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Increasing the Nutritional Value of Plantain Wastes by the Activities of Fungi Using the Solid State Fermentation Technique

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Abstract: Ripe Plantain Peels (RPP) and Unripe Plantain Peels (UPP) were subjected to solid state fermentation using pure cultures of three fungal isolates, namely *Aspergillus niger*, *A. flavus* and *Penicillium* sp. After seven days of fermentation *A. niger*, *A. flavus* and *Penicillium* sp. increased the crude protein content of both UPP and RPP by 34, 30.3, 2.3 and 9.5, 4.5, 4.0%, respectively. Though the UPP fermented with *Penicillium* sp. showed the least percentage increase in the crude protein content after seven days of fermentation, it recorded the highest percentage increase (39.8%) when fermentation was allowed to continue for 21 days. Except in the RPP fermented with *A. niger*, the sugar content of the wastes also showed an increase after seven days of fermentation with the RPP fermented with *A. flavus* recording the highest percentage increase of 142.6%. There was a corresponding reduction in the cellulose content of both UPP and RPP with the RPP fermented with *A. niger* showing the highest percentage reduction of 300%. Available information reveals that the nutritional value of plantain peels is increased by fermentation using *A. niger*, *A. flavus* and *Penicillium* sp.

Key words: Fungal isolates, plantain peels, fermentation, nutritional value

INTRODUCTION

Fermentation is one of the oldest methods of applied biotechnology, having been used in food processing and preservation as well as beverages production for over 6000 years (Motarjemi, 2000). The fermentation processes of staple food serve as a means of providing a major source of nourishment for large rural populations and contributing significantly to food security by increasing the range of raw materials which can be used in the production of edible products (Adewusi *et al.*, 1999). Fermentation increases the nutrient contents of food through the biosynthesis of vitamins, essential amino-acids and proteins. It improves protein quality and fiber digestibility. It also enhances the availability of micro nutrient to organisms for utilization and aids in the degradation of anti-nutritional factors (Achinewhu *et al.*, 1998).

The bioconversion of agricultural and industrial wastes to chemical feedstock has led to extensive studies on cellulolytic enzymes produced by fungi and bacteria. Cellulose is a potentially valuable source of fiber, fuel and feeds. Investigations into the ability of microbes to degrade native and modified cellulose revealed that only a few fungi possess the ability to degrade native cellulose while majority of microbes are capable of degrading modified cellulose. Much emphasis had been given to screening of agricultural wastes for the release of sugars produced by hydrolysis of lignocellulosics.

Plantain peels are agro-industrial-byproducts left behind after the edible portion of plantain has been processed into various food items by cooking, roasting or milling into flour. Locally, ripe or unripe plantain wastes, may be used to feed livestock or in the production of local soap but in the areas

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where these are not feasible, these wastes end up polluting the environment (Williams, 2001). Wastes and their disposal have become an environmental concern worldwide especially when these wastes are biodegradable to useful goods and services (Shide *et al.*, 2004).

Three major wastes management routes have been identified, namely sewage disposal, composting and landfill and bioremediation (Williams, 2001) out of which sewage disposal provides opportunity for possible recovery of useful products after biodegradation. Cultivation of enzymes for degradation of lignocellulosic materials has been reported by Banjo and Kuboye (2000) and Wuyep *et al.* (2003). Okeke and Obi (1995) reported the saccharification of agrowastes by cellulase and hemicellulase from two fungal isolates, viz. *Sporotrichum pruinosum* and *Arthrographis* sp. Baig *et al.* (2004) studied the saccharification of banana agrowaste and the condition affecting the process such as time course, pH, temperature and particle size using *Trichoderma lignorum*.

Shide *et al.* (2004) reported that *Lentinus squarrosulus* (Mont) Singer, a basidiomycete also known as a white rot fungi, immobilized on sodium alginate was able to degrade 0.1 M HCl-pretreated wood sawdust to protein and ethanol by average value of 72.0% over untreated wood sawdust samples, after hydraulic retention time of 72 h. The report shows that *Lentinus squarrosulus* (Mont.) Singer has the potentials of degrading wood sawdust to important chemical compounds that are not hazardous to the environment.

Using liquid from cassava pulp fermented for 3 days with pure strains of *S. cerevisiae*, *L. delbruckii* and *L. coryneformis* to ferment cassava peels for 7 days, analysis of the dried cassava peels, according to Oboh (2006), revealed that there was a significant increase of 21.5% in the protein content of the cassava peels when compared with the unfermented cassava peels that had an increase of just 8.2%. The study also showed that the treatment brought about a significant decrease in the cyanide content from 44.6 to 6.2 mg kg⁻¹. Thus fermented cassava peels could be a good protein source in livestock feeds. Ennouali *et al.* (2006) has reported the biotransformation of algal waste by biological fermentation, results of which showed that there was a decrease in the pH from 7.4 to 3.75 and a reduction of the different pathogenic groups of bacteria; total coliforms, Streptococci and Staphylococci. Physical and chemical analyses also showed that this garbage of algae is rich in mineral elements, proteins, sugars and has a small amount of fat, thus the fermentation product can be integrated in animal feeds or used as fertilizer.

The use of biological means in the degradation of wastes, especially agro-industrial by-products has greater advantages over the use of chemicals because biotechnologically synthesized products are less toxic and environmentally friendly (Liu *et al.*, 1998). Hence the modern world encourages a shift towards the use of microbes in degrading agro-industrial wastes. So far, the literature has been silent on the use of some fungi to achieve this purpose in plantain peels. This study, therefore, intends to report the changes in the protein, cellulose and sugar contents of both ripe and unripe plantain peels when fermented with *A. niger*, *A. flavus* and *Penicillium* sp.

MATERIALS AND METHODS

The fungal isolates used in the study are *A. niger*, *A. flavus* and *Penicillium* sp. and were obtained from the Department of Microbiology, Federal university of Technology, Akure, Nigeria. Each isolate was sub cultured on Potato Dextrose Agar (PDA) in a petri dish. The PDA was already acidified with lactic acid to prevent contamination by bacteria. The sub cultured isolates were then incubated at 25-28°C for 7 days.

Preparation of Plantain Wastes

RPP and UPP were collected, cut into small sizes and sun dried. The sizes of the peels were further reduced by grinding using a grinding machine (SM-1 Retsch GmbH 5667 HAAN, West-Germany).

Twenty grams of each substrate was weighed into a 250 mL conical flask and 20 mL of sterile water added for the purpose of hydration. The mouth of the flasks were clogged with cotton wool and then covered with aluminum foil. Flasks containing the substrates were autoclaved at 121°C for 15 min after which the substrates were separately inoculated with a small portion of mycelia from each fungus. A control was also set up. Samples were withdrawn after 7, 14 and 21 days of fermentation and the action of the fungi terminated by oven drying at 70°C. The samples were thoroughly mixed, milled with mortar and pestle and stored in sterile labelled bottles. Samples from the control flasks were treated alike.

Analysis of Samples

The samples were analyzed for protein by the Kjeldahl method, sugar by the method of Lane and Eynon and cellulose by method of AOAC (1990).

RESULTS AND DISCUSSION

After seven days of fermentation, the protein content of UPP increased by 34, 30.3 and 2.3% due to the activities of *A. niger*, *A. flavus* and *Penicillium* sp., respectively (Fig. 1) while that of RPP increased by 9.5, 4.5 and 4.0% (Fig. 2). However, UPP fermented with *Penicillium* sp. showed a progressive increase in protein level up to the 21st day of fermentation (from 2.3 to 39.8%). The highest percentage increase in protein level (34%) in UPP and RPP after 7 days of fermentation was obtained with *A. niger*, while the overall highest percentage increase in protein level (39.8%) was

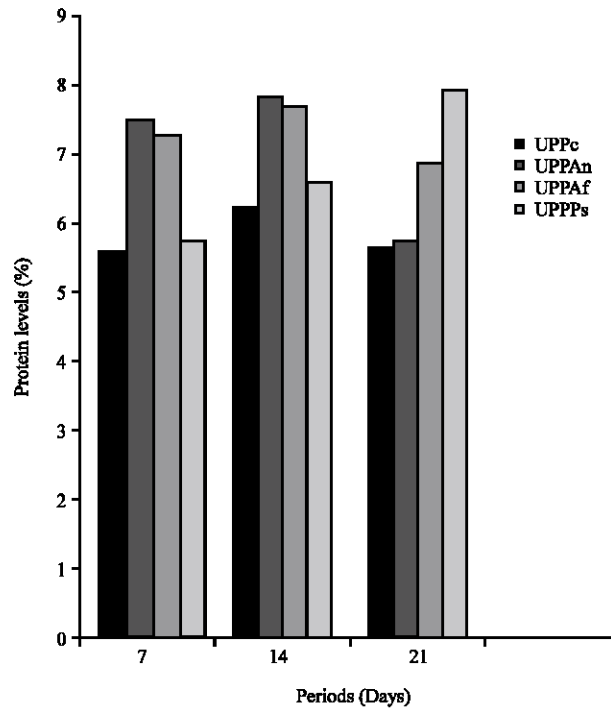


Fig. 1: Changes in levels of crude protein in unripe plantain (UPP) treated with *A. niger* (An), *A. flavus* (Af) and *Penicillium* sp. (Ps) and control (UPPc)

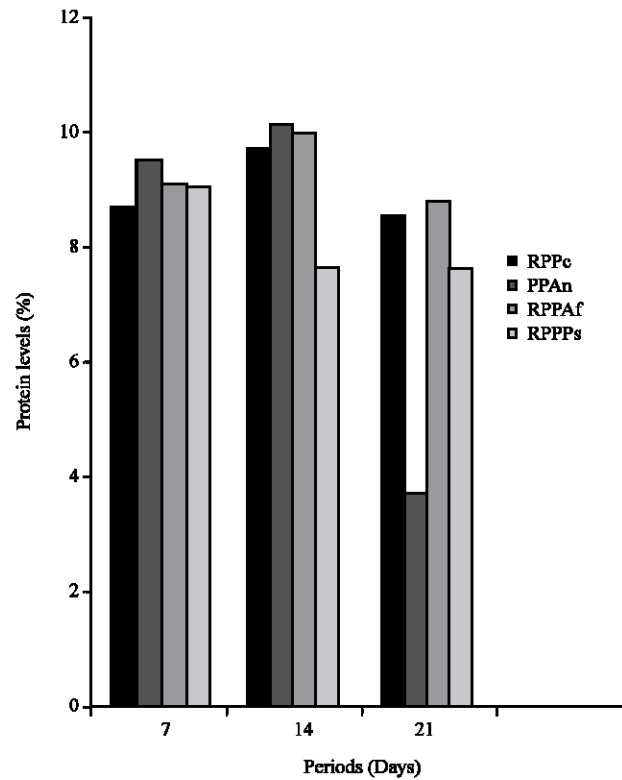


Fig. 2: Changes in levels of crude protein in unripe plantain (RPP) treated with *A. niger* (An), *A. flavus* (Af) and *Penicillium* sp. (Ps) and control (RPPc)

observed in UPP fermented with *Penicillium* sp. Similar results have been reported by Iyayi and Aderolu (2003) where an increase of 61% in protein content was recorded in Corn bran fermented with *Trichoderma viride*. Iyayi (2004) also reported an increase of 41% in the protein level of Wheat offal after 14 days of fermentation using *A. niger*. Ofuya and Nwanjiuba (1990) reported an increase of 185% in the protein content of cassava peels (from 5-6-16%) when *Rhizopus* sp. was cultured on the peels. The increase observed in the protein levels is as a result of the bioconversion of sugar into proteins (Iyayi, 2004).

Results of changes in sugar contents of unripe Plantain Peels (UPP) and ripe Plantain Peels (RPP) after treatment is presented in Fig. 3 and 4 while that of cellulose is presented in Fig. 5 and 6, respectively. Cellulose in RPP and UPP showed considerable changes as seen in Fig. 5 and 6. The changes observed were a decrease in cellulose levels of the treated wastes when compared with untreated. The highest percentage reduction of 300% was observed in RPP fermented with *A. niger* after 7 days of fermentation while the percentage reduction observed in UPP The sugar level also increased up to 7 days after fermentation in RPP fermented with all the fungal isolates. Likewise there was also increase in UPP fermented with *A. niger* and *A. flavus*. The highest percentage increase in sugar level (142.6%) was recorded in RPP fermented with *A. flavus*. The ability of fungi to degrade cellulose has been reported by several authors, namely Ofuya and Nwanjiuba (1990), Iyayi and Losel (2001), Iyayi and Aderolu (2003) and Iyayi (2004). The authors reported that over 35% of the original cellulose content of the substrate was lost during the solid state fermentation.

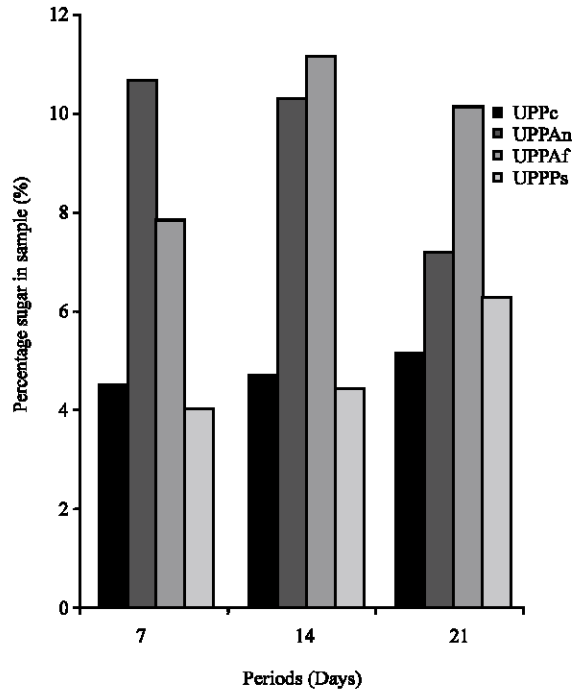


Fig. 3: Changes in levels of sugar in unripe plantain peels (UPP) treated with *A. niger* (An), *A. flavus* (Af) and *Penicillium* sp. (Ps) and control (UPPc)

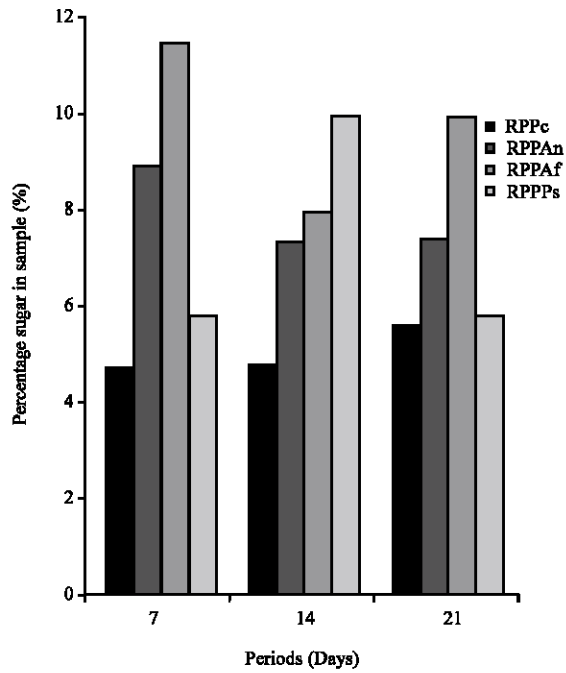


Fig. 4: Changes in levels of sugar in ripe plantain peels (RPP) treated with *A. niger* (An), *A. flavus* (Af) and *Penicillium* sp. (Ps) and control (RPPc)

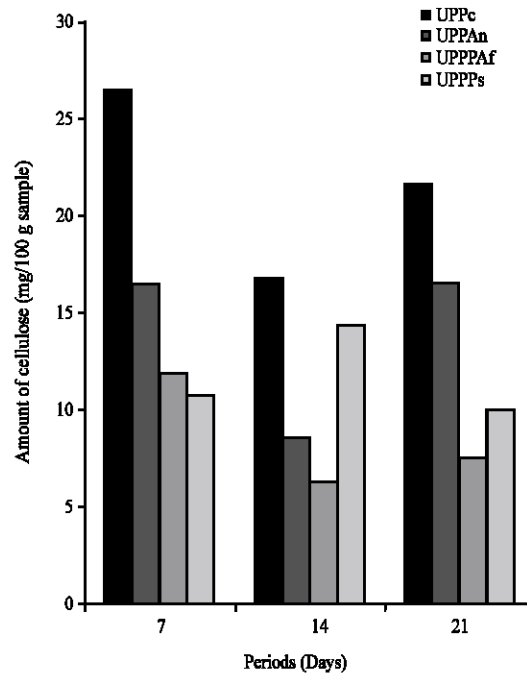


Fig. 5: Changes in levels of cellulose in unripe plantain (UPP) treated with *A. niger* (An), *A. flavus* (Af) and *Penicillium* sp. (Ps) and control (UPPc)

Fungi have the ability to produce a variety of enzymes. *A. niger*, *A. flavus* and *Penicillium* sp. have been reported to be the main sources of cellulase, amylase, hemicellulase, catalase, pectinase and xylanase (Hamilyn, 1998). These enzymes help to degrade the non-starch polysaccharides (NSPs) in the substrate to soluble sugar. Thus with the decrease in the amount of cellulose, a corresponding increase in the sugar content is obtained. *A. niger* and *A. flavus* were able to bring about the highest percentages in the cellulose reduction due to their vigorous growth and therefore have the ability to produce more cellulolytic enzymes within a short period of seven days.

It is possible that synthesis and release of the enzymes are slowed down due to the changes in conditions in the medium. Ofuya and Nwanjuba (1990) have reported that fungal enzyme controlled degradation responds to incubation time, pH and temperature. With fungal biomass increase, the nutrients in the substrate medium are quickly used up. Beyond 7 days, the fungi start to take up the products of breakdown of the NSPs, hence the observed reduction in the sugar level. This means that a period of seven days is the optimum time for breakdown of NSPs in plantain peels using *A. niger* and *A. flavus* as against 14 days, reported by Iyayi and Losel (2001), Iyayi and Aderolu (2003) and Iyayi (2004) for agro-industrial by products such as maize Offal, wheat Offal, corn bran, Brewer's dried grains, Rice bran and Palm kernel meal.

Nevertheless, the ability of the fungi to take up products of polysaccharide degradation as demonstrated by reduced sugar levels after 7 days has been shown by results obtained from this present study. Solid state fermentation as a means of treating wastes and at the same time enriching products with protein content has been attempted by Akindahunsi *et al.* (1999), Balagopalan (1996) and Oboh *et al.* (2002).

In conclusion, the results of the present study have demonstrated that the optimum period for the degradation of UPP and RPP by *A. niger* and *A. flavus* is seven days and 14 days using *Penicillium* sp. These fungi possess the capacity to degrade the non starch polysaccharide content of the plantain peels, converting them to simple sugars with significant increase in protein. The result has also shown

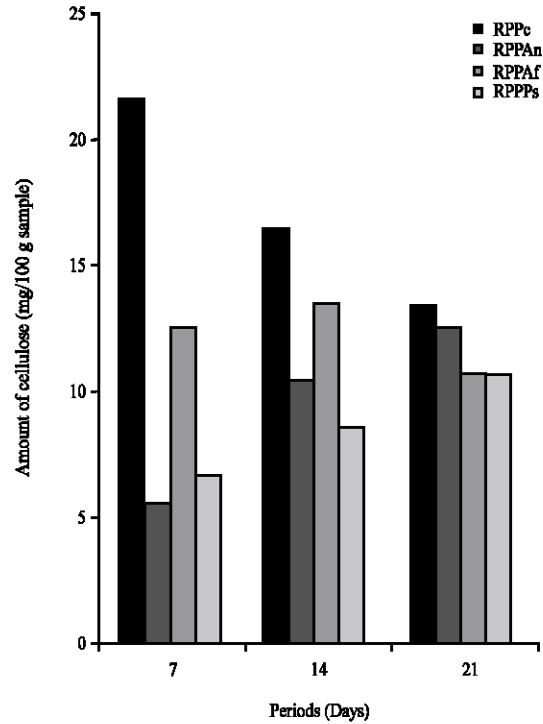


Fig. 6: Changes in levels of cellulose in ripe plantain (RPP) treated with *A. niger* (An), *A. flavus* (Af) and *Penicillium* sp. (Ps) and control (RPPc)

that fungal biotechnology is an effective tool for the enhancement of the nutritive values of agro industrial by-product. This brings the idea of including these biodegradable by-products in poultry, pigs and goats diet to help spare maize in the diet of these animals. The carbohydrate content of plantain peels is high and when broken down it constitutes a good medium for fungal growth. Therefore, the biological treatment using fungi should be employed on a large scale to further increase the nutritive values of these wastes so as to be able to include them in the diet of live stocks.

REFERENCES

- Achinewhu, S.C., L.I. Barber and I.O. Ijeoma, 1998. Physiochemical properties and garification (gari yield) of selected cassava cultivars in Rivers state, Nigeria. *Plant Foods for Human Nutr.*, 52: 133-140.
- Adewusi, S.R., T.V. Ojumu and O.S. Falade, 1999. The effect of processing on total organic acids content and mineral availability of simulated cassava-vegetable diets. *Plant Foods for Human Nutr.*, 53: 367-380.
- Akindahunsi, A.A., G. Oboh and A.A. Oshodi, 1999. Effect of fermenting cassava with *Rhizopus soryzeae* on the chemical composition of its flour and gari, *La Rivista Italiana Delie Soltanze Grasse*, 76: 437-440.
- AOAC, 1990. Official methods of analysis. Association of official Analytical Chemist, Washington, D.C.
- Balagopalan, C., 1996. Nutritional improvement of cassava products using microbial techniques for animal feeding. Monograph of the Central Tuber Research Institute, Kerala, India, pp: 44.

- Baig, M.M.V., M.L.B. Baig, M.A.I. Baig and M. Yasmeen, 2004. Saccharification of banana agro-waste by cellulolytic enzymes. Afr. J. Biotechnol., 3: 447-450.
- Banjo, N.O. and A.O. Kuboye, 2000. Comparison of the effectiveness of some common agro-industrial wastes in growing three tropical edible mushrooms. Proceedings of the Internal Conference on Biotechnology: Commercialization and Food Safety, Nigeria, pp: 161-168.
- Ennouali, M., K. Ouhssine and M. Elyachioui, 2006. Biotransformation of Algal waste by biological fermentation. Afr. J. Biotechnol., 5: 1233-1237.
- Hamilyn, P.F., 1998. Fungal Biotechnology. British Mycological Society Newsletter, pp: 130-134.
- Iyayi, E.A. and D.M. Losel, 2001. Changes in the carbohydrate fractions of cassava peels following fungal solid state fermentation. J. Food Technol. Afr., 6: 101-103.
- Iyayi, E.A. and Z.A. Aderolu, 2003. Enhancement of the feeding value of some agro-industrial by-products for laying hens after their solid state fermentation with *Trichoderma viride*. Afr. J. Biotechnol., 3: 182-185.
- Iyayi, E.A., 2004. Changes in the cellulose, sugar and crude protein contents of agro-industrial by-products fermented with *Aspergillus niger*, *Aspergillus flavus* and *Penicillium* sp. Afr. J. Biotechnol., 3: 186-188.
- Liu, C.Z., Y.C. Wang, F. Ouyang, C.H. Ye and G.F. Li, 1998. Production of artemisinin by hairy root cultures of *Artemisia annua* L. in bioreactor. Biotechnol. Lett., 20: 265-268.
- Motarjemi, Y., 2000. Impact of small scale fermentation technology on food safety in developing countries. Int. J. Food Microbiol., 75: 213-229.
- Oboh, G., A.A. Akindahunsi and A.A. Oshodi, 2002. Nutrient and anti-nutrient content of *Aspergillus niger* fermented cassava products (flour and garri). J. Food Composition Anal., 15: 617-622.
- Oboh, G., 2006. Nutrient enrichment of cassava peels using a mixed culture of *Saccharomyces cerevisiae* and *Lactobacillus* sp. Solid media fermentation techniques. Electronic J. Biotechnol., 9: 46-49.
- Ofuya, C.O. and C.J. Nwanjuiba, 1990. Microbial degradation and utilization of cassava peel. World J. Microbiol. Biotechnol., 6: 144-148.
- Okeke, B.C. and S.K.C. Obi, 1995. Saccharification of agro-waste materials of fungal cellulases and hemicellulases. Bioresour. Technol., 51: 23-27.
- Shide, E.G., P.A. Wuyep and A.J. Nok, 2004. Studies on the degradation of wood sawdust by *Lentinus squarrosulus* (mont). Singer. Afr. J. Biotechnol., 3: 395-98.
- Williams, B., 2001. Biotechnology, From A to Z, 2nd Edn., Oxford Press, New York, pp: 384-385.
- Wuyep, P.A., A. Khan and A.J. Nok, 2003. Production and regulation of lignin degrading enzymes from *Lentinus squarrosulus* (mont.) singer and *Psathyrella atroumbonata* pengler. Afr. J. Biotechnol., 2: 444-447.