

Microbiology of Ivorian Fermented Products: A Review

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ABSTRACT— *Fermented products in Côte d'Ivoire are grouped into tubers (e.g. 'attiéké', 'placali', 'attoupkou'), cereals (e.g. 'baca', 'wômi', 'doklu'), fish (e.g. 'adjuevan'), beverages (e.g. 'bandji', 'tchapalo'), fruits (cocoa beans, 'dockounou'). The mechanism of all these fermentations involves lactic acid fermentation to ensure the quality, organoleptic properties and safety of the final product. The main species of microorganisms involved in fermentation are lactic acid bacteria (Lactobacillus, Lactococcus, Leuconostoc, Enterococcus, Streptococcus, Weissella), yeasts (Candida, Sacharomyces), Bacillus. Efforts are presently geared towards the use of the isolated microorganisms as starter cultures during Ivorian fermented products processing. A high degree of control over the fermentation process and standardization of the end product could be achieved.*

Keywords— lactic acid bacteria, Ivorian fermented products, starter culture, fermentation

1. INTRODUCTION

A majority of traditional fermented products consumed in Côte d'Ivoire are processed by natural fermentation of tuber, fruits, cereals, plant part or fish, and are particularly important as weaning foods for infants and dietary staples for adults. In terms of texture, the fermented products are either liquid (gruel), stiff gels (dough) or dry (fried or dehydrated product). During fermentation, the presence of microorganisms such as lactic acid bacteria (LAB), acetic acid bacteria, *Bacillus*, *Enterobacteriaceae*, yeasts and moulds have been reported (Djè et al, 2009; Coulin et al, 2006; Ouattara et al, 2011; Papalexandratou and De Vuyst, 2011; Papalexandratou et al, 2011; Tagro et al, 2008). However, LAB, yeasts and *Bacillus* are the predominant species involved in most of fermentations studied.

Lactic acid bacteria are the predominant microorganisms involved in all of these fermentations to a varying extent, having either positive or negative effects on the eventual product. In the case of alcoholic fermentation (e.g. 'bandji'), lactic acid bacteria generally deteriorate the quality of the products (Karamoko et al, 2012). However, in traditional cereal alcoholic fermentation (e.g. 'tchapalo'), lactic acid bacteria during the initial stage of fermentation provide a favorable environment for later stage fermentations including alcohol production, thereby contributing to the characteristic taste and aroma of the beverage (Djè et al, 2009). Lactic acid fermentation has been shown to improve flavor, shelf life, nutritional value or digestibility of fermented foods and alter food composition in such a way that it will require minimal energy both in cooking and preservation process (Nout, 1994). A wide variety of LAB have been identified, including mainly *Lactobacillus*, *Leuconostoc*, *Weissella*, *Streptococcus*, and *Pediococcus* species (Assohou et al, 2012 ; Coulin et al, 2006 ; Djè et al, 2009; Kastner, 2008 ; Koffi-vevry et al, 2011). Yeasts are mainly responsible for ethanol production out of glucose (from sucrose) (Djè et al, 2009; Karamoko et al, 2012; Nguessan et al, 2010) and production of pectinolytic enzymes during fermentation (Papalexandratou and De Vuyst, 2011). *Bacillus* species are able to produce a large number of extracellular enzymes such as pectinolytic enzymes (Ouattara et al, 2011 and 2008).

The traditional fermentation techniques are often a small scale and household basis, characterized by the use of simple non-sterile equipment, chance or natural inoculums, unregulated conditions, sensory fluctuations, poor durability and unattractive packing of the processed products resulting in food of unpredictable quality (Olanrewadju et al, 2009). Efforts are presently geared towards the development of inoculants containing high concentrations of live microorganisms in order to ensure the regularity of the final product. Review papers have been done on technological aspects of Ivorian fermented products (Aboua, 1988; Aboua et al, 1989; Mosso et al, 1996), but none have been devoted to the

microorganisms involved during fermentation and their use as starter cultures. The purpose of this paper is to summarize the microbiology of most common Ivorian fermented products using lactic acid fermentation and to highlight current knowledge on their use as starter cultures.

2. TRADITIONAL FERMENTED PRODUCTS IN CÔTE D'IVOIRE

Traditional fermented products prepared from cereals (millet, maize, rice, and sorghum), tuber (cassava), fruits (plantain, cocoa beans), plant part (palm sap), fish, are used as beverages, breakfasts, snack foods, staples, weaning foods and food condiment (**Table 1**). These fermented products can be classified on the basis of either the raw ingredients used in their preparation or the texture of the fermented products.

Classification on the basis of raw ingredients:

- Fermented products from cereals e.g. 'Doklu', 'Wômi'
- Fermented products from crop (cassava) e.g. 'Attiéké', 'Bêdêcouman'
- Fermented products from fruits (plantain, cocoa pods) e.g. 'Dockounou', 'fermented cocoa beans'
- Fermented product from plant part (palm sap) e.g. 'Bandji'
- Food condiments made from fish e.g. 'Adjuevan'

Classification on the basis of texture:

- Liquid (beverage and porridges) e.g. 'Baca', 'Tchapalo'
- Solid (semolina and dough) e.g. 'Attiéké', 'Dockounou'
- Dry (dehydrated and fried product) e.g. 'fermented cocoa beans', 'Wômi'

2.1 Fermented products from tuber (cassava)

Bitter cassava roots are usually used to prepare fermented products. During the first stage of processing, cassava roots are peeled, cut in pieces, washed and grated. During grating the cassava mash is mixed with a traditional starter, using a wooden mortar and pestle. According to cassava technology, the traditional starter likely constitutes the main source of microorganisms which are active in the later fermentation. In general, it takes about 2–3 days to get the traditional starter ready for use and the quality is difficult to control (Assanvo et al, 2006). The fresh pulp is fermented and squeezed into plastic or metallic pans for two or three days. The fermented and partially hydrated mash is then pressed with heavy stones until the remaining moisture is removed. Out of this mash the following products are obtained.

'Attieke'

'Attiéké' is a flavorful starchy ingredient, produced from fermented cassava root. 'Attiéké' was originally prepared and consumed exclusively by some ethnic groups in Côte d'Ivoire. In recent years, the product has become popular among urban consumers beyond the boundaries of Côte d'Ivoire because of its suitability as convenient fast food. Considerable researches have been done and are ongoing on 'attiéké' production in the view to standardize and control the process (Aboua, 1988; Assanvo et al, 2006; Bouaténin et al, 2012; Coulin et al, 2006; Djéni et al, 2011; Kastner, 2008; kouamé et al, 2013; Nimaga et al, 2012; Tetchi et al, 2012; Toka et al, 2008). In 'attiéké' production, the producers begin by preparing a traditional starter (as described above) from cassava. The fermented and pressed pulp is taken from the bags and squeezed through a sieve to obtain granules that are sundried and then cleaned to remove fibres and waste. The dried granules are steamed to produce 'attiéké', which is sold in small plastic bags as a ready-to-eat food. The final product is semolina like product with either coarse, medium or smaller size grains and a moisture content of about 35% (Aboua, 1988). It consists of white semolina (35% moisture content) with an acidulous taste, which could be either consumed as hot or cold.

'Placali'

In, Côte d'Ivoire, 'placali' is commonly consumed and it is the second well known cassava product after 'Attiéké' (Aboua, 1988; Koko et al 2012; Zoumenou et al, 1999). The fermented and dehydrated mass of cassava is cooked in water until a sugary and transparent paste is obtained. It is then kneaded by hand in a wooden mortar and molded into several 'cups' which are eaten with fish, meat or vegetables (Aboua, 1988). The final product is a creamy or white gelatinized cassava paste.

'Attoupkou'

'Attoupkou' is the third cassava based product consumed in Côte d'Ivoire after 'attiéké' and 'placali'. 'Attoupkou' (50% moisture content) is a cassava based product closed to 'attiéké' (35% moisture content) and which processing is less time consuming than that of 'attiéké' (Aboua, 1988; Koffi-Nevry et al, 2007). To produce 'attoupkou' the fermented cassava mash is first squeezed to remove as much water as possible. Then it is sun-dried into granular flour which is steam-cooked in special clay cooker for 45 minutes into a large cake. The final product is a disc of a creamy white to yellowish color of about 1-1.5 cm thick and 15-20 cm in diameter, eaten with fish, vegetables or meat.

'Bêdêcouman or bessiké'

‘Bêdêcouman’ is very popular and mainly produced by populations in south-eastern of Côte d’Ivoire by the Abouré and N’Zima ethnic groups (Aboua, 1988; Koffi-Nevry et al, 2008). To produce ‘bêdêcouman’ the fermented cassava mash is cooked, shelled and shaped into *Tomatococcus danielli* sheets commonly called ‘attiéké leaves’. It is eaten with vegetables, fish or meat and can be kept at room temperature during 4 days. The final product is in the form of a white bread, with size ranging between 10 and 15 cm.

‘N’Bede-papa or big cake’

To produce ‘n’bebe-papa’ the fermented cassava mash is wrapped in *Tomatococcus danielli* leaves and cooked on a grill or in an oven for 45 minutes (Aboua, 1988). The final product is a disc of a creamy white to yellowish color which is powdered with semolina sugar before eating.

‘N’bete gboko’

To produce ‘n’bete-gboko’ the fermented cassava pellets are cooked in palm oil or peanut oil (Aboua, 1988). The final product is a small fried pellet (round in shape) which is eaten with coconut pieces as a snack item.

‘Bito’

‘Bito is obtained by cooking pellets of fermented cassava mash in a sauce containing tomatoes, bell peppers and fish or meat (Aboua, 1988). The product is consumed with the cooking sauce as a staple food.

2.2 Fermented products from cereals

Whole millet, maize, sorghum or rice grains and their corresponding flours are used to obtain traditional dishes (Aboua et al, 1989). Maize grains are dehulled, washed and soaked into cold water for overnight or 4 to 8 h at ambient temperature. Millet and sorghum grains are washed, dehulled and sieved. The soaked maize grains and washed millet or sorghum grains are drained and milled into flours. Rice grains are shelled and milled into fine flour. Out of cereal flour ‘baca’, ‘wômi’ and ‘dagnan’ products are obtained

‘Tchapalo’

In Côte d’Ivoire, sorghum grains (*Sorghum bicolor*) are malted and used to produce a traditional beverage called ‘tchapalo’ (Aka et al, 2008; Djè et al, 2009; N’Guessan et al, 2010). It is generally consumed in both urban and rural areas, popular festivities and funerals and used to welcome and to cool down somebody. The traditional processing of ‘tchapalo’ is complex and involves milling of malted sorghum, mashing, acidification, cooking, cooling and the alcoholic fermentation of the final wort by dried yeast taken from a previous fermentation. The final product is an opaque and sour beer used as beverage.

‘Doklu’

‘Doklu’ is produced after spontaneous fermentation of maize dough and consumed by people in southern and South-East of Côte d’Ivoire (Assouhoun et al, 2012). During ‘doklu’ processing, after cleaning and washing, whole maize grains are soaked in water for 2 or 3 days, milled, mixed in water and left to undergo spontaneous fermentation for 24 to 72 h. The dough obtained is precooked, shaped into balls, wrapped in maize husks and boiled for 2 h. The final product is a dough eaten with vegetables, fish or meat.

‘Baca’

‘Baca’ is a popular traditional fermented gruel obtained from millet, maize or rice usually consumed in Côte d’Ivoire as breakfast by adults and as complementary food by young children (Aboua et al, 1989; Brou et al, 2008). The millet or maize flour is sieved, mixed with a quantity of water and rolled by hand to obtain a granulated product. The granulated product could be left to ferment overnight at ambient temperature. The millet or maize granulated product (fermented or not) and rice flour are added in boiling water and cooked to gelatinization. The final product is a thin grayish gruel which is added with sugar before consumption.

‘Wômi’

‘Wômi is a traditional fried cake made from sorghum, maize or millet flour. To produce ‘wômi’, the cereal flour is added to boiling water and cooked to gelatinization and allowed to cool before mixing with raw flour. The resulting batter inoculated or not with bakers yeast is allowed to ferment over night. The fairly thick batter is added with salt and sugar, stirred vigorously to incorporate air and fried in a cup-like depression in which oil has been added to produce ‘wômi’. The final product is round in shape with brown smooth top and crippling edges which is consumed by all aged groups and it serves as breakfast and snack item. The brown crisp edges and the mild sour taste are considered by many consumers as the quality attribute required of ‘wômi’ as it is the case for Nigerian ‘masa’ (Ayo et al, 2008).

Table 1: Most common fermented products from Côte d'Ivoire

Fermented product	Raw material used	Food category and use	References
'Adjuevan'	Fish (<i>Chloroscombrus chrysurus</i> , <i>Galeoides decadactylus</i>)	Condiment used to season sauces	(Koffi-Nevry and Koussémon, 2012 ; Koffi-Nevry et al, 2011 ; Kouakou et al, 2012, a, b)
'Attiéké'	Cassava	Couscous-like dish eaten with vegetables, fish or meat	(Aboua, 1988 ; Assnavo et al, 2006 ; Bouatenin et al, 2012 ; Coulin et al, 2006 ; Djéni et al, 2011 ; Kastner, 2008 ; Kouamé et al, 2013 ; Nimaga et al, 2012 ; Tetchi et al, 2012 ; Toka et al, 2008)
'Attoupkou'	Cassava	Steamed cake eaten with vegetables, fish or meat	(Aboua, 1988 ; Koffi-Nevry et al, 2007)
'Baca'	Maize, millet or rice	Thin grayish gruel as breakfast or weaning food for babies	(Aboua et al, 1989; Brou et al, 2008)
'Bandji'	Palm sap	Whitish and sweet alcoholic as beverage	(Karamoko et al, 2012)
'Bédécouman'	Cassava	Steamed dough eaten with vegetables, fish or meat	(Aboua, 1988 ; Koffi-Nevry et al, 2008)
'Bito'	Cassava	Stew as staple	(Aboua, 1988)
Cocoa beans	Cocoa pods	Dehydrated fully brown beans for chocolate manufacture	(Tagro et al, 2010, 2008 and 2007)
'Dagnan'	Maize or millet	Grayish dough eaten with vegetables, fish or meat	(Aboua et al, 1989)
'Dockounou'	Over-ripe fruits of plantain	Boiled and brownish dough as staple	(Akoa et al, 2012)
'Doklu'	Maize	Boiled dough eaten with vegetables, fish or meat	(Assohoun et al, 2012)
'N'bede-papa'	Cassava	Sugary cake as snack item	(Aboua, 1988)
'N'bete gboko'	Cassava	Fried pellets as snack item	(Aboua, 1988)
'Placali'	Cassava	Elastic paste eaten with vegetables, fish or meat	(Aboua, 1988 ; Koko et al, 2012 ; Zoumenou et al, 1998)
'Tchapalo'	Sorghum	Opaque and sour beer as beverage	(Aka et al, 2008 ; Djè et al, 2009 ; N'Guessan et al, 2010)
'Wômi'	Maize, sorghum or millet	Brownish cake as breakfast and snack item	This article.

‘Dagnan’

The millet or maize flour cereal is added with water and salt, mixed and left to undergo spontaneous fermentation for 72 h and then dried. The final product is a grayish dough use as staple food (Aboua et al, 1989).

2.3 Fermented product from plant part

‘Bandji’

‘Bandji’ is an alcoholic beverage produced from the sap of palm tree, which is tapped and allowed to undergo spontaneous fermentation (Karamoko et al, 2012) The process of tapping palm wine involves first felling or cutting down the tree, leaving the felled tree for a period of about 2 weeks for the sap to concentrate, followed by tapping for up to 8 weeks. Tapping involves perforation of the trunk, insertion of a tube in the hole and collection of the sap in a container (gourd, clay pot, plastic container, glass bottle or calabash). The sap, which is originally sweet, ferments within 2-3h and develops a stronger alcoholic taste and smell with time. The final product is whitish in appearance and have a pleasant sugary taste, but must also exhibit vigorous effervescence. ‘Bandji’ may also be allowed to undergo further alcoholic fermentation by local distillers, who add sugar to the product and allow it to ferment for a further 4–7 days and then distill it into a local gin called ‘koutoukou’ (Konadio et al, 1986).

2.4 Fermented products from fruits

‘Fermented cocoa beans’

Cocoa fermentation is a key step in the technological transformation of cocoa into chocolate, because the highly bitter, astringent unfermented cocoa beans lack the full chocolate flavor. The fermentation of cocoa beans is therefore the first step of the chocolate-making process, which consists of a natural, microbial fermentation of the pectinaceous pulp surrounding the seeds of the tree *Theobroma cacao* (De Vuyst et al, 2010). In Côte d’Ivoire, most cocoa is produced on small holdings under rural conditions. After the harvest of ripe cocoa pods, the beans are removed from ripe cocoa pods, covered with plantain leaves and subjected to a spontaneous five- to seven-day fermentation in heaps (Tagro et al, 2007). At the end of fermentation, Ivorian cocoa producers spread freshly fermented beans on a meshed wooden tray with area about 30-90 cm and raised 1 m above ground level, mats, polypropylene sheets or the concrete floor of a cocoa house each day to a depth of not less than 5 cm and mixed constantly to promote uniform sun drying and to break agglomerates (Tagro et al, 2010). According to the official standard, cocoa beans with more than 60% fully brown color beans is considered as good quality product.

‘Dockounou’

‘Dockounou’ is a traditional dish in Côte d’Ivoire made from over-ripe fruits of plantain. The empiric process involves seven steps which are fruits washing, peeling, crushing, mixture with flour (maize, rice), fermentation (facultative), wrapping and cooking (Akoa et al, 2012). The resulting dish wrapped in plant (*Thaumatococcus daniellii*, *Musa* sp. or *Cola nitida*) leaves before it cooking, constitutes an inestimable food aid for farmers during camping works. This traditional dish is more and more introduced in urban habit and is widely proposed on markets. ‘Dockounou’ is a smooth, spicy and brownish dough used as staple.

2.5 Food condiment made from fish

‘Adjuevan’ is a traditional Ivorian naturally fermented fish prepared from the Atlantic bumper *Chloroscombrus chrysurus* or the sea fish *Galeoides decadactylus* (Anihouvi et al, 2012 ; Koffi-Nevry and Koussémon, 2012; Koffi-Nevry et al, 2011; Kouakou et al, 2012 a, b). It is produced through a spontaneous and uncontrolled fermentation and by using a high amount of salt. For traditional ‘adjuevan’ production, the fresh fish is scaled, gutted, washed and left overnight before the seemingly deteriorated fish is treated with salt and allowed to ferment for 6 hours to 8 days. The final product is highly concentrated in salt with a strong smell used as a condiment to season sauces.

3. MICROORGANISMS INVOLVED DURING FERMENTATION

Most of fermented products in Côte d’Ivoire are obtained by solid state fermentation. In this process, microbial growth and product formation occurs on the surface of solids materials. Fermentation occurs in the absence of ‘free’ water, where the moisture is absorbed to the solid matrix (Pandey, 2000). In the production of fermented products, the fermentation steps aim to achieve the following:

- Affecting sensory properties (aroma, taste, colour, texture),
- Preservation, which relies mainly on acidification and/or alcohol production (Hammes, 1994),
- Enhancing food safety by inhibition of fecal enteric bacteria, such as *Shigella*, and *Echerichia coli* causing diarrhea in children (Mensah, 1991; Tetteh et al, 2004),

- Improving the nutritive value by removing antinutritive compounds (e.g. phytate, enzyme inhibitors, polyphenols, tannins), and enhancing the bioavailability of components by, e.g. affecting physio-chemical properties of starch and associations of fibre constituents with starch and associations of fibre constituents with vitamins, minerals or proteins (Chavan, 1989),
- Removal of undesired compounds such as mycotoxins (FAO, 1999; Nout, 1994), endogenous toxins, cyanogenic compounds, flatulence producing carbohydrates,
- Reducing energy required for cooking.

Relatively few researches have been done on the microbiology of traditional fermented products from Côte d'Ivoire with a major part devoted to 'attiéké' and cocoa beans fermentation as shown in **Table 2**. It appears from these investigations that the fermentation is natural and involves mixed cultures of LAB, *Bacillus*, *Enterobacteriaceae*, yeasts and fungi. Lactic acid bacteria were the dominant microorganisms in cassava pulp for 'attiéké' production throughout fermentation with the mean numbers being 1.2×10^9 cfu/g after 15 h of fermentation (Coulin et al, 2006; Assanvo et al, 2006). Identification to the species level of microorganisms from one representative 'attiéke' production of good quality showed that, at the start of fermentation, *Leuconostoc mesenteroides* subsp. *mesenteroides* was present in the highest numbers, accounting for 20% of all lactic acid bacteria. As the fermentation proceeded, this specie was replaced by homofermentative lactic acid bacteria, *Lactobacillus salivarius* and *L. delbrueckii* subsp. *delbrueckii*, and obligate heterofermentatives, *L. fermentum* and *L. confusus*. Nimaga et al. (2012) showed that *Lactobacillus* species (9.14 Log cfu/g) were the most important popular microorganism in cassava mash inoculated with different amounts of inoculums (6%, 8%, 10% and 12%), followed by enterococci (7.64 Log ufc/g) species, yeasts and moulds (7.30 Log cfu/g).

During cocoa fermentation process, microbial fermentation induces numerous reactions leading to a deep modification of the biochemical characteristics of beans. These complex biochemical reactions are triggered mainly by yeasts, *Bacillus*, acetic and lactic acid bacteria (Ouattara et al, 2011 and 2008; Papalexandratou and De Vuyst, 2011; Papalexandratou et al, 2011; Tagro et al, 2008). Species diversity of bacteria involved in traditional spontaneous cocoa beans fermentation (heap and box) in an important cocoa-producing region, namely Lagunes –Côte d'Ivoire) was investigated (Papalexandratou et al, 2011). The results showed that *L. fermentum* and *Leu. pseudomesenteroides* were the predominant LAB species. Enterobacterial species, such as *Erwinia soli* and *Pantoea* sp., were among the predominating microbiota during the early stages of both heap and box fermentations. The microbial activity in the cocoa pulp was a microbial succession led by yeasts (*Saccharomyces cerevisiae*), which dominate the microbial community during the first hours, followed by the LAB, which decline after 48h of fermentation, and finally the acetic acid bacteria (*Acetobacter pasteurianus*). The potential of six *Bacillus* species (*B. subtilis*, *B. pumilus*, *B. sphaericus*, *B. cereus*, *B. thuringiensis*, *B.*) to produce pectinolytic enzymes during cocoa beans fermentation was screened (Ouattara et al, 2011 and 2008). Species composition of yeasts involved in traditional spontaneous cocoa bean fermentation (heap and box) showed the presence of *Hanseniaspora* sp., *Pichia kudriavzevii*, *S. cerevisiae*, *Hyphopichia burtonii* and *Meyerozyma caribbica* among the main representative (Papalexandratou and De Vuyst, 2011). Post harvest moulds (*Absidia corymbifera*, *Rhizopus oryzae*, *Aspergillus tubingensis*, *A. tamarii*, *A. flavus*, *Penicillium chrysogenum*) development during raw cocoa beans fermentation from three main Ivorian producing regions (southern, western, western center) was reported (Tagro et al, 2008). For these authors, inadequate and/or poor drying and storage conditions of cocoa beans could explain this fact.

Microorganisms involved in sorghum mash and sour wort during 'tchapalo' processing in Abidjan, was investigated (Djè et al, 2009; N'Guessan et al, 2010). Lactic acid bacteria isolated in sorghum mash before fermentation belonged to the genus *Lactobacillus* (5.5×10^8 cfu/ml), *Enterococcus* (9.8×10^7 cfu/ml), *Pediococcus* (9.7×10^7 cfu/ml) and *Leuconostoc* (5.8×10^7 cfu/ml). This spontaneous fermentation was essentially governed by *Lactobacillus* strains and the load of other lactic acid bacteria and yeasts decreased as increased fermentation time. *Saccharomyces cerevisiae* and *Candida tropicalis* were the main yeasts species identified during the alcoholic fermentation of 'tchapalo'.

16S rDNA amplification and sequencing of representative LAB isolates from fermenting corn dough, collected from 'doklu' producers in Abidjan, revealed a succession of LAB species (Assouhoun et al, 2012). At the beginning of fermentation, *P. pentosaceus* (50%) and *P. acidilactici* (33%) were the predominant LAB species in corn dough with *L. fermentum* (17%). After 24h, *L. plantarum* (64%) was in highest number while *W. cibaria* (22%), *P. acidilactici* (7%) and *L. fermentum* (7%). *L. plantarum* (56%) and *P. pentosaceus* (39%) were the predominant LAB after 48h of fermentation. *L. fermentum* (100%) was predominant in corn dough at the end of fermentation.

Table 2: Fermented product, microorganisms associated and advantages arising out of fermentation

Fermented product	Microorganisms		Enhanced functional attributes over the raw material	References
	Lactic acid bacteria (LAB)	others		
‘Adjuevan’	<i>Leuconostoc lactis</i> , <i>Lactobacillus fermentum</i> , <i>Pediococcus</i> sp., <i>Streptococcus</i> sp., <i>Lactococcus garviae</i> , <i>S. difficilis</i>	<i>Kluyveromyces marxianus</i> , <i>Hansenula anomala</i> , <i>Saccharomyces cerevisiae</i> , <i>Candida tropicalis</i> , <i>C. zeylanoides</i> , <i>Pichia fermentans</i> , <i>Debaromyces hansenii</i> , <i>Hanseniaspora osmophilic</i> , <i>Rhodotorula glutinis</i>	Improved flavor ^a Improved shelf life ^b	(Koffi-Nevry et al, 2011 ; Kouakou et al, 2012 a, b)
‘Attiéké’	<i>Leu. mesenteroides</i> subsp. <i>mesenteroides</i> , <i>L. salivarius</i> , <i>L. delbrueckii</i> subsp. <i>delbrueckii</i> , <i>L. fermentum</i> , <i>L. confusus</i> , <i>Weissella</i> spp., <i>Leuconostoc</i> spp., <i>Lactobacillus</i> spp.	<i>Bacillus circulans</i> , <i>B. lentus</i> , <i>Enterobacter sakazakii</i> , <i>E. cloacae</i> , <i>Klebsiella pneumoniae</i> subsp. <i>pneumoniae</i> , <i>C. tropicalis</i> , <i>Enterococcus</i> spp., <i>Bacillus</i> spp., <i>B.amyloliquefaciens</i> , <i>C. tropicalis</i> , <i>Galactomyces geotrichum</i> , <i>C. krusei</i> , <i>C. humilis</i> , <i>Pichia fermentans</i> , <i>Trametes hirsuta</i>	Improved palatability improved texture cyanogens reduction a, b	(Assanvo et al, 2006 ; Coulin et al, 2006) (Kastner, 2008)
Cocoa beans	<i>L. fermentum</i> <i>Leu. pseudomesenteroides</i>	<i>Erwinia soli</i> , <i>Pantoea</i> sp., <i>Acetobacter pasterianus</i> , <i>S. cerevisiae</i> , <i>B. subtilis</i> , <i>B. pumilus</i> , <i>B. sphaericus</i> , <i>B. cereus</i> , <i>B. thuringiensis</i> , <i>B. fusiformis</i> , <i>Hanseniaspora</i> sp., <i>Pichia kudriavzevii</i> , <i>S. cerevisiae</i> , <i>Hyphopichia burtonii</i> , <i>Meyerozyma caribbica</i> , <i>Absidia corymbifera</i> , <i>Rhizopus oryzae</i> , <i>Aspergillus tubingensis</i> , <i>A. tamaritii</i> , <i>A. flavus</i> , <i>Penicillium chrysogenum</i>	a Improved color	(Papalexandratou et al, 2011) (Ouattara et al, 2011 and 2008) (Papalexandratou and DeVuyst, 2011) (Tagro et al, 2008)
‘Doklu’	<i>Pediococcus pentosaceus</i> , <i>P. acidilactici</i> , <i>L. fermentum</i> , <i>W. cibaria</i> , <i>L. fermentum</i>		a, b	(Assohoun et al, 2012)
‘Tchapalo’	<i>L. plantarum</i> , <i>L. fermentum</i> , <i>L. cellobiosus</i> , <i>L. brevis</i> , <i>L. coprophilus</i>	<i>S. cerevisiae</i> , <i>C. tropicalis</i> .	a, b	(Djè et al, 2009 ; N’Guessan et al, 2010)

Species of lactic acid bacteria isolated and identified from 'adjuevan' samples were *Leu. lactis* (5.7×10^3 cfu/g), *L. fermentum* (1.9×10^4 cfu/g), *Pediococcus* sp (6.5×10^3 cfu/g) and *Streptococcus* sp (2.6×10^2 cfu/g) (Koffi-Nevry et al, 2011). The genera *Lactobacillus* and *Pediococcus* were the predominant LAB genera isolated either from the fresh fish and the fermented product. These results were confirmed by those of Kouakou et al (2012a) which indicated *Lactobacillus fermentum*, *Leuconostoc lactis subsp lactis*, *Pediococcus pentosaceus*, *Lactococcus garviae*, *Streptococcus diffcilis* as predominant LAB species. Yeasts from 'adjuevan samples were identified as *Kluyveromyces marxianus*, *Hansenula anomala*, *S. cerevisiae*, *Candida tropicalis*, *C. zeylanoides*, *Pichia fermentans*, *Debaromyces hansenii*, *Hanseniaspora osmophilic*, and *Rhodotorula glutinis* which had not been previously described in fermented fish (Kouakou et al, 2012b).

Presence of microorganisms such as yeasts and LAB has been reported during fermentation of palm sap for 'bandji' production (Karamoko et al, 2012). The results showed that the yeasts and LAB population changed during tapping with an influence on palm wine quality.

4. THE USE OF STARTER CULTURES DURING PROCESSING OF IVORIAN FERMENTED PRODUCTS

In order to control and standardize the fermentation stage, the development and improvement of inoculants containing high concentrations of live micro-organisms, referred to as starter cultures, is the subject of much research in West African countries. Despite the research undertaken on the microbiology of Ivorian fermented products (as shown above), there is a limit number of research on the use of starter cultures during traditional processing. Two successes stories in this regard have been the use of different species of LAB in combination or not with species of yeasts during cassava and sorghum fermentations at a laboratory scale (Table 2). The potential of a mixed-strain (one *L. fermentum*, one *W. confusa*, two *B. amyloliquefaciens*, one *C. tropicalis*, one *Trametes hirsuta*) starter culture to replace the traditional inoculum for 'attiéké' production under low-technology conditions, was evaluated (Kastner, 2008). The resulting product showed microbial growth kinetics, pH values and metabolite concentrations very similar to traditional 'attiéké'. Furthermore, starch, pectin and cellulose degrading activities, which contribute to texture modification and flavour development in 'attiéké', were also assessed in vitro for *Bacillus* and yeasts strains. These research works provide a broad basis for the continued development of a standard 'attiéké' starter culture which could be widely applied and facilitate the production of a high quality and safe staple food in Côte d'Ivoire.

Saccharomyces cerevisiae and *C. tropicalis* were used as starter culture and tested in pure culture or co-culture of four ratios [2:1, 25:4, 1:4, 2:3 (cells/cells)] for their ability to ferment sorghum wort to produce 'tchapalo' (N'Guessan et al, 2010). Starter cultures with large ratio of *C. tropicalis* produced a higher organic acids and 2-butanone than *S. cerevisiae* in pure culture. However, co-culture *C. tropicalis*+*S. cerevisiae* (2:1) was the alone starter which produced higher ethanol than *S. cerevisiae* in pure culture. The beers produced with *C. tropicalis*+*S. cerevisiae* (25:4), *C. tropicalis*+*S. cerevisiae* (1:4) and *C. tropicalis* were widely different from those produced with the others starter cultures.

Microorganisms isolated from fermented products in Côte d'Ivoire were screened for their ability to produce enzymes of commercial interest. Pectinolytic enzymes are extracellular enzymes which are known to be indispensable for the normal course of the fermentation process and for the development of the quality of fermented cocoa (Schwan, 2004). *Bacillus* species isolated from fermented cocoa beans were screened for their ability to produce pectate lyase (Ouattara et al, 2011). The results showed that the best pectate lyase producers, yielding at least 9 U/mg of bacterial dry weight, belonged to *B. fusiformis*, *B. subtilis*, and *B. pumilus* species. Two kinds of pectate lyase, one with an isoelectric point (pI) of 9.8 (*B. subtilis* and *B. fusiformis*) and the other with a pI of 10.5 (*B. pumilus*) were produced. Enzyme treatment on cocoa beans could significantly reduces the fermentation time and contribute to the formation of sensorial characteristics of the fermented beans.

Large quantities of starter culture in active and pure form are essential to the success of starter in product manufacture. This can be achieved by careful propagation of cultures. Starter propagation is time consuming, laborious, requires skilled personnel and is more prone to contamination. The use of dehydrated starter culture could be envisaged during processing of Ivorian fermented products. The direct addition of selected starter cultures to raw materials could be a breakthrough in the processing of traditional fermented products, resulting in a high degree of control over the fermentation process and standardization of the end product (Yao, 2009)

5. CONCLUSION AND RESEARCH NEEDS

West African countries such as Côte d'Ivoire are experiencing rapid changes in the social and economic environment which are associated with changes in food consumption patterns. Specifically, increased food availability and diversity in urban areas affect the quality of diets and nutritional well-being. With increasing industrialization and urbanization, efforts are presently geared towards the development of large-scale factory production facilities for fermented products where the quality of the finished product will be assured. Modern large-scale production of fermented products is

dependent almost entirely on the addition of appropriate starter cultures to the raw material. A high degree of control over the fermentation process and standardization of the end product could be achieved. The focus of research efforts should be directed to the production of already isolated and identified microorganisms in the dried form. Identification and selection of microorganisms capable of improving the nutritional, sanitary and organoleptic properties of Ivorian cereal gruel used as weaning food should also be realized.

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