

**Amylase production by Solid State Fermentation of agro-industrial wastes
using *Bacillus* species**

ABSTRACT

This study evaluated amylase production by *Bacillus* species employing the solid state fermentation (SSF) method using five agro-industrial wastes namely corn cobs, potato peel and maize straw, groundnut husk and corn chaff. Five *Bacillus* species were tested for amylase production abilities and *Bacillus subtilis* showed the highest amylase production ability after incubation. Corn chaff gave maximum enzyme production (3.25 U/ml) while the least enzyme was recorded on groundnut husk (2.35 U/ml) at 25. Potato peel had maximum enzyme production by *Bacillus subtilis* (3.05 U/ml) at pH 7.0 while the least enzyme production was from groundnut husk (2.84 U/ml) at pH 4.0. Thus there was an increase in enzyme production with corresponding increase in substrate concentration. The results obtained in this study support the suitability of using agro-industrial wastes as solid state fermentation substrates for high production of amylase. It's also a means of solving pollution problems thus making solid state fermentation an attractive method.

Key words: Agro-industrial wastes, amylase, *Bacillus* species, fermentation, solid state.

1.0 INTRODUCTION

Amylase is one of the most widely used enzymes in the industry. It hydrolyses starch and is used commercially for the production of sugar syrups from starch which consist of glucose, maltose, and higher oligosaccharides [1]. Amylases are of great significance in biotechnological applications ranging from food, fermentation, detergent, pharmaceutical, brewing and textile to paper industries [2]. To meet the higher demands of these industries, low cost production of amylase is required.

The amylases can be derived from several sources, such as plants, animals and micro-organisms. Because of their short growth period, the enzymes from microbial sources generally meet industrial demands [3]. The first enzyme produced industrially was an

34 amylase from a fungal source in 1994, which was used for the treatment of digestive
35 disorders [4].

36 Amylase is produced in bacteria, fungi, plants and animals. The major bacteria belong to
37 *Bacillus* species and fungi such as *Aspergillus niger*, *Penicillium* sp., *Cephalosporium* and
38 *Rhizopus* are the major α -amylase producing microorganisms [5]. However, due to efficient
39 production strategies, microorganisms have substantial potential to contribute to a number of
40 industrial applications [6]. Such industrially important microorganisms are found within the
41 *Bacillus* species because of their rapid growth rates that lead to short fermentation cycles,
42 their capacity to secrete proteins into extra cellular medium and general handling safety [7].

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44 Production of these α amylases has been investigated through submerged (SmF) and solid-
45 state fermentation (SSF) [8]. However, the contents of a synthetic medium are very expensive
46 and uneconomical, so they need to be replaced with more economically available agricultural
47 and industrial by-products, as they are considered to be good substrates for SSF to produce
48 enzymes [9]. Therefore this study focused on the production of amylase enzyme by solid
49 state fermentation of different agro-industrial wastes (corn cobs, potato peel and maize straw,
50 groundnut husk and corn chaff) using *Bacillus* species.

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52 1.1 MATERIALS AND METHODS

53 1.2 COLLECTION OF SUBSTRATE

54 Five Agro industrial wastes namely corn cobs, potato peel, maize straw, groundnut husk and
55 corn chaff were collected from different locations in Umuahia. They were washed with
56 distilled water 2-3 times and then treated with 1% NaOH for 30 min. The substrates were
57 autoclaved and dried in oven at 80°C for two days. Dried substrates were ground using a
58 grinder to fine particles [10].

59 **1.3 TEST BACTERIUM**

60 Stock culture plate of *Bacillus* species sourced from National Roots Crops Research Institute,
61 Umudike maintained on Nutrient Agar slant was used as starter culture for the fermentation.

62 **1.4 SCREENING OF TEST BACTERIAL**

63 Primary screening of test bacteria for production of alpha amylase was done by the Starch
64 Agar Plate Method described by Joanne et al. [11]. Species that showed the widest zone of
65 clearance in starch hydrolysis were selected for use in Solid State Fermentation.

66 **1.5 Solid State Fermentation technique**

67 Solid state fermentation experiments as described by Rajshree and Rajni. [12] were
68 conducted in 100ml Erlenmeyer flasks containing 1g of the substrate impregnated with 10ml
69 of sterile liquid nutrient broth (beef extract 3g, peptone 5g). The flasks were autoclaved at
70 121°C for 15min, and inoculated with 1ml of the prepared inoculum, thoroughly mixed and
71 incubated at 37°C for 5 days.

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74 **1.5.1 Enzyme extraction**

75 The amylase enzyme was extracted from Solid State Fermentation medium by a simple
76 contact method described by Jamieson et al. [10]. After incubation, 100 mL sodium
77 phosphate buffer of pH 6.9 was added into each experimental flask. The flaks were shaken
78 (150 rpm) for half an hour and the material was filtered through a filter paper. The filtrate
79 was centrifuged at 1000 (r) for 10 min at -10°C. The supernatant was carefully collected and
80 used as crude enzyme extract.

81 **1.6 AMYLASE ENZYME ASSAY**

82 For assay, previously inoculated nutrient starch broth was centrifuged at 8000g for 12
83 minutes and the supernatant was used as crude enzyme source. The assay of amylase was
84 conducted following the method of [10].

85 1.7 Optimization of fermentation parameters for amylase production and activity

86 Optimization of agro industrial wastes samples fermentation was for the following
87 parameters for amylase production: incubation period, temperature, medium pH, and
88 substrate concentration [13].

89 1.8 Statistical Analysis

90 One-Sample T-Test was used to investigate the significant difference in the effects
91 fermentation parameters of the substrates for amylase activity at 95% confidence interval.
92 The data were analyzed using the program IBM SPSS Version 16.

94 2.0 RESULTS

95 Table 1 shows the shows the identification and characterization of *Bacillus* spp

96 Table 2 shows the effect of incubation period on amylase enzyme. The isolate showed
97 highest production of amylase after 35hours of incubation at 2.11 U/ml, 2.33 U/ml and 2.39
98 U/ml respectively.

99 Table 3 shows the effect of Temperature on amylase production. The maximum enzyme
100 production was detected at 40°C (2.52 U/ml, 2.35 U/ml, 2.45 U/ml, 2.30 U/ml and
101 2.44 U/ml) for each of the substrates respectively.

102 Table 4 shows the effect of pH of the medium on amylase production. Maximum enzyme
103 activity was at pH 7.0, enzyme was produced maximally (2.55 U/ml), (2.54 U/ml),
104 (2.34 U/ml), (2.43 U/ml) and (2.49 U/ml) respectively. It was recorded at pH8 that the
105 activity of enzyme were slightly declined (2.35 U/ml), (2.30 U/ml) and (2.25 U/ml) for each
106 substrate at 24 hours of incubation.

107 Table 5 shows the effect of substrate concentration on amylase production. There was
108 increase in enzyme production with increase in substrate concentration up to 5g.

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Table 1: Identification and characterization of *Bacillus* species

Colonial features	Gram Reaction	Cell Arrangement	Spore stain	Catalase	Oxidase	Coagulase	Indole	Citrate	Motility	Methyl Red	Voges-P	Suspected bacteria
White Moisture	+	Short Rod	+	+	-	-	-	+	+	+	+	<i>Bacillus</i> spp

Key: - = Absent, + = Present

Table 2: Effect of Incubation Period on Amylase Activity (U/ml)

Sample Substrate and Optical Density Reading (540nm)						
Incubation Period (hr)	Corn Cobs	Potato Peels	Maize Straws	Groundnut Husks	Corn chaffs	Standard Values
25	1.46 ^a ± 0.71	1.45 ^a ± 0.71	1.44 ^a ± 0.71	1.32 ^c ± 0.71	1.48 ^a ± 0.71	0.00
30	1.75 ^b ± 0.71	1.79 ^b ± 0.71	1.75 ^c ± 0.71	1.68 ^d ± 0.71	1.81 ^b ± 0.71	0.00
35	2.84 ^c ± 0.71	2.86 ^d ± 0.71	2.83 ^c ± 0.71	2.75 ^b ± 0.71	2.89 ^c ± 0.71	0.00
40	2.61 ^d ± 0.71	2.59 ^d ± 0.71	2.60 ^d ± 0.71	2.55 ^b ± 0.71	2.65 ^d ± 0.71	0.00
45	2.52 ^c ± 0.71	2.55 ^c ± 0.71	2.56 ^c ± 0.71	2.50 ^c ± 0.71	2.02 ^c ± 0.71 ^a	0.00

Same superscripts down the columns are not significantly different (P≤0.05)

Values are mean ± standard deviations from two replicates

Table 3: Effect of Temperature on Amylase Activity (U/ml)

Substrate	Temperature (°C)				
	25	30	35	40	45
Corn Cobs	1.75 ^b ± 0.71	2.45 ^a ± 0.71	2.65 ^a ± 0.71	2.94 ^a ± 0.71	2.80 ^c ± 0.71
Potatoes Peel	1.72 ^c ± 0.71	2.35 ^a ± 0.71	2.70 ^b ± 0.71	2.95 ^b ± 0.71	2.65 ^d ± 0.71
Maize Straw	1.85 ^c ± 0.71	2.55 ^a ± 0.71	2.80 ^c ± 0.71	3.02 ^c ± 0.71	2.72 ^e ± 0.71
Groundnut Husk	1.71 ^a ± 0.71	2.35 ^d ± 0.71	2.76 ^d ± 0.71	2.32 ^d ± 0.71	2.62 ^c ± 0.71
Corn chaff	1.70 ^a ± 0.71	3.25 ^e ± 0.71	2.55 ^e ± 0.71	2.75 ^e ± 0.71	2.57 ^b ± 0.71

Same superscripts down the columns are not significantly different (P≤0.05)

Values are mean ± standard deviations from two replicates

Table 4: Effect of pH Amylase Activity (U/ml)

Substrate	pH				
	4.0	5.0	6.0	7.0	8.0
Corn Cobs	1.90 ^a ± 0.71	2.02 ^b ± 0.71	2.50 ^d ± 0.71	3.04 ^a ± 0.71	2.85 ^a ± 0.71
Potatoes Peel	1.95 ^a ± 0.71	2.05 ^c ± 0.71	2.55 ^d ± 0.71	3.05 ^a ± 0.71	2.80 ^a ± 0.71
Maize Straw	1.92 ^a ± 0.71	2.00 ^d ± 0.71	2.55 ^d ± 0.71	2.99 ^c ± 0.71	2.75 ^b ± 0.71
Groundnut Hust	1.81 ^c ± 0.71	2.45 ^e ± 0.71	2.64 ^a ± 0.71	2.84 ^c ± 0.71	2.65 ^c ± 0.71
Corn chaff	1.85 ^c ± 0.71	1.92 ^e ± 0.71	2.62 ^a ± 0.71	2.93 ^d ± 0.71	2.65 ^c ± 0.71

Same superscripts down the columns are not significantly different ($P \leq 0.05$)

Values are mean \pm standard deviations from two replicates

Table 5: Effect of substrate concentration on Amylase Activity (U/ml)

Substrate	Substrate concentration (g)				
	1	2	3	4	5
Corn Cobs	1.46 ^b \pm 0.71	1.94 ^a \pm 0.71	2.39 ^a \pm 0.71	2.75 ^a \pm 0.71	3.32 ^a \pm 0.71
Potato Peels	1.55 ^a \pm 0.71	1.76 ^b \pm 0.71	2.07 ^b \pm 0.71	2.89 ^b \pm 0.71	3.49 ^b \pm 0.71
Maize Straws	1.02 ^c \pm 0.71	1.34 ^c \pm 0.71	2.70 ^c \pm 0.71	3.06 ^c \pm 0.71	3.21 ^c \pm 0.71
Groundnut Husks	1.52 ^d \pm 0.71	1.71 ^b \pm 0.71	1.94 ^d \pm 0.71	2.82 ^b \pm 0.71	3.05 ^d \pm 0.71
Corn chaffs	1.34 ^e \pm 0.71	1.86 ^e \pm 0.71	2.15 ^e \pm 0.71	2.69 ^a \pm 0.71	2.94 ^e \pm 0.71

Same superscripts down the columns are not significantly different ($P \leq 0.05$)

Values are mean \pm standard deviations from two replicates

DISCUSSION

This study evaluated amylase production by solid state fermentation of agro-industrial wastes using *Bacillus* spp. The amylase production by *Bacillus subtilis* is influenced by number of fermentation parameters. *The Bacillus subtilis* showed the highest amylase production at 24 hours of incubation with Potatoes Peel having the highest production of amylase (2.36 U/ml) at 35°C, followed by Corn Cobs which also recorded high amylase production (2.34 U/ml) at 35°C. Hence Potatoes Peel is the best substrate for enzyme activity when compared to other agro-industrial wastes in this study. Similar result was reported by [14], who found out that wheat bran was a better substrate for α -amylase production by *Bacillus licheniformis*. Gangadharan et al. [15] have reported that maximum amylase production was achieved at 24-48 h incubation period. *Bacillus subtilis* has shorter period of incubation for the production of α -amylase when compared to earlier reports. [16] evaluated the production of amylase at 12, 24, 36, 48 and 60 hours using *B. subtilis* cultured on banana waste and found more production at 24 hours, which corroborate with the present study. Above this incubation period, the amylase enzyme activity started to decrease. This may be due to the decrease in

growth of the isolate. Most of the studies reported the highest enzyme production between 35 hours and 48 hours [17] on the contrary, (B5) showed optimum production after 25 hours, thus proving early harvesting time for industrial use.

Temperature is one of the important physical factors influencing the enzyme production [18]. Corn chaff produced the maximum enzyme production at 30°C (2.75 U/ml). This could be due to the mesophilic nature of the organism. The finding of this present study supports the finding of [19] who found that amylase produced by *Bacillus subtilis* JS2004 gave the best activity at 40°C.

The result of the effect of temperature on enzyme production by *Bacillus subtilis* was almost identical to that reported for *B. lichemiformis* growing on wheat bran [20], for *Bacillus subtilis* growing on banana stalk [21], for *Bacillus megaterium* isolated from cassava waste [22]. Whereas, Vipul et al. [23] reported that the optimum temperature of enzyme activity was 40°C. These results indicate the independent nature of the temperature effect irrespective of the type of solid substrate used. It was also observed in this study that the enzyme production declined below and above 40°C temperature and this was due to lesser growth of the bacteria [24]. [25] also evaluated the influence of temperature on amylase production.

Among the physicochemical parameters, pH of the growth medium plays an important role by inducing morphological changes in the organism and in enzyme secretion. Variation of pH results due to substrate consumption (eg: protein hydrolysis) and metabolite production like organic acids. Increase in pH from 4 to 6 increases enzyme activity, further increase in pH up to 9 decreases activity. *Bacillus subtilis* could grow and produce α -amylase over a wide range of pH (4-11). Potatoes peel had maximum enzyme production (2.55 U/ml) at pH 7.0. Similarly, [26] observed pH 7 as optimum for amylase production by *Bacillus amyloliquefaciens*. For the amylase production, most of the *Bacillus* sp. reported to have optimum pH between 7-10 [27]. [21] reported production of α -amylase by *Bacillus subtilis*

on banana fruit stalk and got optimum activity at pH 7.0. [28] reported production of α -amylase by *Bacillus subtilis* utilizing banana peel and got optimum activity at pH 7.0. It was recorded that at pH 8 the activity of enzyme slightly declined to (2.35 U/ml), (2.30 U/ml) and (2.25 U/ml) for each substrate at 24hours of incubation. When pH is altered below or above the optimum the activity it appears to be decreased or becomes denatured [29]. Different organisms have different pH optima and decrease or increase in pH on either side of the optimum value results in poor microbial growth [30] went on to report 6.8 as an optimum pH for the production of amylase by *B. subtilis*.

It has been suggested that the metabolic activity of bacteria is very sensitive to pH level of media. [31] reported that the initial pH of solid substrate was found to have an impact on α -amylase production by *Bacillus subtilis* grown on Poat Moss (PM). Further, the type of buffer used in nutrient solution is a key factor in governing α -amylase production by the *Bacillus subtilis*.

It was observed in this study that after 24 hours of incubation at 35°C, broth slightly increased from 1g to 5g, having maximum enzyme production at 2.99 U/ml, 2.82 U/ml and 2.71 U/ml from the various substrates. Thus, the ability of enzyme production means the more substrate concentration the more the enzyme production. This could be attributed to the fact that bacteria might have utilized medium faster and has undergone decline phase due to nutrient depletion. The difference in enzyme production could be attributed to certain factors which are associated either with the structure of the substrate or with the composition of individual substrates. These results support the suitability of using agro-industrial wastes as solid substrate for high production of α -amylase [32].

The contents of synthetic media are very expensive and these contents might be replaced with more economically available agricultural by-products to reduce the cost of the media [14]. Therefore, agro-industrial wastes and by-products such as starchy materials had been used for

Biosynthesis of amylases to solve the pollution problems and obtain a low cost media [33].

The use of agricultural wastes makes solid--state fermentation (SSF) an attractive alternative method [34].

CONCLUSION

Among the cheap sources tested, potatoes peel was best for maximum amylase production at 35 °C. The optimum activity of enzyme was obtained at 40°C incubation temperature and 35 hours incubation period.

REFERENCES

1. Hagihara, H., Igarashi, K., Hayashi, Y., Endo, K., Ikawa-Kitayama, K., Ozaki, K., Kawai, S., Ho, S. (2001). Novel α amylase that is highly resistant to chelating reagents and chemical oxidants from the alkaliphilic *Bacillus* isolate KSM.K.38. *Applied Environmental Microbiology*, 67: 1744–1750.
2. Kathiresan, K., and Manivannan, S. (2006). α Amylase production by *Penicillium fellutanum* isolated from mangrove rhizosphere soil. *African Journal of Biotechnology*, 5(10): 829-832.
3. Odee, D.W., Sutherland, J.M., Makatiani, E.T., Mc Inory, S.G., Sprent, J.I. (2007). Plant Soil, International training course on solid state fermentation. Document ORSTOM, Montpellier France, 188: 65-75.
4. Crueger, W., and Crueger, A. (2009). *Industrial Microbiology*. Sinauer Associates, Sunderland, 40: 225-234.
5. Suganthi, R., Benazir, J.F., Santhi, R., Ramesh Kumar, V., Hari, A., Meenakshi, N., Nidhiya, K.A., Kavitha, G. and Lakshmi, R. (2011). Amylase production by *Aspergillus niger* under solid state fermentation using agroindustrial wastes. *International Journal of Engineering Science and Technology*, 3(2): 1756-1763.
6. Sodhi, H.K., Sharma, K., Gupta, J.K., and Soni, S.K. (2005). Production of a thermostable α 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.
7. Pandey, A., Nigam, P., Soccol, C.R., Soccol, V.T., Singh, D. and Mohan, R. (2000). Advances in microbial amylases. *Biotechnology and Applied Biochemistry*, 31(2): 135-152.
8. Perez-Guarre, N., Torrado-Agrasar, A., Lopez-Macias, C., and Pastrana, L. (2003). Main characteristics and application of solid substrate fermentation, *Electron. Journal of Environmental Agriculture and Food Chemistry*, 2: 243–350.
9. Kunamneni, A., Perumal, K., and Singh, S. (2005). Amylase production in solid state fermentation by the thermophilic fungus *Thermomyces Lanuginosus*. *Journal of Bioscience and Bioengineering*, 100(2): 168 – 171.
10. Jamieson, A. D., Pruitt, K. M. and Caldwell, R. C. (2001). An improved amylase assay. *Journal of Dental Research*, 48(3): 483-496.

11. Joanne, M.W., Lind, M.S and Christopher, J.W. (2011). Dyes and Simple Staining. The study of microbial structures. Microscopy and specimen preparation. *Prescott's Microbiology* 8th Edition. Mc Graw-Hill, New-York, 36-37.
12. Rajshree S. and Rajni S.(2011). Amylase production by solid-state fermentation of agro-industrial wastes using *Bacillus sp.* *Brazilian Journal of Microbiology*, 42: 1334-1342.
13. Ramesh, M.V. and Lonsane, B.K. (2007). Effect of cultivation conditions on growth and α -amylase production by a thermophilic *Bacillus sp.* *Biotechnology Letters*, 7: 501-504.
14. Ikram-ul-Haq, H., Ashraf, J. and IqbalQadeer, M.A. (2003). Production of alpha amylase by *Bacillus licheniformis* using an economical medium, *Bio-resources Technology*, 87: 57-61.
15. Gangadharan, D., Sivaramakrishnan, S., Nampoothiri, K.M. and Pandey, A. (2006). Solid Culturing of *Bacillus amyloliquefaciens* for Alpha Amylase Production., *Food Technology and Biotechnology*, 44: 269-274.
16. Chandrashekar, U., Radha, I. K. and Basappa, B. K. (2012). Production of α -amylase Using Banana Waste by *Bacillus subtilis* Under Solid State Fermentation. *European Journal of Experimental Biology*, 2(4): 1044-1052.
17. Raju, E. V. N. and Divakar, G. (2013). Production of amylase by using *Pseudomonas aeruginosa* isolated from garden soil. *International Journal of Advances in Pharmacy, Biology and Chemistry*, 2(1):50-56.
18. Ritesh, P., Arbat, T. and Barkha, S, (2011). Production of Glucoamylase by *Aspergillus oryzae* Under Solid State Fermentation Using Agro Industrial Products. *International Journal of Microbiological Research*, 2(3): 204-207.
19. Asgher, M., Asad, M.J., Rahman, S.U. and Legge, R.L. (2007). A thermostable α -amylase from a moderately thermophilic *Bacillus subtilis* strain for starch processing. *Journal of Food Engineering*, 79(3): 950-955.
20. Ramesh, M.V. and Lonsane, B.K., (2009). Optimization, production and partial purification of extracellular α -amylase from *Bacillus* spp. *Biotechnology Letters*, 11: 49-52.
21. Krishna C., Chandrasekaran, M. (2006). Selection of microorganisms which produce raw-starch degrading enzymes, *Applied Microbiology and Biotechnology*, 27: 443-446.
22. Mukesh, K. D. J., Silambarasanb, T., Renugac, R., Ravi, K.M., Karthigai, D.S., Dhandapani, R. and Kalaichelvana, P. T. (2012). Production of a thermostable α -amylase from *Bacillus* sp. PS-7 by solid state fermentation and its synergistic use in the hydrolysis of malt starch for alcohol production.. *European Journal of Experimental Biology*, 2(3):590-595
23. Vipul, V., Mrigank, S. A., Abhishek, R. G., Monika, S. and Akhilesh, K. (2011). Identification and Characterization of α -Amylase from Yemeni Bean seeds *Euro. Journal of Experimental Biology*, 1(3):90-96
24. Khurshid, S., Ali, K., Ashraf, H., Qadeer, M.A. and Rajoka, I. (2001). Optimization of agro-residual medium for α -amylase production from a hyper-producing *Bacillus subtilis* KCC103 in submerged fermentation *Microbiology and Biotechnology*, 17: 35-37
25. Vasantha, R. and Hemashenpagam, N. (2012). Production and Medium Optimization of Amylase by *Bacillus* using Fermentation Methods. *Journal of Microbiology and Biotechnology Research*, 2(4): 481-484.

26. Tanyildizi, M.S., Özer, D. and Elibol, M. (2007). Optimization of α -amylase production by *Bacillus* sp. using response surface methodology. *Proceedings of Biochemistry*, 40(7): 2291-2296.
27. Saxena, R. and Singh, R. (2011). Amylase production by solid-state fermentation of agro-industrial wastes using *Bacillus* sp. *Brazilian Journal of Microbiology*, 42(4): 1334-1342.
28. Shaista, K., Asghar, M., Rehman, K. and Asad, M.J. (2003). Bioprocessing of Banana Peel for Alpha-amylase production by *Bacillus Subtilis*, *International Journal of Agriculture and Biology*, 6: 56-78
29. Basabrani, B.G., Devi, S.B. Unni, W. and Samanta R. (2012). Immobilization of Partially Purified Alpha-amylase Enzyme Produced by a Soil born *Bacillus spp.* *Advances in Applied Science Research*, 3(5): 2739-2744.
30. Radley, J.A. (2006). Industrial Uses of Starch and Its Derivatives. Applied Science Publishers Ltd, London, 51-85.
31. Kim, J.H., Hosobuchi, M., Kishimoto, M., Seki, T., Yoshida, T., Taguchi, H. and Ryu, D.D.Y. (2005). Cellulase production by a solid state culture system. *Biotechnology and Bioengineering*, 27:1445-1450.
32. Sidhu, G.S., Sharma, P., Chakrabarti, T. and Gupta, J.K. (1997). Strain improvement for the production of a thermostable α -amylase. *Enzyme and Microbiology Technology*, 21(7):525-530.
33. Mukherjee, A.K., Adhikari, H. and Rai, S.K. (2008). Production of alkaline protease by a thermophilic *Bacillus subtilis* under solid-state fermentation (SSF) condition using Imperata cylindrica grass and potato peel as low-cost medium: characterization and application of enzyme in detergent formulation. *Biochemical Engineering Journal*, 39(2): 353-361.
34. Ellaiah, P., K., Adinarayana, Y., Bhavani, P., Padmaja, and Srinivasulu, B., (2002). Optimization of process parameters for glucoamylase production under solid state fermentation by a newly isolated *Aspergillus* species. *Process Biochemistry*, 38: 615-620.