



Full Length Research Paper

Changes in amylase activity, hot-paste viscosity and carbohydrates during natural fermentation of sweet potato (*Ipomoea batatas*)

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Abstract

In order to improve the sensorial qualities of sweet potato for use in infant food formulation, tuber slices were wet-fermented for 5 days and aliquots were collected and treated for various analyses. Acidification during fermentation resulted in pH drop in slices from 6.3 to 3.9 during the process. Amylase activity of sample extracts fell from about 2400 units per 100g fresh weight of slices to about 280 units. Hot-paste viscosity of flour from unfermented slices displayed a typical profile of amylase-rich flours, with values staying at 0.3 Pa.s up to 20% flour concentration in hot water and then climbing gradually to 4.3 Pa.s at 33% flour concentration. Upon fermentation, and for 10% flour concentration, the hot-paste viscosity increased from about 0.3 Pa.s on day 0 to 24 Pa. s on day 5 of fermentation, in line with the loss of amylase activity. Total 80% alcohol-soluble sugars, mostly made of sucrose (90%), fell abruptly and significantly from 12.66 g/100 g dry basis at the start of fermentation to 2.10 g/100 g on day 5, reflecting their use by fermentation microorganisms as substrates for their multiplication and growth. There was a consequential increase in starch levels from 76.56 g/100 g to 91.25 g/100g during the same period. Maltodextrins remained stable, while crude fibre decreased slightly. Fermented flours were void of amylase activity and the sweetness of sweet potato. They were of finer texture than the unfermented flour and produced smooth hot-water gruels with attractive cream colour. Their use for making low viscosity semi-solid gruels for young infants could be achieved by mixing them with the amylase-rich unfermented flour, or any other amylase-rich source, before or during cooking. They could be quite appealing for preparing some African dishes like *fufu*, by virtue of their sweetless taste.

Keywords: Sweet potato, fermentation, viscosity, gruel, carbohydrate

INTRODUCTION

Sweet potato (*Ipomoea batatas*) is an important source of food and energy for millions of people in the tropics where they are grown continuously throughout the year (Huang *et al.*, 2010). It is cultivated for its tubers made up of 80% starch (dry weight basis) and other carbohydrates (Hagenimana *et al.*, 1998; Huang *et al.*, 2007; Kim *et al.*, 1995) and have a high sucrose content which makes them useful in many food preparations (Sistrunk, 1971) They are an excellent source of vitamin A and are rich in vitamin C and iron (Collins, 1981). They provide a significant quantity of high quality protein the content of which has been found to range from about 2 to 10% dry basis by some authors

(Purcell *et al.*, 1972) and by recent studies in our laboratory of 20 cultivars from four different locales in Cameroon (unpublished results).

In the tropics, tubers are usually eaten straight from the farms after boiling, roasting or frying, and are occasionally peeled, cut into slices, dried into chips and grounded into flour. In industrialized countries, they are canned or processed into flakes and used for a variety of food products. Sweet potato tubers are highly cherished by children because of their sweet taste and are known to be rich in amylase enzyme. Both these qualities could make them suitable candidates for use as a base for formulation

of flour for infant complementary feeding. Such flour could be obtained directly as indicated above. Fermenting the tubers before processing into flour could bring some other benefits to the product. Natural lactic acid fermentation is widely used in developing countries of Africa and elsewhere for food processing and conservation in general (Sanni, 1993), and for processing of cereals and tubers used for preparing gruels for infants (Adeyemi, 1988). The process is known to improve the organoleptic quality of foods (Daeschel *et al.*, 1987) as well as prolong their shelf life. It is characterised by the production of organic acids (dominantly lactic), lowering of pH (Odunfa, 1985; Nout, 1993) and the release by lactic acid bacteria of minor quantities of H₂O₂ and CO₂ (Spelhaug and Harlander, 1989) which stabilise the food product through their antimicrobial effects. To date, many studies have been done on the cooking and storage of sweet potato, but very little on its fermentation.

In this paper, we report the changes in alpha-amylase activity, hot-paste viscosity and carbohydrates during natural fermentation of sweet potato tubers in view of making flour for use as a base for infant complementary food formulation.

MATERIALS AND METHODS

Sweet potato sample

Fresh sweet potato sample (IRAD 1112 cultivar) was harvested in Dang, a small locality in the Adamawa Region in Cameroon, transported within twenty four hours to our laboratory in Yaounde and processed immediately upon arrival. The cultivar has a reproductive cycle of 2 to 3 months and produces long oval tubers with cream skin and milky yellow flesh.

Fermentation

Tubers were washed, hand-peeled, cut into thin slices of 3 mm thick using a machine (Crypto Peerless), rinsed with tap water and partitioned into six batches. The first was directly dried at 50°C in an air-convection to water content below 10%, while the other five batches were steeped separately in water in plastic basins, covered with fine-mesh cloth and left to ferment at room temperature (25°C). Every 24 hours for five days, a batch was sacrificed and aliquots of steep water and slices were taken for pH, titratable acidity and dry weight measurements. The remaining slices were dried as above. Dried slices of unfermented and fermented batches were ground separately, passed through a 250 mm sieve and kept in air-tight containers until analyses.

pH and titratable acidity determinations

The pH of steep water was measured directly with a Hanna microcomputer pH meter (model HI 8424), while slices

(30g) were first homogenized with 100ml deionised water and filtered before measurement. Titratable acidity determinations in steep waters and homogenized slices filtrates were done by titrimetry using 0.1N NaOH solution and phenolphthalein as end point indicator (AOAC, 1990). Titratable acidity contents were computed and expressed as lactic acid equivalence.

Amylase activity determination

Amylase activity of sweet potato extract in a 0.1M pH 6.2 citrate-phosphate buffer was measured following hydrolysis of 0.8 ml of a 1% soluble starch solution by 0.1 ml of the extract for different incubation periods at 30°C. Starch content was determined before and after enzyme hydrolysis according to the method of Oteng-Gyang and Anuonye (1987) using potassium iodide/iodine solution. Hydrolysed starch was estimated by difference, and amylase activity determined. A unit of activity was defined as the amount of amylase required to hydrolyse 10 mg of starch in 30 minutes at 30°C.

Hot-paste viscosity measurement

A known weight of flour was mixed into slurry with cold deionised water in a 250 ml beaker, and boiling water was then added to a final content weight of 100g. The whole was cooked for 7 minutes on a hot plate under constant stirring and the weight readjusted to 100g by addition of boiling water to compensate for evaporation. The resulting gruel was homogenized and placed in a 45°C water bath to stabilise, and an aliquot was poured into a thermostated container for viscosity determination using a Haake VT-02 viscotester. Aliquots were also taken for total solids (dry matter) determination.

Chemical analyses

All chemical analyses were done on aliquots of dried powdered and sieved samples. *Total solids content* was determined by drying sample aliquots in a 107°C oven to constant weight. *Total soluble sugars* were determined by the anthron colorimetric method (Loewus, 1952) on hot 80% alcohol extracts of samples. Individual sugars were analysed in the extracts by a two-step colorimetric method (Blakeney and Mutton, 1980) based on the determination of reducing sugars and sucrose before and after invertase digestion using *p*-hydroxybenzoic acid hydrazide (PAHBAH) in one experiment, and then fructose and glucose using 2-thiobarbituric acid in another experiment. The 80% alcohol-insoluble residues (obtained by centrifugation) were further refluxed with 40% alcohol, centrifuged and the supernatant used for analysis of maltodextrins by the anthron method. Starch content was determined on the resulting residue by the enzymatic

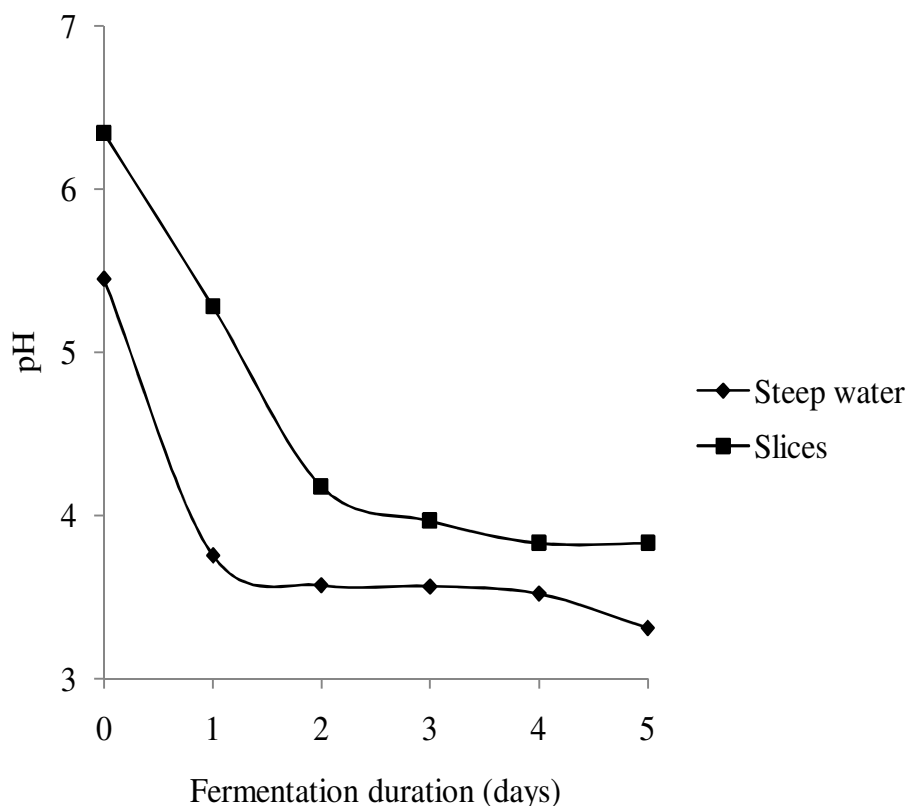


Figure 1. Variations in pH during natural wet fermentation of sweet potato

method of Thivend *et al.*, (1965). Dietary fiber was determined according to the method of Wolff (1968) which measures cellulose, lignin and hemicelluloses.

Statistical analysis

All chemical analyses were done in triplicates. Statistical analyses of data were performed using Stratgraphic 5.1 software. Paired comparison between groups for the different parameters was done by the Anova and Duncan tests, and the significance of values was defined at the 5% level.

RESULTS DISCUSSIONS

pH

Figure 1 shows the evolution of pH of steep water and sweet potato slices during five days of natural fermentation. The trends for both are the same, showing a steep drop of pH from days 0 to 2 and a gradual drop thereafter to day 5. The overall pH drop is from 5.5 to 3.5 for steep water and 6.3 to 3.9 for slices. Lower pH values for steep water are indicative of greater mobility and activity of fermentation microorganisms as they feed on the

surface carbohydrates of potato slices with consequential release of organic acids. The pH variations for slices is similar to those obtained by some authors during steep fermentation of other tubers, namely yams (Medoua *et al.*, 2008) and cassava (Brauman *et al.*, 1995).

Titrateable acidity

Variations in titrateable acidity during wet fermentation of the sweet potato slices are shown in figure 2. The values increase much faster for steep water from about 25 mg lactic acid equivalence/100g of water on day 1 to 60mg/100g on day 5, compared to an increase of only 0.25 to 0.50 mg/100g of fresh slices for the same period. Our results are similar to those obtained by Oguntoyinbo & Dodd (2010) during four days spontaneous fermentation of cassava. As previously mentioned faster increase in steep water titrateable acidity reflects greater microbial activity upon disintegration and leaching of sweet potato material into the medium. Microbial growth inside the solid and rigid structure of the slices is much more limited, hence leading to lower titrateable acidity values.

Amylase activity

Amylase activity of extracts of fresh and fermented sweet potato slices were determined and computed as enzyme

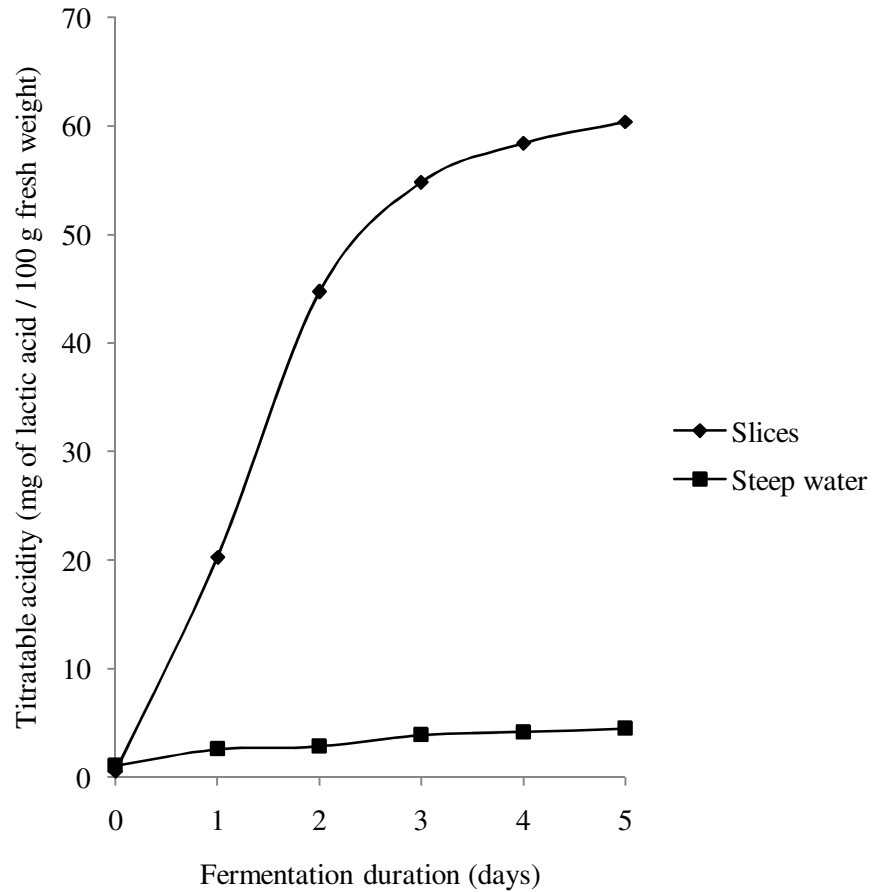


Figure 2. Variations in titratable acidity during natural wet fermentation of sweet potato.

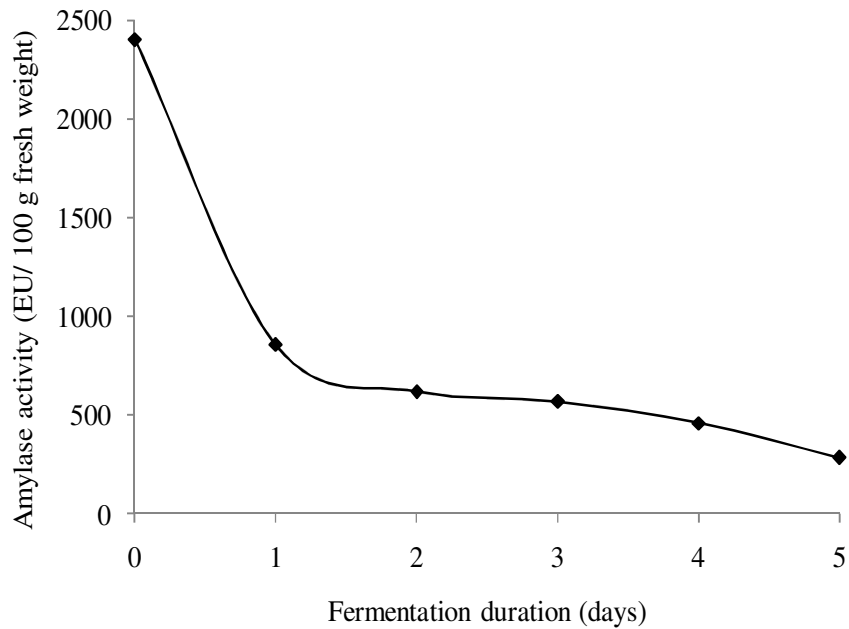


Figure 3. Changes in amylase activity during sweet potato fermentation

activity units (EU) per 100 g fresh weight of slices. The results (figure 3) show that the activity drops suddenly from about 2400 EU/100 g at the start of fermentation to about

850 EU/100 g after 1 day of fermentation, and then to 280 EU/100 g on day 5. Enzyme inactivation could be due to pH drop in sweet potato slices from 6.3 at the start of

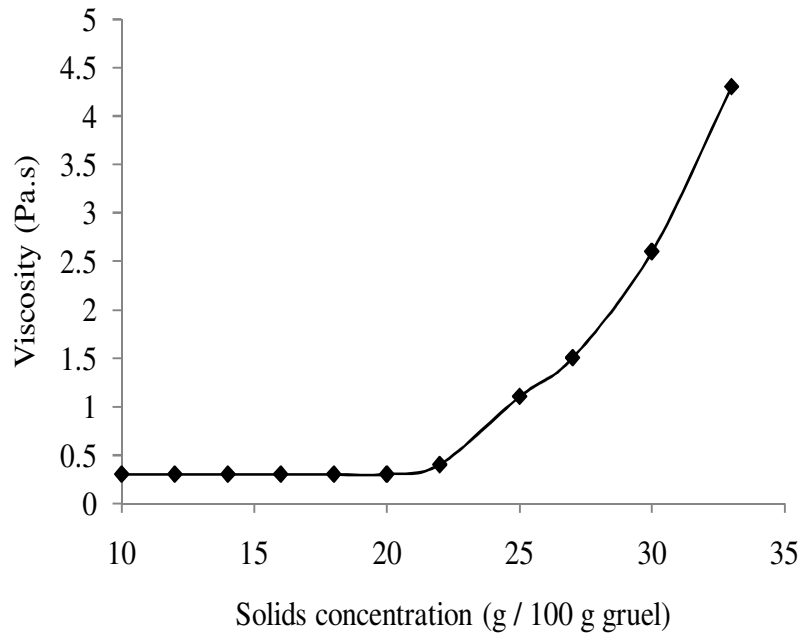


Figure 4. Hot-paste viscosity of unfermented sweet potato flour versus solids concentration

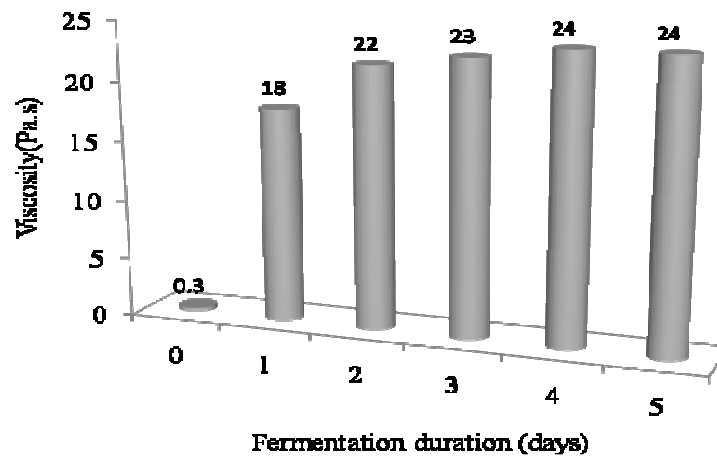


Figure 5. Changes in hot-paste viscosity during fermentation of sweet potato

fermentation to 5.6 and lower on days 1 to 5 of fermentation (figure 1). Thus, the amylase seems quite sensitive to acidification by losing up to 65% of its activity for only a 0.7 pH drop. Our results are similar to those of Kéléké *et al.* (1995) where amylase activity was completely lost within 36 hours of wet fermentation of cassava tubers.

Hot-paste viscosity

Hot-paste viscosity was measured at 45°C at solids (flour) concentrations of 10% and above. The viscosity profile for natural unfermented sweet potato sample is presented in figure 3. The values are below 0.3 Pa.s (lower range of

viscotester) up to 20% solids concentration and then climb steadily to 4.3 Pa.s at 33% concentration. The curve is typical of flours containing alpha-amylase enzyme (Gopaldas *et al.*, 1986; Maung *et al.*, 1995) or that have undergone severe heat-moisture treatment such as drum-drying or extrusion cooking which break down starch and reduce its water-holding capacity. A histogram presentation of the viscosities of fermented flours slurries at 10% concentration are shown in figure 4. The values range from 18 to 24 Pa.s from days 1 to 5 of fermentation, and represent 60 to 80 fold increase compared to that of the natural unfermented tuber (day 0). The sudden rise in viscosity after a day of fermentation could be due to the drop in amylase activity observed above or the

Table 1. Carbohydrate changes during wet fermentation of sweet potato (g /100g dry basis)

Fermentation duration (days)	Starch	Maltodextrins	Sucrose	Total simple sugars	Free fructose	Free glucose	Reducing sugars	Crude fibre
0	76.57 ^a	3.62 ^b	11.42 ^d	12.66 ^c	1.03 ^d	0.53 ^c	1.73 ^e	1.24 ^b
1	87.49 ^b	3.67 ^a	1.67 ^c	3.48 ^{ab}	0.62 ^c	0.25 ^b	0.44 ^c	0.90 ^a
2	89.65 ^{ab}	3.72 ^a	1.25 ^c	2.77 ^a	0.07 ^b	0.05 ^a	0.34 ^b	0.86 ^a
3	90.05 ^b	3.73 ^a	0.81 ^b	2.24 ^a	0.01 ^a	Nd	0.08 ^a	0.87 ^a
4	90.56 ^b	3.74 ^a	0.79 ^b	2.11 ^a	0.01 ^a	Nd	0.05	1.02 ^{ab}
5	91.25 ^c	3.87 ^a	0.55 ^a	2.10 ^a	0.01 ^a	Nd	0.03 ^a	1.03 ^{ab}

Values in the same column with different superscripts are significantly different ($P < 0.05$)
Nd = below detection limit

polymerization of carbohydrates into complex bulking structures as a result of acidification. In this connection, neutralisation of day 2 fermented flour slurry to pH 6.3 (as for unfermented flour) before cooking into porridge did not result in any reduction in viscosity. However, mixing of unfermented and fermented flour produced reduction in viscosity with increasing proportion of the former. Our results are compatible with those of other authors who observed viscosity increases during *ogi* fermentation from maize (Osungbaro, 1990) and during wet fermentation of cassava (Mlingi, 1998). However, the latter author noticed a decrease in viscosity when the cassava was air-fermented.

Changes in carbohydrates

Variations in starch, maltodextrins (soluble in 40% ethanol), simple sugars (soluble in 80% ethanol) and crude fibre contents during sweet potato wet fermentation are presented in table 1. Total sugars concentration falls abruptly and significantly from 12.66 g/100 g dry basis at the start of fermentation to 3.48 g/100 g on day 1, and then gently thereafter. This is surely as a result of the decrease in sucrose, the dominant simple sugar, from 11.42 g/100 g to 1.67 g/100 g for the same period. Free fructose and free glucose levels follow the same trend. Reduction in the concentrations of these sugars is certainly due to their consumption by the fermentation microorganisms as substrates for their multiplication and growth. There is a consequential increase in starch levels in the overall sweet potato material from 76.56 g/100 g at the start of fermentation to 86.49 on day 1 and then to 91.25 g/100g on day 5. The concentration of maltodextrins remains virtually unchanged between 3.6 and 3.8 g/100 g throughout fermentation, while that of crude fibre drops significantly from 1.24 to 0.86 g/100 g on day 2 and then increases gently to about 1.03 g/100 g on day 5.

CONCLUSION

The fermentation of sweet potato was intended to improve its organoleptic quality and confer it with long shelf life and

some protective properties in view of its use as a base for infant complementary food preparation. Flours from fermented tubers are void of the sweetness of sweet potato. They are of finer texture than the unfermented flour and produce smooth hot-water gruels with attractive cream colour. However, fermentation resulted in the loss of amylase activity which is essential for obtaining low viscosity semi-solid gruels suitable for young infants. This could be remedied by mixing appropriate amounts of the fermented flour with the amylase-rich unfermented flour, or any other amylase-rich source, before or during cooking into gruel. Flour from fermented sweet potato could itself offer a new choice of material for the preparation of some African dishes such as *fufu*, just like fermented cassava flour. This could stimulate greater interest in sweet potato whose use as a staple has been limited because of its sweet taste which is generally unappealing for such preparations.

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