Innovative Food Science and Emerging Technologies 57 (2019) 102193

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

journal homepage: www.elsevier.com/locate/ifset

Production of value-added product from pineapple peels using solid state fermentation

T.E. Aruna

Department of Food Science and Technology, College of Agriculture and Veterinary Medicine, Kwara State University, Malete, P.M.B. 1530, Ilorin, Kwara State, Nigeria

ARTICLE INFO

Keywords:
Protein-enrichment
Solid state fermentation
Trichoderma viride
Pineapple peels
Biomass

ABSTRACT

Pineapple (*Ananas comosus*) peels are agricultural plant residues that contribute to waste disposal problem and there is little information on their conversion to useful products. Solid state fermentation (SSF) of pineapple peels (with and without ammonium sulphate) was done with a view to increase their protein content using *Trichoderma viride* ATCC 36316 for 96 h at 30 °C. The study was carried out using conical flasks and on-farm solid state fermenter. Chemical composition (fat, crude and true proteins, carbohydrate and ash) of the unfermented and fermented peels were determined using standard methods. Unfermented pineapple peel had low values of 4.5, 2.84, 0.6, 6.8% for crude protein, true protein, fat and ash contents, respectively. The SSF using *T. viride* with or without the addition of $(NH_4)_2SO_4$ increased the chemical compositions of the pineapple peels. Higher protein yields were recorded when (NH4)$_2$SO4 was used as nitrogen source. *T. viride* and $(NH_4)_2SO_4$ increased the crude protein content from 4.5 to 14.9% when fermentation was done using conical flask. With on-farm scale fermenter, protein yields increased further. SSF of pineapple peels with *T. viride* produced high protein fungal biomass and may be recommended as suitable for animal feed.

1. Introduction

Under-nutrition is a long standing problem in Nigeria due to appreciable decrease in food consumption, both in quantity and quality (Igbedioh, 1993) and there is need to substantially boost food intake, especially protein using alternative protein sources such as protein-enriched agricultural and food processing wastes. Some of these wastes include wastes from sugar, meat, poultry and fish processing industries and root, tuber, fruit and vegetables wastes such as pineapple peels, yam peels, peanut shells, coconut husk and shell, banana and plantain peels, corn cobs and husks, cassava peels, citrus peels, mango peels, sugarcane bagasse, cheese, whey permeates, among others. Biotransformation of these wastes using appropriate technological procedures will remove pollution emanating from wastes, reduce quantity of wastes that are produced annually, minimize waste disposal problems, and at the same time provide commercially valuable products (Iyayi & Losel, 2001) with sufficient protein quantity and quality (Aruna, Aworh, Raji, & Olagunju, 2017). This is possible because these wastes still contain nutrients (chiefly sugars, minerals and proteins) that can serve as suitable substrate on which microorganisms can grow (Aworh, 2010).

Pineapple (*Ananas comosus* (L) Merr.) is a common fruit from a tropical plant. It is native to South America, mostly Paraguay and southern part of Brazil, and has also spread to tropical countries in Africa. In Africa, Nigeria is the highest producer of pineapple with about 6% of the total 881,000 t world production in 2001 (Martyns, 2008). Different products such as jam, fruit pulps and canned juice are produced from pineapple. However, about 20% of the whole pineapple fruit is juice, the remaining parts in form of crown, peeled skin, base and core are discarded as wastes resulting in environmental pollution. These wastes are very rich in cellulose, hemicellulose and other complex carbohydrates but present low protein contents. Enhancement of nutritive value of pineapple peels, especially its protein content will promote its use in the production of foods. It will also find wide application in animal feed formulation thereby replacing expensive conventional protein sources, and of course, reducing costs of livestock production and animal protein. In addition, pineapple processing wastes are essential substrates for bioethanol (important biofuel alternative to gasoline) production (Idiata & Iyasele, 2014; Soontornchaiboon, Chunhachart, & Pawongrat, 2016).

Since pineapple peels contain sugars that can support the growth of microorganisms such as *Saccharomyces cerevisiae*, *Candida utilis* and *Trichoderma viride*, converting these lignocellulosic wastes by fermentation into affordable, nutritious and safe products of value will be a worthwhile venture. In addition, the need for new sources of protein increases daily, hence, it has become very important to maximize the

E-mail address: ennietawa@yahoo.com.

https://doi.org/10.1016/j.ifset.2019.102193
Received 16 January 2019; Received in revised form 7 July 2019; Accepted 11 July 2019
Available online 15 July 2019
1466-8564/ © 2019 Elsevier Ltd. All rights reserved.

use of various agricultural and food processing industry wastes such as pineapple peels in producing safe and highly nutritious animal feeds thereby reducing over-dependence on traditional food protein sources (Anupama & Ravindra, 2000). *T. viride* finds wide application in food and agricultural processing waste fermentation: Ezekiel, Aworh, Blaschek, and Ezeji (2010) enriched the protein content of cassava peels by submerged fermentation with *T. viride* and the protein content of the fermented peels increased significantly. De Gregorio et al. (2002) and Abou-Zeid (1991) also enriched the protein contents of lemon pulp and palm-tree leaflets and midribs respectively using *T. viride*. More importantly, nitrogen is essential for the manufacture of amino acids, nucleic acid (purine and pyrimidine), some carbohydrates and lipids, enzyme cofactors and other substances (Bohra & Parihar, 2012). In most of the previous studies, researchers have paid the most attention to the effect of addition of exogenous nitrogen sources such as urea, nitrate and ammonium sulphate on biomass and protein production during fermentation since fermenting microorganisms usually prefer one source to another. For example, Duru and Uma (2003) reported that *Aspergillus oryzae* utilized urea better than other nitrogen sources during protein enrichment of cocoyam solid wastes. In addition, Awoyele (2010) recorded better protein and biomass production during SSF of cassava peels using *T. viride* and ammonium sulphate than with urea. Therefore, the objective of this study is to develop value-added products from pineapple peels by SSF using ammonium sulphate as nitrogen source.

2. Materials and methods

Fresh pineapple (Smooth cayenne cultivar) peels were collected in May 2015, from Fumman fruit-juice manufacturing company, Apata, Ibadan, Oyo state, Nigeria.

2.1. Microorganisms

Trichoderma viride ATCC 36316 was obtained from America Type Culture Collection (ATCC) and maintained on potato dextrose agar slants at 4 °C.

2.2. Preparation of pineapple peels for analysis

The collected pineapple peels were drained to remove excess of water, dried at 60 °C, cooled, dry-milled with a fabricated hammer mill in Mechanical Engineering Department, University of Ibadan. In following, the samples were sieved to obtain 3.35–4.00 mm particle sizes which were used for solid-state fermentation (Ezekiel & Aworh, 2013b).

2.3. Solid state fermentation of pineapple peels (without the addition of inorganic nitrogen) using T. viride

The fungus, *T. viride*, was subcultured on potato dextrose agar in several petri- dishes for 4 days and sterile water was used to prepare spore suspension containing approximately 2.7×10^6 number of spores per ml. This was followed by solid state fermentation using 250 ml conical flasks. In these flasks were weighted 50 g of the unfermented pineapple peels with 3.35–4.00 mm particle size. In following, the moisture contents were adjusted to 60% and the samples were autoclaved at 121 °C for 15 min and cooled to ambient temperature. Then, substrate in each flask was inoculated aseptically with 15 ml of the spore suspension of *T. viride* and incubated at 30 °C for 96 h. During incubation, fermented samples were taken every 24 h, spread on metallic trays and dried in the oven at 60 °C for 24 h, cooled, packaged in air-tight containers, and then assayed for its moisture, fat, ash, crude fibre, crude protein and true protein contents. The crude protein contents were determined by Kjeldahl method while true protein contents were determined by Lowry's procedure. Moisture, ash, fibre and fat contents were evaluated according to AOAC (2005).

2.4. Crude protein determination

Pineapple peels (1 g each) were weighed on ashless filter papers, folded and placed inside the cleaned Kjeldahl digestion flask, one Kjeldahl tablet and 30 ml of concentrated H_2SO_4 was added to each flask. The flask was placed in the Foss Tecator digestor for digestion process, shaken from time to time until a clear solution was obtained and the digestion flask was allowed to cool, attached tightly to the distillation section of the automated Fosskjeltec 2100 protein apparatus. Boric acid (25 ml) was pipetted into a 250-ml conical flask and was attached to the condenser in the distillation chamber and its delivery tube was dipped below the surface of the boric acid in the conical flask. Thistle funnel that was connected to the distillation chamber, through the tap, was filled with 50% NaOH solution and the apparatus was switched on for 6 min, during which the digestion flask and digest became heated, boiled and made alkaline by the addition of 50% NaOH solution in small portion through the tap. As boiling started, NH_3 gas was released and passed through the delivery tube into the boric acid indicator for 5 min, then the NaOH tap was closed and the boric acid mixture was titrated against 0.1 N HCl and % crude protein was calculated using % N X 6.25 (AOAC, 2005).

2.5. True protein determination

True protein content was determined by Folin-Ciocalteau method (Lowry, Rosebrough, Farr, & Randall, 1951). Pineapple peels (2 g each) were mixed with 20 ml of 50% ethanol, filtered with a Whatman No. 1 paper, 0.3 ml of the filtrate was added to 3 ml of a solution containing 1 ml of 0.5% CuSO4 in 1% Sodium potassium tartarate and 50 ml of 2% Na_2CO3 in 1 M NaOH, shaken properly and allowed to stand for 10 min. Standard protein solutions (with known concentrations) were prepared using bovine serum albumin (BSA) and treated as the samples. Then, 0.3 ml of 33.3% Folin reagent solution was added, mixed thoroughly and allowed to stand for 30 min. Absorbances were read at 500 nm. Blank was also prepared with 0.3 ml distilled water. Then, standard curves were prepared by plotting absorbances against BSA concentrations and the concentration of the samples was obtained from the standard curves.

2.6. SSF of pineapple peels (with addition of nitrogen) using T. viride

Solid state fermentation was carried out in 250 ml conical flasks. In conical flasks, 50 g of the unfermented dried pineapple peels were added and their moisture contents were adjusted at 60%. In following, a calculated amount of ammonium sulphate was added (10 g N/kg substrate), and the resulting mixture was sterilized at 121 °C for 15 min, cooled to ambient temperature and inoculated aseptically with 15 ml of spore suspension of *T. viride* (containing approximately 2.7×10^6 number of spores per ml). All the samples were incubated at 30 °C and aliquots were collected at each 24 h during fermentation. The fermentation was stopped by drying the collected samples in the oven at 60 °C, following by cooling and packaging in airtight containers. Fermented peels were then assayed for its moisture, fat, ash, crude fibre, crude protein and true protein contents as earlier described.

2.7. On-farm scale solid state fermentation of pineapple peels

Fermentation was carried out in a fabricated on-farm solid state fermenter, putting into consideration the various optimal fermentation conditions obtained from the conical flask experiments. These conditions include: substrate particle size (3.35 mm > p > 4.00 mm), initial moisture content (60%), nitrogen source (ammonium sulphate, 10 g N/kg substrate) and incubation conditions (30 °C for 96 h). Fermentation was terminated by drying the fungal biomass in the oven at 60 °C followed by cooling, milling in a hammer mill and packaging in air-tight containers. Moisture, ash, crude protein, crude fat, crude fibre

Table 1
Chemical composition of *Trichoderma viride* enriched pineapple peel without addition of inorganic nitrogen.

Composition (%)	Fermentation Period (hours)				
	0	24	48	72	96
Crude protein	$4.53 \pm 0.27_e$	$7.85 \pm 0.01_d$	$10.06 \pm 0.03_c$	$13.56 \pm 0.07_a$	$11.21 \pm 0.01_b$
True protein	$2.85 \pm 0.03_e$	$5.82 \pm 0.00_d$	$8.15 \pm 0.01_c$	$10.86 \pm 0.06_a$	$9.34 \pm 0.01_b$
Crude fibre	$13.96 \pm 0.14_d$	$15.21 \pm 0.35_c$	$16.49 \pm 0.01_b$	$18.39 \pm 0.03_a$	$18.27 \pm 0.01_a$
Crude fat	$0.63 \pm 0.03_c$	$1.15 \pm 0.01_b$	$1.19 \pm 0.01_a$	$1.23 \pm 0.03_a$	$1.21 \pm 0.0_a$
Ash	$6.80 \pm 0.28_a$	$6.68 \pm 0.01_a$	$6.75 \pm 0.02_a$	$6.83 \pm 0.00_a$	$6.78 \pm 0.06_a$
Carbohydrate	$74.08 \pm 0.98_a$	$69.11 \pm 0.34_b$	$65.51 \pm 0.10_c$	$59.99 \pm 0.04_e$	$62.53 \pm 0.11_d$

Data presented on dry matter basis. Each value is a mean of three independent experiments. Means followed by the same subscript in the same row are not significantly different ($p > 0.05$).

and true protein contents of the protein enriched products obtained from on-farm scale solid state fermenter were determined as earlier described.

3. Statistical analysis

All analyses were performed in triplicate. Data were subjected to Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS) V. 17.0. Means were separated using Duncan Multiple Range Test (DMRT) at 95% confidence level ($p \leq 0.05$).

4. Results and discussion

4.1. Chemical composition of T. viride enriched pineapple peels without addition of inorganic nitrogen

Pineapples peels have low crude and true protein contents. However, solid state fermentation of pineapple peels with *T. viride* without adding nitrogen source resulted in protein production. Changes in the chemical composition of the fermented products are given in Table 1. The crude and true protein contents of pineapple peels increased considerably from 4.52 and 2.84% to 13.56 and 10.86%, respectively, during the first 72 h of fermentation but the values declined to 11.21 and 9.34% respectively when fermentation reached 96 h. These facts, therefore, indicated that breaking of starch to sugar, metabolism of the sugar produced by *T. viride* and enrichment of the peels occurred during this study. Higher crude protein contents recorded in the fermented peels could be also due to additional crude protein synthesized in the fungal mycelia while its decline as fermentation period progress may probably due to proteolysis or depletion of reducing sugar within the fermenting medium (Oboh et al., 2002). Fermentation also increased the fat and crude fibre contents of the fermented peels while carbohydrate contents decreased significantly ($p < 0.05$). In addition, the increased in fat contents recorded in this study was presumably due to carbohydrate metabolism to fat (Oboh et al., 2002).

4.2. Solid state fermentation of pineapple peels using T. viride with addition of inorganic nitrogen

The changes observed in chemical composition of dried *T. viride* fermented pineapple peels, with ammonium sulphate supplementation, are presented in Table 2. Dried fermented pineapples peels increased in fat, crude protein and true protein contents while carbohydrate contents declined with increase in fermentation period. The results obtained showed the effects of ammonium sulphate addition on the chemical composition of the pineapple peels during the study. Crude and true protein contents increased to 14.89 and 12.02% respectively after 72 h of fermentation. High crude protein yields obtained during this study was similar to Duru and Uma (2003), who reported an increase in crude protein content during the protein enrichment of solid waste from cocoyam cormel using *Aspergillus oryzae* with ammonium sulphate supplementation.

4.3. Effects of ammonium sulphate supplementation on protein enriched pineapple peel products

The addition of $(NH_4)_2SO_4$ to the substrates (pineapple peels) as nitrogen source (10 g N/kg substrate) prior to fermentation resulted in protein enrichment of the peels. The fermenting organism utilized the exogenous nitrogen source efficiently and bioconversion of sugar to protein took place. This result, therefore, resulted in changes in chemical composition of the final product. Crude protein, crude fibre, fat, true protein and ash contents increased considerably while carbohydrate contents reduced significantly ($p < 0.05$) (Table 3). The crude protein contents of enriched pineapple peels after $(NH_4)_2SO_4$ supplementation were 2-fold (4.52 to 14.89%) higher than those ones determined in unfermented peels. Biniyam, Tesfaye, and Amutha (2010) also reported higher crude protein contents in the final product during bioconversion of orange wastes into fungal biomass using *Aspergillus niger* and *Chaetomiu* spp. The decreased carbohydrate levels obtained during the solid state fermentation of pineapple peels, with or without nitrogen supplementation, showed the ability of the fermenting organisms, *T. viride*, to secrete hydrolytic enzymes (Balagopalan, 1996) that are capable of breaking down high molecular weight compounds such as starch and cellulose into simple sugars that are easily metabolized. Carbohydrate contents of the fermented pineapple peels with addition of ammonium sulphate were significantly ($p < 0.05$) lower when compared with the non-supplemented fermented peels while unfermented peels had highest carbohydrate contents (Table 3).

Nitrogen supplementation also increased the ash contents of the fermented pineapple peels. The ash content of the supplemented pineapple peel products was higher than the ash levels in the non-supplemented peels. Oboh and Akindahunsi (2003) reported an increase in ash contents in *Saccharomyces cerevisiae* fermented cassava products. Ezekiel et al. (2010) also reported an increase in ash content of the fermented cassava peel during submerged fermentation of cassava peels with *T. viride*. However, there was a significant increase ($p < 0.05$) in fat contents in the supplemented *T. viride* fermented pineapple peels when compared with the unfermented peels. This is in line with the report of Akindumila and Glatz (1998) that certain fungal species are capable of building fat during fermentation. Energy contents also differ significantly ($p < 0.05$) (Table 3).

4.4. Chemical composition of fermented pineapple peels using on-farm scale solid state fermenter

The changes in chemical composition of *T. viride* fermented pineapple peels using on-farm scale solid state fermenter are shown on Table 4. With the exception of crude protein and carbohydrate values, there were no significant differences between the protein-enriched products obtained from conical flask and fermenter (Table 4). On-farm

Table 2
Changes in chemical composition of *T. viride* fermented pineapple peels with addition of inorganic nitrogen.

Composition (%)	Fermentation period (hours)				
	0	24	48	72	96
Crude protein	$4.53 \pm 0.27_e$	$9.15 \pm 0.03_d$	$10.52 \pm 0.03_c$	$12.87 \pm 0.01_b$	$14.89 \pm 0.05_a$
True protein	$2.85 \pm 0.03_e$	$7.24 \pm 0.01_d$	$8.02 \pm 0.00_c$	$10.12 \pm 0.00_b$	$12.02 \pm 0.02_a$
Crude fat	$0.63 \pm 0.03_b$	$1.18 \pm 0.01_a$	$1.20 \pm 0.01_a$	$1.22 \pm 0.03_a$	$1.26 \pm 0.01_a$
Crude fibre	$13.96 \pm 0.14_c$	$16.27 \pm 0.03_b$	$16.71 \pm 0.01_b$	$18.27 \pm 0.06_a$	$18.95 \pm 0.12_a$
Ash	$6.80 \pm 0.28_a$	$7.08 \pm 0.01_a$	$7.22 \pm 0.06_a$	$7.42 \pm 0.00_a$	$7.58 \pm 0.02_a$
Carbohydrate	$74.08 \pm 0.98_a$	$66.32 \pm 0.03_b$	$64.35 \pm 0.06_c$	$60.22 \pm 0.15_d$	$57.32 \pm 0.20_e$

Data presented on dry matter basis. Each value is a mean of three independent experiments. Means with same subscripts in the same row are not significantly different ($p > 0.05$).

Table 3
Effects of ammonium sulphate supplementation on nutrient composition of *T. viride* fermented pineapple peels.

Composition (%)	Unfermented Pineapple Peel	Non-supplemented *T. viride* fermented pineapple peel	Supplemented *T. viride* fermented pineapple peel
Crude protein	$4.53 \pm 0.27_c$	$13.56 \pm 0.07_b$	$14.89 \pm 0.05_a$
True protein	$2.85 \pm 0.03_c$	$10.86 \pm 0.06_b$	$12.02 \pm 0.02_a$
Crude fat	$0.63 \pm 0.03_b$	$1.23 \pm 0.03_a$	$1.26 \pm 0.01_a$
Crude fibre	$13.96 \pm 0.14_b$	$18.39 \pm 0.03_a$	$18.95 \pm 0.12_a$
Ash	$6.80 \pm 0.28_b$	$6.83 \pm 0.00_b$	$7.58 \pm 0.02_a$
Carbohydrate	$74.08 \pm 0.98_a$	$59.99 \pm 0.04_b$	$57.32 \pm 0.20_c$
Energy (Kcal/100 g)	320.11_a	299.12_b	293.88_c

Data presented on dry matter basis. Each value is a mean of three independent experiments. Means followed by the same subscript in the same row are not significantly different ($p > 0.05$).

Table 4
Chemical compositions of fermented pineapple peels on laboratory and on-farm scales.

Composition (%)	*T. viride* Fermented Pineapple Peel (Laboratory scale)	*T. viride* Fermented Pineapple Peel (On-farm scale)
Crude protein	$14.89 \pm 0.05_b$	$16.00 \pm 0.01_a$
Crude fat	$1.26 \pm 0.01_a$	$1.29 \pm 0.01_a$
Crude fibre	$18.95 \pm 0.12_a$	$18.98 \pm 0.75_a$
Ash	$7.58 \pm 0.02_a$	$7.60 \pm 0.10_a$
Carbohydrate	$57.32 \pm 0.20_b$	$56.13 \pm 0.06_a$

Data presented on dry matter basis. Each value is a mean of three independent experiments. Means followed by the same subscript in the same row are not significantly different ($p > 0.05$).

scale solid state fermenter's protein-enriched products had higher crude protein contents than the results obtained from conical flask experiments' products. The crude protein of *T. viride* enriched pineapple peels was also 16.0% when on-farm solid scale fermenter was used, while 14.89% was obtained from the conical flask experiment. This result was in line with Ezekiel et al. (2010) that reported higher crude protein contents during protein enrichment of cassava peel with *T. viride* using on-farm scale solid state fermenter. Higher protein yields obtained with on-farm scale solid state fermenter could be due to adequate aeration provided by the fan and high relative humidity that was maintained throughout the fermentation period in the fermenter (Athapol, Hangantileke, & Bautista, 1992). The carbohydrate contents of enriched products from fermenter were significantly different from that conical flask. This could be due to conversion of solid carbohydrate waste into high protein biomass. Similar result was reported by Aruna et al. (2017) when white yam peels were fermented by *Saccharomyces cerevisiae* BY4743. Decrease in the carbohydrate contents could as well account for significant increase in protein contents recorded in the fermented peels (Oboh et al., 2002), either from the conical flask or on-farm-scale experiments.

5. Conclusion

Protein enrichment of pineapple peels was achieved with or without the addition of exogenous nitrogen source; however, when an on-farm solid-state fermenter was used for fermentation with addition of ammonium sulphate, higher protein yields were recorded due to better aeration and additional nutrient (nitrogen) for the fermenting microorganism.

Declaration of Competing Interest

I declared that these findings do not contain any conflict of interest.

Acknowledgement

Authors acknowledge Factory Operation Manager of Fumman fruit-juice manufacturing company, Apata, Ibadan, Oyo state, Nigeria, Mr. Adeniji, for providing pineapple peels used for this work.

References

Abou-Zeid, A. (1991). Increasing the protein content of palm by-products. *Bioresource Technology, 37*, 239–242.
Akindumila, F., & Glatz, B. A. (1998). Growth and oil production of *Apiotrichum curvatum* in tomato juice. *Food Protect, 61*, 1515–1517.
Anupama, P., & Ravindra, P. (2000). Value-added food: Single cell protein. *Biotechnology Advances, 18*(6), 459–479.
AOAC (2005). *Official methods of analysis of the association of official analytical chemists.* Washington DC, USA: AOAC.
Aruna, T. E., Aworh, O. C., Raji, A. O., & Olagunju, A. I. (2017). Protein enrichment of yam peels by fermentation with *Saccharomyces cerevisiae* (BY4743). *Annals of Agricultural Science, 62*(1), https://doi.org/10.1016/j.aoas.2017.01.002.
Athapol, N., Hangantileke, S., & Bautista, M. B. (1992). Factors in protein enrichment of cassava by solid state fermentation. *Journal of Food and Agriculture, 52*, 117–123.
Aworh, O. C. (2010). *Food technology and national development: A global perspective University of Ibadan Lecture.* 67–78.
Awoyele, O. O. (2010). *Fermentation of cassava peel with Trichoderma viride and Candida utilis for protein enrichment.* Ibadan: University of Ibadan (PhD Thesis).
Balagopalan, C. (1996). *Nutritional improvement of cassava products using microbial techniques for animal feeding. Monograph of the Central Tuber Crops Research Institute, Kerala India.* 44.
Biniyam, Y., Tesfaye, A., & Amutha, S. (2010). Solid substrate fermentation and conversion of orangewaste into fungal biomass using *Aspergillus niger* KA-06 and *Chaetomium* Spp KC-06. *African Journal of Microbiology Research, 4*(12), 1275–1281.
Bohra, A., & Parihar, P. (2012). *Food microbiology* (Student ed.). *342 003*, 92 Behind Nasrani Cinema, Chopasani Road, Jodhpur.
De Gregorio, A., Mandalari, G., Arena, N., Nucita, F., Tripodo, M. M., & Lo Curto, R. B. (2002). Single cell protein and crude pectinase production by slurry-state fermentation of lemon pulps. *Bioresource Technology, 83*(2), 89–94.
Duru, C. C., & Uma, N. U. (2003). Protein enrichment of solid waste from cocoyam (*Xanthosoma sagittifolium* (L.) Schott) cormel processing using *Aspergillus oryzae* obtained from cormel flour. *African Journal of Biotechnology, 2*(8), 228–232.
Ezekiel, O. O., & Aworh, O. C. (2013b). Construction and performance evaluation of an on-farm scale solid state fermenter. *Journal of Tropical Agriculture, Food, Environment and Extension, 12*(2), 40–44.

Ezekiel, O. O., Aworh, O. C., Blaschek, H. P., & Ezeji, T. C. (2010). Protein enrichment of cassava peel by submerged fermentation with *Trichoderma viride* (ATCC 36316). *African Journal of Biotechnology, 9*(2), 187–194.

Idiata, D. J., & Iyasele, J. U. (2014). Waste to wealth: Production of bioethanol from pineapple waste. *Journal of Multidisciplinary Engineering Science and Technology (JMEST), 1*(4) ISSN: 3159-0040.

Igbedioh, S. O. (1993). Undernutrition in Nigeria: Dimension, causes and remedies for alleviation in a changing socio-economic environment. *Nutrition and Health, 9*(1), 1–14.

Iyayi, E. A., & Losel, D. M. (2001). Protein enrichment of cassava by-products through solid state fermentation by fungi. *The Journal of Food Technology in Africa, 6*(4), 116–118.

Lowry, O. H., Rosebrough, N. J., Farr, A. L., & Randall, R. J. (1951). Protein measurement with Folin-phenol reagent. *Journal of Biological Chemistry, 193*, 265–275.

Martyns, W. (2008). *Nigeria leads pineapple production in Africa. In a paper presented in a workshop organized by National Export Promotion Council.* Port Harcourt, Nigeria: Delta Hotels.

Oboh, G., & Akindahunsi, A. A. (2003). Biochemical changes in cassava products (flour and gari) subjected to *Saccharomyces cerevisae* solid media fermentation. *Food Chemistry, 82*, 599–602.

Oboh, G., Akindahunsi, A. A., & Oshodi, A. A. (2002). Nutrient and anti-nutrient content of *Aspergillus niger* fermented cassava products (flour and gari). *J. Food Comp. Anal. 15*, 617–622.

Soontornchaiboon, W., Chunhachart, O., & Pawongrat, R. (2016). Ethanol production from pineapple waste by co-culture of *Saccharomyces cerevisiae* TISTR 5339 and *Candida shehatae* KCCM 11422. *KKU Research Journal, 21*(2), 347–355.