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Research Article

Physico-Chemical Characterization of Brew during the Brewing Corn Malt in the Production of Maize Beer in Congo

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Abstract: The study consists in the production of a traditional beer from maize in the Congo. The traditional method of brewing corn malt has three main stages: malting corn, brewing corn malt and fermentation. During the brewing corn malt, endogenous amylase activity is destroyed during the stiffening of the starch to about 80°C. A pre-cooking of the mash is necessitated to promote amylolyse at 50°C with an exogenous enzyme. The use of a preparation of α-amylase can liquefy the mash and produce a sweet wort (average density = 12.5° Balling) rich in dextrin corresponding to an apparent extract of 4° Balling in beer. The rising profile of the pH of the corn malt mash, from mashing to extract the wort does not affect the pH of the beer produced. This beer, slightly alcoholic (3.6% ethanol), is characterized by a nomal acid pH (pH = 4.15 on average) and a brown color (25 EBC units). Its slight bitterness (21 EBU) and the fine aroma of a beer closer barley produced industrially in the Congo.

Keywords: Amylolyse, brewing, corn malt, maize beer, wort

INTRODUCTION

The beer is a fermented drink regarded as liquid bread its chemical composition and nutritional value (B vitamins, essential amino acids and calcium) and by the method of its preparation (Bramforth, 2007). It is consumed as a refreshing drink or tasting (De Clerck, 1945).

Moderate consumption of beer, made with intelligence, is recommended as the dose of ethanol in it can bring benefits in terms of health benefits, including by preventing and reducing the risk of cardiovascular disease, gallstones and stomach ulcers and protection of brain against mental decline due to aging (Ogbonna, 2009). The beer is a tonic, nutritive, appetizer, digestive, soothing and sedative beverage. It is galactogene and advised pregnant women and lactating. But its abuse is prohibited because at high content the ethyl alcohol contained in the beer may have toxic effects on some physiological processes and organs including the heart, brain, liver and kidney, promoting conditions of anemia-causing disease (Ogbonna, 2009). This led some countries to encourage the production of low-alcohol beers (Kavanagh *et al*., 1991).

The beer manufacture dates back over 8,000 years (Deglas, 2005) and undergoes significant technological change in favor of numerous works devoted to it Vène and Le Corvaisier (1967), De Clerck (1984) and Boivin (2005). The process occurs in three stages: malting corn, brewing corn malt andf ermenting wort.

Brewing is a critical operation and takes the following steps: grinding the malt, mashing, wort extraction, cooking and cooling of the wort. In connection with various levels of mashing temperature, biochemical and physicochemical transformations of starchy biomass occur as a function of operating conditions (De Clerck, 1984; Norris and Lewis, 1985; Home, 1991; Boivin, 2001; Hébert, 2003; Laurent, 2007). It is during this operation that the alcohol content of beer is defined.

From the 1990s a new trend towards consumption of craft beers, some unfiltered, has led to the emergence of micro breweries even in areas not displaying great brewing traditions (Anonyme, 2002). The Congo produces only six brands of beer (Diafouka-Nkounkou, 2010) against more than 300 in France and 700 in Belgium (Wilkipedia, 2008). The various traditional African beers are produced with rudimentary methods and are considered as poor beverages. Their production is made from various local starchy biomass (cereal, banana, cassava) and differs according to regions and processes involved (Devautour and Nago, 1989; Mwesigye and Okia Okurut, 1995; Gadaga *et al*., 1999; Hébert, 2003; Nout *et al*., 2003). Because of their

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unstable and erratic quality, the trade in these traditional beverages is very limited.

The traditional process of brewing malt corn is very tedious and takes longer compared to other cases of cereal. His mastery should lead to innovations that may lead to the industrialization (Devautour and Nago, 1989).

This study aims to develop, from malt of maize, local beer refreshing, lightly alcoholic (Kavanagh *et al*., 1991) and can be produced locally in the various departments of Congo and other countries of the CEMAC (Economic and Monetary Community of Central African States). So from a brewing diagram defined temperatures, changing physicochemical parameters (pH, acidity and sugars) has been followed in our study.

MATERIALS AND METHODS

Material: The malt used for brewing is corn malt (*cultivar nzaka-nzaka*) sufficiently disaggregated (30% grain divers). It is characterized by a moisture content of 8.4% and a rate of dry matter of 91.6% (Diakabana, 2006). The hop extract CO_2 was used during the wort boiling for bittering beer. A commercial strain of yeast high (*Saccharomyces cerevisiae*) was used for fermentation of the wort. A commercial enzyme preparation of fongical α-amylase was used for amylolyse of the mash at 50°C.

Method of making beer:

Method of mashing: The standard infusion method of mashing was used with erlenmeyer glass 1,000mL. The process of brewing corn malt is done in seven steps related to levels of temperatures. A brewing temperature diagram was drawn from the ranges of temperatures necessary for the physico-chemical transformations and biochemical desired (De Clerck, 1984; Norris and Lewis, 1985; Boivin, 2001; Laurent, 2007; Ugboaja *et al*., 1991; Stewart *et al*., 2007): proteolysis 1 (40°C), proteolysis 2 (50°C), cooking the mash (100°C), amylolyse by α-amylase (50°C), extraction of wort (76°C), wort boiling (100°C), cooling of wort (20°C).

Deacidification brewing: In order to reduce the pH of the brew brewing standards, the excess of organic acids from maize malt was neutralized by chemical deacidification (Navarre and Collette, 1986) using a sodium solution (1N NaOH) at the start mashing to correct the initial pH at 5.60 (De Clerck, 1984; Ugboaja *et al*.**,** 1991).

Fermentation of wort: A commercial strain of *Saccharomyces cerevisiae* was planted in the wort cooled to 20°C at a rate of 16.10^6 cells / ml (Heineken, 1986; Diakabana, 1988; Oyeyiola, 1991) after its activation in an aqueous solution containing 4% sucrose.

After planting, the wort contained in an erlenmeyer flask (fermentometer) of 1,000ml, was fermented giving a primary fermentation up to 8° Balling. The young beer that has resulted has been bottled and underwent a second fermentation for its maturation. The secondary fermentation or safekeeping permits to the yeast to ferment the remaining fermentable sugars, refine and naturally saturate beer by CO_2.

Analytical methods:

Operating temperature: The temperature was measured during different stages of brewing to regulate the heating and during the course of the fermentation process.

pH: The pH was measured during different stages of brewing by electrometric method. The change in pH, ΔpH between the cooled wort and finished beer for a given test was determined as following:

physico-chemical $\Delta pH(\%) = (pH_{wort}\text{-}pH_{beer}/pH_{wort}) \times 100$ as indicated by Dornier *et al*. (1993).

Titratable acidity: The titrable acidity was appreciated by titrimetry using the modified method of De Clerck (1963), Navarre and Collette (1986), Oyeyiola (1991), Ugboaja *et al*. (1991), Jong *et al*. (1999) and Diakabana *et al*. (2007). Given the buffering capacity could influence the assay, the knowledge of the titratable acidity was used to compare the evolution of the worts of the same type of brewing fermentation.

Sacharification: The sacharification was appreciated by the iodine test dilute (0.05N) performed on the mash during the enzymatic amylolyse and extraction of wort (Ugboaja *et al*.**,** 1991; E.B.C., 1975; Diakabana *et al*., 2008).

Extract sweet: Sugar was assayed at different stages during the brewing and fermentation of wort from the following:

- Conventional method of Bertrand (Diakabana, 2006; Manilal *et al*., 1991) for measure the reducing sugar content at each stage of operation to assess the conditions of their training and their disappearance
- Densitometric method, from Balling hydrometer (Density $d_{15,\ 56}$ in g/mL) to track changes in sweetened extract content (in degree Balling) of wort during filtration, boiling, cooling and fermentation
- Refractometry method for determination of sugar content in degrees Brix (wt/wt), the mashing and mash during the brewing

Measurement of cell concentration: The direct method of counting yeast cells by light microscopy was used by the Malassez cell (Ugboaja *et al*., 1991; Diakabana, 1988; Oyeyiola, 1991; E.B.C., 1975; Manilal *et al*., 1991) for determine as quickly as possible cellular concentration of the solution to activate yeast during the sowing of the wort.

Evaluation of the ethanol content: The technique of using the method pycnometry (E.B.C**.**, 1975; Heineken, 1986) was used to assay the ethanol content in beer.

Determination of apparent extract Ea and mitigation: The apparent extract expresses the non-fermentable sugars, mitigation expresses the amount of sugar consumed. After determining the density of the beer sample degassed by pycnometry, the value of the extract is obtained by converting the density on the table of Goldiner and Klemann (Heineken, 1986; De Clerck, 1963). Mitigation is achieved by the following formula: Attenuation (%) = (Ewort - Ea/Ewort) x 100, with Ewort: wort extract and Ea: apparent extract in °Balling.

Evaluation of the color of the beer: The beer color was assessed from the extent of extinction of the sample visible spectrophotometer at 430 nm using the Heineken (1986). It is expressed in units on E.B.C. (European Brewery Convention) scale obtained by multiplying the value of extinction by a factor of 25.

Determination of the degree of bitterness: The degree of bitterness was assessed from the Heineken (1986). In 10 mL sample of beer decarbonated, 1 mL of 3N HCl and 20 mL of iso-octane are successively added. The mixture is shaken for 10 min and left to rest for 30 min. Reading the optical density at 275 nm is made and the degree of bitterness is obtained using the following formula:

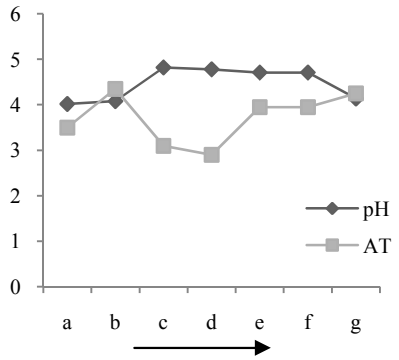
Degree of bitterness (EBU) = $DO_{275nm} \times 50$, with the EBU = European Bitterness Unit.

RESULTS

In order to develop a beer of maize malt**,** six main stages of brewing malt were examined:

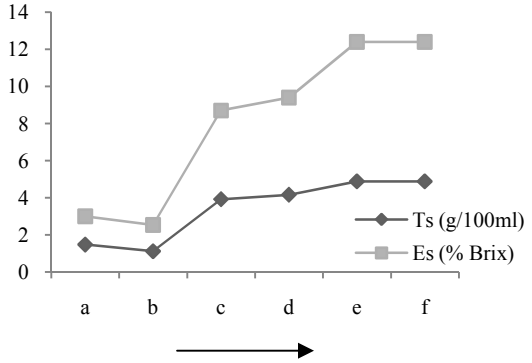
- Proteolysis 1
- Proteolysis 2
- Amylolyse by α-amylase
- Extracting of the wort
- Bittering agent in the cooking
- Cooling of the wort

The influence of the quality of maize wort in fermentation was also examined. All tests were repeated three times and averaged results are presented in the Figures and accompanying Tables.



Operating stages during the manufacture of maize beer

Fig. 1: Evolution of pH and titratable acidity (TA = mL of 0.1 N NaOH) during the manufacture of beer, a: proteolysis1; b: proteolysis2; c: amylolyse; d: must extraction; e: hopping and cooking, f: cooling, g: fermenting wort



Operating stages during the manufacture of the maize wort

Fig. 2: Evolution of sugar content (Ts: reducing sugars and Es: sweet extract) during the preparation of wort from corn malt; a: proteolysis1; b: proteolysis2; c: amylolyse; d: wort extraction; e: hopping and cooking; f: cooling

Evolution of pH and titratable acidity of the brew: During the brewing malt corn (Fig. 1), the pH, low at the beginning of mashing (pHa = 4.02 at the end of the first proteolysis at 40° C), significantly increases at the extraction of wort (pHc = approximately 4.82). It decreases slightly at the end of cooking and cooling of the wort (pHe/f = 4.71 on average) and significantly during the fermentation with a pH change ΔpH = 12.1%. As for the titratable acidity TA, it increases significantly during mashing (TAa = 3.50 mL of 0.1 N NaOH at the end of the first proteolysis at 40°C and TAb = 4.35mL of 0, 1N NaOH at the end of the second proteolysis at 50°C) (Fig. 1). It decreases markedly at the end of the amylolyse (TAc = 3.10 mL of 0, 1N NaOH) and the extraction of wort (TAd = 2.90 mL of 0.1 N NaOH). Then it rises significantly at the end of cooking the wort (TAe/f = 3.95 mL of 0.1 N NaOH) but only weakly during the fermentation (Fig. 1) with a variation of titratable acidity ΔTA = 7.6%.

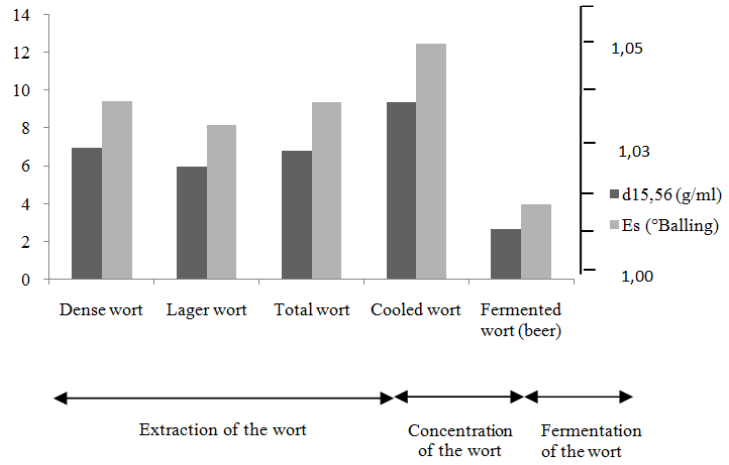


Fig. 3: Evolution of the density and extract sweet wort during the preparation of maize beer

Evolution of sugar content during the brewing: During the mashing (Fig. 2), the sugar content increases from the first thermal step at 40°C [proteolysis 1: reducing sugar content of 1.48% and sweet extract = 3°Brix] to the cooling wort [content = 4.9% reducing sugars and sweet extract = 12.20°Brix] before the start of the fermentation (Fig. 2).

The first wort extracted is more dense ($d_{15, 56}$ = 1.035 g/mL) and sweet (sugar content = 9.45° Balling) than the second ($d_{15, 56}$ = 1.030 g/mL and sugar content = 8.20° Balling) (Fig. 3). This second wort extracted is lighter because it is obtained by washing the spent grains with hot water at 76°C.

The wort boiled and bittered was concentrated (sugars content = 12.5° Balling) and dense ($d_{15.56}$ = 1.047 g/mL) (Fig. 3). The sugar content and density of the must decrease sharply during the fermentation (sugar content of extract = 4°Balling and $d_{15, 56}$ = 1.0135 g/mL at the end of fermentation).

Effect of deacidification of the mash on the changing pH of the brew: Compared to low pH values recorded during different stages of brewing corn malt and taking into account the brewery realities, a pH correction of experimental brew was considered (Table 1). The profile of the pH evolution of experimental brew made by deacidification with sodium hydroxyl was almost stable (pH = 5.5 on average), while the mash control without deacidification was significantly increasing from proteolysis (pHa = 4.03 approximately) to cooking (pHe = 4.8 approximately). The pH of the wort of brew with deacidification decreases more rapidly at a rate of 21.1% (from pHf = 5.31 to pHg = 4.19) compared to that of the mash witness, at the rate of 13.42% (from pHf = 4.77 to pHg = 4.13).

Effect of deacidification of mash on the evolution of sugars during the preparation of corn beer: The profile of the evolution of content of sweet extract presents the same speed in both cases processing of corn malt brew (with or without deacidification of the mash) (Fig. 4). The extract content grows from mashing (a: 3.2% of sugars) to the extraction of wort (d: 8.9% of sugars). During fermentation, sugar consumption is almost identical in both treatment wort (attenuation = 50.8% of sugar consumed in the must witness against 48.77% for the de-acidified wort) (Fig. 4).

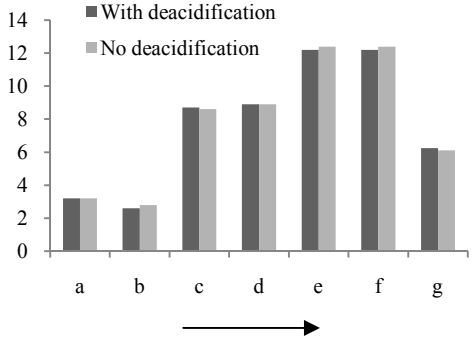


Fig. 4: Effect of deacidification of the mash on the evolution of sugar (%) during the preparation of corn beer; a: proteolysis1; b: proteolysis2; c: amylolyse; d: must extraction; e: hopping and cooking; f: cooling; g: fermenting wort

Table 1: Effect of deacidification of the mash on the evolution of the pH of the brew during the preparation of maize beer

Operating stages	pH brew	
Bre-wing of corn malt	With deacidification	Without deacidification
a : Proteolysis 1	5.58±0.3	4.05±0.2
b : Proteolysis 2	5.52±0.2	4.03±0.2
c : Amylolyse	5.32±0.3	4.61±0.1
d : Extraction of wort	5.55±0.2	4.80±0.3
e : Wort boiling	5.31±0.2	4.77±0.3
f : Cooling	5.31±0.2	4.77±0.3
g : Fermentation	4.19±0.3	4.13±0.2

Physicochemical quality of corn malt beer: The results of physicochemical analysis of beer have to

Table 2: Physico-chemical parameters of maize beer. Mean values of nine samples; EBC: European Brewery Convention; EBU: European Bitterness Unit

Physico-chemical parameters							
Alcohol (% wt)	pH	Colour (EBC scale)	Bitterness (EBU)	Apparent Extract (% Balling)	Total acidity (mL NaOH/100 mL)	Apparent attenuation (%)	ΔpH (%)
3.60±0.2	4.15±0.02	25.5±0.5	21±1	4.17±0.2	2.0±0.1	68±0.5	12.1±0.1

assess the quality of experimental maize beer (Table 2). The pH values (pH = 4.20±0.2), ethanol (3.60±0.2%), degree of bitterness (20±2 EBU), apparent extract (Ea = 4 0° Balling) and attenuation (68%) characterize the quality of this beer of corn malt. The value of color (25 EBC units) of this beer experimental measured on EBC scale is related to the color of corn malt used. The change in pH of the wort during fermentation is ΔpH = 12.1% on average.

DISCUSSION

At each step of mashing temperature corresponds to specific biochemical or physico-chemical transformations of the biomass starch revealed by: the change in pH and titratable acidity (De Clerck, 1984; Boivin, 2001), the stiffening of the starch of corn leading to the formation of a porridge which afterwards is subjected to an enzymatic amylolyse liquefying and saccharifying (Potus, 1993), extracting the sweet wort facilitated by an optimal temperature of 76°C (De Clerck, 1984), the increase in intensity of the wort (final color = 25 EBC units) by the Maillard reactions (Derdelinck, 1990; Potus, 1993), the bittering wort by isomerization of humulone in isohumulone (Meel, 1973; De Clerck, 1984) and the break hot or training coarse disorder by complexing macromolecular protein-polyphenols during the cooking to 100°C.

During fermentation the pH reduction of wort corn was lower (ΔpH = 12.1%) compared to barley malt wort (ΔpH = 19, 23%) (Dilou-Vouka, 2005). The buffering capacity of corn malt is more important because of the calcium ion content higher compared to barley malt.

The various levels of temperature brewing generate specific activities of biochemical and physicochemical transformations (Laurent, 2007). For the levels of proteolytic activities (40 and 50°C) are associated with two important technological parameters: the pH (pHa = 4.02 at 40°C and pHb = 4.08 at 50°C) and titratable acidity (TAa = 3.5 mL of 0.1 N NaOH at 4O°C and TAb = 4.35 mL of 0.1 N NaOH at 50°C). A discrete enzymatic acidification would intervene during proteolysis, including the phytase activity that liberates inorganic phosphate from phytin and endopeptidase activity which liberates oligopeptides as indicated by De Clerck (1984) and Boivin (2001).

In the light of thickening of porridge during the mash cooking and its low sugar content (extract = 2.60% Brix and reducing sugars = 0.13 g/100mL), a contribution of exogenous amylolytic enzyme preparation is necessary for the liquefaction and saccharification of the mash to facilitate both the extraction of juice and the rational increase of the extract mellitus (Norris and Lewis, 1985; Boivin, 2001; Ugboaja *et al*., 1991).

A trial of deacidification brew malt mash of corn was performed as is the case for correction of brewing barley malt (De Clerck, 1984; Ugboaja *et al*., 1991), but did not significantly improve the physicochemical quality of beer produced.

The low foam stability of beer from malt experimental corn is due to the negative effect of unsaturated fatty acids from malt grain maize (Ugboaja *et al*.**,** 1991; Stewart *et al*., 2007).

This experimental method provides a slightly alcoholic beer (3.6% ethanol) more and more popular in many countries (Kavanagh *et al*., 1991) and consumed as a refreshing and nourishing drink. The use of grain malt local maize is justified by the facts: the local corn is a grain used in the manufacture of fermented foods and beverages in many tropical countries (Devautour and Nago, 1989; Okoruwa, 1992), the use of malt local maize for brewing beer soils (Hébert, 2003; Anonyme, 2002; Devautour and Nago, 1989) could promote research on suitable varieties and encourage local farmers.

CONCLUSION

The acidity of the mash of malt and corn decreases gradually with increasing pH of the mash to extract wort unlike the case of malt barley. This acidity slightly increases the extraction of the wort at the end of fermentation resulted in a beer whose pH is within the standards brewing (experimental beer pH = 4.14 on average). The rising profile of the mash pH of the mash to extract wort corn does not affect the pH of the beer produced.

For saccharify the starch from corn in the manufacture of beer, it is necessary to intervene during an incubation at 50°C of the coarse grind gelled (mash), an exogenous amylolytic enzyme preparation. The extraction of must will be made by a filtration method at 76°C for a better resolution.

The foam stability of beer produced is poor probably because of the presence of unsaturated fatty acids contributed by the corn malt. The foam stability

could be improved by eliminating the fat on the must by centrifugation.

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