Contribution of fungi in the production of West Africa indigenous fermented foods and beverages.

**Essodolom TAALE1\*, Ali Kpatcha KADANGA1, Amakoé ADJANKE1, Tiatou SOUHO1, and Sabiba Kou’santa AMOUZOU1**

1 : Laboratoire des Sciences Agronomiques et Biologiques Appliquées (LaSABA), BP 404, Campus Nord, Route Nationale N°1, Université de Kara, Kara, Togo.

\*Auteur correspondant : Email : e.taale@univkara.net; etaale1981@gmail.com; Tel : (+228) 93 18 28 86 / 98 04 69 64

Abstract

In West Africa countries, several traditional fermented foods, non-fermented and beverages *like Agbélima, Attiéké, Dégué, Doklu, Gari, Gowé, fura, Kenkey, Koko, Kunun drink, lafun, Mawè, Nunu, Obiolor, Ogi, Pito, Tchapalo, Tchoukoutou, Wagashie, Wara, bissap, gnamakoudji, zoom koom*, etc…. are homemade with artisanal technology. Those traditional foods provide a means of food preservation, improve their shelf life, and add nutrients in the food products. From those foods, LAB is reported to be the most predominant microorganism involved in the fermentation process. Still, also fungi species play a key role in the development of different characteristics of those foods, especially their organoleptic attributes, and contribute to increasing their lifetime by producing different compounds. So, this study attempts to show the role played by yeasts in these various foods. Most of the West African home-made foods harbor a diversity of microorganisms (microbes, yeasts, molds, and mushrooms) that work in a synergic manner in order to make a desired product. More studies are needed to characterize fungi and assess their biotechnology application fully.

**Keywords:** West Africa, Yeasts, Fungi, Beverages, fermented foods

# **Introduction**

In West Africa, people consume a wide range of fermented and non-fermented products[1] made from cereals (maize, millet, sorghum, etc.), manioc, milk, ginger, etc., as a result of uncontrolled spontaneous fermentation by a mix of micro-organisms made up of moulds, bacteria and yeasts. The technology used to make these products is artisanal or traditional, handed down from generation to generation, and in some cases is part of the family heritage.

Yeasts, molds and fungi are eukaryotic organisms belonging to the fungi group. Among them, yeasts play a key role in food processing, using different types of substrates (millet, sorghum, milk, maize, cassava, banana, etc.) to produce a wide range of fermented products such as *pito, gowè, kunu, wagashie*. According to Rai, Kumari [2], yeasts enhance bioactive components through the production of enzymes and metabolites, and also act synergistically with other groups of micro-organisms, particular with lactic acid bacteria (LAB), to improve organoleptic properties. Yeasts, molds and lactic acid bacteria are responsible for the production of various traditional West African fermented food products because of their enzymatic equipment. These contain useful metabolites that improve digestion, boost immunity and improve people's health [3]. Traditional fermented foods are an important source of income for local households, particularly for women, helping to improve the population's standard of living [3].

Traditional fermentation processes provide a means of food preservation, improving the shelf life and adding to the nutrients in the food products in several African countries[4]. As with any fermented foods, the associated food microbiota is of great importance and interest, this paper aimed to highlight fungi species colonizing west Africa traditional fermented food and which role they play.

# **Types of West Africa indigenous foods**

Benin, Burkina Faso, Cape Verde, Côte d’Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo are countries belonging to western sub-region of Africa. In this region, several traditional fermented foods, non-fermented and beverages like *Akamu, Agbélima, Attiéké, Dégué, Doklu, Gari, Gowé, fura, Kenkey, Koko, Kunun drink, lafun, Mawè, Nunu, Obiolor, Ogi, Pito, Tchapalo, Tchoukoutou, Wagashie, Afitin, Iru, Sonru, Wara, bissap, gnamakoudji, zoom koom*, etc….[1, 3] are produced and widely consumed by the population belonging to all classes (farmers, workers, drivers, teachers, students, …) and all ages (children, adults, teenagers, youths, old men and old women) and all sex (male and female).

# **Fungi species involved in West Africa indigenous foods**

Yeast has been reported to be involved in several types of indigenous African fermented foods and beverages [5, 6]. As showed by table1, the most predominant fungi species involved in the production of west Africa traditional fermented food are *Saccharomyces species especially Saccharomyces cerevisiae.*

Table 1 Some west African traditional foods and involved fungi species

| **Indigenous foods** | **Yeast strains**  | **References** |
| --- | --- | --- |
| *Agbélima*  | *Candida krusei*, *C. tropicalis* and *Zygosaccharomyces bailii* | [7] |
| *Akamu*  | *Candida tropicalis*, *C. albicans*, *Clavispora lusitaniae, Saccharomyces paradoxus, S. cerevisiae*, *Aspergillus oryzae*, *A. niger*, *Penicillium citrinum*, *Rhizopus microsporus*, and *R. oligosporus* | [8] |
| *Attiéké*  | *Candida valida, Candida tropicalis, C. holmii, C. krusei, Kloeckera japonica, Saccharomyces cerevisiae* | [9, 10] |
| *Dégué*  | *Cyberlyndnera fabianii*, *Candida glabrata*, *Kluyveromyces marxianus*, and *Meyerozyma caribbica.* | [11] |
| *Fura*  | *Candida tropicalis*, *Galactomyces geotricum*, *Issatchenkia orientalis*, *Pichia anomala*, *S. pastorianus*, *S. cerevisiae*, and *Yarrowia lipolytica*  | [12] |
| *Gowé*  | *Clavispora lusitaniae, Pichia anomala,* Kluyveromyces marxianus, Candida krusei, C. tropicalis, C. rugosa, C. fabianii, C. norvegensis and Trichosporon asahii. | [13, 14] |
| *Kunu*  | *Aspergillus fumigatus*, *A. niger, Candida albicans*, *Fusarium* spp., *Penicillium* spp*., Rhizopus nigrican, Saccharomyces cerevisiae,* Rhizopus oryzae | [15-18] |
| *Lafun*  | *Debaryomyces* sp., *Saccharomyces cerevisiae*, *Candida tropicalis*, *C. glabrata, Pichia scutulata*, *P. kudriavzevii*, *P. rhodanensis, Kluyveromyces marxianus*, *Hanseniaspora guilliermondii*, , and *Trichosporon asahii*. | [19, 20] |
| *Mawè*  | *Clavispora lusitaniae, Candida krusei, C. kefyr, C*. *glabrata,* and *S. cerevisiae,* Kluyveromyces marxianus, Pichia kudriavzevii | [13, 21, 22] |
| *Nunu*  | *Candida kefyr, C. parapsilosis, C. rugosa, C. stellata, C. tropicalis, Galactomyces geotrichum, Kluyveromyce maxianus, Pichia kudriavzevii, Saccharomyces cerevisiae, S. pastorianus, Yarrowia lipolytica, Zygosaccharomyces bisporus, and Z. rouxii* | [23] |
| *Ogi*  | *Saccharomyces pastorianus, S. cerevisiae, C. mycoderma, C. krusei, C. tropicalis, Geotrichum candidum, G. fermentans,* *Rhodotorula graminis,* Clavispora lusitaniae, *Aspergillus niger, Rhizopus nigricans,*  | [6, 24, 25] |
| *Pito*  | *Candida albicans, C. tropicalis, Hansenula anomala, Kloeckera apiculata, Kluyveromyces africanus, Schizosaccharomyces pombe, Saccharomyces cerevisiae, Torulaspora delbrueckiiare, Aspergillus clavatus, Mucor hiemalis, Cladosporium sphaerospemum, C. herbarum, Debaryomyces hansenii and Pichia anomala* | [26, 27] |
| *Tchoukoutou*  | *Clavispora lusitaniae, S. cerevisiae, Candida krusei, C. rugosa, C. ethanolica, Saccharomyces cerevisiae*, *Pichia kudriavzevii,* and *Debaryomyces hansenii* | [13, 21, 28] |
| *Tchapalo*  | *Candida tropicalis*, *Saccharomyces cerevisiae*  | [5, 29, 30] |
| *Dolo* | *Saccharomyces cerevisiae, Pichia manshurica, Candida albicans* | [31, 32] |
| *Palm wine*  | *Saccharomyces cerevisiae, S. globosus, S. carlsbergensis, Clavispora lusitaniae, Kodamaea ohmeri, Candida haemulonii, C. phangngensis, C. silvae, Pichia kudriavzevii, Hanseniaspora jakobsenii, Hanseniaspora guilliermondii, Meyerozyma caribbica, Geotrichum candidum ADR3, Yarrowia lipolytica ADR4, Hanseniaspora jakobsenii ADR2* | [32-36] |
| *Adjuevan* | *Kluyveromyces marxianus, Hansenula anomala, Saccharomyces cerevisiae, Candida tropicalis, C. zeylanoides, Pichia fermentans, Debaromyces hansenii, Hanseniaspora osmophilic, Rhodotorula glutinis* | [37] |
| *Masa*  | *Saccharomyces cerevisiae* | [38] |
| *Burukutu*  | *S. cerevisiae, Candida albicans, Aspergillus niger* | [26, 39] |
| *Rabilé*  | *Saccharomyces and Rhodotorula, Candida pseudorhangii, C. heliconiae, C. utilis, Shizosaccharomyces pombe, Sporobolomyces odoratus* | [40, 41] |
| *eblima and epoma* | *Candida guilliermondii, C. krusei, C. tropicalis, Saccharomyces cerevisiae*  | [42] |
| *Soumbara*  | *Fusarium oxysporum, Penicillium chrysogenum, P. sclerotiorum, Aspergillus flavus, Absidia corymbifera, Cladosporium uredinicola.* | [43] |
| *Lait caillé*  | *Candida parapsilosis*, *Saccharomyces cerevisiae* | [44] |
| *Kulikuli*  | *Aspergillus flavus, A. tamarii, A. niger, Cercospora personata and C. Arachidicola* | [45] |
| *fresh and dried vegetable* | Aspergillus flavus, A. niger, A. parasiticus, Mucor spp., Penicillum brevicopactum, P. chrysogenium, Fusarium culmorum | [46] |
| *Smoked, Fermented and Dried Fishes*  | *Aspergillus parasiticus, A. fumigatus, A. wentii, A.clavatus, A. ochraceus, A. tamarii, A. candidus* A. *versicolor, Mucors sp.*, *Rhizopus sp., Rhizomucor* sp., *Penicillum sp.* | [47] |
| *Kokonte*  | *Aspergillus* spp*., Alternaria* spp., *Cladosporium* spp., *Colletotrichum* spp., *Drechslera* spp., *Fusarium* spp., *Monilia* spp., *Nigrospora oryzae, Phoma sorghina, Geotrichum* spp., *Aureobasidium* spp*., Mucor* spp., *Rhizopus* spp., *Penicillium* spp., *Paecilomyces variotii e Wallemia sebi*  | [48]  |
| *Cassava chips*  | *A. flavus, Fusarium verticillioides, F. oxysporum, Penicillium chrysogenum, P. sorghina, M. piriformis, R. oryzae, N. oryzae, R. nigricans, A. niger,* *Aspergillus aculeatus, A. candidus, A. clavatus, A. flavipes, A. flavus, A. fumigatus, A. niger, A. nomius, A. ochraceous, A. parasiticus, A. tamarii, A. terreus, A. versicolor*  | [49, 50] |
| *Cassava flour*  | *A. niger*, *A. fumigatus,* *P. chrysogenum, Aspergillus* spp*., Penicillium* spp., *Mucor* spp., *Neospora* spp., *Choanophora* spp., *Cladosporium* spp., *Rhizopus* spp., *Rhodotorula* spp., *S. cerevisiae, F. oxysporium, B. theobromae, Helminthosporium* spp. *and Trichoderma* spp.  | [51, 52] |
| *Sesame*  | *Aspergillus candidi, Aspergillus flavi, Aspergillus nigri, Cladosporium* sp*., Fusarium fujikuroi* | [53] |

# **Role of yeast in the West Africa indigenous foods process**

For Johansen, Owusu-Kwarteng [54], indigenous fermented foods and beverages represent a cultural heritage of the people of sub-Saharan Africa. Moreover, Sub-Saharan Africa has one of the richest collections of fermented food products in the world. Yeasts play an important role in obtaining these foods, as they are found on raw materials in symbiosis with other microbial genera. Yeast diversity in native fermented foods is influenced by processing methods, hygiene conditions and interactions between yeasts and other commensal microorganisms.

The main beneficial microorganisms that are responsible for the fermentation of African indigenous fermented foods and beverages are lactic acid bacteria and yeasts which may be present as microflora on the substrates or added as starter cultures. The synergistic interaction between these microorganisms in the fermented food matrices result in improved nutrient availability, food quality, palatability, organoleptic properties, increased shelf life, safety, digestibility and also play beneficial roles in modulating host immune system thereby minimizing the risk of certain diseases as reported by [55]. Possible roles described are :

1. In general yeasts contribute to the organoleptic properties of the final fermented products [56];
2. capable of upgrading the nutritional value of the foods [57, 58];
3. and reported to have several probiotic effects[12, 52, 59, 60] that can contribute to the improvement of human health [53, 61].

# **Key roles play by certain species of yeast in foods**

Each strain of fungus or yeast plays a key role in the food process. Some of these roles are described below:

* *Candida krusei* plays an important role in flavor development through its proteolytic activity [62]. It is used as a starter culture in dairy products to maintain the activity and increase the longevity of LAB and can also have a positive impact on the organoleptic quality of fermented corn dough [63] ;
* *C. glabrata* used as a starter culture [64] is in fact a major pathogen responsible for nosocomial fungal infections;
* *Candida* species are ubiquitous organisms and their ability to co-metabolize with lactic acid bacteria has been reported as desirable for adequate fermentation of traditional African foods [57, 58, 65, 66]. Their high resistance to acidity and high environmental temperatures may explain their predominance in mawè fermentation [67] ;
* *P. kudriavzevii* and LAB are in symbiotic association in *nunu*, where they play a useful role in flavor development [23] ;
* *Lactobacillus* and *Saccharomyces cerevisiae* are involved in flavor development during fermentation of maize for *ogi* production [68] ;
* *Saccharomyces cerevisiae* is responsible for the final alcoholic fermentation that increases the alcohol yield of *burukutu* [39], as for sorghum beer [69] and is fully accepted for human consumption because is the most common food-grade yeast [70].

# **Metabolites produced by fungi cells in foods**

Yeasts spoil food and beverages, and some can be pathogenic [71]. Indeed, according to Rai, Kumari [2], agricultural produce is susceptible to invasion by fungi such as *Aspergillus, Penicillium, Fusarium* and *Claviceps* species, which can produce mycotoxins in products before harvest, during harvest, or during storage and processing. In fact, the fungal strain, climatic and geographical conditions, cultivation technique and crop protection, particularly during cultivation and storage, are all factors that influence mycotoxin production. Fungal species are also known to produce exopolysaccharides (EPS) [72]. The metabolites produced by fungal species in foods are listed below:

* **Exopolysaccharides (EPS)** have antioxidant, anti-tumour and anti-viral activities. They also improve soil aridity and the nutritional value of foods consumed by humans. Their innocuous domestic and commercial versatility and biotechnological relevance are a reliable confirmation of the recent attention given to EPS by the global research community [72].
* **Aflatoxins (AF)** are mycotoxins produced by certain species of *Aspergillus* (*flavus, parasiticus* and *nomius*). There are more than 20 types of aflatoxin, but the four most common are aflatoxin B1 (AFB1), aflatoxin B2 (AFB2), aflatoxin G1 (AFG1) and aflatoxin G2 (AFG2) [73]. Aflatoxin B1 (AFB1) is carcinogenic and genotoxic in vitro and in vivo [74], and has been classified in group 1 by the International Agency for Research on Cancer. Contamination of foodstuffs and beverages by mycotoxins can compromise the safety of the supply of foodstuffs intended for human and/or animal consumption and is therefore a cause of the appearance of harmful effects on the health of humans and animals [75]. In Togo, aflatoxin B1 was detected in 38% of maize samples with maximum contamination levels of 256 μg/kg, and in 25% of sorghum samples (range 6-16 μg/kg) [76]. These aflatoxin producers colonise peanuts, cereals, oilseeds, cow's milk and spices [77].
* **Ochratoxin A (OTA)** is a fungal secondary metabolite produced by *Aspergillus niger, A. ochraceus, Aspergillus carbonarius* and *Penicillium verrucosum*. OTA has a number of adverse effects on animals and humans, including nephrotoxicity, teratogenicity, embryotoxicity, immunotoxicity, genotoxicity and neurotoxicity [78]. OTA has been found in human and animal foods such as cereals, wine, cocoa, dried vine, fruit, olives, coffee, beer and spices [79, 80]. Their production in these products is influenced by temperature, water activity, pH, nutrient availability and the competitive growth of other microorganisms. Mycotoxin contamination of food can represent a direct source of human exposure through direct consumption or an indirect source through consumption of products derived from animals fed on contaminated food.
* **Phytate** is considered an anti-nutritional factor due to its ability to chelate cations such as Fe3+, Zn2+, Ca2+ and Mg2+ (which reduces the absorption of minerals by the human intestine). Phytate complexes can only be absorbed in the human intestine if they are digested by phytases, a class of phosphatases that catalyse the hydrolysis of phytate phosphate [81]. The enzyme is naturally synthesised in plants and certain microorganisms. The phytate content of foods could be reduced by using micro-organisms with high phytase activity, in addition to food phytases, as recommended by Fischer, Egli [82]. The authors [83] noted a reduction in phytases in traditional Senegalese foods fermented with yeast.
* A study conducted in Togo showed that maize and sorghum were contaminated by fungi that produced fumonisins (88 and 67% for maize and sorghum respectively) with concentrations ranging from 101 to 1838 μg/kg for maize and 81.5 to 361 μg/kg for sorghum, respectively [76].

Conclusion

The main spoilage agents in human and animal foodstuffs are fungi, which are ubiquitous in the environment and in plants and animals. There are two types of fungi: macroscopic fungi (some of which are edible) and microscopic fungi. The presence of microscopic fungi compromises the nutritional and organoleptic quality and safety of foodstuffs intended for animals and humans. In addition to their negative impact on nutritional and organoleptic properties, moulds and fungi are known to be producers of mycotoxins, which can be more dangerous to humans than phytosanitary residues. Fungal cells are our daily companions. African industries need to focus their research on fungal species isolated from traditional African foods to add more value to our indigenous foods.

Conflict of Interest

“The authors declare no conflict of interest.”

**References**

1. Taale, E., et al., *Indigenous Food and Food Products of West Africa: Employed Microorganisms and Their Antimicrobial and Antifungal Activities Non Ribosomal Peptide Synthetase View project Fight against diabetes in Benin View project*, in *Microbiology for food and health: Technological development and advances*, D.K. Verma, et al., Editors. 2020, Apple Academic Press, Inc., Canada. p. 149-194.

2. Rai, A.K., et al., *Production of bioactive protein hydrolysate using the yeasts isolated from soft chhurpi.* Bioresource Technology, 2016. **219**: p. 239-245.

3. Zannou, O., et al., *Traditional fermented foods and beverages: Indigenous practices of food processing in Benin Republic.* International Journal of Gastronomy and Food Science, 2022. **27**: p. 100450-100450.

4. Obafemi, Y.D., et al., *African fermented foods: overview, emerging benefits, and novel approaches to microbiome profiling.* npj Science of Food 2022 6:1, 2022. **6**(1): p. 1-9.

5. N'Guessan, K.F., et al., *Identification of yeasts during alcoholic fermentation of tchapalo, a traditional sorghum beer from Côte d’Ivoire.* Antonie van Leeuwenhoek 2011 99:4, 2011. **99**(4): p. 855-864.

6. Omemu, A.M., *Fermentation dynamics during production of ogi, a Nigerian fermented cereal porridge.* Report and Opinion, 2011. **3**(4): p. 8-17.

7. Amoa-Awua, W.K.A., F.E. Appoh, and M. Jakobsen, *Lactic acid fermentation of cassava dough into agbelima.* International Journal of Food Microbiology, 1996. **31**(1-3): p. 87-98.

8. Obinna‐Echem, P.C., V. Kuri, and J. Beal, *Evaluation of the microbial community, acidity and proximate composition of akamu, a fermented maize food.* Journal of the Science of Food and Agriculture, 2014. **94**(2): p. 331-340.

9. Assanvo, J.B., et al., *Microflora of traditional starter made from cassava for "attiéké" production in Dabou (Côte d'Ivoire).* Food Control, 2006. **17**(1): p. 37-41.

10. Coulin, P., et al., *Characterisation of the microflora of attiéké, a fermented cassava product, during traditional small-scale preparation.* International journal of food microbiology, 2006. **106**(2): p. 131-136.

11. Angelov, A.I., et al., *Molecular Identification of Yeasts and Lactic Acid Bacteria Involved in the Production of Beninese Fermented Food Degue.* The Open Biotechnology Journal, 2017. **11**(1): p. 94-104.

12. Pedersen, L.L., et al., *Biodiversity and probiotic potential of yeasts isolated from Fura, a West African spontaneously fermented cereal.* International Journal of Food Microbiology, 2012. **159**: p. 144-151.

13. Greppi, A., et al., *Determination of yeast diversity in ogi, mawè, gowé and tchoukoutou by using culture-dependent and -independent methods.* International Journal of Food Microbiology, 2013. **165**(2): p. 84-88.

14. Vieira-Dalodé, G., et al., *Lactic acid bacteria and yeasts associated with gowé production from sorghum in Bénin.* Journal of Applied Microbiology, 2007. **103**(2): p. 342-349.

15. Aboh, I.M. and P. Oladosu, *Microbiological assessment of kunun-zaki marketedin Abuja Municipal Area Council (AMAC) in The Federal Capital Territory (FCT), Nigeria.* African Journal of Microbiology Research, 2014. **8**(15): p. 1633-1637.

16. Badua, M.H., et al., *Article Microbial Quality Evaluation of Tiger Nut Beverage (Kunun Aya) Processed Sold in University of Maiduguri Article · February.* EC Nutrition, 2018. **13**: p. 138-142.

17. Noah, A.A., A. Rukayat, and F. Foluso, *Microbiological, physicochemical and sensory assessment of improved Kunun-Zaki beverage made from Millet and stored under different storage conditions.* Nutrition, Public Health and Technology, 2013. **5**(2): p. 8-13.

18. Orutugu, L.A., S.C. Izah, and E.R. Aseibai, *MICROBIOLOGICAL QUALITY OF KUNU DRINK SOLD IN SOME MAJOR MARKETS OF YENAGOA METROPOLIS, NIGERIA.* Continental Journal of Biomedical Sciences, 2015. **9**(1): p. 9-16.

19. Omafuvbe, B.O., et al., *Microbial diversity in ready-to-eat fufu and lafun-fermented cassava products sold in Ile-Ife, Nigeria.* Research Journal of Microbiology, 2007. **2**(1): p. 831-837.

20. Padonou, S.W., et al., *The microbiota of Lafun, an African traditional cassava food product.* International journal of food microbiology, 2009. **133**(1-2): p. 22-30.

21. Greppi, A., et al., *Yeast dynamics during spontaneous fermentation of mawè and tchoukoutou, two traditional products from Benin.* International Journal of Food Microbiology, 2013. **165**: p. 200-207.

22. Motey, G.A., et al., *Probiotic potential of Saccharomyces cerevisiae and Kluyveromyces marxianus isolated from West African spontaneously fermented cereal and milk products.* Yeast, 2020. **37**(9-10): p. 403-412.

23. Akabanda, F., et al., *Taxonomic and molecular characterization of lactic acid bacteria and yeasts in nunu, a Ghanaian fermented milk product.* Food Microbiology, 2013. **34**: p. 277e283-277e283.

24. Izah, S.C., L. T Kigigha, and I.P. Okowa, *Microbial quality assessment of fermented maize Ogi (a cereal product) and options for overcoming constraints in production.* Biotechnological Research, 2016. **2**(2): p. 81-93.

25. Kehinde, A., *FERMENTED SPROUTED AND UNSPROUTED MAIZE FOR OGI PRODUCTION Antibacterial Properties of the Predominant Microorganisms Isolated from Fermenting Cassava Tubers during fufu Production against Selected Enteropathogenic Bacteria View project.* Article in International Journal of Advanced Research, 2013.

26. Fadahunsi, I.F., S.T. Ogunbanwo, and A.O. Fawole, *Microbiological and nutritional assessment of burukutu and pito (indigenously fermented alcoholic beverages in West Africa) during storage.* Nature and Science, 2013. **11**(4): p. 98-103.

27. Zaukuu, J.L.Z., I. Oduro, and W.O. Ellis, *Processing methods and microbial assessment of pito (an African indigenous beer), at selected production sites in Ghana.* Journal of the Institute of Brewing, 2016. **122**(4): p. 736-744.

28. Tokpohozin, S.E., et al., *Phenotypical and molecular characterization of yeast content in the starter of “Tchoukoutou,” a Beninese African sorghum beer.* European Food Research and Technology 2016 242:12, 2016. **242**(12): p. 2147-2160.

29. N'Guessan, F.K., et al., *Saccharomyces cerevisiae and Candida tropicalis as starter cultures for the alcoholic fermentation of tchapalo, a traditional sorghum beer.* World Journal of Microbiology and Biotechnology 2009 26:4, 2009. **26**(4): p. 693-699.

30. Yves, K.D., et al., *Diversity of yeasts in otchÃ¨, a traditional starter used in fermentation of an opaque sorghum beer â€ œchakpaloâ€.* African Journal of Microbiology Research, 2014. **8**(37): p. 3398-3404.

31. Sanata, B., et al., *Characterization of the fungal flora of dolo, a traditional fermented beverage of Burkina Faso, using MALDI-TOF mass spectrometry.* World Journal of Microbiology and Biotechnology 2017 33:9, 2017. **33**(9): p. 1-5.

32. Tapsoba, F., et al., *Diversity of Saccharomyces cerevisiae strains isolated from Borassus akeassii palm wines from Burkina Faso in comparison to other African beverages.* International Journal of Food Microbiology, 2015. **211**: p. 128-133.

33. Nwaiwu, O. and M. Itumoh, *Molecular Phylogeny of Yeasts from Palm Wine and Enological Potentials of the Drink.* Annual Research & Review in Biology, 2017. **20**(3): p. 1-12.

34. Tapsoba, F., et al., *Microbial diversity and biochemical characteristics of Borassus akeassii wine.* Letters in Applied Microbiology, 2016. **63**(4): p. 297-306.

35. Tra Bi, C.Y., et al., *Identification of yeasts isolated from raffia wine (Raphia hookeri) produced in Côte d’Ivoire and genotyping of Saccharomyces cerevisiae strains by PCR inter-delta.* World Journal of Microbiology and Biotechnology 2016 32:8, 2016. **32**(8): p. 1-9.

36. Ukwuru, M.U. and J.I. Awah, *Properties of palm wine yeasts and its performance in wine making.* African Journal of Biotechnology, 2013. **12**(19): p. 2670-2677.

37. Kouakou, A.C., et al., *Identification of yeasts associated with the fermented fish, adjuevan, of Ivory Coast by using the molecular technique of PCR-denaturing gradient gel electrophoresis (DGGE).* African Journal of Microbiology Research, 2012. **6**(19): p. 4138-4145.

38. Sanni, A.I. and A.T. Adesulu, *Microbiological and physico-chemical changes during fermentation of maize for masa production.* African Journal of Microbiology Research, 2013. **7**: p. 4355-4362.

39. Atter, A., K. Obiri-Danso, and W.K. Amoa-Awua, *Microbiological and chemical processes associated with the production of burukutu a traditional beer in Ghana.* International Food Research Journal, 2014. **21**(5).

40. Keita, I., et al., *Isolation and molecular identification of yeast strains from <i>“Rabilé”</i> a starter of local fermented drink.* African Journal of Biotechnology, 2016. **15**(20): p. 823-829.

41. Mogmenga, I., et al., *Isolation and Identification of Indigenous Yeasts from “<i>Rabilé</i>”, a Starter Culture Used for Production of Traditional Beer “<i>dolo</i>”, a Condiment in Burkina Faso.* Advances in Microbiology, 2019. **09**(07): p. 646-655.

42. Kogno, E., et al., *Microbiological profile of agbelima, eblima and epoma, three traditional fermented products in Togo.* International Journal of Applied Biology and Pharmaceutical Technology, 2017. **8**(2): p. 31-38.

43. Yves, A.K., et al., *Molecular identification and species diversity of the microbiota associated with soumbara, a traditional fermented food commonly consumed in Côte d’Ivoire.* Research Journal of Food Science and Nutrition, 2019. **4**(2): p. 48-57.

44. Bayili, G.R., et al., *Identification of the predominant microbiota during production of lait caillé, a spontaneously fermented milk product made in Burkina Faso.* World Journal of Microbiology and Biotechnology 2019 35:7, 2019. **35**(7): p. 1-13.

45. Cake, G., et al., *FUNGI AND AFLATOXIN B1 OF FRESHLY.* PAT, 2017. **13**(1): p. 26-29.

46. Suleiman, M.S., et al., *Fungi and aflatoxin occurrence in fresh and dried vegetables marketed in Minna, Niger State, Nigeria.* 2017.

47. Adjovi, Y.C.S., et al., *Morphologic and Molecular Characterization of Aspergillus flavus Isolated from Smoked, Fermented and Dried Fishes Sold in Main Markets of Cotonou (Benin).* J Food Ind Microbiol, 2019. **5**(131): p. 2-2.

48. Wareing, P.W., et al., *Consumer preferences and fungal and mycotoxin contamination of dried cassava products from Ghana.* International journal of food science & technology, 2001. **36**(1): p. 1-10.

49. Gnonlonfin, G.J.B., et al., *Mycoflora and absence of aflatoxin contamination of commercialized cassava chips in Benin, West Africa.* Food Control, 2012. **23**(2): p. 333-337.

50. Kaaya, A.N. and D. Eboku, *Mould and aflatoxin contamination of dried cassava chips in Eastern Uganda: Association with traditional processing and storage practices.* Journal of Biological Sciences, 2010. **10**(8).

51. Aghimien, M.O. and M.J. Ikenebomeh, *Community structure of aflatoxin producing fungi in cassava products from Nigerian geo-political zones.* NISEB Journal, 2019. **17**(4).

52. Mesquita, J.d.S., S.K.P.R.d. Araújo, and F.C.d.S. Pereira, *Análise micológica da farinha de mandioca vendida nas feiras do produtor na cidade de Macapá-AP.* Revista Ciência e Sociedade, 2017. **2**.

53. Esan, A.O., et al., *Distribution of fungi and their toxic metabolites in melon and sesame seeds marketed in two major producing states in Nigeria.* Mycotoxin Research, 2020. **36**(4): p. 361-369.

54. Johansen, P.G., et al., *Occurrence and Importance of Yeasts in Indigenous Fermented Food and Beverages Produced in Sub-Saharan Africa.* Frontiers in Microbiology, 2019. **10**: p. 1789-1789.

55. Adesulu-Dahunsi, A.T., S.O. Dahunsi, and A. Olayanju, *Synergistic microbial interactions between lactic acid bacteria and yeasts during production of Nigerian indigenous fermented foods and beverages.* Food Control, 2020. **110**: p. 106963-106963.

56. Romano, P., et al., *Secondary products formation as a tool for discriminating non-Saccharomyces wine strains.* Antonie van Leeuwenhoek 1997 71:3, 1997. **71**(3): p. 239-242.

57. Haefner, S., et al., *Biotechnological production and applications of phytases.* Applied Microbiology and Biotechnology 2005 68:5, 2005. **68**(5): p. 588-597.

58. Hjortmo, S., et al., *Inherent biodiversity of folate content and composition in yeasts.* Trends in Food Science & Technology, 2005. **16**(6-7): p. 311-316.

59. Mumy, K.L., et al., *Saccharomyces boulardii interferes with Shigella pathogenesis by postinvasion signaling events.* American Journal of Physiology - Gastrointestinal and Liver Physiology, 2008. **294**(3): p. 599-609.

60. Greppi, A., et al., *Determination of yeast diversity in ogi, mawè, gowé and tchoukoutou by using culture-dependent and-independent methods.* International journal of food microbiology, 2013. **165**(2): p. 84-88.

61. Moslehi-Jenabian, S., L.L. Pedersen, and L. Jespersen, *Beneficial Effects of Probiotic and Food Borne Yeasts on Human Health.* Nutrients 2010, Vol. 2, Pages 449-473, 2010. **2**(4): p. 449-473.

62. Frazier, W.C. and D.C. Westhoff, *Enumeration and identification of yeasts isolated from Zimbabwean traditional fermented milk.* International Dairy Journal, 2001. **10**: p. 459-466.

63. Annan, N.T., et al., *Volatile compounds produced by Lactobacillus fermentum, Saccharomyces cerevisiae and Candida krusei in single starter culture fermentations of Ghanaian maize dough.* Journal of Applied Microbiology, 2003. **94**(3): p. 462-474.

64. Fidel, P.L., J.A. Vazquez, and J.D. Sobel, *Candida glabrata: Review of epidemiology, pathogenesis, and clinical disease with comparison to C. albicans.* Clinical Microbiology Reviews, 1999. **12**(1): p. 80-96.

65. Odds, F.C., *Ecology and Epidemiology of Candida Species.* Zentralblatt für Bakteriologie, Mikrobiologie und Hygiene. 1. Abt. Originale. A, Medizinische Mikrobiologie, Infektionskrankheiten und Parasitologie, 1984. **257**(2): p. 207-212.

66. Oguntoyinbo, F.A., *Evaluation of diversity of Candida species isolated from fermented cassava during traditional small scale gari production in Nigeria.* Food Control, 2008. **19**(5): p. 465-469.

67. Watanabe, I., T. Nakamura, and J. Shima, *Strategy for simultaneous saccharification and fermentation using a respiratory-deficient mutant of Candida glabrata for bioethanol production.* Journal of Bioscience and Bioengineering, 2010. **110**(2): p. 176-179.

68. Osungbaro, T.O., *Physical and nutritive properties of fermented cereal Foods.* African J. Food Sc., 2009. **3**(2): p. 23-27.

69. Lyumugabe, F., et al., *Production of traditional sorghum beer “Ikigage” using Saccharomyces cerevisae, Lactobacillus fermentum and Issatckenkia orientalis as starter cultures.* Food and nutrition sciences, 2014. **2014**.

70. Bekatorou, A., C. Psarianos, and A.A. Koutinas, *Production of food grade yeasts.* Food Technology & Biotechnology, 2006. **44**(3).

71. Erten, H., et al., *Importance of yeasts and lactic acid bacteria in food processing.* Food Engineering Series, 2014: p. 351-378.

72. Osemwegie, O.O., et al., *Exopolysaccharides from bacteria and fungi: current status and perspectives in Africa*, in *Heliyon*. 2020.

73. Hernandez-Martinez, R. and I. Navarro-Blasco, *Aflatoxin levels and exposure assessment of Spanish infant cereals.* Food Additives and Contaminants, 2010. **3**(4): p. 275-288.

74. European Food Safety, A., *Report for 2008 on the results from the monitoring of veterinary medicinal product residues and other substances in food of animal origin in the Member States.* EFSA Journal, 2010. **8**(4): p. 1559-1560.

75. Marin, S., et al., *Mycotoxins: Occurrence, toxicology, and exposure assessment.* Food and chemical toxicology, 2013. **60**: p. 218-237.

76. Hanvi, D.M., et al., *Natural occurrence of mycotoxins in maize and sorghum in Togo*, in *Mycotoxin Research*. 2019.

77. Mushtaq, M., et al., *Occurrence of aflatoxins in selected processed foods from Pakistan.* International journal of molecular sciences, 2012. **13**(7): p. 8324-8337.

78. Wangikar, P.B., et al., *Teratogenic effects in rabbits of simultaneous exposure to ochratoxin A and aflatoxin B1 with special reference to microscopic effects.* Toxicology, 2005. **215**(1-2): p. 37-47.

79. Roussos, S., et al., *Characterization of filamentous fungi isolated from Moroccan olive and olive cake: toxinogenic potential of Aspergillus strains.* Mol. Nutr. Food Res., 2006. **50**: p. 500-506.

80. Terra, M.F., et al., *Detection of ochratoxin A in tropical wine and grape juice from Brazil.* Journal of the Science of Food and Agriculture, 2013. **93**(4).

81. Raboy, V., *myo-Inositol-1, 2, 3, 4, 5, 6-hexakisphosphate.* Phytochemistry, 2003. **64**(6): p. 1033-1043.

82. Fischer, M.M., et al., *Phytic acid degrading lactic acid bacteria in tef-injera fermentation.* International Journal of Food Microbiology, 2014. **190**: p. 54-60.

83. Antai, S.P. and G. Nkwelang, *Reduction of some toxicants in Icacina mannii by fermentation with Saccharomyces cerevisiae.* Plant Foods for Human Nutrition, 1998. **53**(2): p. 103-111.