World J Microbiol Biotechnol (2008) 24:2369–2374
DOI 10.1007/s11274-008-9749-8

SHORT COMMUNICATION

Improving the quality of agro-wastes by solid-state fermentation: enhanced antioxidant activities and nutritional qualities

A. Lateef · J. K. Oloke · E. B. Gueguim Kana · S. O. Oyeniyi · O. R. Onifade · A. O. Oyeleye · O. C. Oladosu · A. O. Oyelami

Received: 9 January 2008 / Accepted: 8 April 2008 / Published online: 26 April 2008

Abstract Solid substrate fermentations of some agro-wastes, namely cocoa pod husk (CPH), cassava peel (CP), and palm kernel cake (PKC) were carried out for the production of fructosyltransferase (FTase) by a newly isolated fungal strain *Rhizopus stolonifer* LAU 07. The fermented substrate were studied for improved nutritional quality by determining the crude protein, crude fibre, ash and lipid contents, and antioxidant activities. The cyanide content of cassava peels was also determined. Some levels of value-addition occured as a result of the fermentation. The protein contents of the substrates increased by 33.3, 55.4, and 94.8%, while the crude fibre contents decreased by 44.5, 8.6, and 7.2% in PKC, CP, and CPH, respectively. The cyanide content of cassava peel was reduced by 90.6%. Generally, fermentation of the substrates by *R. stolonifer* LAU 07 increased the antioxidant activity in a DPPH (1,1-diphenyl-2-picrylhydrazyl) assay. The IC_{50} (mg/ml) values of the methanolic extracts (fermented/unfermented) were obtained as 7.0/14.9, 4.4/10.6, and 5.5/14.7 mg/ml for PKC, CP, and CPH, respectively. Results herein reported showed that the nutritional qualities and antioxidant activities of all the investigated solid substrates were enhanced by fungal fermentation. Thus, scope exists for microbial upgrading of these low-quality agro-wastes and development of healthy animal feed supplements.

A. Lateef (✉) · J. K. Oloke · E. B. Gueguim Kana · S. O. Oyeniyi · O. R. Onifade · A. O. Oyeleye · O. C. Oladosu · A. O. Oyelami
Biotechnology Group, Microbiology Unit, Department of Pure and Applied Biology, Ladoke Akintola University of Technology, PMB 4000 Ogbomoso, Nigeria
e-mail: agbaje72@yahoo.com; agbaje@alphabiotech.org

Keywords *Rhizopus* · Solid state fermentation · Fructosyltransferase · Antioxidant · Nutritional quality · Feed supplement

Introduction

Solid-state fermentation (SSF) is defined as a process in which micro-organisms are grown on solid substrates in the absence of free water (Lagemaat and Pyle 2001). SSF resembles the natural microbiological processes like composting and ensiling. In industrial applications, it can be utilized in a controlled way to produce desired products. This process has been known from ancient times and different fungi have been cultivated in SSF for the production of food. These include the fermentation of rice by *Aspergillus oryzae* to initiate the koji process and *Penicillium roquefortii* for cheese production. Also, in China, SSF has been used extensively to produce brewed foods (such as Chinese wine, soy sauce, and vinegar) since ancient times (Chen 1992). In Japan, SSF is used commercially to produce industrial enzymes (Suryanarayan 2003). Since 1986 in Brazil, a series of research projects for the value-addition of tropical agricultural products and sub-products by SSF has been developed due to the generation of large amounts of agricultural residues (Soccol and Vandenberghe 2003).

In Nigeria, large quantities of different types of agro-wastes are dumped in the environment due to low nutritional qualities and presence of antinutritional factors. Nigeria is the largest producer of cassava in the World, and the fifth largest producer of cocoa. It produced some 760,000 metric tonnes of palm oil in 1999/2000, ranking the third largest producer in the World (USDA 2000). About 205,000 tonnes of cocoa was produced during 1999–2000 (Koekoek 2003),

while approximately 34 million tonnes of cassava was produced in 2002 (FAO 2004).

Processing of these crops into finished or semi-finished products generates large amounts of solid waste annually. For instance, about 10 million tonnes of cassava are processed into 'garri' alone in Nigeria (Oboh 2006), and the peels could make up to 10% of the wet weight of the roots which are discarded as wastes. Similarly, about 8 million tonnes of cocoa pod husk (CPH) are discarded as waste annually in Nigeria (Egunjobi 1975). With this, 64,000–94,000 tonnes of nutrients such as K, Ca, and P, and 6,000–9,000 tonnes of N are lost annually, due to the richness of CPH in these nutrients. In a well run palm oil mill, each 100 tonnes of fresh fruit bunches (FFB) yields 20–24 tonnes of crude palm oil and about 4 tonnes of palm kernels. Thus, 72–76% of the FFB comes out at various stages of the process as wastes, including the palm kernel cake (PKC) which is obtained as a by-product of extraction of palm kernel oil from palm kernel.

In this work, SSF was carried out using a locally isolated fungal strain *Rhizopus stolonifer* LAU 07 to produce fructosyltransferase (E.C. 2.4.1.9) on some abundant Nigerian agro-wastes, namely cocoa pod husk (CPH), cassava peel (CP), and palm kernel cake (PKC). Fructosytransferase (FTase) catalyses the formation of fructooligosaccharides from sucrose, which have broad applications in the food and pharmaceutical industries due to their physiological and physico-chemical properties. At the end of fermentation, the substrates were then studied for value-addition, interms of improved nutritional qualities and antioxidant activities. The value-addition, as a result of microbial upgrading of these low-quality lignocellulolytic agro-wastes may expand the scope of their utilization particularly as feed supplements in animal husbandry in Nigeria.

Materials and methods

Isolation of microorganism and preparation of inoculum

Rhizopus stolonifer LAU 07 was isolated from spoilt orange fruit using potato dextrose agar (PDA) that was supplemented with 20% sucrose. Dark patches were scrapped with sterile scapel to inoculate the medium and incubated at 30 ± 1°C for 48 h. The pure culture was subsequently stored in PDA slants at 4°C. It was identified conventionally according to its macroscopic and microscopic features following the scheme of Domsch et al. (1980). Inoculum was developed by transfering a loopful of mycelium into the inoculum medium (1% sucrose, 0.2% yeast extract, pH 5.50). The flasks were incubated at 30 ± 1°C on a shaker at 100 rev/min for 24 h.

Preparation of solid substrates

Dried substrates (CPH, CP, and PKC) were sourced locally in Ogbomoso, Nigeria, and dried at 60°C for 8 h before pulverization. While CPH was obtained from a cocoa plantation, CP, and PKC were obtained from cottage industries. The moisture contents were determined by drying to constant weight at 110°C in a hot-air oven. SSF was carried out in 250 ml capacity bottles containing 25 g of the substrates, moistened to a final moisture contents of 65% for CP; 69% for CPH; and 72% for PKC, respectively. The bottles were sterilized at 121°C for 1 h, cooled, inoculated with the inoculum, and then fermented for 5 days at 30 ± 1°C. The pH values of CP (6.7) and PKC (6.4) were not adjusted prior to fermentation, while the CPH (initial pH of 8.9) was adjusted with 0.1 N HCl to the final pH of 6.4 before fermentation. The substrates were supplemented with or without sucrose and yeast extract.

Harvesting

At the end of fermentation, cultures were harvested to determine the pH and FTase activity. Contents of each bottle were mixed with 50 ml of water and agitated at 100 rpm for 1 h. The filtrates (crude FTase) were squeezed out in a muslin cloth, and then centrifuged at 5,000 rev/min at 10°C for 25 min. The fermented substrate with highest FTase activity in each case was selected for further work. The substrates were oven dried at 60°C overnight, and then used for analysis.

Nutritional composition

Ash, fat, and crude fibre contents of both fermented and unfermented substrates were determined following the methods of Cordenunsi et al. (2004), while the crude protein contents were determined using micro-Kjeldhal method ($N \times 6.25$). The cyanide content of cassava peel was determined by the silver nitrate method (Oboh et al. 2002).

Antioxidant or free-radical scavenging activities

Preparation of methanol extracts

After drying at 60°C overnight, the fermented and unfermented substrates (CPH, CP, and PKC) were pulverized to pass 30-mesh screen. Samples were extracted with methanol (1:5 w/v) at 55°C for 2 h in a shaking water bath at 100 rev/min. After filtering through Whatman No. 1 filter paper, the extracts were concentrated to dryness.

Measurement of DPPH radical-scavenging activity

The modified methods of Shimada et al. (1992) and Mensor et al. (2001) were used to study the free radical-scavenging

activities of the extracts using 1,1-diphenyl-2-picrylhydrazyl, DPPH (Fluka Chemika). Graded concentrations of extracts in 2.0 ml methanolic solution was added to 1.0 ml methanolic solution of 0.3 mM DPPH. The mixture was shaken and left in a dark box to stand for 30 min at room temperature (30 ± 1°C). The blank was prepared with sample solution, 2.0 ml with 1.0 ml of methanol instead of DPPH, while 1.0 ml of methanolic DPPH plus 2.0 ml of methanol served as the control. The absorbance of the resulting solution was measured at 517 nm on a UV/Vis spectrophotometer model 6405 (Jenway Ltd. Essex, UK). The inhibitory percentage of DPPH was calculated accordingly: Scavenging/antioxidant activity (%) = $\{1 - (\text{absorbance}_{\text{sample}}/\text{absorbance}_{\text{control}})\} \times 100\%$.

The IC_{50}, the efficient concentration of methanolic extracts decreasing the initial concentration of DPPH radical by 50% was obtained by interpolation from linear regression analysis (Lin et al. 2006).

Results

Nutritional quality of substrates: CPH, PKC, and CP

The fermentation of substrates with *R. stolonifer* LAU 07 improved the nutritional qualities of the substrates, however, these varied from one substrate to another (Table 1). The crude fibre contents of the substrates were reduced by 44.5, 8.6, and 7.2% in PKC, CP, and CPH, respectively. The protein contents of the fermented substrates were increased by 33.2, 55.4, and 94.8% in PKC, CP, and CPH, respectively. Generally, fermentation of the substrates led to reduction in the crude fat contents. The reductions were 15.4, 36.5, and 10.6% in PKC, CP, and CPH, respectively (Table 1). The ash contents of all the fermented substrates were improved at varying degrees (Table 1). Since the ash content determination is a measure of mineral levels in the substrates, it can be infered that fermentation contributed to the higher levels of the minerals obtained. Similar improved levels of ash content, following fermentation have been reported by various authors (Oboh 2006). The fermentation of cassava peel with *R. stolonifer* LAU 07 reduced the cyanide content by 90.6%.

Table 2 The IC_{50} of methanolic extracts of substrates in DPPH radical scavenging ability

Substrates	IC_{50} (mg/ml)	% improvement
Unfermented palm kernel cake	14.9	NA
Fermented palm kernel cake	7.0	53.1
Unfermented cassava peel	10.6	NA
Fermented cassava peel	4.4	58.4
Unfermented cocoa pod husk	14.7	NA
Fermented cocoa pod husk	5.5	62.2

NA, not applicable

Antioxidant activity (DPPH-scavenging capacity)

The antioxidant capacities of fermented substrates were generally increased. The half-inhibition concentration (IC_{50}), is shown in Table 2. The IC_{50} of the substrates (fermented/unfermented) were obtained as 7.0/14.9, 4.4/10.6, and 5.5/14.7 mg/ml for PKC, CP, and CPH, respectively. Amongst the unfermented substrates, PKC had the highest IC_{50}, while fermented cassava peel was the most potent DPPH-radical scavenging substrate, having the lowest IC_{50} of 4.4 mg/ml.

Discussion

The reduction in the crude fibre contents of the fermented substrates is an indication of secretion of cellulose/hemicellulose-degrading enzymes by the fungus during fermentation. Several fungi including *Aspergillus niger*, *Trichoderma longibrachiatum*, *Trichoderma* spp., and *Trichoderma reesei* have been reported to degrade cellulose/hemicellulose in similar manner (Gritzali and Brown 1979; Sheperd and Kung 1996; Nsereko et al. 2000; Iluyemi et al. 2006). Iluyemi et al. (2006) reported reductions in the hemicellulose content of palm kernel cake to the tune of 2.23, 27.80, 36.98, 49.32, and 57.24% when fermented with *Sclerotium rolfsii*, *T. harzianum*, *T. koningii*, *T. longibrachiatum*, and *A. niger*, respectively. Fermentation of

Table 1 Approximate composition (%) of the substrates

Substrate	Crude fibre	Protein	Crude fat	Ash	Cyanide (ppm)
Palm kernel cake (PKC) 1	22.5	19.7	8.3	5.0	NA
Palm kernel cake (PKC) 2	12.5	26.3	7.1	8.6	NA
% change	−44.5	33.3	−15.4	72.6	NA
Cassava peel (CP) 1	14.7	12.3	5.8	9.4	14.7
Cassava peel (CP) 2	13.5	19.0	3.7	11.8	1.4
% change	−8.6	55.4	−36.5	26.0	90.6
Cocoa pod husk (CPH) 1	18.3	8.2	4.7	11.3	NA
Cocoa pod husk (CPH) 2	16.9	16.0	4.2	20.8	NA
% change	−7.2	94.8	−10.6	83.1	NA

1, unfermented; 2, fermented; −, % reduction; NA, not applicable

cassava peels with a mixed culture of *Saccharomyces cerevisiae* and *Lactobacillus* spp. also decreased both the crude fibre and carbohydrate contents of the peels by 6.4 and 20.9%, respectively (Oboh 2006). The results herein reported show that the fungal strain can effectively lower the crude fibre contents of the substrates, particularly PKC, and this will improve its digestibility by animals.

The rapid increase in growth of the fungus on all the substrates may account for the increase in the protein contents of fermented substrates, with the fungal hyphae serving as single cell protein. In a related study, Ofuya and Nwajiuba (1990) reported an increase of 185% (5.6–16%) in the protein content of cassava peels when fermented with *Rhizopus* spp. Iluyemi et al. (2006) also reported real increase in the protein content of PKC in the range of 29.4–54.5% when fermented with different fungal isolates. The protein content of CPH increased from 8.2 to 16.0%, and this report to the best of our knowledge is the first such investigation on the solid state fermentation of cocoa pod husk to increase its protein content. Typically, CPH is low in protein but very rich in crude fibre, a combination of factors which ultimately limits its utilization as feed in animal husbandry (Donkoha et al. 1991; Sobamiwa and Longe 1994). The most common usage of CPH in Nigeria and other West African countries, is in the production of black soap (Taiwo and Osinowo 2001). Therefore, the present study may serve as value-addition to CPH, CP, and PKC.

The reduction in lipid content as obtained in this study may be attributed to the accumulation of lipids by *R. stolonifer* LAU 07. It has been reported that during fungal processing, some lipolytic strains assimilate lipids from substrates for biomass production leading to a general reduction of the overall lipid content of the substrate (Das and Weeks 1979). These fungi are generally able to secrete lipases for lipid hydrolysis. In a similar study, Iluyemi et al. (2006) reported reduction in the lipid content of PKC fermented with *A. niger*, *S. rolfsii*, and *T. harzianum*.

Cassava peels usually have higher concentration of cyanogenic glucosides than the parenchyma (pulp), which makes the peel unsuitable as animal feed (Oboh 2006). It has been reported that fungal solid state fermentation can effectively lower the cyanide content of cassava (Ofuya and Obilor 1994; Essers et al. 1995; Oboh 2006). The concentration of cyanide in the cassava peels fermented with *R. stolonifer* LAU 07 was low (1.39%), when compared with the usual cyanide content of cassava products in Nigeria [19.0 mg/kg (gari); 25 mg/kg (fufu)], and that of the cyanide content of some micro-fungi-fermented cassava products (9.1–17.2 mg/kg) (Oboh et al. 2002; Oboh and Akindahunsi 2003).

A wide variety of oxygen free radicals and other reactive oxygen species can be formed in the human body and food system. In addition to inducing lipid peroxidation that causes the deterioration of foods (Duthie 1993), these radicals may also cause oxidative damage by oxidizing biomolecules leading to cell death and tissue damage (Kehrer 1993). Indeed, many common maladies, such as atherosclerosis, cancer, emphysema, cirrhosis, and arthritis are correlated with oxidative damage (Kehrer 1993; Jacob 1994). While oxidative damage no doubt plays a significant pathological role in disease, it has been suggested that the intake of food-derived antioxidants may reduce oxidative damage and have a corresponding beneficial effect on human health (Lin and Yen 1999). These antioxidants may be in the form of phenolic substances that are widely present in plants. However, it has been shown that fermentation can increase the concentrations of such substances. For example, the antioxidative activity of fermented soybean products such as miso, tempeh, and natto, inoculated with *A. oryzae*, *R. oligosporum*, and *Bacillus natto*, respectively, was significantly higher than in non-fermented steamed soybean (Santiago et al. 1992; Berghofer et al. 1998). More recently, Lin et al. (2006) reported a work on soybean koji fermented with various GRAS filamentous fungi, including *Aspergillus sojae* BCRC 30103, *Aspergillus oryzae* BCRC 30222, *Aspergillus awamori*, *Actinomucor taiwanensis*, and *Rhizopus* sp, where total phenolic content increased in soybean after fermentation. The DPPH-free radical scavenging activity (IC_{50}) of the fermented soybean ranged from 2.4 to 17.8 mg/ml, while the unfermented control had IC_{50} of 12.6 mg/ml.

As far as we know, there is no report on the evaluation of antioxidant activities of extracts obtained from the substrates used in this work, namely: cocoa pod husk, palm kernel cake, and cassava peel. Related studies were only reported by Azizah et al. (1999), Lecumberri et al. (2007) and Othman et al. (2007). Azizah et al. (1999) evaluated antioxidant activities of extracts obtained from cocoa by-products, namely: cocoa powder, natural cocoa powder, cocoa nib, and cocoa shell. Othman et al. (2007) evaluated the antioxidant activities of extracts obtained from cocoa beans, and reported EC_{50} (DPPH assay) of 1.3, 1.3, and 1.5 mg/ml for Malaysian, Ghanaian, and Ivory coast cocoa beans, respectively. Lecumberri et al. (2007) reported a low antioxidant activity (7.73 ± 0.47 μmol Trolox equivalents/g of dry matter) for a fibre-rich product obtained from cocoa bean husk by determining the free radical (ABTS, 2, 2′-azinobis-3-ethylbenzothiazoline-6-sulphonic acid, diammonium salt)-scavenging capacity using TEAC assay.

In the case of cassava, the only related study is that of Nassar et al. (2007), which reported the rare occurence of lycopene (an important antioxidant) in one of the indigenous clones of cassava in Brazil. Lycopene occurs in

tomato, guava, watermelon, and pink grapefruit and its consumption appears to be associated with reduced degenerative diseases.

Red palm oil is a rich source of β-carotene, α-tocopherol, and tocotrienols (Ong and Goh 2002). Similarly, recovered fibre from pressed palm fruits, which is burned as fuel to provide energy for the palm oil mills, has been found to be a rich source of carotenoids, vitamin E, and sterols (Choo et al. 1996). However, there is paucity of report on the evaluation of the antioxidant potential of palm kernel cake itself. The improved antioxidant activity of the fermented substrates investigated in this study to the tune of 53–62% (Table 2) is a clear indication that the fungal strain may be helpful in the creation of healthy and functional feeds that will not only meet a large section of the nutritional requirements of animals, but also prevents the development of degenerative diseases that are associated with the deleterious effects of free radicals.

The present study has shown the potential of a new fungal isolate, *Rhizopus stolonifer* LAU 07 in improving the nutritional qualities of some agro-wastes that are abundant and of low utilization in Nigeria. The strain improved the protein contents and the antioxidant activities of all the substrates. It gave a good performance in the elimination of cyanide in the cassava peel, while reducing the crude fibre contents of the substrates to varying degrees. It can be concluded that the strain will be useful in value-addition of the agro-wastes, towards their utilization as healthy feed supplements in animal husbandry. Furthermore, the enrichment of the substrates, particularly in protein content and antioxidant activities may reduce the level of fortification in the preparation of animal feeds as it is done at present, thereby reducing the cost of producing the feeds.

Acknowledgement The authors thank the authority of Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria for the provision of some facilities used in this study, and also Dr. M.A. Aderogba of Department of Chemistry, Obafemi Awolowo University (OAU), Ile-Ife, Nigeria for the kind provision of DPPH.

References

Azizah AH, Nik Ruslawati NM, Tee TS (1999) Extraction and characterization of antioxidant from cocoa by-products. Food Chem 64:199–202

Berghofer E, Grzeskowiad B, Mundigler N, Sentall WB, Walcak J (1998) Antioxidative properties of faba bean-, soybean- and oat tempeh. Int J Food Sci Nutr 49:45–54

Chen HZ (1992) Advances in solid-state fermentation. Res Appl Microbiol (China) 3:7–10

Choo YM, Yap SC, Ooi CK, Ma AN, Goh SH, Ong ASK (1996) Recovered oil from palm-pressed fiber: a good source of natural carotenoids, vitamin E, and sterols. J Am Oil Chem Soc 73:599–602

Cordenunsi BR, de Menezes WE, Genovese MI, Colli C, de Souza GA, Lajolo FM (2004) Chemical composition and glycemic index of Brazilian Pine (*Araucaria angustifolia*) seeds. J Agric Food Chem 52:3412–3416

Das DVM, Weeks G (1979) Effects of polyunsaturated fatty acids on the growth and differentiation of the cellular slime mold, *Dictyostelium discoideum*. Exp Cell Res 118:237–243

Domsch KH, Gams W, Anderson TH (1980) Compendium of soil fungi. Academic Press, London, England, p 865. ISBN 978–0122204012

Donkoha A, Atuahenea CC, Wilsona BN, Adomakob D (1991) Chemical composition of cocoa pod husk and its effect on growth and food efficiency in broiler chicks. Anim Feed Sci Technol 35:161–169

Duthie GG (1993) Lipid peroxidation. Eur J Clin Nutr 47:759–764

Egunjobi OA (1975) On the possible Utilization of discarded cocoa pod husk as fertilizer and nematicide. In: proceeding of 5th international cocoa research conference, Cocoa Research Institute of Nigeria (CRIN) Ibadan, Nigeria, pp 541–547

Essers AJE, Carien MG, Jurgens A, Nout MJR (1995) Contribution of selected fungi to the reduction of cyanogen levels during solid substrate fermentation of cassava. Int J Food Microbiol 26:251–257

FAO (2004) Online Statistical Database. Food and Agriculture Organization of the United Nations, Rome, Italy. www.fao.org

Gritzali MK, Brown RD (1979) The cellulase system of *Trichoderma*. Relationships between purified enzymes from induced or cellulose-grown cells. Adv Chem Ser 181:237–260

Iluyemi FB, Hanafi MM, Radziah O, Kamarudin MS (2006) Fungal solid state culture of palm kernel cake. Bioresour Technol 97:477–482

Jacob RA (1994) Nutrition, health and antioxidants. Inform 5:1271–1275

Kehrer JP (1993) Free radicals as mediators of tissue injury and disease. Crit Rev Toxicol 23:21–48

Koekoek FJ (2003) The organic cocoa market in Europe: market study. November 2003. Export Promotion of Organic Products from Africa (EPOPA)

Lagemaat JV, Pyle DL (2001) Solid state fermentation and bioremediation: development of a continous process for the production of fungal tannase. Chem Eng J 84:115–123

Lecumberri E, Mateos R, Izquierdo-Pulido M, Rupérez P, Goya L, Bravo L (2007) Dietary fibre composition, antioxidant capacity and physico-chemical properties of a fibre-rich product from cocoa (*Theobroma cacao* L.). Food Chem 104:948–954

Lin MY, Yen CL (1999) Antioxidative ability of lactic acid bacteria. J Agric Food Chem 47:1460–1466

Lin CH, Wei YT, Chou CC (2006) Enhanced antioxidative activity of soybean koji prepared with various filamentous fungi. Food Microbiol 23:628–633

Mensor LL, Menezes FS, Leitao GG, Reis AS, Santos TC, Coube CS, Leitao SG (2001) Screening of Brazilian plant extracts for antioxidant activity by the use of DPPH free radical method. Phytother Res 15:127–130

Nassar N, Vizzotto CS, Schwartz CA, Pires Júnior OR (2007) Cassava diversity in Brazil: the case of carotenoid-rich landraces. Genet Mol Res 6:116–121

Nsereko VL, Morgavi DP, Rode LM, Beauchemin KA, McAllister TA (2000) Effects of fungal enzyme preparations on hydrolysis and subsequent degradation of alfalfa hay fibre by mixed rumen microorganisms in vitro. Anim Feed Sci Technol 88:153–170

Oboh G (2006) Nutrient enrichment of Cassava peels using a mixed culture of *Saccharomyces cerevisiae* and *Lactobacillus* spp. solid media fermentation techniques. Electron J Biotechnol 9:46–49

Oboh G, Akindahunsi AA (2003) Biochemical changes in Cassava products (flour and gari) subjected to *Saccharomyces cerevisiae* solid media fermentation. Food Chem 82:599–602

Oboh G, Akindahunsi AA, Oshodi AA (2002) Nutrient and antinutrient content of *Aspergillus niger* fermented cassava products (flour and gari). J Food Compost Anal 15:617–622

Ofuya CO, Nwajiuba CJ (1990) Microbial degradation and utilization of cassava peel. World J Microbiol Biotechnol 6:144–148

Ofuya CO, Obilor SN (1994) The suitability of fermented cassava peel as a poultry feedstuff. Bioresour Technol 44:101–104

Ong ASH, Goh SH (2002) Palm oil: a healthful and cost-effective dietary component. Food Nutr Bull 23:11–22

Othman A, Ismail A, Abdul Ghani N, Adenan I (2007) Antioxidant capacity and phenolic content of cocoa beans. Food Chem 100:1523–1530

Santiago LA, Hiramatsu M, Mori A (1992) Japanese soybean paste miso scavenges free radicals and inhibits lipid peroxidation. J Nutr Sci Vitaminol 38:297–304

Sheperd AC, Kung L Jr (1996) Effects of an enzyme additive on composition of corn silage ensiled at various stages of maturity. J Dairy Sci 79:1767–1773

Shimada K, Fujikawa K, Yahara K, Nakamura T (1992) Antioxidative properties of xanthan on the anti-oxidation of soybean oil in cyclodextrin emulsion. J Agric Food Chem 40:945–948

Sobamiwa O, Longe OG (1994) Utilization of cocoa pod pericarp fractions in broiler chick diets. Anim Feed Sci Technol 47:237–244

Soccol RS, Vandenberghe LPS (2003) Overview of applied solid-state fermentation in Brazil. Biochem Eng J 13:205–218

Suryanarayan S (2003) Current industrial practice in solid state fermentations for secondary metabolite production: the Biocon India experience. Biochem Eng J 13:189–195

Taiwo OE, Osinowo FAO (2001) Evaluation of various agro-wastes for traditional black soap production. Bioresour Technol 79:95–97

USDA (2000) World palm oil production. Production estimates and crop assessment division. Department of Agriculture, United States