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

**Essodolom TAALE1\*, Tiatou SOUHO1, Ali Kpatcha KADANGA1 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](mailto: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 microorganisms involved in the fermentation process, but also fungi species play a key role in the development of different characteristics of those foods especially their organoleptic attributes and contribute increasing their lifetime by producing different compounds. So, this study attempts to show the role played by yeasts in these various foods. Most of west African home-made foods harbour a diversity of microorganisms (microbes, yeasts, molds and mushrooms) which work in synergic manner in order to make a desire product. More studies are needed to fully characterize fungi and assess their biotechnology application.

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

# **Introduction**

In Benin, Burkina Faso, Cape Verde, Côte d’Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritanie, Niger, Nigeria, Senegal, Sierra Leone and Togo a variety of traditional fermented and unfermented foods and beverages are largely consumed. Among these foods and beverage we can distinguish *Akamu, 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. [1]. Those products are obtained by leaving raw material (cereals, ruber, milk, …) to a spontaneous fermentation process favourite by the presence of a mixed microorganisms such as moulds, bacteria and yeasts. They are thus produced by a house art which is transmitted generation to generation and sometimes still as family heritage. According to [2], yeasts have gained researchers especially African’s because of the enormous functions they perform in the fermentation of foods, aroma formation and maturation.

Yeasts, molds, and mushrooms are eukaryotic organisms belonging to fungus (plural: fungi or funguses) group. Amount them especially, yeasts play key role in food transformation using different types of substrates (millet, sorghum, milk, maize, cassava, banana, …) to produce a wide range of fermented products such as *pito, gowè, kunu, wagashie*, …. For [3], yeasts enhance bioactive components by the production of enzymes, metabolites and they also act in a synergistic manner with other groups of microorganisms especially Lactic Acid Bacteria (LAB) resulting in the improvement of functional properties. By the action of yeasts, molds and LAB, west African traditional fermented food products contain useful metabolites that improve digestion, boost immunity and promote a healthy weight[4]. As reported by [4], traditional fermented food are an important source of income for local households, especially women, resulting in an improved living standard for the population.

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[5]. 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, Mauritanie, 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, 4] 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[6, 7]. 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* | [8] |
| *Akamu* | *Candida tropicalis*, *C. albicans*, *Clavispora lusitaniae, Saccharomyces paradoxus, S. cerevisiae*, *Aspergillus oryzae*, *A. niger*, *Penicillium citrinum*, *Rhizopus microsporus*, and *R. oligosporus* | [9] |
| *Attiéké* | *Candida valida, Candida tropicalis, C. holmii, C. krusei, Kloeckera japonica, Saccharomyces cerevisiae* | [10, 11] |
| *Dégué* | *Cyberlyndnera fabianii*, *Candida glabrata*, *Kluyveromyces marxianus*, and *Meyerozyma caribbica.* | [12] |
| *Fura* | *Candida tropicalis*, *Galactomyces geotricum*, *Issatchenkia orientalis*, *Pichia anomala*, *S. pastorianus*, *S. cerevisiae*, and *Yarrowia lipolytica* | [13] |
| *Gowé* | *Clavispora lusitaniae, Pichia anomala,* Kluyveromyces marxianus, Candida krusei, C. tropicalis, C. rugosa, C. fabianii, C. norvegensis and Trichosporon asahii. | [14, 15] |
| *Kunu* | *Aspergillus fumigatus*, *A. niger, Candida albicans*, *Fusarium* spp., *Penicillium* spp*., Rhizopus nigrican, Saccharomyces cerevisiae,* Rhizopus oryzae | [16-19] |
| *Lafun* | *Debaryomyces* sp., *Saccharomyces cerevisiae*, *Candida tropicalis*, *C. glabrata, Pichia scutulata*, *P. kudriavzevii*, *P. rhodanensis, Kluyveromyces marxianus*, *Hanseniaspora guilliermondii*, , and *Trichosporon asahii*. | [20, 21] |
| *Mawè* | *Clavispora lusitaniae, Candida krusei, C. kefyr, C*. *glabrata,* and *S. cerevisiae,* Kluyveromyces marxianus, Pichia kudriavzevii | [14, 22, 23] |
| *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* | [24] |
| *Ogi* | *Saccharomyces pastorianus, S. cerevisiae, C. mycoderma, C. krusei, C. tropicalis, Geotrichum candidum, G. fermentans,* *Rhodotorula graminis,* Clavispora lusitaniae, *Aspergillus niger, Rhizopus nigricans,* | [7, 25, 26] |
| *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* | [27, 28] |
| *Tchoukoutou* | *Clavispora lusitaniae, S. cerevisiae, Candida krusei, C. rugosa, C. ethanolica, Saccharomyces cerevisiae*, *Pichia kudriavzevii,* and *Debaryomyces hansenii* | [14, 22, 29] |
| *Tchapalo* | *Candida tropicalis*, *Saccharomyces cerevisiae* | [6, 30, 31] |
| *Dolo* | *Saccharomyces cerevisiae, Pichia manshurica, Candida albicans* | [34]  [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* | [33-37] |
| *Adjuevan* | *Kluyveromyces marxianus, Hansenula anomala, Saccharomyces cerevisiae, Candida tropicalis, C. zeylanoides, Pichia fermentans, Debaromyces hansenii, Hanseniaspora osmophilic, Rhodotorula glutinis* | [38] |
| *Masa* | *Saccharomyces cerevisiae* | [39] |
| *Burukutu* | *S. cerevisiae, Candida albicans, Aspergillus niger* | [27, 40] |
| *Rabilé* | *Saccharomyces and Rhodotorula, Candida pseudorhangii, C. heliconiae, C. utilis, Shizosaccharomyces pombe, Sporobolomyces odoratus* | [41, 42] |
| *agbelima, eblima and epoma* | *Candida guilliermondii, C. krusei, C. tropicalis, Saccharomyces cerevisiae* | [43] |
| *Soumbara* | *Fusarium oxysporum, Penicillium chrysogenum, P. sclerotiorum, Aspergillus flavus, Absidia corymbifera, Cladosporium uredinicola.* | [44] |
| *Lait caillé* | *Candida parapsilosis*, *Saccharomyces cerevisiae* | [45] |
| *Kulikuli* | *Aspergillus flavus, A. tamarii, A. niger, Cercospora personata and C. Arachidicola* | [46] |
| *fresh and dried vegetable* | Aspergillus flavus, A. niger, A. parasiticus, Mucor spp., Penicillum brevicopactum, P. chrysogenium, Fusarium culmorum | [47] |
| *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.* | [48] |
| *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* | [49] |
| *Cassava chips* | *A. flavus, Aspergillus spp., F. verticillioides, P.chrysogenum, P. sorghina, M. piriformis, R. oryzae, N. oryzae*  *R. nigricans, A. niger, F. oxysporum*  *Aspergillus: A. 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*  *Aspergillus* spp., *Penicillium* spp., *Fusarium* spp., *Mucor* spp., *Rhizopus* spp. | [50, 51] |
| *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. | [52, 53] |
| *Sesame* | *Aspergillus candidi, Aspergillus flavi, Aspergillus nigri, Cladosporium* sp*., Fusarium fujikuroi* | [54] |

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

For [55] indigenous fermented food and beverages represent a valuable cultural heritage in subSaharan Africa, having one of the richest selections of fermented food products in the world. In many of these indigenous spontaneously fermented food and beverages, yeasts are of significant importance. Several factors including raw materials, processing methods, hygienic conditions as well as the interactions between yeasts and other commensal microorganisms have been shown to influence yeast species diversity and successions

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 [56]. Possible roles described are : (i) In general yeasts contribute to the organoleptic properties of the final fermented products [57]; (ii)capable of upgrading the nutritional value of the foods [58, 59]; and (iii) reported to have several probiotic effects[13, 60] [14, 53] that can contribute to the improvement of human health [61][54].

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

Generally, each fungi strain plays a key role in the food process. Some of these role are below:

* *Candida krusei* can have a positive impact on the organoleptic quality of African fermented maize dough[62]; also used as dairy starter cultures to maintain the activity and increase the longevity of LAB. *C. krusei* plays an important role in flavor development due to its proteolytic activity[63];
* *C. glabrata* is emerging as a major pathogen that accounts for an increasingly large population of nosocomial fungal infections. Also can be used as starter culture [64];
* Candida species are ubiquitous organisms and their ability for co-metabolism with lactic acid bacteria has been reported as desirable for adequate fermentation of traditional African food[65, 66] [58, 59]. The strong resistance to acidity and high environmental temperature can explain their dominance in mawè fermentation [67];
* *P. kudriavzevii* and LAB are in symbiotic association in nunu were they play a useful role in flavor development[24];
* *Lactobacillus* and *Saccharomyces cerevisiae* are implicated in flavour development during fermentation of maize for the production of ogi[68];
* *Saccharomyces cerevisiae* is responsible for the final alcoholic fermentation which increase alcohol yield in burukutu [40]. Also responsible for the spontaneous fermentation of sorghum beer [69]. *S. cerevisiae* is fully accepted for human consumption and is the most common food grade yeast[70].

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

Yeasts also play detrimental role in the spoilage of foods and beverages and some can be pathogenic[71]. Indeed, according to [3] agricultural products are susceptible to fungal invasion such as *Aspergillus, Penicillium, Fusarium* and *Claviceps* species, which may produce mycotoxins in the field before harvest, during harvesting, or during storage and processing. In fact, fungal strain, climatic and geographical conditions, cultivation technique, and crop protection, particularly during cultivation and storage are factors, which influence mycotoxin production. The fungies species are also know as exopolysaccharides (EPSs) producers[72]. The metabolites produced by fungi species in foods are listed below:

* Exopolysaccharides (EPSs): have been shown to have, antioxidant, anti-tumor and antiviral activities. They also enhance soil aridity and nutritional value of food consumed by humans. Their innocuous domestic and commercial versatility and biotechnological relevance is a reliable confirmation of the recent attention accorded to EPSs by the global research community [72].
* Aflatoxins (AFs) are mycotoxins produced by certain species of Aspergillus (*flavus, parasiticus* and *nomius*). There are more than 20 distinct AF compounds but the four most commonly found are known as 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 it has been classified in the group 1 by the International Agency for Research on Cancer. Extensive contamination of food and drinks with mycotoxins is the main problem over the world since they can also compromise the safety of food and feed supplies and adversely affect health to humans and animals[75]. In Togo, Aflatoxin B1 was detected in 38% of the maize samples with maximum contamination levels of 256 μg/kg, and 25% of the sorghum samples (range 6–16 μg/kg) [76]. Those AF producers colonize peanuts, oilseed cereals, cow’s milk, sorghum, spices [77].
* Ochratoxin A (OTA) is a fungal secondary metabolite produced by *Aspergillus niger, A. ochraceus, Aspergillus carbonarius* and *Penicillium verrucosum*. OTA causes several negatives effects on animals and humans including nephrotoxic, teratogenic, embryotoxic, immunotoxic, genotoxic, and neurotoxic effects [78]. OTA has been found in human food and animal feed like cereals, wine, cocoa, dried vine fruits, olives, coffee, beer, and spices [79, 80]. Thus, their production in such commodities can be influenced by several factors, including temperature, water activity, pH, nutrients availability and competitive growth of other microorganisms. The contamination of food by mycotoxins can represent a direct source of human exposure by direct consumption or an indirect source through the consumption of derived products from animals fed with contaminated feed.
* Phytate is regarded as an anti-nutritional factor due to its ability to chelate cations such as Fe3+, Zn2+, Ca2+ and Mg2+(reduce minerals intake by the human intestine). Phytate complexes are not available for absorption in the human intestine unless digested by phytases, a class of phosphatases that catalyze the hydrolysis of phosphate from phytate[81]. The enzyme is naturally synthetized in plants and some microorganisms. Phytate content in foods could be reduced by using high phytase-active microorganisms, in addition to food phytases as recommended by [82]. [83] have noted phytases reduction in Senegalese traditional food fermented by yeasts.
* A study conducted in Togo showed that maize and sorghum were contamined by fungi who 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(s)

The major spoilage agents of foods and feedstuffs are Fungi who are omnipresent in the environment, plant and animals’ we can distinguish two type: macroscopic (like vegetal and some are comestible) and microscopic. Indeed, the presence of microscopic fungi in crops or feed, most often compromise the nutritional quality, organoleptic attributes and the safety of the food and feeds that humans and animals solely rely on. Aside of their negative impact on the nutritional and organoleptic properties, moulds and fungi are known to be notorious synthesisers of mycotoxins, which can cause serious damage on human or animal health. The fungy cells are our daily companied. African industries must focuse their research on those fungies species isolated from African traditional foods.

Conflict of Interest

“The authors declare no conflict of interest.” or delete this entire section

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