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Valorization of banana peel waste for alpha amylase production by *Fusarium solani* under solid state fermentation

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Abstract

Alpha amylase is an industrially important enzyme widely applied in food, pharmaceutical, textile, and biotechnological industries. This study investigated the production and characterization of alpha amylase by *Fusarium solani* using banana peels as a low cost agro industrial substrate. The fungus was cultivated under solid state fermentation conditions, and the crude enzyme extract was evaluated for optimal temperature, pH, thermal stability, tolerance to metallic salts, and substrate specificity. Enzyme activity increased with temperature, reaching a maximum at 80 °C, after which a decline was observed at higher temperatures, indicating thermal denaturation beyond the stability limit. The enzyme exhibited optimal activity at pH 6.0 and the enzyme also maintained activity in the presence of low concentrations of selected metallic salts. Among the substrates tested, pectin supported the highest enzyme activity (19.44 U ml^{-1} min^{-1}), followed by starch (18.06 U ml^{-1} min^{-1}), while lower activities were obtained with pineapple peel and plantain peel, each yielding approximately 15.28 U ml^{-1} min^{-1}. These findings demonstrate the potential of *Fusarium solani* for the sustainable production of thermostable alpha amylase using banana peels, highlighting the feasibility of converting agro industrial waste into value added bioproducts. The study underscores the industrial relevance of the enzyme and its contribution to sustainable biotechnological processes.

Keywords: Alpha amylase; *Fusarium solani;* Banana peels; pH; Thermostability; Enzyme activity

Introduction

Microbial enzymes play a central role in modern bioprocessing, and their applications continue to expand across food, environmental, and industrial sectors. Increasing interest in sustainable enzyme production has encouraged the exploration of diverse microbial species capable of secreting extracellular biocatalysts with desirable functional properties (Bilinski and Stewart, 1995; Akpan *et al*., 1999; Buzzini and Martini, 2002). Among these enzymes, amylases remain particularly important due to their ability to hydrolyze starch and related polysaccharides into simpler sugars, thereby supporting key operations in food manufacturing, fermentation, and waste valorization (Nigam and Singh, 1995; Pandey *et al*., 2000).

Alpha amylase is widely used in food processing, brewing, sweetener production, and other industrial applications because of its catalytic efficiency and broad operational stability. Microbial systems provide an attractive platform for alpha amylase production because they offer high productivity, ease of culture manipulation, and potential for process optimization (Omemu *et al*., 2005). Fungal species, in particular, are recognized for their effective secretion of extracellular amylases and for producing enzymes with favorable stability profiles compared with bacterial counterparts (Sanghvi *et al*., 2011). As global demand for amylases increases, the use of low cost and renewable substrates for fermentation is gaining significance.

Solid state fermentation (SSF) offers a cost effective approach for enzyme production, especially when agro industrial residues are used as substrates. These residues serve as sources of carbon and nutrients while also functioning as physical support for fungal growth. Various plant based by products including citrus peels, wheat bran, cassava waste, and banana peel have been evaluated as substrates for microbial enzyme production (Kareem *et al*., 2009; Djekrif-Dakhmouche *et al*., 2006). Utilizing such materials aligns with global efforts to reduce biomass waste, enhance resource circularity, and convert underused residues into value added products of relevance to food systems.

Banana peel constitutes a substantial proportion of post-consumer fruit waste and is often discarded without further use. Its disposal raises environmental concerns, yet the material contains carbohydrates and other nutrients suitable for microbial growth. Previous studies have demonstrated the potential of banana peel for the synthesis of metabolites such as alcohol and ligninolytic enzymes (Johann *et al*., 2007b). However, there is limited information on its suitability as a substrate for fungal production of alpha amylase. Addressing this gap may support the development of scalable, low-cost enzyme production processes and contribute to the broader goal of sustainable biotransformation of food waste.

This study therefore investigates the potential of *Fusarium solani* to produce extracellular alpha amylase using banana peel as substrate under solid state fermentation. The work further characterizes the physiological and stability properties of the enzyme, providing insights relevant to food processing operations and valorization of agro industrial residues.

Materials and Methods

Microorganism and Culture Maintenance

Fusarium solani used in this study was obtained from the Department of Science Laboratory Technology Culture Collection, Ladoke Akintola University of Technology (LAUTECH), Ogbomoso, Nigeria. The isolate was maintained on Potato Dextrose Agar (PDA) slants and incubated at 30°C for 5 days. The slants were stored at 4°C and subcultured biweekly to ensure viability.

Preparation of Banana Peel Substrate

Fresh banana peels were collected from Ogbomoso central market (Wazo), washed thoroughly with potable water, and oven dried at 60°C for 48 hours to constant weight. Dried peels

were milled into powder using a laboratory blender (Qlink Model QBL-800), sieved through a 1 mm mesh, and stored in sterile airtight containers until use.

Screening of *Fusarium solani* for Amylase Production

Preliminary screening was conducted on starch agar (soluble starch 10 g L^{-1}, yeast extract 2 g L^{-1}, agar 15 g L^{-1}). Plates were inoculated with 5 mm agar plugs of actively growing fungal culture and incubated at 30°C for 72 hours. After incubation, plates were flooded with Gram's iodine solution. The presence of a clear halo indicated starch hydrolysis and positive amylase activity.

Solid-State Fermentation for Alpha Amylase Production

Solid-state fermentation (SSF) was carried out using banana peel powder as substrate. Ten grams of the substrate were dispensed into 250 mL Erlenmeyer flasks and moistened with 10 mL of 0.1 M phosphate buffer (pH 6.5) to achieve 60 % moisture content. The flasks were sterilized at 121°C for 15 minutes and cooled to room temperature. A standardized inoculum of 1×10^7 spores mL^{-1} was prepared in sterile 0.85 % saline containing 0.1 % Tween-80. Each flask was inoculated with 1 mL of the spore suspension, mixed thoroughly, and incubated at 30°C for 120 hours. Crude enzyme extraction was performed by adding 100 mL of 0.1 M phosphate buffer (pH 6.5) to each flask, shaking at 150 rpm for 30 minutes, and filtering through Whatman No. 1 filter paper. The filtrate served as the crude enzyme extract.

Enzyme Activity Assay

Alpha amylase activity was determined using the 3,5-dinitrosalicylic acid (DNS) method (Miller, 1959). The reaction mixture contained 0.5 mL of crude enzyme, 0.5 mL of 1 % soluble starch (prepared in 0.1 M phosphate buffer, pH 6.5), and was incubated at 50°C for 10 minutes. The reaction was stopped by adding 1 mL DNS reagent followed by heating at 90°C for 5 minutes. Absorbance was measured at 540 nm using a UV–Vis spectrophotometer (Jenway 7315). One unit of enzyme activity was defined as the amount of enzyme that released 1 µmol of reducing sugar per minute under assay conditions.

Protein Estimation of the Crude Enzyme

Protein concentration of the crude enzyme was determined using the Bradford method (Bradford, 1976), with bovine serum albumin used as the standard. A standard calibration curve was prepared using known concentrations of bovine serum albumin. The reaction mixture consisted of 10 µl of enzyme solution and 1.0 ml of Bradford reagent. The mixture was allowed to stand at room temperature for 5 minutes, after which the absorbance was measured at 595 nm. Protein concentration was determined by interpolation from the standard curve.

Evaluation of the Physiological Properties of the Enzyme

The physiological properties of the enzyme were evaluated by determining the effects of temperature, pH, metallic salts, substrate specificity, and thermal stability on enzyme activity. In each experiment, the parameter optimized in the preceding assay was maintained at its optimum value in subsequent experiments.

Effect of Temperature on Enzyme Activity

The effect of temperature on enzyme activity was determined by assaying the enzyme at temperatures ranging from 30 °C to 90 °C. The reaction mixture contained 0.25 ml of enzyme extract and 0.5 ml of 1 % soluble starch prepared by dissolving 1 g of starch in 100 ml of distilled water followed by boiling. The reaction mixture was incubated at the respective temperatures for 30 minutes. Enzyme blanks contained substrate and distilled water in place of the enzyme. The reaction was terminated by the addition of 1.0 ml of 3,5dinitrosalicylic acid reagent, followed by boiling for 5 minutes. After cooling, absorbance was measured at 540 nm.

Effect of pH on Enzyme Activity

The effect of pH on enzyme activity was evaluated using different buffer systems: 50 mM citrate buffer (pH 4–5), 50 mM phosphate buffer (pH 6–7), 50 mMTris buffer (pH 8–9), and 50 mM borate buffer (pH 10). The reaction mixture contained 0.5 ml of enzyme extract and 0.5 ml of 1 % soluble starch prepared in the appropriate buffer. The mixture was incubated at 37 °C for 30 minutes. Enzyme blanks contained substrate without enzyme. The reaction was terminated using DNS reagent, and absorbance was measured at 540 nm after boiling and cooling.

Effect of Metallic Salts on Enzyme Activity

The effects of metallic salts on enzyme activity were evaluated using NaCl, $MnCl_2$, $AlCl_3$, and $FeCl_3$ at concentrations of 0.1 mM, 0.5 mM, and 1.0 mM. The reaction mixture contained 0.25 ml of enzyme extract, 0.5 ml of 1 % soluble starch, and 0.05 ml of the respective salt solution. The reaction mixture without metallic salts served as the control and was taken as 100 % activity. Incubation was carried out at 37 °C for 30 minutes. Enzyme blanks contained substrate and salt solution without enzyme. The reaction was terminated with DNS reagent, followed by boiling and absorbance measurement at 540 nm.

Substrate Specificity

Substrate specificity was determined by replacing soluble starch with pectin, pineapple peel extract, and plantain peel extract in a typical enzyme assay. Substrates were prepared at equivalent concentrations. The reaction mixture contained 0.5 ml of substrate and 0.25 ml of enzyme extract. Incubation was carried out at 37 °C for 30 minutes. Enzyme blanks contained substrate and distilled water in place of enzyme. The reaction was terminated using DNS reagent, and absorbance was measured at 540 nm after boiling and cooling.

Thermal Stability of the Enzyme

Thermal stability of the enzyme was evaluated by incubating the enzyme extract at temperatures ranging from 30 °C to 90 °C for one hour. Aliquots were withdrawn at 15 minute intervals and assayed for residual enzyme activity under standard assay conditions. The reaction mixture contained 0.25 ml of enzyme extract and 0.5 ml of 1 % soluble starch. Incubation for the assay was carried out at the respective temperatures for one hour. Enzyme blanks contained substrate and distilled water in place of enzyme. The reaction was terminated with DNS reagent, followed by boiling and absorbance measurement at 540 nm.

Results and Discussion

The *Fusarium solani* isolate produced a clear and well-defined hydrolysis zone on starch agar after iodine staining, while the control plate exhibited uniform blue-black coloration with no clearance. The presence of the halo confirms extracellular starch degradation and demonstrates that *F. solani* actively secretes alpha amylase under the screening conditions. Similar clearance patterns have been widely reported as reliable indicators of amylolytic activity in fungi. Omemu *et al.* (2005) and Adeniran *et al.* (2010) observed comparable starch hydrolysis zones during preliminary screening of fungal and bacterial isolates for amylase production. Likewise, Sanghvi *et al.* (2011) reported that filamentous fungi, particularly species of *Fusarium*, *Aspergillus*, and *Rhizopus*, exhibit strong amylolytic potential detectable through iodine -starch plate assays. The ability of *F. solani* to form a pronounced hydrolysis zone aligns with earlier studies demonstrating its capability to produce extracellular carbohydrate-degrading enzymes. Johann *et al.* (2007a) and Kumar and Duhan (2011) also showed that fungal isolates grown on agricultural substrates produce measurable amylase activity, further supporting the present findings. The observed activity in this study therefore confirms that *F. solani* is a competent amylase-producing organism and is suitable for subsequent optimization under solid state fermentation.

Banana peel was selected as the fermentation substrate due to its high carbohydrate content and its abundance as an underutilised waste material

that contributes to environmental burden. Solid state fermentation using 20 grams of banana peel yielded 350 millilitres of crude enzyme extract. Alpha amylase activity was quantified using the DNSA assay, the reaction mixture exhibited an absorbance of 0.009 at 540 nanometres, corresponding to an enzyme activity of 155 U per millilitre per minute (Table 1). The blank showed no detectable activity. The enzyme activity reported in this study is comparable with findings from related studies. Johann *et al.* (2007a) reported activities between 120 and 310 U per millilitre for fungal alpha amylase produced from agro-wastes. Pandey *et al.* (2000) and Sodhi *et al.* (2005) documented values ranging from 180 to 750 U per millilitre, depending on fermentation conditions, substrate composition, and inoculum load. de Souza *et al.* (2010) similarly observed activities between 150 and 500 U per millilitre using fruit-based solid substrates.

Table 1: Assay of the Crude Enzyme Activity

Test	Enzyme (In µl)	Distilled water (in µl)	1% starch (In µl)	INCUBATED at 37°C FOR 30 MINUTES	Reagent DNS (In µl)	Absorbance at 540nm	Enzyme activity (U/ml/min)
Blank	-	400	100		500	0.000	0.000
Crude Enzyme (Banana Peel)	50	350	100		500	0.009	155±0.78

The Bradford assay showed that the crude enzyme extract contained 0.23 milligrams per millilitre of protein when 100 microlitres of the sample were analysed (Table 2). The protein concentration obtained falls within the expected range for crude extracellular fungal enzyme, which commonly contain between 0.1 and 1.0 milligrams per millilitre depending on the organism, substrate, and extraction method. The measurable protein concentration in the crude extract is consistent with the enzyme activity previously observed, indicating that *Fusarium solani* produced a substantial amount of extracellular protein under solid state fermentation using banana peel as substrate. Comparable studies have also reported similar protein concentrations in crude fungal amylase extracts, where protein levels correlate with catalytic performance and overall fermentation efficiency. Thus, the protein value of 0.23 milligrams per millilitre supports the conclusion that banana peel is a suitable substrate for supporting fungal growth and enzyme secretion.

Table 2 Protein Estimation of the Crude Enzyme

Test	Enzyme (In µl)	Distilled water (In µl)	INCUBATED at 37°C FOR 30 MINUTES	Bradford reagent (In µl)	Absorbance at 540nm	Concentration of protein (mg/ml)
Blank	-	150		500	0.000	0.000
Crude Enzyme	100	-		500	0.009	0.23±0.01

Temperature is a critical factor influencing enzyme activity and stability. As shown in Table 3, alpha amylase activity increased progressively with rising temperature from 30 °C to 80 °C following 30 minutes of incubation. The highest activity of 52.78 U ml^{-1} min^{-1} was recorded at 80 °C, which was significantly higher ($p < 0.05$) than activities observed at all other temperatures, indicating that 80 °C is the optimum temperature for enzyme activity. A sharp decline in activity was observed at 90 °C, where enzyme activity decreased to 15.29 U ml^{-1} min^{-1}, suggesting partial thermal denaturation at higher temperatures. The high optimum temperature observed in this study suggests that the enzyme possesses good thermal tolerance, a desirable characteristic for industrial applications where elevated processing temperatures are often required. Thermal stability is a key criterion for the industrial utilization of alpha amylases, particularly in starch processing and food industries (Ray and Nanda, 1996). In comparison, Aquino *et al.* (2003) reported an optimum temperature of 60 °C for alpha amylase produced by *Scytalidium thermophilum*, while Coronado *et al*. (2000) documented an optimum temperature of 50 °C for alpha amylase from *Fusarium* species, with substantial loss of activity above 70 °C. The higher optimum temperature observed in the present study therefore indicates enhanced thermostability of the enzyme produced by *Fusarium solani* under solid state fermentation using banana peel substrate.

Table 3: Effect of temperature on enzyme activity

Temperature (^{o}C) at 30 minutes incubation	Activity (U/ml/min)
30	4.20 ± 0.10^{a}
40	4.30 ± 0.32^{a}
50	6.67 ± 0.02^{b}
60	14.17 ± 0.12^{c}
70	15.28 ± 0.22^{c}
80	52.78 ± 0.13^{d}
90	15.29 ± 0.11^{c}

Values are mean ± standard deviation. Means with different superscripts within the column are significantly different at $p < 0.05$.

The effect of pH on alpha amylase activity is presented in Table 4. Maximum enzyme activity of 11.50 U ml^{-1} min^{-1} was observed at pH 6.0, which was significantly higher ($p < 0.05$) than activities recorded at all other pH values. Enzyme activity increased progressively from pH 4.0 to pH 6.0, indicating favourable catalytic performance under mildly acidic conditions. Beyond the optimum pH, enzyme activity declined significantly, with reduced activity observed at pH 7.0 and 8.0, and complete loss of activity at pH 9.0 and 10.0. The observed pH profile suggests that the enzyme is acid tolerant and exhibits optimal functionality within the acidic pH range. This behaviour is consistent with previous reports on fungal alpha amylases. Spier (2005) similarly reported an optimum pH of 6.0 for alpha amylase produced by *Fusariumsolani*. Okolo*et al*. (2001) also noted that most fungal amylases display optimal activity within a pH range of 4.5 to 6.0. In addition, Souza and Magalhães (2010) observed that the majority of fungal amylases examined were inactive or poorly active under alkaline conditions, while Michelin *et al*. (2010) reported maximum alpha amylase activity at acidic pH for *Paecilomycesvariotii*. Changes in pH are known to alter enzyme conformation and affect the ionisation state of amino acid residues at the active site, leading to reduced catalytic efficiency beyond the optimum pH. The pH-dependent activity profile observed in this study therefore reflects typical fungal alpha amylase behaviour and suggests suitability for applications requiring acidic processing conditions.

Table 4: Effect of pH on enzyme activity

pH	Activity (U/ml/min)
4	6.50±0.11[c]
5	7.00±0.13[c]
6	11.50±0.24[a]
7	8.50±0.14[b]
8	2.00±0.10[d]
9	00.00[e]
10	00.00[e]

Values are mean ± standard deviation of triplicate determinations.
Means in the same column with different superscript letters are significantly different ($p < 0.05$).

The effect of metallic salts on alpha amylase activity is presented in Table 5. The presence of all tested salts enhanced enzyme activity compared with the control, indicating that metallic ions play an important role in modulating catalytic performance. Among the salts evaluated, $MnCl_2$ exerted the strongest stimulatory effect, producing the highest enzyme activity at all concentrations tested. This was followed by $FeCl_2$, while NaCl and $AlCl_2$ showed comparatively lower levels of activation. For NaCl and $AlCl_2$, enzyme activity increased with increasing salt concentration, suggesting a concentration-dependent stimulatory effect. In contrast, $MnCl_2$ and $FeCl_2$ exhibited relatively stable activity across the concentration range tested, indicating that even low concentrations of these ions were sufficient to achieve maximal enzyme activation. $MnCl_2$-treated samples were significantly higher ($p < 0.05$) than those treated with other salts at corresponding concentrations. The observed enhancement of enzyme activity in the presence of metallic salts supports previous reports that certain metal ions act as cofactors, stabilising enzyme structure or facilitating substrate binding (Morita *et al*., 1998). The ability of the enzyme to retain high activity in the presence of trace concentrations of these salts suggests good tolerance to metal ions, which is advantageous for industrial applications where metal ions may be present due to raw materials or processing equipment. Similar stimulation of amylase activity by metallic salts has been reported for fungal amylases produced under solid state fermentation conditions (Shanti *et al*., 2013).

Table 5: Effect of metallic salts on the enzyme activity

Salts	Activity (U/ml/min)		
	0.10mM	0.50mM	1.00mM
NaCl	38.89±0.24[c]	40.00±0.32 [c]	80.00±0.69[c]
$AlCl_2$	15.00±0.36[d]	30.00±0.24[d]	45.00±0.48[d]
$FeCl_2$	90.20±0.78[b]	91.00±0.89[b]	93.00±0.96[b]
$MnCl_2$	126.40±1.24[a]	126.40±1.02[a]	127.00±1.16[a]

Values are mean ± standard deviation of triplicate determinations.
Within each column, means with different superscript letters are significantly different ($p < 0.05$)

Figure 1 shows the effect of different carbon sources on amylase activity. Pectin supported the highest enzyme activity (19.44 U ml^{-1} min^{-1}), followed by starch (18.06 U ml^{-1} min^{-1}). Lower enzyme activities were obtained when pineapple peel and plantain peel were used as carbon sources, both yielding approximately 15.28 U ml^{-1} min^{-1}. This indicates that pectin was the most effective substrate for enhancing amylase production under the experimental conditions. The superior performance observed with pectin may be attributed to its structural composition and ease of utilization, which can enhance microbial metabolism and enzyme biosynthesis. The availability of readily metabolizable carbon sources has been reported to significantly influence the production of extracellular enzymes, including amylases (Teodoro and Martins, 2000). Although the agro waste substrates supported enzyme production, their comparatively lower activities suggest limited accessibility of fermentable components. In contrast, Ozdemir *et al.* (2009) reported high alpha amylase production from *Bacillus subtilis* using banana peel, while Haq *et al.* (2012) identified potato peel as a highly effective substrate for amylase production by *Paenibacillus amylolyticus*. These variations highlight that substrate efficiency for enzyme production is strongly influenced by the microbial strain and fermentation conditions employed.

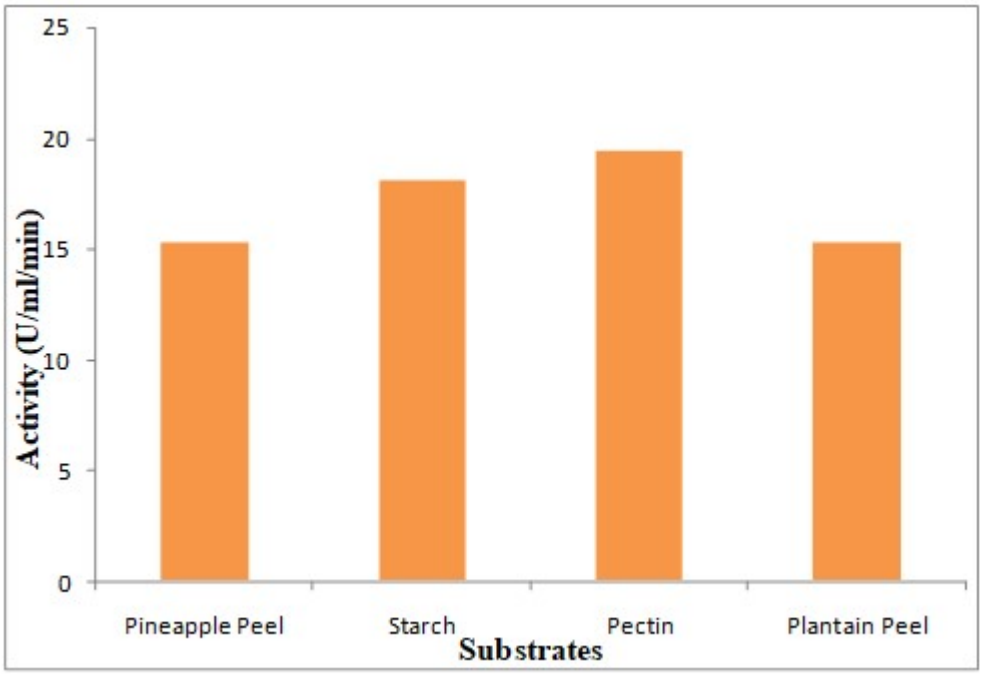

Figure 1: Effect of substrates on enzyme activity

The crude amylase extract exhibited significant temperature dependent stability after one hour of incubation, as shown in Table 6. Enzyme activity increased progressively from 30 °C (4.23 ± 0.24 U/ml/min) to 80 °C (52.75 ± 1.02 U/ml/min), with the highest activity recorded at 80 °C. This value was significantly higher ($p < 0.05$) than activities observed at all other temperatures, indicating that 80 °C represents the optimum temperature for enzyme stability under the experimental conditions. At lower temperatures between 30 and 50 °C, enzyme activity remained relatively low and did not differ significantly, suggesting reduced catalytic efficiency at these temperatures. A notable increase in activity was observed between 60 and 70 °C, followed by a sharp peak at 80 °C. However, a marked decline in activity occurred at 90 °C, indicating partial thermal denaturation of the enzyme beyond its stability limit. The observed thermostability at high temperatures is consistent with previous reports of thermostable amylases. Rasiah and Rehm (2009)

reported an amylase that remained stable at 85 °C, supporting the high temperature tolerance observed in this study. The ability of alpha amylase to function under extreme conditions, including elevated temperatures, extreme pH, and the presence of surfactants and organic solvents, has been well documented (Tanaka and Hoshino, 2002). The industrial relevance of thermostable amylases lies in their ability to operate efficiently at high reaction temperatures, which minimizes microbial contamination and enhances reaction rates. Consequently, thermostable amylases are of considerable importance in biotechnological processes such as starch processing and fermentation industries (Nwaguand Okolo, 2011). Furthermore, understanding enzyme thermo stability is essential for determining appropriate processing conditions, allowing for either preservation of enzymatic activity during heat treatment or intentional inactivation once the desired catalytic effect has been achieved (Onofre *et al*., 2012).

Table 6: Effect of temperature on the stability of the enzyme

Temperature (^{o}C) at 1hour incubation	Activity (U/ml/min)
30	4.23±0.24^{e}
40	4.73±0.12^{e}
50	6.89±0.66^{d}
60	14.21±0.84^{c}
70	15.30±0.98^{b}
80	52.75±1.02^{a}
90	15.30±0.86^{b}

Values are mean ± standard deviation of triplicate determinations.
Means in the same column with different superscript letters are significantly different ($p < 0.05$).

Conclusion

Fusarium solani demonstrated effective production of alpha amylase using banana peels as substrate, highlighting the feasibility of utilizing agro industrial wastes for enzyme production. The enzyme exhibited optimal activity at 80 °C and pH 6.0, with notable thermostability at 80 °C, indicating its suitability for high temperature industrial applications. These findings confirm the potential of *Fusarium solani* to serve as a cost effective and sustainable source of alpha amylase when cultivated on cheap and readily available substrates. The thermostable nature of the amylase, together with its retention of activity in the presence of low concentrations of metallic salts, further enhances its applicability in industrial processes requiring robust enzymes or their hydrolytic products. Although further optimization is required to maximize enzyme yield and performance, the present study provides a strong foundation for its potential industrial exploitation. From a sustainability perspective, this work directly contributes to Sustainable Development Goal 12 (Responsible Consumption and Production) by promoting the valorization of agro industrial wastes and reducing environmental burden. It also supports SDG 9 (Industry, Innovation and Infrastructure) through the development of locally sourced biotechnological solutions, and SDG 13 (Climate Action) by encouraging resource efficient processes that may lower waste related emissions. Overall, the study aligns with global efforts toward sustainable industrial biotechnology and circular bioeconomy development.

References

Adeniran, H.A., Abiose, S.H., Ogunsua, A.O. (2010). Production of fungal alpha amylase and cellulase using waste peels. *African Journal of Biotechnology* 9(32): 5091–5096.

Akpan, I., Bankole, M.O., Adesermowo, A.M. (1999). Production of alpha amylase by *Aspergillus niger* in a cheap solid medium using rice bran and agricultural materials. *Brazilian Archives of Biology and Technology* 44: 79–88.

Aquino, A.C.M.M., Jorge, J.A., Terenzi, H.F., Polizeli, M.L.T.M. (2003). Studies on a thermostable alpha amylase from the thermophilic fungus *Scytalidium thermophilum*. *Applied Microbiology and Biotechnology* 61(4): 323–328.

Bilinski, C.A., Stewart, G.C. (1995). Production and characterization of alpha amylase from *Aspergillus niger*. *International Journal of Engineering Science and Technology* 18: 551–556.

Bradford, M.M. (1976). A rapid and sensitive method for the quantitation of microgram quantities of protein utilizing the principle of protein dye binding. *Analytical Biochemistry* 72: 248–254.

Buzzini, P., Martini, A. (2002). Extracellular enzymatic activity profiles in yeast and yeast like strains isolated from tropical environments. *Journal of Applied Microbiology* 93: 1020–1025.

Coronado, M.J., Vargas, C., Hofemeister, J., Ventosa, A., Nieto, J.J. (2000). Production and biochemical characterization of alpha amylase from the moderate halophile *Halomonas meridiana*. *FEMS Microbiology Letters* 183(1): 67–71.

de Souza, P.M., de Oliveira Magalhães, P. (2010). Application of microbial alpha amylase in industry: a review. *Brazilian Journal of Microbiology* 41: 850–861. https://doi.org/10.1590/S1517-83822010000400004

Djekrif Dakhmouche, S., Gheribi Aoulmi, Z., Meraihi, Z., Bennamoun, L. (2006). Application of a statistical design to the optimization of culture medium for alpha amylase production by *Aspergillus niger* ATCC 16404 grown on orange waste powder. *Journal of Food Engineering* 73: 190–197.

Haq, I., Hameed, U., Mahmood, Z., Javed, M.M. (2012). Solid state fermentation for the production of alpha amylase by *Paenibacillus amylolyticus*. *Pakistan Journal of Botany* 44: 341–346.

Johann, D.A., Gomes, E., da Silva, R. (2007a). Production of extracellular amylase by *Fusarium* species using agroindustrial residues. *Brazilian Journal of Microbiology* 38: 208–217.

Johann, F.O., Herrera, J.L., Couto, S.R. (2007b). Banana skin: a novel waste for lactase production by *Trametes pubescens* under solid state conditions and application to synthetic dye decolouration. *Dyes and Pigments* 75: 32–37.

Kareem, S.O., Akpan, I., Oduntan, S.B. (2009). Cowpea waste: a novel substrate for solid state production of amylase by *Aspergillus oryzae*. *African Journal of Microbiology Research* 3(12): 974–977.

Kumar, V., Duhan, J.S. (2011). Production and characterization of amylase enzyme from *Aspergillus niger*. *International Journal of Pharmaceutical Sciences and Research* 2(5): 1121–1126.

Michelin, M., Silva, T.M., Benassi, V.M., PeixotoNogueira, S.C., Moraes, L.A.B., Leão, J.M., Jorge, J.A., Terenzi, H.F., Polizeli, M.L.T.M. (2010). Purification and characterization of a thermostable alpha amylase produced by the fungus *Paecilomyces variotii*. *Carbohydrate Research* 345(16): 2348–2353.

Miller, G.L. (1959). Use of dinitrosalicylic acid reagent for determination of reducing sugars. *Analytica Chimica Acta* 31: 426–428.

Morita, H., Mizuno, K., Matsunaga, M., & Fujio, Y. (1998). A comparison of raw starch-digesting glucoamylase production in liquid and solid cultures of *Rhizopus* strains. *Journal of General and Applied Microbiology* 44(3): 211–216

Nigam, P., Singh, D. (1995). Enzyme and microbial systems involved in starch processing. *Enzyme and Microbial Technology* 17: 770–778.

Nwagu, T.N., Okolo, B.N. (2011). Production of amylolytic enzymes by microbial isolates. *Brazilian Archives of Biology and Technology* 54(4): 649–658.

Okolo, B.N., Ire, S., Ezeogu, L.I., Anyanwu, C.U., Odibo, F.J.C. (2001). Purification and some properties of a novel raw starch digesting amylase from *Aspergillus carbonarius*. *Journal of the Science of Food and Agriculture* 81: 329–336.

Omemu, A.M., Akpan, I., Bankole, M.O. (2005). Stimulated amylase production by *Bacillus* species isolated from yam peel. *African Journal of Biotechnology* 4(8): 19–25.

Onofre, S.B., Groff, S.A., Sartori, A., Bertolini, J., Kagimura, F.Y., Rotta, D., Mazzali, L., Steilmann, P. (2012).Production of alpha amylase and amyloglucosidase by *Cylindrocladium* sp. in semi solid state fermentation. *Journal of Microbiology Research* 2: 123–126.

Ozdemir, S., Guven, K., Baysal, Z., Uyar, F. (2009).Screening of various organic substrates and development of a suitable low cost fermentation medium for the production of alpha amylase by *Bacillus subtilis*.*Food Technology and Biotechnology* 47(4): 364–369.

Pandey, A., Nigam, P., Soccol, C.R., Soccol, V.T., Singh, D., Mohan, R. (2000). Advances in microbial amylases. *Biotechnology and Applied Biochemistry* 31(2): 135–152. https://doi.org/10.1042/BA19990073

Rasiah, I.A., Rehm, B.H.A. (2009). One step production of immobilized alpha amylase in recombinant *Escherichia coli*.*Applied and Environmental Microbiology***75**(7): 2012–2016. https://doi.org/10.1128/AEM.02782-08

Ray, R.R., Nanda, G. (1996). Microbial beta amylases: biosynthesis, characteristics and industrial applications. *Critical Reviews in Microbiology* 22: 181–199.

Sanghvi, G., Shah, A., Shah, A. (2011). Enhanced production and partial purification of amylase from *Aspergillus oryzae* using solid state fermentation. *Journal of Biochemical Technology* 2(4): 210–216.

Shanti, V., Jha, S., Rai, H., Chattopadhyay, R., Kaur, V.P., Indupriya, M. (2013).Recent research in amylase production.*Recent Research in Science and Technology* 5(2): 52–53.

Sodhi, H.K., Sharma, K., Gupta, J.K., Soni, S.K. (2005). Production of a thermostable alpha amylase from *Bacillus* sp. PS 7 by solid state fermentation and its synergistic use in the hydrolysis of malt starch for alcohol production.*Process Biochemistry* 40: 525–534. https://doi.org/10.1016/j.procbio.2004.01.053

Spier, M.R. (2005). Production of fungal amylolytic enzymes alpha amylase and amyloglucosidase by solid state fermentation. MSc Thesis, Federal University of Paraná, Curitiba, Brazil.

Tanaka, A., Hoshino, E. (2002). Thermodynamic and activation parameters for the hydrolysis of amylose with *Bacillus* alpha amylases in a diluted anionic surfactant solution. *Journal of Bioscience and Bioengineering* 93: 485–490.

Teodoro, C.E.D., Martins, M.L.L. (2000). Culture conditions for the production of thermostable amylase by *Bacillus* sp. *Brazilian Journal of Microbiology* 31: 288–302.

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