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MICROBIOLOGICAL AND NUTRIONAL QUALITY OF DRIED OKRA SOLD IN ABIDJAN MARKETS.

ASBTRACT

A nutritional and microbiological study was made on okra, an important food consumed in Côte d'Ivoire. The nutritional analysis made on the 2 okra varieties (Yelen and Tomi) were to determined moisture, protein, sugar, lipid, fiber, vitamin C, β-carotene and mineral. Microbiological consist, always in the studied varieties, to evaluated germs evolution weekly from the beginning of drying process to the storage during 9 weeks under ambiant temperature. On the other hand, powdered dried okra and whole dried okra sold on Abidjan markets were analysed. The microbiological analysis consist in the research of Salmonella and Staphylococcus aureus and in the counting of faecal coliforms, yeasts, moulds and anaerobic sulfito-reductors germs. Protein rate, Lipid , Total sugar ,Vitamin C , β-carotene level were different according the genus of okra. In Yelen and Tomi varieties, the others nutriments rate were different too. In this investigation, Salmonella and Staphylococcus aureus were not found. During the storage, faecal coliforms load increased. For Yeast, the load increased and decreased after a time with a peak of 1.8. $10^4 \pm 3.4.10^3$ CFU/g (Yelen) and $3.5.10^4 \pm 7.4.10^3$ CFU/g (Tomi). In powdered dried okra the presence of microorganisms differ according the market.

Dried okra sold on markets have an unsatisfactory quality. To avoid sanitary risk, okra should be well dried and consumed at most during the first 5 weeks of storage.

Key words: nutritive value, microbial load, quality, dried okra, evolution, sanitary risk, storage.

INTRODUCTION

In Côte d'Ivoire, okra production is around 115.867 tons (Anonymous, 2009). This vegetable is primarily grown for it immature pods generally harvested between 3 - 7 days old after flowering. Okra fruits contain many nutrients such as proteins, vitamins and minerals (Agbo et al., 2008). As the other green vegetable, okra is perishable. So, the common conservation method used is the drying. This process allows people to make okra more durable and preserve them for food insecure periods (Adambounou et al., 1983). In Côte d'Ivoire, dried okra is commonly called "djumble". The young tender fruits (2-3 days old) are sundried whole until becoming brittle, but, the old fruits are sliced in thin disks, dried and powdered (Shippers, 2002). However, in practice, the drying is mainly made on an artisanal scale. In fact, okra is either put on mat or metal sheet laying on the ground and sundried during 3 or 4 days (Amon, 1985). In these conditions, dried okra is exposed to microbiological contamination (Mpuchane and Gashe, 1996). The incriminated germs (coliforms, Pseudomonas, Staphylococcus, Clostridium, Salmonella, yeasts and moulds) may be already present on fresh okra or could appear during drying process if it is made under unhygienic conditions. Moreover, if dried okra is stored in dusty humidity weather, many microbes, especially fungi, can grow and secrete toxic substances which can induce hazardous risks for human health (Youssef, 2008).

In Côte d'Ivoire, reports of microbial contamination of dried vegetables, particularly dried okra are rare while climatic conditions, drying and conservation are favourable for micro-organisms development. Indeed, mycotoxins and fungal contamination on dried vegetables have been investigated by some authors. So, Youssef (2008) revealed the presence of moulds and their toxins in sundried okra on markets after 22 weeks of conservation. Similarly, Hell et al. (2009) showed that the load of moulds was very high in dried okra and dried hot chilli. They also detected aflatoxin.

The purpose of this research is, after the determination of some nutrients, to evaluate microbial load evolution during the storage. The

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hygienic quality of dried okra sold on market will be also determined and correlate to the evolution value in order to appreciate the length of conservation of dried okra exposed on markets.

MATERIAL AND METHODS

Material

The study was conducted in one hand, with two okra varieties (Yelen and Tomi) harvested in fresh form and dried on laboratory and in another hand, with whole dried and powdered dried okra sold on markets.

Sampling procedure

The two okra varieties were harvested in the experimental station of the National Agronomic Research Center (CNRA) at Anguédédou (5° 22 of North latitude, 4° 8 of West longitude and 95 m of altitude) localized at 30 km of Abidjan in Côte d'Ivoire. Fruits were placed in an isothermic box with ice packs and carried to the laboratory for analysis.

For the microbial load evolution study, 2 kg fresh okra of each varieties were used. Before the drying process, 25 g of fresh okra were taken off for microbial analysis and the rest were sliced and dried in an oven (Selecta Memmert, Germany) during 3 days at 45 °C. Dried okra was share out in part of 25 g, put in sterile Stomacher bag and stored at ambient temperature in a cardboard during 9 weeks.

The samples of powdered and whole dried okra were collected from 4 markets in Abidjan (Treichville, Yopougon, Abobo and Adjamé). At all, 144 dried okra included 72 powdered dried okra and 72 whole dried okra were purchase with 12 sellers selected randomly. Each sample about 50 g was packed in a sterile polyethylene bag, placed in an isothermal box equipped with ice packs and tranferred to the laboratory for analysis.

Sample preparation

For the microbiological analysis, a portion of samples (25 g) was taken into sterile Stomacher bag with 225 ml of plugged water (Bio-Rad). The mixture was homogenized in a Stomacher (Lab-Blender 400). Decimal dilution was made by adding 1 ml of the first solution to 9 ml of a solution of plugged water. This dilution was name the 10^{-1} dilution. Further serial dilutions to 10^{-5} dilution were made like the same process.

Methods

The nutritional analyses consist in determined moisture and protein by AOAC (2005). Total sugars were analyzed by the phenol-sulphuric acid method (Dubois et al., 1956) and lipids were extracted with hexane in Soxhlet apparatus (Soxtherm automatic Gerhardt SE 3M, Denmark) during 4hr. Ascorbic acid was analyzed by Tomohiro (1990) and β-carotene by Tee et al. (1996) methods. Phosphorus content was measured by molybdo-vanadate method at 410 nm using a Spectrophotometer Shimadzu (Kyoto, Japan) (AOAC, 2005). Calcium and potassium were determined using Shimadzu AA-680 Atomic Absorption spectrophotometer (Japan) at their specified wavelengths (422.7 nm for calcium and 766.5 nm for potassium). Iron concentration was estimated using an UV visible spectrophotometer (Jasco V–530, Japan) at 510 nm. Soluble and insoluble fibbers were also determined (Van Soest, 1963).

The microbial flora examination was based on the research of Salmonella and Staphylococcus aureus and the numeration of faecal

coliforms, yeasts, moulds and anaerobic sulfito-reductors germs (fruiting forms and sporeformers).

For Salmonella detection (NF V 08-052), the mother suspension was incubated 24 h at 37 °C. Then 0,1 ml of this suspension was incorporated to 9 ml of Rappaport-Vassiliadis broth (Bio-Rad) and incubated 24 h at 37 °C. The isolation was made on Hektoen agar (Bio-Rad). Suspected colonies were identified using Le Minor middle incubated 24 h at 37 °C. The coagulase-positive Staphylococcus aureus (NF V 08-057-1) was detected on Baird Parker (Biomerieux) 48 h at 37 °C. The suspected colonies were identified using the coagulase test with rabbit plasma. Faecal coliforms (NF V 08-060) were counted on double layer on Desoxycholate agar (Bio-Rad) 24 h at 44 °C and the characteristic colonies were small and red with a diameter inferior to 1.5 mm. Yeasts and moulds (NF ISO 7953) were counted on Sabouraud with Chloramphemicol agar (Biomerieux) 72 h at 37 °C. Yeasts colonies were small or large, white or beige, with a creamed aspect, a smooth surface and a distinct outline. Moulds colonies were circular or invasive, plate with crater in center and a down or powdery aspect. Only moulds colonies were identified because for Guiraud (1998), they were responsible of dried products alterations during the storage. The identification was based on morphology and microscopic features such as spores and fruiting structures in blue methylen at x 40 objective. For anaerobic sulfito-reductors germs (XP V 08-061), fruiting forms and spores were counted in Trypton Sulfite Neomycin agar (Biomerieux) 48 h at 46 °C. To isolate sporeformer, samples were heat treated for 5 minutes at 80 °C and put in ice before plating in agar. The characteristic colonies were black with or without a translucent halo and a diameter include between 2 and 5 mm.

Microbiological criteria

The microbiological criteria for dried vegetables analysis at ordinary cooking was used to appreciate the microbiological quality of dried okra (Guiraud, 1998). The following standards (m, M) were used: m was defined as the permissible level of bacterial counts and M as the maximum allowable number of organisms per gramm of product (currently defined as 10 x m) (Table 1). The number (n) of sample unit is 5 and the tolerancy (c) is 2. Dried okra hygienic quality is satisfactory if the load is inferior or equal to m. It is acceptable if the load is comprise between m and M for two samples unit and unsatisfactory if the load is greater than M or if there is presence in 25 g for Salmonella.

Statistical analysis

Results were expressed as mean ± standard deviation of the triplicate assays. Data were analyzed using STATISTICA 7.1 (Oklahoma, USA). A one-way analysis of variance (Anova) was performed and means were separated using a Duncan multiple range test (p=0.05). A principal element analysis was also used to correlate microbiological data between dried okra sold on market and dried okra stored in laboratory with XLSTAT (Adinosoft Incorporation, 2009). This analysis regroup measured variable in factors. The orthogonal rotation of principal element (Varimax) allowed obtaining a structure easy to analyse.

Results and discussion
Nutritional composition

Moisture was determined in different samples. In fresh okra, the moisture values of the 2 varieties, Yelen and Tomi, are respectively about 88.71 ± 1.57 and 88.58 ± 2.03 % (Table 2).

During the storage of okra dried in laboratory, moisture content varied from 9.66 % to 10.13 % for Tomi and from 11.41 % to 10.45 % for Yelen (Figure 1). Moisture content of whole dried and powdered dried okra sold on markets ranged between 14 – 16.4 % and 14.1 – 18.6 % respectively (Table 3). On Treichville, Yopougon and Adjamé markets, moisture content of whole dried and powdered dried okra

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differed significantly. But, on Abobo market it did not differ. According to Asiedu (1991), dried okra sold on markets have not been well dried or conserved because their moisture value is higher than the standard value which is about 15 % for dried vegetables.

Protein rate is about 16 ± 0.08 g/100 g DM in Yelen and 17.31 ± 0.11 g/100 g DM in Tomi (Table 2). These values are higher than that of some vegetables. Indeed, in the eggplant, french beans and pepper, protein content is respectively 1.5 g/100 g DM, 1.9 g/100 g DM and 0.9 g/100 g DM (Grubben et al., 2004). Okra fruit contain a low rate of lipid with is around 2.42 ± 0.12 % for Yelen and 1.43 ± 0.08 % for Tomi. Total sugar, however, is high in this vegetable (133.67 ± 16.86 mg/100g DM for Yelen and 101.61 ± 8.67 mg/100g DM for Tomi). These values are more elevated than that revealed by Longe (1981) (102 mg/100 g DM) and may be due to the metabolic activity in the fruit.

The two okra varieties (Yelen and Tomi) contain respectively 9.15 ± 1.04 and 13.64 ± 0.67 mg/100g FW of vitamin C (Table 4). This values are lower than that of Souci et al. (1994) who revealed a rate of 36 mg/100 g. These differences could be due to sun exposition, fruits ageing and genetic factors (Herzog et al., 1993). β-carotene rate which is 68 ± 1.13 µg/100g FW in Yelen and 180 ± 13.18 µg/100g FW in Tomi contribute to strengthen the plant capacity to remain stable the complex pigment-protein conformation and to struggle against free radicals (Sen and Mukherji, 1999). However, β-carotene rate differed significantly between the 2 varieties. β-carotene Yelen value is similar to that of violet eggplant which is 70 µg/100g. For the 2 varieties there is any statistical difference on soluble fibers value which is respectively 18 ± 1.61 % and 17.67 ± 2.52 % (Table 4). But, there is a significant difference between insoluble fibers rate. According to Rémésy et al. (1998), soluble fibers improve the glucose assimilation during the digestion processus and insoluble fibers make easier the intestinal transit. However in okra fruit, cell wall lignification which is tied up to dietary fibers augmentation contribute to the hardening of the fruit. But, the harden fruits are less appreciated but the consummers who prefered the young fruit (Makhadmeh and Ereifej, 2004).

In Yelen and Tomi varieties, phosphorus rate is respectively about 9.63 ± 0.05 and 9.44 ± 0.08 mg/100g DM (Table 5). These value are lower than that of FAO (1995) who revealed a rate of 90 mg/100g. However, these lower values could lead to some deficiencies in okra (Rao et al., 1993). Indeed phosphorus has a key role in Calvin cycle. So, its deficiency in the plant could cause a drop of the photosynthesis activity. Moreover, lake of phosphorus could disrupt calcium assimilation and reduce energetic activity in human organism (Jacotot et al., 2003). Yelen variety contains 1.15 ± 0.08 mg/100g DM of iron and Tomi variety 0.72 ± 0.02 mg/100g DM (Table 5). These values differe significantly and iron rate in Yelen variety is close to that of french beans (1.2 mg/100g DM) (Grubben et al., 2004). In addition, iron rate in okra is low because human organism could absorb only 1 to 5 % of vegetable iron (AFSSA, 2008). Calcium rate is around 103 ± 3.12 mg/100g DM in Yelen variety and 99 ± 2.06 mg/100g DM in Tomi variety (Table 5). There is a significant difference between the to varieties. Morever, calcium rate in this study is lower than that of Sen and Mukherji (2002), Fergusson et al. (1993) and Boukari et al. (2001) who indicated respectively 174 mg/100g DM, 722 mg/100g DM, 1330 mg/100g DM. This difference could be explain by genetic factors or by the fact that calcium is implicated in cell wall renewal, so, in fruits growing. On the other hand, potassium rate which is respectively 2.4 ± 0.2 and 2.55 ± 0.31 g/100g DM in Yelen and Tomi, is higher than that revealed by some authors (Table 5). In fact, Souci et al. (1994) and Sen and Mukherji (2002) showed respectively a rate of 285 mg/100g DM and 219 mg/100g DM. According to Herzog et al, (1993) and Boukari et al. (2001) our elevated values could be due to the soil, to the environment factors and to the fertilizers used. Furthermore, potassium elevated rate is benefic for growing, metabolism and enzymatic activity in the plant. Indeed, when potassium is low, carbohydrate rate decrease in fruits and in leaves (Sen and Mukherji, 2002)

Identification of St. aureus and Salmonella

St. aureus and Salmonella were not found in dried okra sold on markets, neighter in dried okra conserved at laboratory. This is in accord to Mpuchane and Gashe (1996) who had not identified St. aureus in dried leafy vegetables purchased with street vendors in Botswana.

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The absence of these 2 germs reduce the sanitary risk due to dried okra consumption. Indeed, Salmonella and St. aureus are pathogenic microorganisms which corrupted food and could induce food infection (Berrebi, 2006). Morover, the absence of St. aureus showed any sellers handle manipulation.

Microbial load evolution during dried okra conservation

Before the drying process, in fresh okra, the initial faecal coliforms load was about $8.7.10^2 \pm 7.5.10^2$ CFU / g and $10^3 \pm 10^2$ CFU / g for Yelen and Tomi respectively (Figure 2). The average load of yeast was $1.4.10^4 \pm 2.2.10^3$ CFU / g for Yelen and $1.1.10^3 \pm 1.2.10^2$ CFU / g for Tomi. Moulds have been counted only in Yelen variety at the load of 67 CFU / g. Fruiting forms and spores of anaerobics sulfite-reductors germs were not counted.

During the conservation faecal coliforms microbial load increased. Thus, between the 1st and the 2nd week, the growth was rapid increasing from $2.1.10^3 \pm 1.2.10^2$ to $2.10^4 \pm 9.5.10^3$ CFU / g for Yelen and $2.6.10^3 \pm 6.5.10^2$ to $4.10^3 \pm 10^2$ CFU / g for Tomi (Figure 3). Between the 2nd and the 5th weeks, the microbial load was constant. However, there was a crucial augmentation between the 5th and the 6th week and the variation was ranged about $4.1.10^4 \pm 1.1.10^3$ to $7.3.10^7 \pm 2.9.10^6$ CFU / g for Yelen and $2.1.10^4 \pm 9.8.10^3$ to $3.10^7 \pm 3.1.10^6$ CFU / g for Tomi. These loads used to decrease between the 7th and the 9th week.

Fruiting form of anaerobics sulfito-reductors germs have been counted during the 1st and the 8th week of conservation in Tomi at the constant load of 5 ± 2 CFU / g. The load increased to 7 ± 2 CFU / g at the 9th week. For Yelen, fruiting forms of anaerobics sulfito-reductors germs were isolated only at the 8th and the 9th weeks at the load of 7 ± 2 CFU / g (Figure 4).

Yeasts microbial load increased progressively from the 1st to the 5th week of storage and decreased until the 9th week (Figure 5). So, for Yelen variety, the load increased from $1.5.10^3 \pm 5.10^2$ CFU / g (1st week) to $1.8.10^4 \pm 3.4.10^3$ CFU / g (5th week) and decreased until $1.7.10^2 \pm 50$ CFU / g at the 9th week. For Tomi, the load increased from $2.7.10^2 \pm 2.5.10^2$ CFU / g (1st week) to $3.5.10^4 \pm 7.4.10^3$ CFU / g (6th week) and decreased until 0 CFU / g at the 9th week. Between the 5th and the 6th week yeasts microbial load of the two varieties is superior to the acceptability threshold which is about 10^4 CFU / g. The moulds microbial load in Tomi variety increased between the 1st and the 3rd week from 0 to $1.1.10^4 \pm 10^3$ CFU / g and decreased at 66.7 ± 57.7 CFU / g until cancel out at the 7th week (Figure 6). However, for Yelen, moulds have been counted only at the 6th week at the microbial load of $7.10^2 \pm 3.10^2$ CFU / g.

In general, microbial load in fresh okra decreased after the drying process. This could be due to the water activity declining which result from the lost of humidity in samples, causing the inhibition of microbial growth (Adom et al., 1997). But faecal coliforms load increase rapidly during the conservation. This phenomenon could be due firstly to okra nutritive value which contributes to give to micro-organisms the nutrients necessary to their metabolism (Adambounou et al., 1983). Secondly, this evolution could be due to contamination or subsequent growth of micro-organisms during the 1-2 days of drying when the moisture content is still high (Mpuchane and Gashe, 1996). So, to ameliorate the hygienic quality, okra should be washed and disinfected or blenched before being dried. In addition, Lorougnon (1996) has showed that a disinfection with bleach (sodium hypochlorite water) 1° chlorimetric reduce of 100 % the microbial load of vegetables.

A few moulds and anaerobics sulfito-reductors germs colonies appeared during dried okra storage. This lower isolation frequency could indicate a good drying. However, the fact that yeasts were identified during all the conservation period is justified by their capacity to resist in dried products. Between the 5 first weeks they were increasing because of nutrients in dried okra, but, while there was any revivification in dried okra, the load decreased (Annan et al., 2003).

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Isolation frequency of germs in dried okra sold on markets

The isolation frequency of faecal coliforms in powdered dried okra (98.6 %) was higher than in whole dried okra (88.9 %) (Figure 7). However, anaerobic sulfito-reductors germs, yeasts and moulds have been more isolated in whole dried okra than in powdered dried okra. So, whole dried okra sold on markets was contaminated and this can be due to the fact that it have been dried incorrectly and could contain water. An inappropriate drying is favorable for micro-organisms development.

Microbial load of dried okra sold on markets

The average load of faecal coliforms ($2.6.10^5 \pm 9.9.10^4$ CFU / g) and that of anaerobic sulfito-reductors germs, fruiting form and spore (respectively 58 ± 8 et 57 ± 6 CFU / g) of powdered dried okra sold in Adjamé market differ significantly to that of the others markets (Table 6). However, there is no significant difference concerning yeasts and moulds load between the four markets. On Treichville market, microbial load in whole dried okra is low and the values are around $9.1.10^2 \pm 83$ CFU / g for faecal coliforms, 9 ± 2 and 5 ± 2 CFU / g for fruiting forms and spores of anaerobics sulfito-reductors germs respectively and $1.6.10^3 \pm 3.3.10^2$ CFU / g for yeasts (Table 7). The highest load rate of faecal coliforms was found on Adjamé market ($7.1.10^4 \pm 7.6.10^3$ CFU / g) and that of moulds on Abobo market ($2.5.10^4 \pm 3.1.10^3$ CFU / g).

The higher faecal coliforms load could be due to insalubrities in markets or to the exposition of dried okra in contact with fly, dust and potential microbial spores. Yeasts and moulds presence in samples could be due to relative air humidity and moisture content of the product and to inappropriate handling and storage method often associated with poor hygiene (Abou-Arad et al., 1999). In fact, in markets, sellers used to store dried vegetable in warehouses where the temperature is elevated and where there is a lack of aeration which favors humidification of dried vegetables and then, the microbial growth (Adom et al., 1996). So, Youssef (2008) has isolated moulds in dried okra and dried jew's mallow leaves to the respective load of $4.8.10^4$ CFU / g and $1.7.10^4$ CFU / g. The presence of anaerobic sulfito-reductors germs, fruiting forms and spores, could be due to a contamination during the drying. Indeed, for Hell et al. (2009), foodstuffs contamination with spoilage fungi was the result of natural extraneous pollution with dust particles containing spores during storage. Mpuchane and Gashe (1996) have isolated sporeformers of anaerobic sulfito-reductors germs in dried leaves of bush okra and in African spider herb to the respective load ranged between $2.10^3 – 8.10^5$ and $10^4 – 10^7$ CFU / g.

Microbial quality of dried okra

According to microbiological criteria, on Yopougon market, only 5.6 % of powdered dried okra has a satisfactory microbiological quality, 16.7 % an acceptable microbiological quality and 77.7 % an unsatisfactory microbiological quality. However, on Treichville market, 5.6 % of powdered dried okra has an acceptable microbiological quality and 94.6 % an unsatisfactory microbiological quality. On Adjamé and Abobo markets the microbiological quality of powdered dried okra is unsatisfactory (Figure 8). The microbiological quality of whole dried okra sold on Abobo market is also unsatisfactory. But, on Treichville market, 33.3 % of samples have a satisfactory microbiological quality, 27.8 % an acceptable microbiological quality and 38.9 % an unsatisfactory microbiological quality (Figure 9).

The fact that several samples have an unsatisfactory microbiological quality revealed a serious problem of sanitary quality of dried vegetables because some coliforms are pathogenic and anaerobics sulfito-reductors germs and moulds were able to secrete toxins.

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Approximation of the conservation length of dried okra sold on markets according to the principal elements analysis of microbial load.

The principal elements analysis allows us to reduce the measurable variable (load of faecal coliforms, anaerobics sulfito-reductors germs, yeasts and moulds) in 2 principal elements (F_1 and F_2) that proper value is higher than 1. According to the varieties, F_1 and F_2 could explain at least 75 % of the total variation. Yeasts, moulds and anaerobics sulfito-reductors germs contributed significantly to axis F_1 formation while faecal coliforms were more implicated in axis F_2 formation (Table 8). There is correlation between the micro-organisms load and the factors if the absolute value of the factors is superior or equal to 0.72. So, the principal elements analysis representation showed some common characteristics between the microbial load of whole dried okra sold on Treichville, Yopougon and Adjamé markets and the 2 varieties (Yelen and Tomi) during the firsts five weeks of storage (Figure 10 and 11). Indeed, representative points of these variables were gathered, near the axis F_2 in the negative sense, so, characterized by a low load in faecal coliforms. In contrast, whole dried okra sold on Abobo market were characterized by a high load in anaerobics sulfito-reductors germs, yeasts and moulds and had any common characteristics with microbial load of the varieties dried and stored in laboratory. For powdered dried okra, only the microbial load of that sold on Yopougon and Treichville markets have the same microbiological characteristics with the load of the 2 varieties during the firsts five weeks of storage. There were characterized by a low load in faecal coliforms. But, the microbial load of powdered dried okra sold on Adjamé and Abobo markets were characterized by a high load in anaerobics sulfito-reductors germs, yeasts and moulds. From the 6^{th} to the 9^{th} week of conservation Yelen and Tomi were characterized by their high load in faecal coliforms.

It resulted of this analysis that dried okra sold on market which loads were near that of the 2 okra varieties conserved during the firsts five weeks have been dried recently because they contained a low load of faecal coliforms. On the other hand, dried okra which loads were different might have been on markets during a long period or contaminated by markets environment (Hell et al., 2009) because they were characterized by a high load in anaerobics sulfito-reductors germs, yeasts and moulds. So, the dried okra conservation deadline could be fixed at 5 weeks after the drying. However, these criteria were insufficient to determine dried okra optimum utilization deadline. In fact, other tests, such as toxins research of anaerobics sulfito-reductors germs and moulds must be done taking account the fact that these toxins were susceptible to cause foods intoxications and could lead too much greater health risks than previously perceived (Yandja et al., 1995).

CONCLUSION

This showed that okra is a nutritive fruit which contain proteins, sugar, fibers, vitamin C, β-carotene and mineral. For its conservation it is usually dried. However, because of this best nutritive value and because of drying and conservation conditions dried okra is contaminated with several germs. Indeed, dried okra sold on Abidjan markets have an unsatisfactory quality due essentially by a high load in faecal coliforms, yeasts and moulds. But, a good drying is an inhibitor for anaerobics sulfito-reductors germs presence in foods. So dried okra sold on markets must be washed, disinfected, dried under aseptic conditions and consumed before 5 storage weeks in order to avoid sanitary risk due to germs proliferation and toxins secretions. Moreover, such products should pass strict quality control inspection before being marketed to consumers.

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TABLES

Microorganisms	m	M
Salmonella	Absence in 25 g	
Staphylococcus aureus	1 CFU / g	10^2 CFU / g
Faecal coliforms	10^2 CFU / g	10^3 CFU / g
Yeasts and moulds	10^3 CFU / g	10^4 CFU / g
anaerobic sulfito-réductors germs	10^2 CFU / g	10^3 CFU / g

Table 1: Microbiological criteria of dried vegetables at ordinary cooking (Guiraud, 1998).

m = criterion

M = maximum thershold

Varieties	Moisture (%)	Proteins (g/100g)	Lipids (%)	Total sugar (mg/100g)
Yelen	$88.71^{a} \pm 1.57$	$16^{a} \pm 0.08$	$2.42^{b} \pm 0.12$	$133.67^{b} \pm 16.86$
Tomi	$88.58^{a} \pm 2.03$	$17.31^{b} \pm 0.11$	$1.43^{a} \pm 0.08$	$101.61^{a} \pm 8.67$

In column, means values followed by different superscript are statistically different (Duncan test) ($p \leq 0.05$).

Table 2: Moisture, proteins, lipids and total sugar content in okra varieties.

Markets	Powdered dried okra (%)	Whole dried okra (%)
Treichville	$16.4^{a} \pm 1$	$18.6^{b} \pm 1.4$
Yopougon	$14.3^{a} \pm 2.1$	$17.9^{b} \pm 2.9$
Adjamé	$14.7^{a} \pm 1.9$	$17.4^{b} \pm 3.5$
Abobo	$14^{a} \pm 2.1$	$14.1^{a} \pm 4.02$

In line, means values followed by different superscript are statistically different (Duncan test) ($p \leq 0.05$).

Table 3: Moisture content of dried okra sold on markets.

Varieties	Vitamin C (mg/100g)	β-carotene (µg/100g)	Soluble fiber (%)	Insoluble fiber (%)
Yelen	$9.15^{a} \pm 1.04$	$68^{a} \pm 1.13$	$18^{a} \pm 1.61$	$22.23^{b} \pm 0.75$
Tomi	$13.64^{b} \pm 0.67$	$180^{b} \pm 13.18$	$17.67^{a} \pm 2.52$	$17.1^{a} \pm 0.92$

In column, means values followed by different superscript are statistically different (Duncan test) ($p \leq 0.05$).

Table 4: Vitamin C, β-carotene, soluble and insoluble fiber content in okra varieties.

Varieties	Phosphorus (mg/100g)	Iron (mg/100g)	Calcium (mg/100g)	Potassium (g/100g)
Yelen	$9.63^{a} \pm 0.05$	$1.15^{b} \pm 0.08$	$103^{b} \pm 3.12$	$2.4^{a} \pm 0.2$
Tomi	$9.44^{a} \pm 0.08$	$0.72^{a} \pm 0.02$	$99^{a} \pm 2.06$	$2.55^{a} \pm 0.31$

In column, means values followed by different superscript are statistically different (Duncan test) ($p \leq 0.05$).

Table 5: Minerals content in okra varieties

THE EXPERIMENT
INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN-2319-2119

RESEARCH ARTICLE

Markets	Coliforms (CFU / g)	ASR (FF) (CFU / g)	ASR (S) (CFU / g)	Yeasts (CFU / g)	Moulds (CFU / g)
Treichville	$3.03.\ 10^{3a} \pm 1.7.\ 10^{2}$	$16^{a} \pm 8$	$15^{ab} \pm 8$	$3.5.\ 10^{3a} \pm 1.6.\ 10^{2}$	$2.5.\ 10^{3\,a} \pm 1.6.\ 10^{2}$
Yopougon	$8.8.\ 10^{3a} \pm 9.\ 10^{2}$	$8^{a} \pm 3$	$11^{ab} \pm 6$	0^{a}	$3.2.\ 10^{3\,a} \pm 3.2.\ 10^{2}$
Adjamé	$2.6.\ 10^{5\,b} \pm 9.9.\ 10^{4}$	$58^{b} \pm 8$	$57^{b} \pm 6$	$3.6.\ 10^{3a} \pm 6.2.\ 10^{2}$	$1.5.\ 10^{4\,a} \pm 2.8.\ 10^{3}$
Abobo	$8.7.\ 10^{3a} \pm 5.8.\ 10^{2}$	$8^{a} \pm 3$	0^{a}	$4.8.\ 10^{3a} \pm 4.9.\ 10^{2}$	$2.02.\ 10^{4\,a} \pm 4.9.\ 10^{3}$

In column, means values followed by different superscript are statistically different (Duncan test) ($p \leq 0.05$).

Table 6: Microbial load of powdered dried okra sold on markets

Markets	Coliforms (CFU / g)	ASR (FF) (CFU / g)	ASR (S) (CFU / g)	Yeasts (CFU / g)	Moulds (CFU / g)
Treichville	$9.1.\ 10^{2a} \pm 83$	$9^{a} \pm 2$	$5^{a} \pm 2$	$1.6.\ 10^{3a} \pm 3.3.\ 10^{2}$	$1.1.\ 10^{3\,a} \pm 1.4.\ 10^{2}$
Yopougon	$3.1.\ 10^{3a} \pm 1.7.\ 10^{2}$	$15^{a} \pm 4$	$16^{b} \pm 10$	$4.7.\ 10^{3a} \pm 2.2.\ 10^{2}$	$7.\ 10^{3\,a} \pm 7.3.\ 10^{2}$
Adjamé	$7.1.\ 10^{4\,b} \pm 7.6.\ 10^{3}$	$17^{a} \pm 4$	$15^{b} \pm 5$	$1.6.\ 10^{3a} \pm 1.7.\ 10^{2}$	$2.2.\ 10^{3\,a} \pm 2.6.\ 10^{2}$
Abobo	$2.\ 10^{4\,a} \pm 1.9.\ 10^{3}$	$43^{b} \pm 8$	$10^{a} \pm 5$	$4.3.\ 10^{4a} \pm 1.4.\ 10^{3}$	$2.5.\ 10^{4\,b} \pm 3.1.\ 10^{3}$

In column, means values followed by different superscript are statistically different (Duncan test) ($p \leq 0.05$).

Table 7: Microbial load of whole dried okra sold on markets

FF: fruiting form of anaerobic sulfito-réductors germs

S: spores of anaerobic sulfito-réductors germs

Varieties	Micro-organisms	F_1	F_2
Yelen	Faecal coliforms	-0,102	0,994
	Anaerobics sulfito-reductors germs	0,833	-0,099
	Yeasts	0,744	-0,044
	Moulds	0,910	-0,168
Tomi	Faecal coliforms	-0,089	0,981
	Anaerobics sulfito-reductors germs	0,821	-0,158
	Yeasts	0,748	0,103
	Moulds	0,863	-0,182

F_1 and F_2: Regroupment factor of values.

Table 8 : Variables (micro-organisms) correlation with principal elements analysis factors

THE EXPERIMENT
INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY
ISSN-2319-2119
RESEARCH ARTICLE

FIGURES

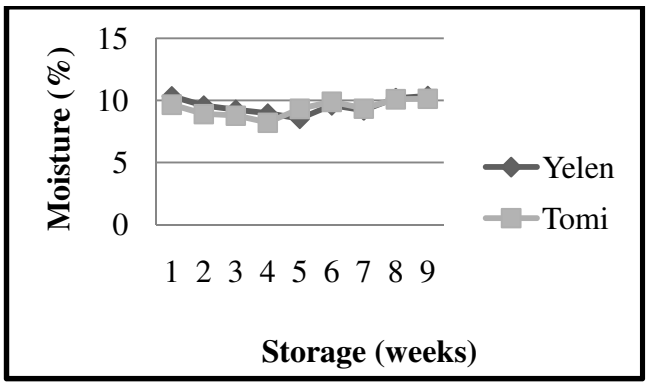

Figure 1: Moisture content evolution in dried okra during storage.

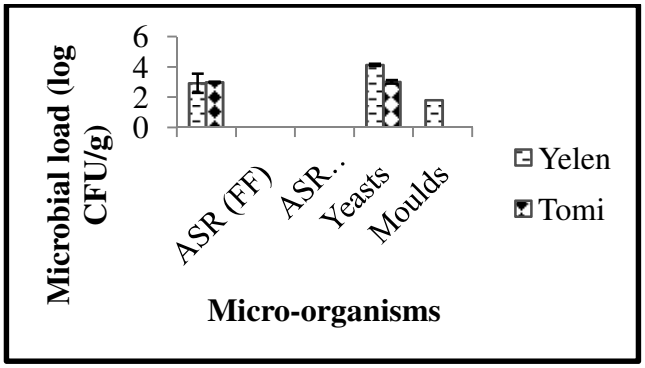

Figure 2: Microbial load in fresh okra before the drying process.

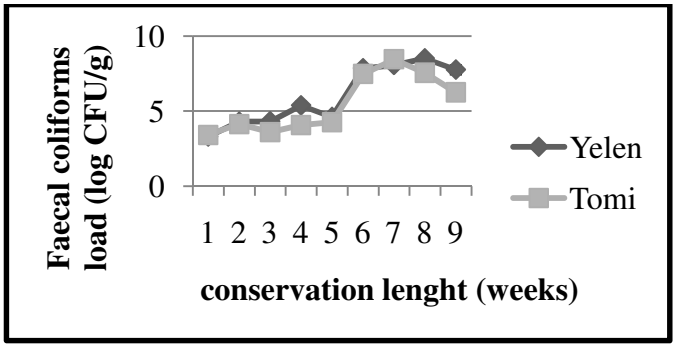

Figure 3: Evolution of faecal coliforms load in okra varieties during the storage.

THE EXPERIMENT
INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN-2319-2119

RESEARCH ARTICLE

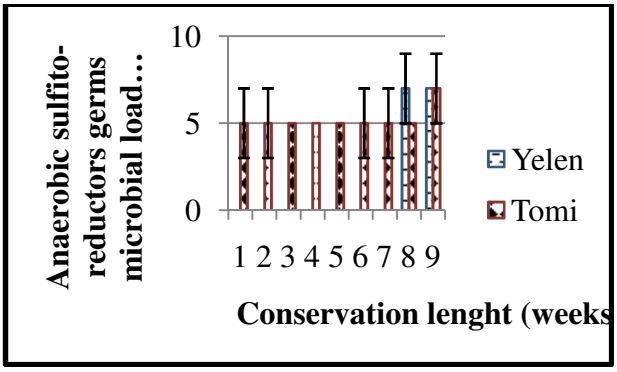

Figure 4: Evolution of anaerobic sulfite-reductors germs load in okra varieties during the storage.

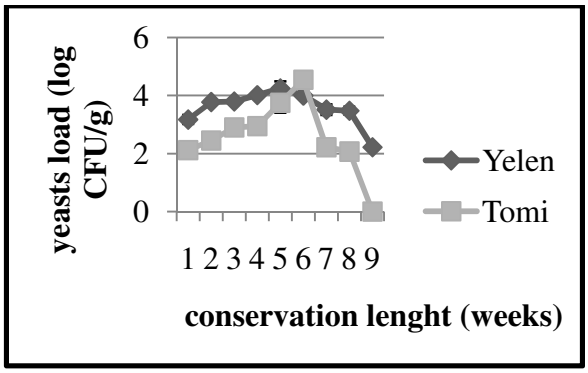

Figure 5: Evolution of yeasts load in okra varieties during the storage.

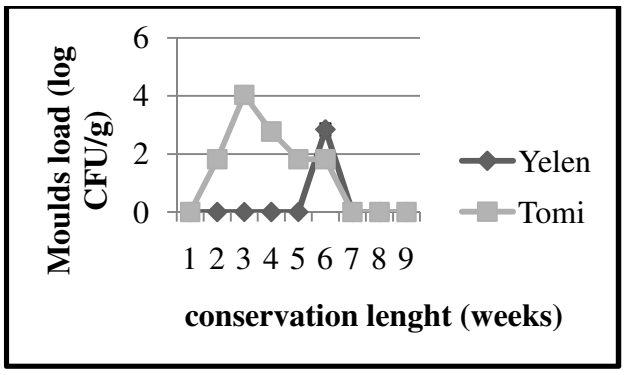

Figure 6: Evolution of moulds load in okra varieties during the storage.

THE EXPERIMENT
INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN-2319-2119

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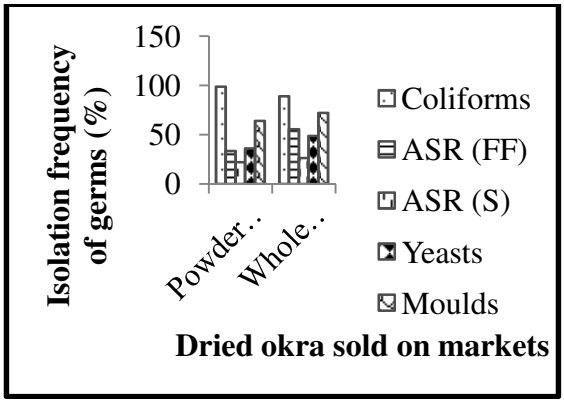

Figure 7: Isolation frequency of germs in dried okra sold on markets.

ASR: anaerobic sulfito-réductors germs

FF: fruiting form of anaerobic sulfito-réductors germs

S: spores of anaerobic sulfito-réductors germs

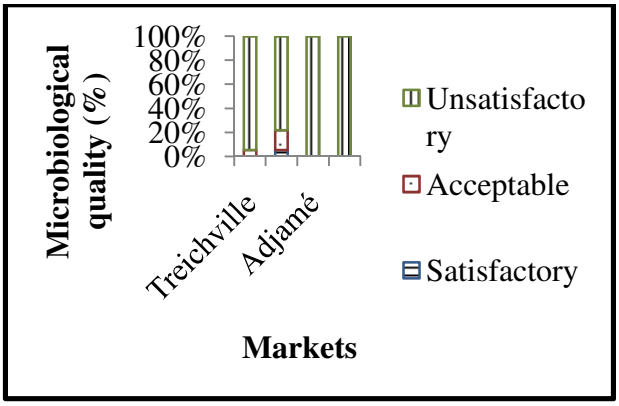

Figure 8: Microbiological quality of powdered dried okra.

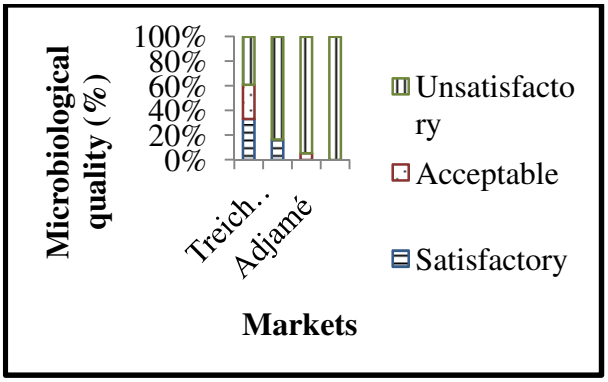

Figure 9: Microbiological quality of whole dried okra.

THE EXPERIMENT
INTERNATIONAL JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN-2319-2119

RESEARCH ARTICLE

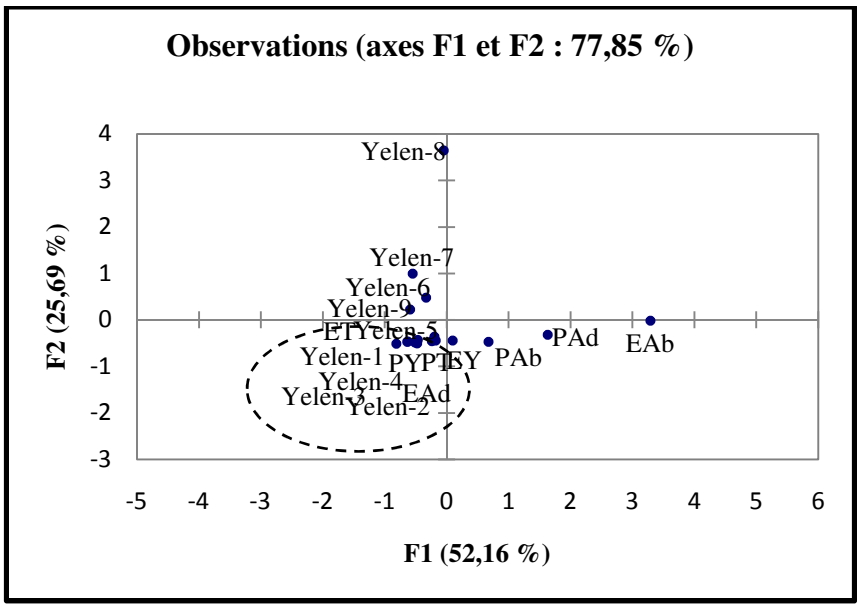

Figure 10: Distribution of Yelen variety and dried okra sold on markets according to F_1 and F_2

Yelen-1 to Yelen-9: Yelen variety stored from the 1st to the 9th week.

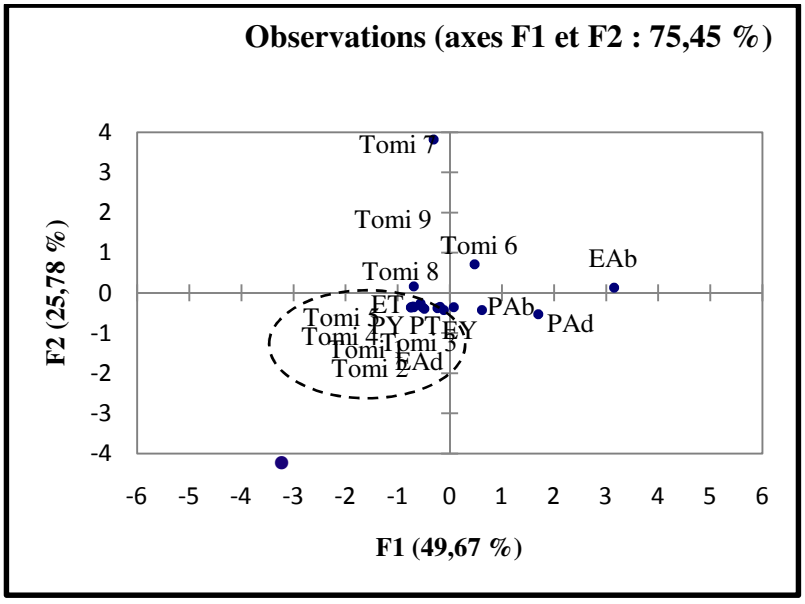

Figure 11: Distribution of Tomi variety and dried okra sold on markets according to F_1 and F_2

Tomi-1 to Tomi-9: Tomi variety stored from the 1st to the 9th week.

- Cloud points representation of dried okra répartition.

PT: powdered dried okra sold on Treichville market.
ET: whole dried okra sold on Treichville market.
PY: powdered dried okra sold on Yopougon market.
EY: whole dried okra sold on Yopougon market.
PAd: powdered dried okra sold on Adjamé market.
EAd: whole dried okra sold on Adjamé market.
PAb: powdered dried okra sold on Abobo market.
EAb: whole dried okra sold on Abobo market.

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