griseofulvin respectively. The lowest zone of inhibition to Ketoconazole and Fluconazole of 1.47 ± 0.12 and 0.47 ± 0.12 mm were exhibited by *Asperrgillus niger*. There was significant difference between the isolates at *p* value ≤ 0.01.

Comparison of the efficacy of the fungicides on the fungal isolates

The findings in Table 8 revealed the comparison of the efficacy of the fungicides on the fungal isolates. These shows that isolates were more sensitive to Ketoconazole than Fluconazole and Grisofulvin. Griseofulvin exhibited the lowest efficacy against the fungal isolates. Increase in the days of exposure of the isolates to the antibiotic led to increased zone of inhibition. *Asperrgillus niger* recorded the highest resistant value of 1.47 ± 0.12 mm against the Ketoconazole compare to other isolates after 5 days. The results showed significant differences between the antibiotics compared at *p*value ≤ 0.05 and 0.01.

Table 1: Total viable fungal counts of white and yellow garri obtained from different markets in Jos North

Markets	White Garri (sfu g^{-1} x 5)	Yellow Garri (sfu g^{-1} x 5)	t-test	*P*-value
Terminus	14.50 ± 1.26[a]	23.50 ± 2.18	3.576	0.023*
Katako	6.50 ± 2.25[c]	14.93 ± 2.83	2.333	0.080
New market	10.67 ± 2.40[b]	15.67 ± 4.91	0.915	0.412
Busa buji	5.50 ± 1.53[c]	22.67 ± 3.18	4.866	0.008**
Average (TFU)	9.23 ± 0.96	19.31 ± 0.51	9.302	0.001**
ANOVA	4.073	1.620		
P-value	0.033*	0.244		

Key: * Significant difference exists at $P \leq 0.05$; ** Significant difference exists at $P \leq 0.01$, Values are mean of triplicate readings. Mean values were separated using Duncan Multiple Range Test. Mean values with different superscripts in the same column are significantly different

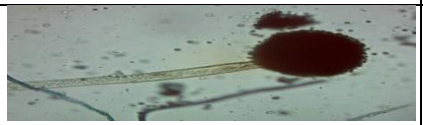
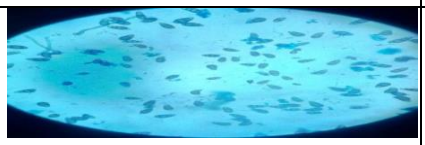
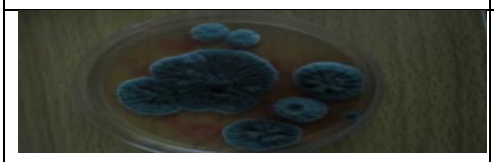
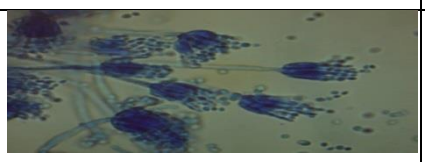
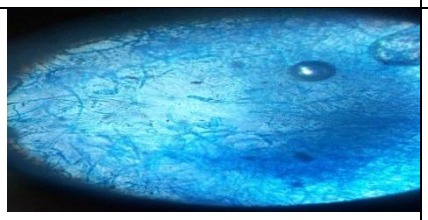
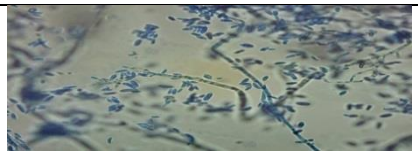
Macroscopic view	Microscopic view	Isolates
		*Aspergillus niger*
		*Cuvurlaria lunata*
		*Penicillum* sp
		*Cladosporium* sp
		*Geotricum* sp
		*Microsphaeropsis* sp
		*Fusarium oxysporum*

Plate 1: Macroscopic and microscopic features of the fungal isolates from Yellow and White garri

Table 2: Frequency Distribution and Percentage of Fungal Isolates from Garri

S/N	Isolates	Frequency occurrence	Percentage (%)
1	*Microsphaerosis* sp	1	2.63
2	*Cladosporium* sp	2	5.26
3	*Cuvurlaria* sp	4	10.53
4	*Geotrichum* sp	4	10.53
5	*Fusarium oxysporum*	7	18.42
6	*Asperrgillus niger*	9	23.68
7	*Penicillum* sp	11	28.95
Total		38	100

Table 3: Changes in pH content of white and yellow garri at ambient temperature

Markets	pH (Mean ± SEM)			
	White	Yellow	t-test	*P*-value
Terminus	5.47 ± 0.63	5.21 ± 0.40	0.347	0.746
Katako	6.15 ± 0.04	5.29 ± 0.37	2.316	0.082
New market	5.26 ± 0.37	5.47 ± 0.68	0.280	0.793
BusaBuji	5.67 ± 0.32	5.14 ± 0.43	0.979	0.383
ANOVA	0.900	0.086		
P-value	0.482	0.966		

Key: * Significant difference exists at $P \leq 0.05$; ** Significant difference exists at $P \leq 0.01$, Values are mean of triplicate readings. Mean values were separated using Duncan Multiple Range Test. Mean values with different superscripts in the same column are significantly different

Table 4: Changes in moisture content of white and yellow garri at ambient temperature

Markets	Moisture (Mean ± SEM)			
	White	Yellow	t-test	*P*-value
Terminus	11.79 ± 0.87	21.76 ± 1.24	6.573	0.003**
Katako	13.16 ± 0.35	16.95 ± 2.57	1.462	0.218
New market	15.18 ± 1.95	16.05 ± 2.26	0.293	0.784
Busabuji	14.45 ± 0.01	20.15 ± 0.55	10.405	< 0.001**
ANOVA	1.900	2.118		
P-value	0.208	0.176		

Key: * Significant difference exists at $P \leq 0.05$; ** Significant difference exists at $P \leq 0.01$, Values are mean of triplicate readings. Mean values were separated using Duncan Multiple Range Test. Mean values with different superscripts in the same column are significantly different

Table 5: Antifungal sensitivity (Zone of Inhibitions (mm) At Day 3 Incubation

Isolate	Day 3		
	Ketoconazole	Fluconazole	Griseofulvin
Asperrgillus niger	1.20 ± 0.06^{e}	0.40 ± 0.06^{g}	0.00 ± 0.00^{f}
Cuvurlaria sp	1.73 ± 0.09^{d}	0.90 ± 0.06^{f}	0.40 ± 0.06^{e}
Penicillum sp	2.10 ± 0.06^{c}	1.70 ± 0.06^{e}	0.50 ± 0.06^{e}
Cladosporium sp	3.67 ± 0.09^{b}	3.70 ± 0.06^{b}	3.67 ± 0.09^{c}
Geotrichum sp	4.07 ± 0.09^{a}	4.00 ± 0.06^{a}	4.00 ± 0.06^{b}
Microsphaerosis sp	4.13 ± 0.03^{a}	4.13 ± 0.03^{a}	4.23 ± 0.09^{a}
Fusariumoxysporum	3.77 ± 0.07^{b}	3.00 ± 0.06^{c}	3.07 ± 0.03^{d}
ANOVA	240.505	700.875	1232.198
P-value	< 0.001**	< 0.001**	< 0.001**

Key: * Significant difference exists at $P \leq 0.05$; ** Significant difference exists at $P \leq 0.01$, Values are mean of triplicate readings. Mean values were separated using Duncan Multiple Range Test. Mean values with different superscripts in the same column are significantly different

Table 6: Antifungal sensitivity (Zone of Inhibitions (mm) At Day 4 Incubation

Isolate	Day 4		
	Ketoconazole	Fluconazole	Griseofulvin
Asperrgillus niger	1.43 ± 0.03^{d}	0.40 ± 0.10^{e}	0.00 ± 0.00^{f}
Cuvurlaria sp	2.07 ± 0.12^{c}	1.07 ± 0.09^{d}	0.57 ± 0.03^{e}
Penicillum sp	2.20 ± 0.12^{c}	1.77 ± 0.12^{c}	0.67 ± 0.03^{d}
Cladosporium sp	3.90 ± 0.06^{b}	3.87 ± 0.09^{b}	3.57 ± 0.07^{b}
Geotrichum sp	4.10 ± 0.10^{ab}	4.03 ± 0.09^{ab}	3.80 ± 0.40^{ab}
Microsphaerosis sp	4.33 ± 0.03^{a}	4.17 ± 0.07^{a}	4.10 ± 0.00^{a}
Fusariumoxysporum	4.27 ± 0.09^{a}	3.10 ± 0.12^{c}	3.00 ± 0.06^{c}
ANOVA	229.066	291.421	169.575
P-value	< 0.001**	< 0.001**	< 0.001**

Key: * Significant difference exists at $P \leq 0.05$; ** Significant difference exists at $P \leq 0.01$, Values are mean of triplicate readings. Mean values were separated using Duncan Multiple Range Test. Mean values with different superscripts in the same column are significantly different

Table 7: Antifungal sensitivity (Zone of Inhibitions (mm) At Day 5 Incubation

Isolate	Day 5		
	Ketoconazole	Fluconazole	Griseofulvin
Asperrgillus niger	1.47 ± 0.12^{d}	0.47 ± 0.12^{e}	0.00 ± 0.00^{f}
Cuvurlaria sp	2.03 ± 0.09^{c}	1.27 ± 0.12^{d}	0.60 ± 0.06^{e}
Penicillum sp	2.67 ± 0.07^{b}	1.90 ± 0.06^{c}	0.77 ± 0.09^{d}
Cladosporium sp	4.07 ± 0.09^{a}	3.97 ± 0.07^{a}	3.60 ± 0.06^{b}
Geotrichum sp	4.10 ± 0.10^{a}	4.07 ± 0.09^{a}	4.13 ± 0.07^{a}
Microsphaerosis sp	4.30 ± 0.12^{a}	4.13 ± 0.03^{a}	4.17 ± 0.07^{a}
Fusarium oxysporum	4.13 ± 0.09^{a}	3.07 ± 0.09^{b}	3.00 ± 0.06^{c}
ANOVA	153.100	294.866	1113.210
P-value	< 0.001**	< 0.001**	< 0.001**

Key: * Significant difference exists at $P \leq 0.05$; ** Significant difference exists at $P \leq 0.01$, Values are mean of triplicate readings. Mean values were separated using Duncan Multiple Range Test. Mean values with different superscripts in the same column are significantly different

Table 8: Comparison of the efficacy of the fungicides on the fungal isolates

Day	Isolate	Ketoconazole	Fluconazole	Griseofulvin	*P*-value
3	*Asperrgillusniger*	1.20 ± 0.06^{a}	0.40 ± 0.06^{b}	0.00 ± 0.00^{c}	< 0.001**
	Cuvurlariasp	1.73 ± 0.09^{a}	0.90 ± 0.06^{b}	0.40 ± 0.06^{c}	< 0.001**
	Penicillumsp	2.10 ± 0.06^{a}	1.70 ± 0.06^{b}	0.50 ± 0.06^{c}	< 0.001**
	Cladosporiumsp	3.67 ± 0.09	3.70 ± 0.06	3.67 ± 0.09	0.943
	Geotrichumsp	4.07 ± 0.09	4.00 ± 0.06	4.00 ± 0.06	0.746
	Microsphaerosissp	4.13 ± 0.03	4.13 ± 0.03	4.23 ± 0.09	0.422
	Fusariumoxysporum	3.77 ± 0.07^{a}	3.00 ± 0.06^{b}	3.07 ± 0.03^{b}	< 0.001**
4	*Asperrgillusniger*	1.43 ± 0.03^{a}	0.40 ± 0.10^{b}	0.00 ± 0.00^{c}	< 0.001**
	Cuvurlariasp	2.07 ± 0.12^{a}	1.07 ± 0.09^{b}	0.57 ± 0.03^{c}	< 0.001**
	Penicillumsp	2.20 ± 0.12^{a}	1.77 ± 0.12^{b}	0.67 ± 0.03^{c}	< 0.001**
	Cladosporiumsp	3.90 ± 0.06^{a}	3.87 ± 0.09^{a}	3.57 ± 0.07^{b}	0.031*
	Geotrichumsp	4.10 ± 0.10	4.03 ± 0.09	3.80 ± 0.40	0.676
	Microsphaerosissp	4.33 ± 0.03^{a}	4.17 ± 0.07^{b}	4.10 ± 0.00^{b}	0.021*
	Fusariumoxysporum	4.27 ± 0.09^{a}	3.10 ± 0.12^{b}	3.00 ± 0.06^{b}	< 0.001**
5	*Asperrgillusniger*	1.47 ± 0.12^{a}	0.47 ± 0.12^{b}	0.00 ± 0.00^{c}	< 0.001**
	Cuvurlariasp	2.03 ± 0.09^{a}	1.27 ± 0.12^{b}	0.60 ± 0.06^{c}	< 0.001**
	Penicillumsp	2.67 ± 0.07^{a}	1.90 ± 0.06^{b}	0.77 ± 0.09^{c}	< 0.001**
	Cladosporiumsp	4.07 ± 0.09^{a}	3.97 ± 0.07^{a}	3.60 ± 0.06^{b}	0.009**
	Geotrichumsp	4.10 ± 0.10	4.07 ± 0.09	4.13 ± 0.07	0.864
	Microsphaerosissp	4.30 ± 0.12	4.13 ± 0.03	4.17 ± 0.07	0.355
	Fusariumoxysporum	4.13 ± 0.09^{a}	3.07 ± 0.09^{b}	3.00 ± 0.06^{c}	< 0.001**

Key: * Significant difference exists at $P \leq 0.05$; ** Significant difference exists at $P \leq 0.01$Values are mean of triplicate readings. Mean values were separated using Duncan Multiple Range Test. Mean values with different superscripts in the same row are significantly different

DISCUSSION

The moulds isolated from both the yellow and white garri sample were *Aspergillus niger, Penicillium sp, Fusarium oxysparum, Curvularia lurana, Geotricum sp, Microsphearopsis arundinis*. Similar moulds were reported by other studies in different parts of Nigeria (Olopade *et al.,* 2014; Okolo and Makanjuola, 2021; Obi *et al*., 2022). The findings of these study is an evident that garri sold in open market was infested with fungi. The slight difference in fungal species from other studies might be due to varying production process (Obi *et al*., 2022). The fungi recorded in this study may be due unhygienic practice involved in processing and handling garri. These processes exposes cassava and it products to fungal spores (Ogugbue *et al*., 2011).

The Yellow Garri in this study indicated higher fungal load compared to White garri, this is contrary to the work of Onyeke *et al*. (2010), which reported fewer colony in yellow garri compared to white garri. The presence of palm oil support fungal growth (Enemuor *et al*., 2012). The high fungal load

in yellow garri could attributed to high content of degradable sugar associated with palm oil used in processing yellow garri (Schmidt and Michele, 2020). The variation could also be due to difference in oxygen and carbon dioxide permeability and water vapour (Ebidor *et al*., 2015)

Penicillium spp and *Aspergillus niger* recorded the highest occurrence in the garri sample (yellow and white), supported by the study of Rabiu *et al*. (2021). The high occurrence of *Aspergillus* species in both Garri could be linked to their abundance and wide distribution in nature. The presence of these fungal species in garri studied indicates poor sanitary processes in garri production and handling and this pose a serious health challenge to consumers. *Aspergillus, Fusarium* and *Penicillum* isolated in this study are major food and environment contaminant. The ability of these fungi to produce spores and mycotoxin make them very potent (Oranusi *et al.*, 2013; Olopade *et al.,* 2014) and of medical important.

The percentage moisture content of yellow and white Garri in this study revealed higher moisture content compared with previous studies (Halliday *et al*, 1967; Ogugbue and Obi 2011; Aguoru *et al*., 2014). In this study it was observed that yellow Garri recorded higher moisture content than white Garri, contradicting the work reported by Aguoru *et al*. (2014) and Rabiu *et al*. (2020). The disparity observed in moisture content could be attributed to variation in temperature, extent of dry frying/roasting and storage condition of the finished product (Okolo and Makanjuala, 2021). Aguoru et al. (2014) reported that the major important factor that could encourage mould contamination and proliferation in Garri was the high initial moisture content. Moisture is one of the factor that could lead to fungal infestation and multiplication in Garri (Halliday *et al*., 1967).

The pH values of white and yellow garri in this study ranges from 5-6. The findings shows no significant in pH among the various markets and comparative analysis indicates no significant different between yellow and white garri. The pH values recorded in this study was within the ranges of those reported by Olapade *et al*. (2018). A study conducted by Orji *et al*. (2016) in Ebonyi State, Nigeria reported pH value of 5.47 to 6.61 which is agreement with this study. The pH obtained in this study is a reflection of the presence of high fermentative fungi (Okolo and Makanjuala, 2021). This condition could create an enabling environment for fungal growth and proliferation.

The antibiogram study with antifungal agent on the fungal isolates obtained indicated that the fungi were sensitive to the antifungal agents used. The antifungal agents used in this study are similar to the report of Bamidele *et al.* (2014) and Mohammed *et al*. (2019) who used antifungal drugs: fesovin, fluconazole, itraconazole, griseofulvin, and ennotab vab to study the antibiogram against different fungal isolates. The findings in this study contradict the report of Mohammed *et al*. (2019), who demonstrated zone of inhibition as high as 17mm. This variation could be due to difference in antifungal agent and concentrations used. Maurizio and Posteraro (2018) had earlier reported that the fungal isolates sensitive and resistance were dose dependent to antifungal agents used. The fungal isolates reacted differently to the antifungal agent as the days of exposure increased. According to Mohammed *et al*. (2019) it could be attributed to physiology and enzyme produced by some of the fungi. Variation in genetic makeup and species diversity could also cause difference in sensitivity. The high fungal load observed in this study could pose a great health challenge to consumer if not mitigated. This group of fungi have been implicated in several diseases due to mycotoxin production. The ingestion of toxin produced by some of these fungi leads to acute and chronic toxicity that may compromise human organs. Hence the need for hygienic approaches in processing and handling of garri sold in Jos and Nigeria at large.

CONCLUSION

The present study indicated high fungal load and different species of fungi in garri sold in Jos, Plateau state. Yellow garri recorded the highest fungi load in this study compare to white garri. The pH obtained in this study reflected presence of high fermentative fungi. The antibiogram of the fungal isolates were said to be sensitive while some were resistant to antifungal drugs. The presence of fungi associated with Garri could be attributed to the production processes of the products especially the yellow garri. Therefore, proper processing techniques and handling that provides adequate hygiene and very low relative humidity and moisture is needed to prevent moulds proliferation and survival in garri that causes public health concerns consumers.

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