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Short Communication

Characterization of the solid-state fermentation of cassava

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The solid-state fermentation of cassava (*Mannihot esculenta* Crantz) was characterized by determining pH and biological oxygen demand (BOD). The results showed a strong association ($\rho = 0.73$) between pH of the fermenting slurry and that of the waste liquor. BOD of the liquor decreased as fermentation progressed. After 96 h fermentation, BOD was about 6×10^2 mg/l. Progress of cassava fermentation can probably be determined indirectly by following the changes in the pH and BOD profiles of the liquor.

La fermentation en milieu solide du manioc (*Mannihot esculenta* Crantz) a été caractérisée en déterminant le pH et la demande biologique en oxygène (DBO). Les résultats montrent une forte corrélation ($\rho = 0.73$) entre le pH de la pâte en fermentation et celui de la liqueur résiduaire. La DBO de la liqueur décroît au fur et à mesure que la fermentation progresse. Après 96 h de fermentation, la DBO était de 6×10^2 mg/l. L'avancement de la fermentation du manioc peut probablement être déterminée indirectement en suivant l'évolution des profiles en pH et en DBO de la liqueur.

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Most fermented foods consumed in developing countries are products of a low-technology process involving a solid-state fermentation (SSF) system. The technique is usually cheap and simple to operate but can be time-consuming and labour-intensive. Biochemically, SSF is a complex system that has not yet been fully characterized and understood. The technology has been used to produce foods such as *gari*, *foofoo*, *farinha-de-manioc*, *chikwangue*, *tempeh*, *koji* and others (Aidoo *et al.* 1982; Mudgett 1986; Steinkraus *et al* 1983). These are consumed mostly in Africa, South America and East Asia. In certain countries, the use of SSF has been largely industrialized. However, its use for the conversion of cassava into edible foods is still rudimentary. Cassava fermentation is done under sub-optimal physiological conditions. It is obvious that eventually a fermenter will be required for industrial fermentations. To design a suitable fermenter, and to advance knowledge of SSF of cassava, it is believed that the system needs to be characterized and properly described. Certain fermentation parameters are needed to describe and determine the progress of fermentation, especially in an industrial setting.

The objective of this study was to describe and establish relationships among the variables affecting the fermentation of cassava slurry into *gari*. The objective arose out of the desire to ensure that the slurry in the anticipated fermenter is minimally perturbed by the reaction-monitoring procedure.

Materials and Methods

Cassava Slurry

Cassava slurry was obtained as previously described (Ofuya & Nnajiofor 1989). Briefly: the freshly harvested tubers were first hand-peeled; the pulp washed in running tap water, grated with a commercial grating machine, and 0.5 kg placed in sterile 500 ml flasks and incubated under aseptic conditions at 30°C. Because the slurry is self-inoculating and the fermentation self-propagating, no special efforts were made to inoculate it deliberately. The pH of the fermenting slurry was determined at different times.

Waste Liquor

The waste liquor was generated from the traditional production method for *gari* (Okafor 1977; Steinkraus *et al.* 1983). Sterile cloth bags (Peterson and Zochonis Industries Ltd, Lagos, Nigeria) were filled with the slurry, fastened and then placed on a perforated metal tray at ambient temperature (30°C ± 2°C). Heavy (20 kg) weights were placed on the bags to de-water the slurry during the fermentation. At appropriate times, the liquor was collected in sterile 1 l beakers and analysed for pH and biological oxygen demand immediately after collection, or stored at −20°C until needed.

Determination of pH

The pH of the fermenting slurry was determined as previously described (Ofuya *et al.* 1989). That of the liquor was measured on 10 ml portions immediately after collection. The determinations were repeated three times.

Determination of Biological Oxygen Demand (BOD_5)

The amount of O_2 uptake by the liquor in 5 days, was used as a measure of BOD (APHA 1981). This involved measuring the initial dissolved O_2 (DO) content of three separate samples by titrating the samples or blank with 0.025 M sodium thiosulphate to a pale straw colour. Two ml of freshly prepared starch solution was added to each sample and the titration was continued until the first disappearance of the blue colour of the starch–iodine complex. The samples were then incubated in the dark at 20°C for 5 days. Afterwards, the dissolved oxygen was measured. The BOD for 5 days (BOD_5) was calculated as follows:

$$BOD_5 = (\text{initial } DO_s - \text{final } DO_s \text{ after 5 days}) - (\text{initial } DO_b - \text{final } DO_b \text{ after 5 days}),$$

where DO_s = dissolved oxygen of sample and DO_b = dissolved oxygen of blank. The DO of each sample (200 ml) in mg/l was equivalent to volume of sodium thiosulphate used.

Statistical Analysis

The data were statistically analysed for associations and reliability of the association using regression analysis.

Results and Discussion

pH and Biological Oxygen Demand

The results showed a decrease in both pH and BOD as fermentation progressed (Table 1). The initial pH of the liquor and the slurry was 6.0 and 6.1, respectively. After 96 h, pH dropped by about 2 log units. Statistical analysis of the results showed that the variables were correlated. There was a strong positive correlation

Table 1. Biological oxygen demand and pH of cassava waste liquor and fermenting cassava slurry

Fermentation period (h)	Mean pH (liquor)	BOD_5* (liquor) (mg/l)	Mean pH (slurry)
0	6.0 (1.2)†	2800 (90.4)	6.1 (0.3)
24	5.1 (0.9)	2000 (32.0)	5.2 (0.1)
48	4.9 (0.7)	1600 (10.6)	4.6 (0.1)
72	4.4 (0.4)	1000 (42.5)	4.5 (0.2)
96	4.2 (0.3)	600 (25.0)	4.2 (0.1)

* BOD_5—biological oxygen demand over 5 days.
† Values in parenthesis represent standard deviations.

($\rho = 0.73$) between pH of the slurry and that of the liquor. The degree of association was significant at the 5% level. BOD_5 of the liquor also decreased gradually as fermentation progressed, dropping from 2800 mg/l to 600 mg/l after 96 h (Table 1). The observed decrease in the pH of the slurry during fermentation is believed to be due to increased metabolism of the fermenting microorganisms on cassava polysaccharides leading to the production of organic acids, particularly lactic acid (Steinkraus *et al.* 1983). In comparison with most other food wastes, BOD_5 of the waste liquor was quite low. This suggests that minimal treatment will be required if the liquor is to be used as a raw material in industrial processes. BOD_5 was a good indicator of the state of the fermentation, but it is a difficult parameter to determine. However, because pH is more rapidly obtained, it is suggested that pH of the liquor (pH_l) be used as an *a priori* estimate of BOD_5. The relationship can be expressed as,

$$BOD = 4.04\ pH_l e^{-0.01036t},$$

where t = time.

Since the pattern of pH change in the slurry was similar to that of the liquor, it is therefore possible, and easier, to monitor the pH of the inaccessible fermenting slurry (pH_s) by measuring the pH of the liquor. The relationship could be expressed as

$$pH_s = 0.901 pH_l e^{9.6475 \times 10^{-4}t}.$$

The results have far-reaching implications for solid-state fermentations where the waste liquor can be easily collected. For the solid-state fermentation of cassava, the results could be used to determine fermentation rate in line with a previous suggestion (Ofuya *et al.* 1989) and in the design of a very simple configuration of a *gari* fermenter, which we hope would meet the expectations of the low-technology prevalent in developing countries.

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