International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 01 | Jan 2019 www.irjet.net p-ISSN: 2395-0072

A REVIEW OF LITERATURE ON ISOLATION OF BACTERIA α- AMYLASE

Lemo Ayodeji Oluwadamilare[1], Odutayo, E. Oluwatofunmi[2], Ametefe, George Dzorbenya[3], Farinu Adekunle.O[4]

[1]PhD Scholar, Department of Biochemistry, Covenant University, Ogun State, Nigeria
[2,3]PhD Scholars, Department of Biochemistry, Covenant University, Ota, Ogun State, Nigeria.
[4]Lecturer, Department of Biochemistry, Federal College of Agriculture, Moor Plantation, Ibadan. Oyo State, Nigeria.

Abstract - *Alpha-amylases are enzymes that catalyses the hydrolysis of starch into oligosaccharides, maltose and glucose. They are widely distributed in microbial, plant and animal kingdoms. α-amylases are one of most important and used enzymes whose range of application has widened in many sectors, which include manufacture of High Fructose Corn Syrup (HFCS).This study is aimed at reviewing related literature on isolating and production of amylase from bacteria. Literature reviewed in this article include those on isolation of bacteria producing amylase, production and optimization processes involved and other closely related and recent literature.*

This study also seeks to discover research gap in this field of study that needs to be filled by researchers and appropriate recommendations made. A thorough literature was conducted to come up with the conclusions in this review article.

Key Words: **Bacillus Subtillis, α- Amylase, amylolytic enzyme, bacteria, isolation.**

1. INTRODUCTION

Amylases are enzyme that catalyses the hydrolysis of starch into sugars. They are present in the saliva of humans and some other mammals, where it begins the chemical process of digestion. Foods that contain large amounts of starch but little sugar, such as rice and potato, taste slightly sweet as they are chewed because amylase turns some of their starch into sugar in the mouth. The pancreas and salivary gland makes amylase (alpha amylase) to hydrolyse dietary starch into disaccharides and trisaccharides which are converted by other enzymes to glucose to supply the body with energy. Plants and some bacteria also produce amylase. Amylase was the first enzyme to be discovered and isolated (by Anselme Payen in 1833). (Richard, 2002)

The history of amylases began in 1811 when the first starch degrading enzyme was discovered by Kirchhoff this was followed by several reports of digestive amylases and malt amylases. It was much later in 1930 that Ohlsson suggested the classification of starch digestive enzymes in malt as α and β amylases according to the anomeric type of sugars produced by the enzyme reaction.

Amylases can be classified into different types; alpha, beta amylase and debranching enzyme. The α-amylases (EC 3.2.1.1) (alternative names: 1,4-α-D-glucan glucanohydrolase; glycogenase) are calcium metalloenzymes, completely unable to function in the absence of calcium. They act at random locations along the starch chain, α-amylase breaks down long-chain carbohydrates, yielding maltotriose and maltose from amylose, maltose, glucose and "limit dextrin" from amylopectin. Because it can act anywhere on the substrate, α-amylase tends to be faster-acting than β-amylase. In animals, it is a major digestive enzyme, and its optimum pH is 6.7–7.0. The α-amylases form is also found in plants, fungi (ascomycetes and basidiomycetes) and bacteria (*Bacillus*).

Another form of amylase, β-amylase (EC 3.2.1.2) (alternative names: 1,4-α-D-glucan maltohydrolase; glycogenase; saccharogen amylase) is also synthesized by bacteria, fungi, and plants. They act from the non-reducing end, β-amylase catalyzes the hydrolysis of the second α-1,4 glycosidic bond, cleaving off two glucose units (maltose) at a time. During the ripening of fruit, β-amylase breaks starch into maltose, resulting in the sweet flavor of ripe fruit. Both α-amylase and β-amylase are present in seeds; β-amylase is present in an inactive form prior to germination, whereas α-amylase and proteases appear once germination has begun. Many microbes also produce amylase to degrade extracellular starches. Animal tissues do not contain β-amylase, although it may be present in microorganisms contained within the digestive tract. The optimum pH for β-amylase is 4.0–5.0

Alpha amylases are one of most important and used enzymes whose range of application has widened in many sectors. They have found applications in food, baking, brewing, textile and paper industries. Increasing utility and consumption of alpha amylase in different industries has placed a greater stress on increasing indigenous enzyme production and search of more rapid processes (Carlsen *et al*., 1996; Ramachandran *et al*., 2004; Kathiresan and Manivanan, 2006; Gupta *et al*., 2008).

Though α-amylase can be derived from several sources such as plants, animals and microorganisms, the production from plants and animals is limited because of low concentration of enzymes in the plant material, thus requiring the processing of large amount of plant material; on the other hand enzyme of animal origin is by- product of meat industry. However bacteria can produce large amounts of the enzyme through fermentation to meet the market demands.

1.1 STUDY OBJECTIVES

This study is aimed at reviewing related literature on isolating and production of amylase from bacteria and also production and optimization processes involved. Literature reviewed in this article include those on isolation of bacteria producing amylase, production and optimization processes involved and other closely related and recent literature.

This study also seeks to discover research gap in this field of study that needs to be filled by researchers in this field and appropriate recommendations made.

2.0 LITERATURE REVIEW

2.1 Historical Background

Amylase is one of the oldest enzymes known, the history of amylase began in 1815 when Kirchhoff laid the foundation for the discovery of amylase, Kirchhoff preformed an experiment, which converted four parts of water, two parts of starch, and malt into a starch paste. This paste began to liquefy into sweet syrup; his results showed that gluten had the capacity to convert a larger quantity of starch into sugar. In 1831, Erhard Friedrich Leuchs described the hydrolysis of starch by saliva, due to the presence of an enzyme in saliva, "ptyalin", an amylase (Erhard 1831). In 1833, Anselme Payen and Jean-François Persoz further describe and isolate diastase (amylase) in powder form from barley malt, showing it to be heat labile (Encyclopedia.com).

Enzymes capable of hydrolysing starch and related saccharides are produced by both prokaryotes and eukaryotes, i.e. by organisms belonging to all the three domains of life: Bacteria, Archaea and Eucarya. In other words, different amylolytic enzymes are known to be of animal, plant and microbial origins. Since degradation of starch usually requires co-operation of several amylolytic enzymes, starch-degrading organisms often have several amylolytic activities (Vihinen & Mäntsälä, 1989). On the other hand, not all the living organisms able to utilise starch and/or related saccharides always produce all the enzymes necessary for complete degradation of these substrates. α-Amylases and related enzymes (e.g. α- glucosidases, pullulanases) as well as glucoamylases have been reported to occur in a wide variety of organisms, especially of microorganisms (Fogarty, 1980; Vihinen & Mäntsälä, 1989). They are produced also by animals and plants (Janeèek & Balaz, 1992; Pandey, 1995). On the other hand, β-amylases have been found to be distributed in higher plants and some microorganisms only (Adachi *et al*. 1998; Mikami *et al*., 1999).

Due to the improvement of the industrial starch degradation process there has been a great interest in extremely thermostable amylolytic enzymes, especially in glucoamylase involved in the second step, i.e. in conversion of starch dextrin to glucose (Legin *et al*., 1998; Reilly, 1999). In the first step, degradation of starch into the limit dextrin, the highly thermostable α-amylase from Bacillus licheniformis is used at about 95°C (Legin *et al*., 1998). The used glucoamylase, which is produced by filamentous fungi, works at 60°C (Reilly, 1999). Having thermostable glucoamylase suitable for the industrial use would reduce the cost of the starch degradation process by reducing the process to a single step. Since Archaea were found to be a good source of hyperextremostable enzymes (Woese, 1987), many efforts have been aimed at finding, isolation and biochemical characterisation of amylolytic enzymes, especially glucoamylase, of archaeal origin.

2.2 Different forms amylases

At present there are more than about 30 different amylolytic and related enzymes (Janeèek, 1997). Degradation of starch is essentially performed by the four groups of enzymes (Guzmán-Maldonado & Paredes-López, 1995): endo and exo-amylases acting primarily on α-1,4-linkages, debranching enzymes attacking mainly the α-1,6-linkages, and cyclodextrin glycosyltransferases that degrades starch by catalysing mainly cyclisation and disproportionate reactions.

Endoamylases cleave only the α-1,4-bonds in starch in the inner regions of the starch molecule by passing the α-1,6-branching points of amylopectin (Vihinen & Mäntsälä, 1989).

The α- amylase (EC 3.2.1.1) is the best known endoamylase. It causes a rapid loss of viscosity of the starch solution. These enzymes are often divided according to degree of hydrolysis of substrate into two categories: liquifying (30-40%) and saccharifying (50-60%). This division is widely used to describe the properties of α--amylases (Vihinen & Mäntsälä, 1989). Thus the products of endoamylases are oligosaccharides of varying lengths.

Exoamylases also cleave the α-1,4-bonds, e.g. β-amylase (EC 3.2.1.2), but some of them are able to attack the α-1,6-bonds, e.g. glucoamylase (EC 3.2.1.3). These enzymes act externally on substrate bonds from the non-reducing end of starch and hence produce only low molecular weight products from starch, e.g. maltose and glucose, respectively (Wind, 1997).

Pullulanase (EC 3.2.1.41) and isoamylase (EC 3.2.1.68) may be the examples of debranching enzymes. Both are specific for α-1,6-bonds in starch (amylopectin) and related polysaccharides and branched limit dextrins. According to the inability or ability to degrade also the α-1,4- glucosidic bonds, pullulanases are classified into two categories (Wind, 1997): pullulanase I and pullulanase II, respectively. Pullulanase type II is usually referred to as _-amylase-pullulanase or amylopullulanase.

The fourth group of starch-degrading enzymes is the cyclodextrin glycosyltransferases (CGTases, EC 2.4.1.19). They produce cyclodextrins from starch, the rings which are composed of 6, 7 or 8 glucose units bound by α-1,4- bonds (Pócsi, 1999). The CGTases catalyse intra and intermolecular reaction of glycosyl transfer (Svensson & Sogaard, 1993).

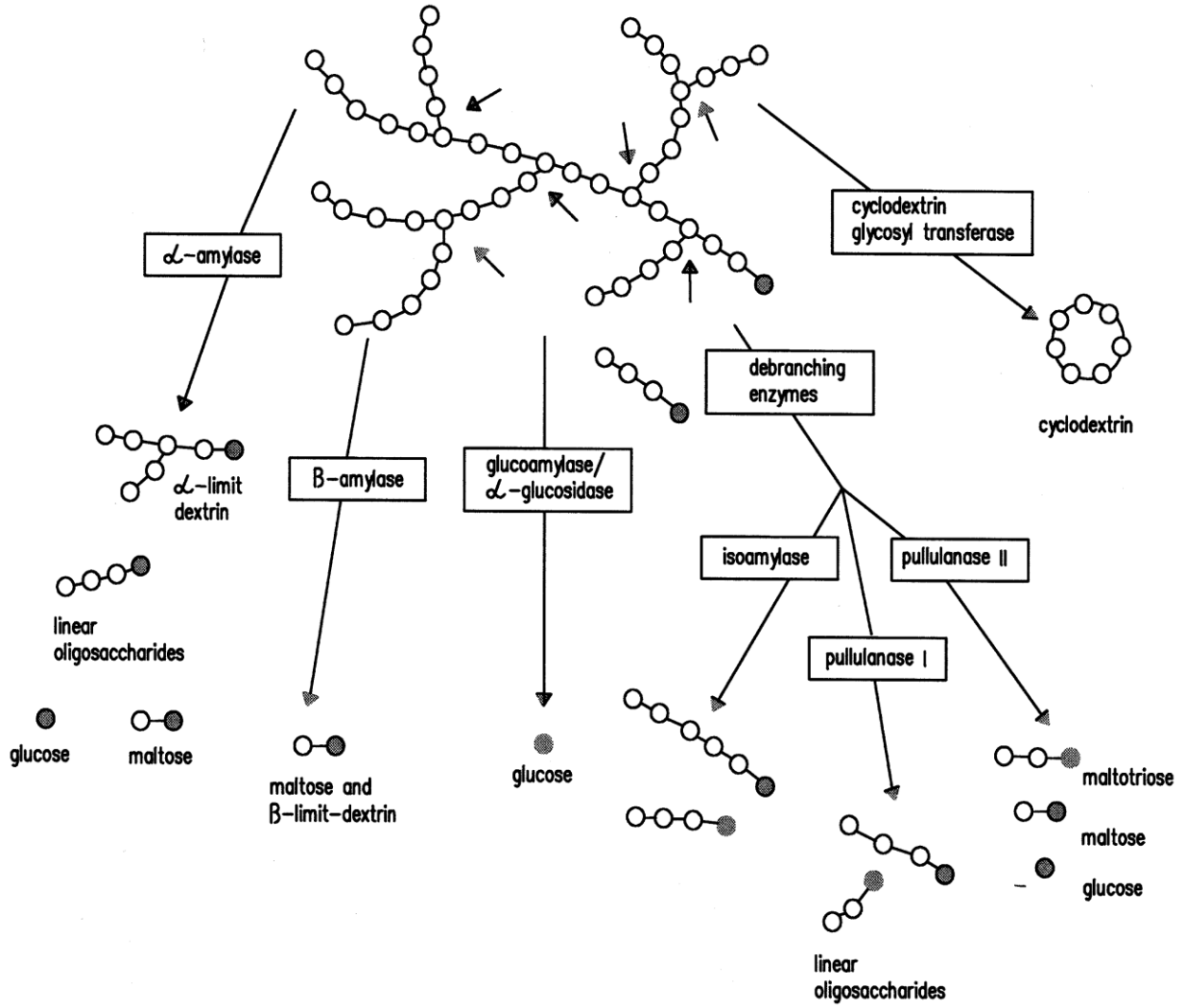

Figure 2.1. Action of starch-degrading enzymes on starch molecule. (Antranikian, 1991)

2.3 Sources of amylases

Amylases are ubiquitous enzymes produced by plants, animals and microbes, where they play a dominant role in carbohydrate metabolism (Varel *et al*, 1994). Amylases from plant and microbial sources are employed for centuries as food additives (Mabel *et al*, 2008). Barley amylases are used in Brewing industry. Fungal amylases are widely used in preparation of oriental foods (Popovic *et al*, 2009). Fungal and bacterial amylases are mainly used for industrial applications due to their cost effectiveness, consistency, less time and space requirement for production and ease of process optimization and modification (Ellaiah *et al*, 2002).

Among bacteria, *Bacillus.sp* is widely used for the production of amylases. Species like B.*subtilis, B.stearothermophilus, B.licheniformis,* and *B.amyloliquefaciens* are known to be good producers of alpha amylase (Harshemi *et al*, 2011). Similarly filamentous fungi have been widely used for the production of amylases for centuries (Juliana *et al*, 2011). As these moulds are known to be prolific producers of extracellular proteins, they are widely exploited for the production of different enzymes including alpha amylases (Kozunari *et al*, 2011). Fungi belonging to the genus Aspergillus have been most commonly employed for the production of alpha amylase.

2.4 Fermentative production of amylase

Low cost medium is required for the production of amylase, to meet the demand of industries (Aliyu *et al*., 2011). Both Solid State Fermentation (SSF) and submerged fermentation (SMF) could be used for the production of amylase, although traditionally these have been obtained from submerged cultures because of easy handling and greater control of environmental factors such as temperature and pH (Xusheng *et al*., 2011).Mostly synthetic media have been used for the production of bacterial amylase through SmF (Ajay *et al*., 2010). The contents of synthetic media such as nutrient broth, soluble starch, as well as other components are very expensive and these could be replaced with cheaper agricultural by products for the reduction of the cost and the medium(Solange *et al*., 2010). The solid substrate may provide only support and nutrition (Hashemi *et al*., 2011). SSF is considered as an interesting alternative since the metabolites so produced are concentrated and purification is of less quality (Nasrin *et al*., 2010). SSF is preferred to SmF because of simple technique, low capital investment, lower levels of catabolite repression and end product inhibition, low waste water output better product recovery and high quality has been reported to produce promising results (Ajay *et al*., 2010) other substrates such as sunflower meal, rice husk, cotton seed meal, soybean meal, rice husk, cotton seed meal, soy bean meal, and pearl millet and rice bran have been tried for SSF (Maryam *et al*., 2010).

SSF technique is generally confined to the process involving fungi (Kiran *et al*., 2010). However, successful bacterial growth in SSF is known much in natural fermentation (Lonsane *et al*., 1990). The production of alpha amylase by SSF is limited to the genus *Bacillus like B.subtilis, B.polymaxa, B.mesentiricus, B.vulgarus, B.coagulans, B.megaterium and B.licheniformis* have been used for alpha amylase production in SSF (Natasa *et al*., 2011).The production of bacterial amylase using alpha amylase technique requires less fermentation time which leads to considerable reduction in the capital and recurring expenditure (Li Zhuang *et al*., 2011). Research on the selection of suitable substrates for SSF has mainly been centred around agro industrial residues due to their potential advantages for filamentous fungi which are capable of penetrating into the hardest of these solid substrates, aided by the presence of turgor pressure at the tip of the mycelium (Maryam *et al*., 2010). In addition, the utilization of these agro industrial wastes, not only provides alternative substrates but also on the other hand helps in solving pollution problems (Priya *et al*., 2011).

Table 2.1: Various agro-industrial residues (agrosubstrates) used for α-amylase production

Substrate	Organism	Activity, U/g	Reference
Wheat bran	*Bacillus* sp. PS-7	464000	Sodhi *et al*., 2005
Spent brewing grain	A. oryzae NRRL 6270	6 583	Francis *et al*., 2003
Maize bran	B. *coagulans*	22 956	Babu &Satyanarayana 1995
Rice bran	*Bacillus* sp. PS-7	145 000	Sodhi *et al*., 2005
Rice husk	*B. subtilis*	21 760	Baysal *et al*., 2003
Coconut oil cake	*A. oryzae*	3 388	Ramachandran *et al*., 2004
Mustard oil cake	*B. coagulans*	5953	Babu &Satyanarayana 1995
Corn bran	*Bacillus sp.* PS-7	97600	Sodhi *et al*., 2005
Amaranthus grains	*Aspergillus flavus*	1920	Vishwanthan & Surlikar 2001
Gram bran	*B.coagulans*	8984	Babu &Satyanarayana 1995

2.4.1 Process optimization

Optimization of the various parameters and manipulations of media are one of the most important techniques used for the over production of amylase in large quantities (Balasubramanien *et al*., 2011). To meet industrial demands production of alpha amylase in bacteria is known to depend on both morphological and metabolic state of the culture (Juliana *et al*., 2011). Various physical and chemical factors have been known to effect the production of alpha amylase such as pH, temperature, Incubation period, carbon, nitrogen sources, surfactants, phosphate, different metal ions, moisture and agitation with respect to SSF and SmF (Ellaiah *et al*., 2002).

2.4.2 Temperature

The influence of temperature on amylase production is related to the growth of the organism (Pandey *et al*., 1990). Hence the optimum temperature depends on whether the culture is mesophilic or thermophilic. Among the fungi most amylase production studies have been done with mesophilic fungi within the temperature range of 25-37^{o}C (Takahiro *et al*., 2011). A raw starch degrading amylase was produced by Aspergillus ficum at 30oC by Hayashida *et al* in 1986. Amylase production at optimum level has been reported between 50-55^{o}C for the thermophilic fungal cultures such as Talaromyces emersonni, Thermomonospora fusca etc (Ahmad *et al*., 2010).

2.4.3 pH

pH is one of the important factors that determine the growth and morphology of microorganisms as they are sensitive to the concentration of hydrogen ions present in the medium(Ellaiah *et al*., 2002). Earlier studies have revealed that fungi required slightly acidic pH and bacteria required neutral pH for optimum growth. pH is known to effect the synthesis and secretion of alpha amylase (Yakup *et al*., 2010). Fungi of *Aspergillus* sp. such as A.oryzae, A.ficuum and A.niger were found to give significant yields of alpha amylase at pH equal to 5.0 to 6.0 in SmF (Parveen *et al*., 2011). Alpha amylase producing yeast strains such as S.cerevisiae and S.kluyveri exhibited maximum enzyme production at pH 5.0 (Samrat *et al*., 2011).

2.4.4 Carbon sources

Carbon sources such as galactose, glycogen and Inulin have been reported as suitable substrates for the production of amylases by B.licheniformis and Bacillus.sp.1-3 (Xusheng *et al*., 2011). Starch and glycerol were known to increase enzyme production in B.subtilis IMG22, Bacillus sp, PS-7 and Bacillus sp.1-3(Maryam *et al*., 2010). Soluble starch has been found as the best substrate for the production of alpha amylase by B.stearothermophilus (Srivastava *et al*., 1986). Bacillus sp. was noted to give a maximum raw starch digesting amylase in a medium containing lactose (1%) and yeast extract (15%). Agricultural wastes are being used for both liquid and solid fermentation to reduce the cost of fermentation media. The waste consists of carbon and nitrogen sources necessary for the growth and metabolism of organism. These nutrients sources include orange waste, peer millet starch, potato, corn, tapioca, wheat and rice as flours (Lin Hui *et al*, 2011).

2.4.5 Nitrogen sources:

Soybean meal was found as the best nitrogen source for alpha amylase by Bacillus sp. 1-3. Tanyildizi *et al* reported that peptone increased enzyme activity while yeast extract exhibited no effect on alpha amylase production (Arpana *et al*., 2011). Strains of Bacillus stearothermophilus and B.amylolyticus secreted maximum alpha amylase in a medium supplemented with 1% peptone, 0.5% yeast extract and 0.5% malt6ose under vigorous shaking conditions (Elif *et al*., 2005). L-asparagine was reported to be one of the most promising nitrogen sources for alpha amylase production by Thermomyces lanuginosus (Adinarayana *et al*., 2005).

2.4.6 Moisture content:

Moisture is one of the most important parameters in SSF that influences the growth of the organism and thereby enzyme production (Pandey *et al*, 2000). Low and high moisture levels of the substrate effect the growth of the microorganisms resulting (Ellaiah *et al*, 2002). High moisture content leads to reduction in substrate porosity, changes in the structure of substrate particles and reduction of gas volume. Bacteria are generally known to require initial moisture of 70-80%. Alpha amylase production by Bacillus licheniformis M27 was highest with 65% initial moisture content in an SSF system (Namita *et al*., 2007). Significant decrease in enzyme production was observed with high increase in moisture content which was due to the decrease in the rate of oxygen transfer. A thermotolerant B.subtilis requires initial moisture of 30% for its growth and maximum enzyme production (Ahmad *et al*, 2010).

3.0 RECOMMENDATION AND CONCLUSION

Among the microorganisms, the *Bacillus spp* are one of the extracellular enzyme producing bacteria and from this review it has been seen that *bacillus spp* are great producers of α-amylase. This study shows a critical literature review and from the study, it is recommended further research should be carried out using other agricultural products for the isolation and production of amylase. While there is so much study on the isolation of *Bacillus Subtillis* α-amylase, there is limited literature on other related bacteria such as Bacillus amyloliquefaciens etc.

REFERENCES

1) Adeyanju, M. M., Adeshola, A. O., Adeleye, A. O., Titilayo, K., Oghenedaji, M., Oluwaseyi, F. A., et al. (2012). Characterization of a thermostable Bacillus subtilis β-amylase isolated from decomposing peels of Cassava (Manihot esculenta). International Journal of the Nigerian Society for Experimental Biology , 24 (1), 23-30.

2) Adinarayana, K., Kugen, P., & Suren, S. (2005). Amylase production in solid state fermentation by the thermophilic fungus Thermomyces lanugionosu. Journal of Biosciences and Bioengineering , 100 (2), 168-171.

3) Ahmad, A., Jamshid, K. C., & Miland, L. (2010). a novel thermostable, acidophilic alpha amylase from a new thermophilic —Bacillus sp.ferdowsicous isolated from ferdows hot mineral spring in Iran: Purification and biochemical characterization. International Journal of Macromolecules , 46 (3), 289-297.

4) Ajay, P., & Farhath, K. (2010). Production and extraction optimization of xylanase from Aspergillus niger DFR-5 through solid-state-fermentation. Bioresource Technology , 101, 7563-7569.

5) Ali, F., & Abdel-Moneim, A. (1989). Physiochemical properties of Aspergillus flavus var.columnaris alpha amylase. Zentralbl Mikrobiology , 144, 615-621.

6) Aliyu, S., Alam, M. Z., Ismail, A. M., & Hamzah, S. M. (2011).). Optimization of lipase production by Candida cylindracea in palm oil mill effluent based medium using statistical experimental design. Journal of Molecular Catalysis B: Enzymatic , 69, 66-73.

7) Allen, J., & Thoma, J. (1978). Repetitive attack by Aspergillus oryzae alpha amylase. Carbohydrate Resources , 61, 377-385.

8) Arpana, K., & Arvind, K. M. (2011). Immobilization of soybean (Glycine max) α-amylases onto Chitosan and Amberlite MB- 150 beads: Optimization and characterization. Journal of Molecular Catalysis , 69 (1), 8-14.

9) 9. Asoodeh, A., Khan, J., & Lagzian, M. (2010). A novel thermostable, acidophilic alpha amylase from a new thermophilic —Bacillus sp.ferdowsicous‖ isolated from ferdows hot mineral spring in Iran: Purification and biochemical characterization. International Journal of Macromolecules , 46 (3), 289-297.

10) 10. Augustin, J., Zemek, J., Fassatiova, O., & Kuniak, L. (1981). Production of alpha amylase by microscopic fungi. Folia Micrrobiology , 26, 142-146.

11) Balasubramaniem, A., Nagarajan, K., & Paramasamy, G. (2011). Optimization of media for β-fructofuranosidase production by Aspergillus niger in submerged and solid state fermentation. Process Biochemistry , 37, 331-338.

12) Banks W, G. (1975). Starch and its components. Edinberg University Press.

13) Babu, K.R., Satyanarayana, T., (1995). α-Amylase production by thermophilicBacillus coagulansin solid-state fermentation, Process Biochem., 30, 305–309.

14) Barkworth, M. 2003. Sorghum Moench. In: Flora of North America Vol 25 Magnoliophyta: Commelinidae (in part): Poaceae, Part 2. Oxford Univ. Press, New York. p. 626–630.

15) Baysal, Z., Uyar, F., Aytekin, C., (2003). Solid-state fermentation for production of α-amylase by a thermotolerantBacillus subtilis from hot-spring water, Process Biochem., 38, 1665–1668.

16) Bernfeld, P. (1955). Amylases alpha and beta. Methods in Enzymology , 1, 149. Clark, A. (ed.) 2007. Managing cover crops profitably, 3rd ed. National SARE Outreach Handbook Series Book 9. Natl. Agric. Lab., Beltsville, MD.

17) Damien, M., Catherine, J., Patrice, d., & Christopher, b. (2010). Enhanced mechanical properties of partially beta – amylase trimmed starch for material application. Carbohydrate Polymers , 80 (3), 747-752.

18) Dayan, F.E., A.M. Rimando, Z. Pan, S.R. Baerson, A.L. Gimsing, and S.O. Duke. 2010. Sorgoleone. Phytochemistry 71:1032–1039.

19) Demirkan, E. (2010). Production, purification, and characterization of α-amylase by Bacillus subtilis and its mutant derivates. Turkey Journal of Biology , 35, 705-712.

20) Dhanya, G., Madhavan, N. K., Swetha, S., & Ashok, P. (2009). immobilized bacterial alpha amylases for effective hydrolysis of raw starch and soluble starch. Food Research.International , 42 (4), 436-442.

21) Dinu, D., Nechifor, M. T., Stoian, G., Costache, M., & Dinischiotu, A. (2007).). Enzymes with new biochemical properties in the pectinolytic complex produced by Aspergillus niger MIUG 16. Journal of Biotechnology , 131, 128-137.

22) E.A, K. (1983). Effect of the physiological condition on alpha amylase and glucoamylase formation by selected strain of Aspergillus oryzae. Microbiology , 53, 422-427.

23) Elif, S. D., Bunzo, M., Motoyasu, A., Takahiko, H., & Shigeru, U. (2005).). α- amylase from B. amyloliquefaciens: purification, characterization, raw starch degradation and expression in E. coli. Process Biochemistry , 40, 2629-2636.

24) Ellaiah, P., Adinarayana, K., Bhavani, Y., Padmaja, P., & Srinivasulu, B. (2002). Optimization of process parameters for glucoamylase production under solid-state fermentation by a newly isolated Aspergillus sp. Process Biochemistry , 38 (4), 615-620.

25) Fabian, C., Ayucitra, A., Ismadji, S., & Ju, Y.-H. (2011). Isolation and characterization of starch from defatted rice bran. Journal of the Taiwan Institute of Chemical Engineers , 42, 86-91.

26) Fan, X., Wang, Q., Cui, L., & Wang, P. (2008). Hydrolysis of modified starches with amylases used for textile desizing. Journal of Biotechnology , 136, 5384-5385.

27) Francis, F., Sabu, A., Nampoothiri, K.M., Ramachandran, S., Ghosh, S., Szakacs, G., Pandey, A., (2003). Use of response surface methodology for optimizing process parameters for the production of α-amylase by Aspergillusoryzae, Biochem. Eng. J., 15, 107–115.

28) Fratt, J., Douglas, P., Moranelli, F., Seligy, F., & Seligy, V. (1984). The induction of alpha amylase by starch in Aspergillus oryzae: evidence for controlled mRNA. Can. Journal of Biochemistry and Cell Biology , 62, 678-690.

29) Guzmán-Maldonado, H., & Paredes-López, O. (1995). Amylolytic enzymes and products derived from starch: A review. Critical Review in Food Science and Nutrition , 35, 373-403.

30) Hashemi, M., Mousavi, M. S., Razavi, S. H., & Shojaosadati, S. A. (2011). Mathematical modeling of biomass and α-amylase production kinetics by Bacillus sp. in solid-state fermentation based on solid dry weight variation. Biochemical Engineering Journal , 53 (2), 159-164.

31) Hashemi, M., Razavi, S. H., & Abbas, S. (2010). Development of a solid state fermentation process for production of an alpha amylase with potentially interesting properties. Journal of Bioscience and Bioengineering .

32) Henrissat. (1991). A classification of glycosyl hydrolases based on amino acid sequence similarities. Biochemistry Journal , 280, 309-316.

33) Hernandez, M. S., Rodriguez, M. R., Guerra, N. P., & Roses, R. P. (2006). Amylase production by Aspergillus niger in submerged cultivation on two wastes from food industries. Journal of Food Engineering , 73, 93-100.

34) Janeèek, S. (1997). Progress in Biophysics and Molecular Biology. 67, 67-97.

35) Juliana, H. C., Aline, B., Graciele, V., Luiz, F. d., Nadia, K., & David, A. M. (2011). A three-dimensional discrete lattice-based system for modeling the growth of aerial hyphae of filamentous fungi on solid surfaces: a tool for investigating micro-scale phenomena in solid state fermentation. Biochemical Engineering Journal .

36) Kazunari, I., Kawase, T., Sammoto, H., Gomi, K., Kariyama, M., & Miyake, T. (2011). Uniform culture in solid state fermentation with fungi and its efficient enzyme production. Journal of Bioscience and Bioengineering , 111, 300-305.

37) Khoo, S., Amirul, A., Kamaruzaman, M., Nazalan, N., & Azizan, M. (1994). Purification and characterization of alpha amylase from Aspergillus. Folia Microbiology , 39, 392-398.

38) Kiran, B. U., Ramagopal, N., & Rami, R. D. (2010). Optimization of L-Asparaginase production from Isolated Aspergillus niger by using Solid State fermentation on sesame cake via application of Genetic Algorithm, and Artificial Neural Network-based design model. Journal of Biotechnology , 150, 538-539.

39) Li, Z., Shungui, Z., Yuegiang, W., & Rongxian, X. (2011). Cost-effective production of Bacillus thuringiensis biopesticides by solid state fermentation using wastewater sludge: Effects of heavy metals. Bioresource Technology , 102, 4820-4826.

40) Lin, C.-W., Wu, C.-H., Tran, D.-T., Li, W.-H., & Wu, C.-F. (2011). Mixed culture fermentation from lignocellulosic materials using thermophilic lignocellulose-degrading anaerobes. Process Biochemistry , 46, 489-493.

41) Lineweaver, H., & Burk, D. (1934). The Determination of enzyme constants. American Chemistry Society , 56, 658.

42) Losane, B., & Ramesh, M. (1990). Production of bacterial thermostable α-amylase by solid state fermentation: a potential tool for achieving economy in enzyme production and starch hydrolysis. Advanced Applied Microbiology , 35, 1-56.

43) Lowry, O. H., Rosebrough, A., Farr, R., & Randal, J. (1951). Protein measurement with Folin phenol reagent. Journal of Biology and Chemistry , 193-256.

44) Magdoff, F., and H. Van Es. 2009. Building soils for better crops, sustainable soil management. Sustainable Agric. Publ., Waldorf, MD.

45) Mahmoud, S., Abdel-Hafez, A., Mashhoor, W., & Refaat, A. (1978). Utilization of industrial and agricultural by-products for fungal amylase production. Zentralbl Bakteriol Naturwiss , 133 (2), 115-120.

46) Mendez-Montealvo, G., Wang, Y.-J., & Campbell, M. (2011). Thermal and rheological properties of granular waxy maize mutant starches after β-amylases modification. Carbohydrate Polymers , 83, 1106-1111.

47) Mohammad, S., Aded-Ali, Z., & Mohammad Ali, A. (2010). Purification and biochemical characterization of a novel SDS and surfactant stable, raw starch digesting and halophilic alpha amylase from a moderately halophilic bacterium, Nesternkonia sp.strain. Process Biochemistry , 45, 694-699.

48) Nasrin, M., Khajeh, K., Saman, H., & Bahareh, D. (2010). Purification and characterization of a thermostable phytate resistant alpha amylase from Geobacillus sp.LH8. International J of Biological Macromolecules , 46, 27-36.

49) Natasa, B., Jordi, R., Josep, L.-S., & Zoran, V. (2011). Production and properties of the highly efficient raw starch digesting α-amylase from a Bacillus licheniformis ATCC 9945. Biochemical Engineering Journal , 53 (2), 203-209.

50) Nisa, B. U., Gokhan, C., Omer, C., Ashabil, A., & Osman, G. (2008). Enzymatic properties of a novel thermostable, thermophilic, alkaline and chelator resistant amylase from an alkaliphilic Bacillus sp, isolate ANT-6,. Process Biochemistry , 38, 1397-1403.

51) Oyeleke, S., & Oduwole, A. (2010). Production of amylase by bacteria isolated from a cassava waste dumpsite in Minna, Niger State, Nigeria. African Journal of Microbiology , 3 (4), 143-146.

52) Pandey, A. (1990). Improvement in solid state fermentation for glucoamylase production. Biology Wastes , 34, 11-19.

53) Parveen, J., Zulkarnain, I. M., & Alam, M. Z. (2011). Effects of physicochemical parameters on the production of phenolic acids from palm oil mill effluent under liquid-state fermentation by Aspergillus niger IBS-103ZA. Food Chemistry , 124, 1595-1602.

54) Popovic, M. K., Jamrath, T., & Linder, C. (2009). Production of thermostable alpha amylase using food industry wastes. New Biotechnology , 25 (1), 206-210.

55) Priya, P., Sweta, M., & Archana, G. (2011). Statistical optimization of production and tannery applications of a keratinolytic serine protease from Bacillus subtilis P13. Process Biochemistry .

56) Ramachandran, S., Patel, A.K., Nampoothiri, K.M., Francis, F., Nagy, V., Szakacs, G., Pandey, A., (2004). Coconut oil cake – A potential raw material for the production of α-amylase, Bioresour. Technol., 93, 169–174.

57) Richard, B. (2002). The Organic Chemistry of Enzyme-catalyzed Reactions, 2nd ed. London, England: Acadamic Press.

58) Rousset, S., & Schlich, P. (1989). Amylase production in submerged culture using principal component analysis. Journal of Fermentation & Bioengineering , 68, 339-343.

59) Samrat, C., Abhijeet, K., Ren, B., Wang, J., Xiang-Yang, L., Kakasaheb, M., et al. (2011). Characterization and stability studies on surfactant, detergent and oxidant stable α-amylases from marine haloalkaliphilic Saccharopolyspora sp. A9. Journal of Molecular Catalysis B: Enzymatic , 68 (1), 52-58.

60) Sangeeta, N., & Rintu, B. (2009). Characterization of amylase and protease produced by Aspergillus awamori in a single bioreactor. Food Research International , 42 (4), 443-448.

61) Shah, N., Ramamurthy, V., & Kothari, R. (1991). Comparative profiles of fungal alpha amylase production by submerged and surface fermentation. Biotechnology Letter , 13, 361-364.

62) Shoemaker, C.E., and D.I. Bransby. 2010. The role of sorghum as a bioenergy feedstock. In: R. Braun, D. Karlen, and D. Johnson, editors, Sustainable alternative fuel feedstock opportunities, challenges and roadmaps for six U.S. regions, Proceeedings of the Sustainable Feedstocks for Advance Biofuels Workshop, Atlanta, GA. 28–30 September. Soil and Water Conserv. Soc., Ankeny, IA. p. 149–159.

63) Solange, M. I., & Jose, T. A. (2010). Increase in the fructo oligosaccharides yield and productivity by solid-state fermentation with Aspergillus japonicus using agro-industrial residues as support and nutrient source. Biochemical Engineering Journal , 53, 154-157.

64) Sodhi, H.K., Sharma, K., Gupta, J.K., 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 Biochem., 40, 525–534.

65) Stapleton, J., C.G. Summers, J.P. Mitchell, and T.S. Prather. 2010. Deleterious activity of cultivated grasses (Poaceae) and residues on soilborne fungal, nematode and weed pests. Phytoparasitica 38:61–69.

66) Svensson, B., & Sogaard, M. (1993). Mutational analysis of glycosylase function. Journal of Biotechnology , 29, 1-37.

67) Takahiro, K., & Shigehiko, H. (2011). Local entropy difference upon a substrate binding of a psychrophilic α-amylase and a mesophilic homologue. Chemical Physics Letters , 501, 517-522.

68) Tsekova, K., Dentchev, D., Vicheva, A., & Dekovska, M. (1993). Amylase activity of Aspergillus strains producers of organic acids. Acta Microbiology Bulg , 30, 47-50.

69) Undersander, D. 2003. Sorghums, Sudangrasses, and sorghum-Sudan hybrids. Univ. of Wisconsin Focus on Forage 5:5, Madison.

70) V.H, V., & Kreikemeier, K. K. (1994). Response to Various Amounts of Aspergillus oryzae fermentation Extract on Ruminal Metabolism in Cattle. Journal of Dairy Science , 77, 3081-3086.

71) Viera, H., Stefan, J., & Ernest, S. (2000). Amylolytic enzymes: their specificities, origins and properties. Biologia, Bratislava , 55 (6), 605-615.

72) Vihinen, M., & Mäntsälä, P. (1989). Microbial amylolytic enymes. Critical Review in Biochemistry and Molecular Biology , 24, 329-418.

73) Vishwanathan, P.,Surlikar, N.R., (2001). Production of α-amylasewith Aspergillusflavus on Amaranthus grains by solid-statefermentation, J. Basic Microbiol., 41, 57–64. Wind, R. (1997). Ph.D. Thesis. Rijksuniversiteit Groningen, The Netherlands.

74) Xusheng, C., Lei, T., Shu, L., Lijuan, L., Jianhua, Z., & Zhonggui, M. (2011). Optimization of fermentation for enhancement of ε-Poly-L-Lysine production by Streptomyces sp. M-Z18 with glycerol as carbon source. Bioresource Technology , 102, 1727-1732.

75) Yakup, K., Ahmet, C., Ozlem, F., & Ali, O. B. (2010). Cloning, expression and characterization of highly thermo- and pH-stable maltogenic amylases from a thermophilic bacterium Geobacillus caldoxylosilyticus TK4. Process Biochemistry , 45 (6), 821-828.

76) Zieba, T., Szumny, A., & Kapelko, M. (2011). Properties of retrograded and acetylated starch preparations: Part 1. Structure, susceptibility to amylase, and pasting characteristics. Food Science and Technology , 44, 1314-1320.