Purification and Characterization of Protease From Bacillus sp. TBRSN-1

Sebastian Margino1*, Jumi’ati2, Ngadiman2

2Biotechnology Postgraduate School, Universitas Gadjah Mada
1Department of Agricultural Microbiology, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta, Indonesia

Abstract
Potato Cyst Nematode (PCN), Globodera rostochiensis, is one of the important potato's pests and caused economic losses up to 70% in the several centrals of potato plantations in Indonesia. PCN's shell component of egg shell containing chitin (inner layer) and viteline/protein (outer layer). The purpose of this research was to purify of protease Bacillus sp. TBRSN-1, isolate from tomato's rhizosfer in Yogyakarta province. The purified protease could be used for cutting the life cycle of PCN. Results showed that Bacillus sp. TBRSN-1 could produce extracellular protease and purification using DEAE-cellulose ion-exchange chromatography and Sephacryl S-300 gel filtration chromatography resulted in specific activity 4.31 fold and 1.68% recovery. Analysing using SDS-PAGE 12.5% and molecular weight 48.1 kDa. Km and Vmax values of the protease for casein substrate were 7.83 mg/ml and 4.03 μg/h, respectively. The optimum activity at the temperature 30°C and pH 7.0.

Keywords: protease, purification, indigenous Bacillus sp. TBRSN-1

Introduction
Plant-parasitic nematodes cause serious losses to a variety of agricultural crops worldwide. Since the traditional methods based on the use of nematicides and antihelminthic drugs are associated with major environmental and health concerns, the development of biocontrol agents to control nematodes is of major importance (Duncon, 1991). The potato cyst nematode Globodera rostochiensis is the major pests for the potato cultivars in several countries in the world (Margino et al., 2009). Soil treatment with nematicides for controlling Globodera, it is very expensive for farming community. In recent years biological control agents such as chitinolytic and proteolytic bacteria, fungi, actinomycetes were applied to control potato cyst nematode (PCN) eggs shell, for cutting their life cycle. Previous research succeeded in controlling PCN up to 60% using mixed cultures inoculum (Margino et al., 2009) and succeeded in purifying chitinases of selected bacteria and actinomycetes (Margino et al., 2010,Margino et al., 2012). Because of the fast breeding, easy cultivation and production compared to fungi, nematophagous bacteria have been used extensively as bioinsecticides against nematodes in soil, and levels of control equivalent to those of chemical pesticides development (Zhou et al., 2002). Egg cell of PCN containing vitelin (protein) and chitin layers so that protease can be used for controlling PCN through the nematode's egg.

Proteolytic enzymes are ubiquitous in occurrence, being found in all living organisms, and are essential for cell growth and differentiation. The extracellular proteases are commercial value and find multiple applications for example in biological control (bionematicide). Although there are many microbial sources are available for producing proteases, only a few are
recognized as commercial producers, that is strains of Bacillus sp. (Gupta et al., 2002b). In this work, we present the purification and characterization protease of Bacillus sp. TBRSN-1, isolated from tomato’s rhizosfer.

Material And Methods

Microorganism and inoculum preparation

A culture of Bacillus sp. TBRSN-1 previously isolated from soil and identified by standard method for bacterial identification. Stock cultures were maintained in nutrient broth medium (Difco) with 70% glycerol, cultures were preserved at -20°C. One loopful of bacteria strain (Bacillus sp. TBRSN-1) was transferred to a tube of sterile containing of nutrient broth and allowed to grow overnight at 37°C (Shafee et al., 2005; Sharmin et al., 2005) before being used to inoculation.

Protease activity

The protease enzyme activity was determined as previously mentioned by Secades and Guijarro (1999) using casein as a substrate. Briefly, 120 μL of a suitable dilution of enzyme solution was added to 480 μL of casein (2% wt/vol) in reaction buffer, and the mixture was incubated at 30°C for 30 min. The reaction was terminated by adding 600 μL of 10% (v/w) TCA and left for 30 min on ice, followed by centrifugation at 15,000 x g, at 4°C for 10 min. Eight hundred μL of the supernatant was neutralized by adding 200 μL of 1.8 N NaOH, and the OD value was measured using spectrophotometer at 420 nm (λ420). One units of enzyme activity was defined as the amount of enzyme which required to produce an increase in OD value at 420 nm equal to 1.0 in 30 min, at 30°C.

The protein content of protease was determined by the method of Lowry et al., (1951) as mentioned in Bradford (1976) using bovine serum albumin as a standard and during the course of enzyme purification by measuring at OD value at λ280 nm.

The specific activity of the protease protein was expressed in terms of units/mg protein/ml according the following equation: Specific activity = enzyme activity/protein content (mg/ml⁻¹).

Protease production (Singh et al., 1999)

Protease crude enzyme was produced by fermentation. Bacillus sp. TBRSN-1 was cultivated in minimal medium consisting of (g/l): K₂HPO₄ 0.7, KH₂PO₄ 0.3, MgSO₄·7H₂O 0.5, FeSO₄·7H₂O 0.01, ZnSO₄ 0.001, MnCl₂ 0.001, skim milk 1%, and distilled water 1 L, pH 7.0. Media were autoclaved at 121°C for 20 min. Cultivations were performed on different condition (inoculum concentration, pH, substrate (skim milk) concentration, agitation, temperature, and incubation period) in 250 ml erlenmeyer flasks with a working volume of 20 ml. The cultures were centrifuged and the supernatants were used for estimation of proteolytic activity.

Optimization of growth conditions: Optimization was done under the inoculum concentration (2.5, 5.0, 10, and 15% (v/v)); different pH values (50 ml of selected medium of different pH 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, and 8.0 respectively; different substrate (skim milk) concentrations (g/l⁻¹) was performed using 0.5, 1.0, 2.0, 3.0 and 4.0% (w/v), then incubated 48 h at 30°C; different agitation (150, 200, and 250 rpm); incubation temperature (30°C and 37°C); The best results of these condition treatments were applied to the fermentor for looking best conditions of aeration, desolved oxygen, and time of proteasevproduction, during incubation for 96 hours.

Purification of the protease

The culture supernatant was first subjected to ammonium sulphate precipitation (Scopes, 1994). Proteins presents in culture broth were extracted by ammonium sulphate 40%, 50%, 60%, 70%, 80%, and 90% (w/v). Extractants were collected by centrifugation at 10,000 g, 4°C for 45 min, and the pellet was suspended in 20 mM buffer phosphate, pH 7.0. The 40% (w/v) ammonium sulphate fraction was subjected to gel filtration on Sephacryl S-300 column (1.5x 60 cm) equilibrated with
20 mM Tris-HCl, pH 8.0 containing 0.2 M NaCl and 0.02% NaN3. Fractions of 1.5 ml were collected at a flow rate of 46 ml/h with the same buffer. Protein content and protease activity were determined. All purification steps were conducted at temperatures not exceeding 4°C.

Polyacrylamide gel electrophoresis (Laemmli, 1970)

Sodium Dodecyl Sulfate-Poly-Acrylamide Gel Electrophoresis (SDS-PAGE) was carried out for the determination of purity and molecular weight of the enzyme as described by Laemmli (1970) using a 5% (w/v) stacking gel and 10% (w/v) separating gel. The molecular weight of the enzyme was estimated using a low molecular weight calibration kit as markers consisting of: phosphorylase b (97 kDa), bovine serum albumin (66 kDa), chicken egg ovalbumin (45 kDa), bovine carbonic anhydrase (29 kDa), and bovine α-lactalbumin (14.2 kDa). Protein bands were visualized by staining with Coomassie Brilliant blue 0.25% (w/v) and nitrate silver 0.1% (w/v).

pH optimum and pH stability (Harman et al., 1993)

The optimum pH of the purified protease was studied over a pH of 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, 6.0, 6.5, 7.0, 7.5, 8.0, 9.0, and 10 with casein as a substrate. For the measurement of pH stability, the enzyme was incubated for 30 min at 30°C in different pH buffers and the residual proteolytic activity was determined under standard assay conditions. The following buffer system were used: 100 mM phosphate buffer, pH 6.0-7.5; 100 mM Tris-HCl buffer, pH 8.0-8.5; and 100 mM glycine-NaOH buffer, pH 9.0-12.

Temperature effect on protease activity and stability

To investigate the effect of temperature, the activity was measured using casein as a substrate at the temperature range from 10°C to 50°C in 100 mM phosphate buffer, pH 7.0. Thermal stability was examined by incubating the purified enzyme at different temperatures. Aliquots were withdrawn at desired time intervals to test the remaining activity at pH 7.0 and 30°C. The non-heated enzyme was considered as control (100%).

Enzyme kinetics determination

$k_m$ and $V_{max}$ were determined by the kinetics of Michaelis-Menten Model reactions as described by Wilson and Walker (2005).

Result And Discussion

Production of protease and precipitation using ammonium sulphate

Bacillus sp. TBRSN-1 was originally isolated from soil around rhizosphere of tomato plant in (Sleman, Yogyakarta) and had high protease and chitinase activities in the culture broth medium. This isolate was also one of the mixed cultures inoculum candidate of bionematicides (data Margino et al., 2009). Production of extracellular protease by new strain Bacillus sp. TBRSN-1 was done in the two liter fermentor, based on the optimization of growth conditions (5%, v/v) of inoculums, substrate concentration (1%, w/v), pH value 7, agitation 150 rpm, temperature at 30°C, and incubation time 60 hours.

Enzyme precipitation and purification

Present tproteins in the culture filtrate were extracted by ammonium sulfate 40, 50, 60, 70, 80, and 90% (w/v). Result showed that 40% saturation was able to produce a maximum protease activity, 324.13 U/mg, and followed 277 U/mg for saturation 50% (w/v) (Figure 1). Furthermore, ammonium sulphate in this 40% saturation level was used for precipitating protein in crude enzyme. The added ammonium sulphate will press out of water molecule from protein and cause the hydrophobic condition of protein compounds (Harris and Angal, 1990). In addition to, ammonium sulphate also leads to the protein precipitation and reduces its solubility. While the solubility...
of protein decrease, interaction between hydrophobic regions formed aggregates, then aggregates of proteins which contained of big molecules suddenly precipitated and resulted in more precipitates until its optimum concentration, Figure 1 (Scope, 1994). Ammonium sulphate purification increased the protease activity 1.46 fold. The precipitation step also decreased the overall protein concentration compared to the protein in the crude enzyme. Increasing of the Bacillus sp. TBRSN-1 protease activity using ammonium precipitation 1.46 fold are consistent with published literature, which shows a purification (fold) up to 9.6 (Liao et al., 1998). The precipitation also gave lower result compared to precipitation of protease Burkholderia strain 2.2 N, using ammonium sulphate 40-60% (w/v) produce protease activity 20 fold (Jewell, 2000). A little bit different result showed by protease activity from Bacillus sp. PS719 which precipitated using ammonium sulphate 80%, resulted in 1.5 fold (Towatana et al., 1999).

The results of ammonium sulphate precipitation in saturation level 40% (w/v) as much as one ml (formerly been dialyzed with 0.05 PBS pH 7.0) applied into the column ion exchange chromatography containing DEAE Cellulose. The 100 fractions were measured in early experiment to find out protein concentration of each fractions (based on the absorbton value at 280 nm). Results showed that two peak of protein but only one had protease activity, that fraction numbers 7-14 and 15-25. After collecting the samples and then be run using SDS-PAGE was found out two lines with a little bit far of their distance (data unshown). Furthermore analysis was done using gel filtration chromatography method by Sephacryl S-300 (Figure 3). This experiment has measured 70 fractions to find out the protein contents of each fraction (based on absorption value at 280 nm). In the gel filtration, one protein peak was observed, which formed by fraction number 51, but fraction numbers 50 and 52 have closed protein peaks and they

![Figure 1. Different effect of ammonium sulphate concentration on purifying protease protein of Bacillus sp. TBRSN-1](image1.png)

![Figure 3. Elution profile of protease purification with gel filtration on Sephacryl S-300](image3.png)
had high protease activities. Furthermore, the samples were collected into one tube, then to be freezed-dried for characterization of enzyme. Enzyme purification using Sephacryl S-300 may increased enzyme purity as much as 4.31 times. The yield and purity for each purification steps were summarized at Table 1.

The protease purification using DEAE-Cellulose at Table 1, showed 3.07 fold compared to crude enzyme, its specific activity 653.60 U/mg protein, and its recovery was 2.15%. This result a little bit different with purification of extracellular protease from *Bacillus subtilis* EAG-2, using DEAE-Cellulose, the overall recovery 29% and the purity level was 11 fold (Ghafoor and Hasnain, 2010).

All operations were carried out 4°C. Only 40% ammonium sulphate was subjected to gel filtration on Sephacryl S-300.

**Characterization of protease**

The characterization of protease were done including SDS-PAGE analysis, molecular weight, pH value and temperature effect.

The character of protease protein produced by *Bacillus* sp. TBRSN-1 could be

---

Table 1. Summary of the purification of *Bacillus* sp. TBRSN-1 protease

| Total Protein (mg) | Total activity (10^3 U) | Specific activity (10^3 U/mg) | Purification (fold) | Recovery (%) |
|--------------------|-------------------------|-------------------------------|---------------------|--------------|
| Crude enzyme       | 116.45                  | 24761.90                      | 212.64              | 1.00         | 100.00       |
| 40% ammonium sulfate fraction and dialysis | 38.37                  | 11901.67                      | 310.16              | 1.46         | 48.06        |
| DEAE Cellulose     | 0.82                    | 533.33                        | 653.60              | 3.07         | 2.15         |
| Sephacryl S-300    | 0.45                    | 416.67                        | 916.76              | 4.31         | 1.68         |

Figure 4. SDS-PAGE of the purified protease from *Bacillus* sp. TBRSN-1. (a) Staining with coomassie brilliant blue 0.25% (w/v); (b) Staining with nitrate silver 0.1% (w/v). M = Markers; I = purified protease.
performed on 10% SDS-PAGE (Figure 4). This figure showed that one band of protease protein was found in this experiment. The molecular weight of single protein that resulted in Sephacryl S-300 isolation was determined using relative mobility calibration curve of standard polypeptide (Figure 5). The molecular weight estimation was determined using regression equation $Y = 2.3235 - 1.7473 X$ (with $r=0.99$), Figure 5.

The purified protease was homogenous on SDS-PAGE and its molecular weight was estimated to be 48.1 kDa (Figure 4).

The estimation of protease molecular weight of Bacillus sp. TBRSN-1 was about 48.1 kDa (Figure 5). It was supposed that this band is protease, this was approved by increasing of protease activity and its enzyme purity. Padmapriya and Williams (2012) reported that the purified neutral protease of Bacillus subtilis had molecular weight 50 kDa, while purified serine protease from Bacillus sp. from marine had molecular weight 37 kDa (Padmapriya et al., 2012). Towatana et al. (1999) reported that purified an extracellular protease from alkalophilic thermophile Bacillus sp. PS 719 using DEAE-Cellulose ion-exchange chromatography had molecular weight 42 kDa. Yang et al. (2000) reported that Bacillus subtilis isolated from soil in Taiwan, which purified using DEAE-Sepharose ion-exchange chromatography and Sephacryl S-200 gel-permeation chromatography showed that protease had molecular weight 44 kDa.

Based on the several of researches showed that molecular weight of protease from Bacillus sp. TBRSN-1 had the similar types of them.

**Effect of pH on enzyme activity**

The pH profile of the purified enzyme was determined using different buffers of varying pH values. The purified enzyme was active in the pH range 3.5 – 9.0, with an optimum activity at pH 7.0 (Fig. 6a) with protease activity was 24.58 U/ml. Similarly, Abdul-Rouf (1990) reported that the optimum pH for all purified 4 proteases enzymes in their reaction mixture was found to be 7.2. Purified protease of Bacillus sp. isolated from soil samples around the Bungalore had specific activity at pH neutral (Josephine et al., 2012), other purified protease of Bacillus subtilis also had activity at pH 7.0 (Padmapriya and Williams, 2012).

**Effect of temperature on the enzyme activity**

The effect of temperature on the activity of protease enzyme was examined at various
temperatures. The purified protease was active between 10°C to 40°C, with an optimum around 30°C (protease activity 30.36 U/ml) (Figure 6b). The protease activity at 10°C and 40°C were about 8.75 U/ml and 10.24 U/ml, respectively. The enzyme was completely inactivated after 30 min incubation at 50°C. While the temperature below or above 30°C exhibited lower activities of protease. Secades and Guijarro (1999) reported that a novel exoprotease, that was purified from the culture supernatant of *Yersinia ruckeri* (fish pathogen), had more activity in the range of 25 to 42°C and had an optimum condition at 37°C. Asker et al. (2013) reported that protease of *Bacillus megaterium* had the optimum activity at 50°C, while other purified protease from *Bacillus subtilis* had optimum activity at 37°C. This illustration showed that optimum temperature of protease from several *Bacillus* sp. had the large variation.

**Determination of K_m and V_max value of protease**

The result of enzyme kinetic analysis (K_m and V_max) are shown in Table 2. Determination of K_m and V_max values were based on the pH condition and optimum temperature that have been procured. In this event, the increasing of substrate saturation will increase enzyme activity to achieve a certain limitations at the certain substrate saturation as well, so that the with the increasing of substrate after optimum limitations will not increase the enzyme activity.

Michaelis Menten’s (K_m) constant value analysis and maximum speed (V_max) can be seen at Table 2. According to above computation, there was quantitative relation between the speed (V_i) with substrate saturation (S). Michaelis Menten’s (K_m) constant was procured about 7.83 mg/ml and maximum speed (V_max) was 4.03 μg/h with regression equation; Y = 1942.7X – 248.29 and have correlation value about r = 0.998. Wilson (2005) explained that enzyme activity more higher, if the its K_m values was small. The correlation between of reaction velocity (v) with substrate concentration as shown at Figure 7.

**Conclusion**

The best conditions for protease production by *Bacillus sp. TBRSN-1* were: substrate concentration (skim milk) 1.0% (w/v), inoculum concentration 5.0% (v/v), growth temperature 30°C, pH 7.0, agitation at 150 rpm, and incubation time for 60 hours.

Purification of *Bacillus sp. TBRSN-1* protease using DEAE-Cellulose and Sephacryl
Table 2. Data of \( K_m \) and \( V_{max} \) values of protease

| No | [S]  | 1/[S] | Vi  | 1/Vi | Regression equation                  |
|----|------|-------|-----|------|--------------------------------------|
| 1. | 0.5  | 2.00  | 0.000280 | 3570.400 | \( Y = 1942.7 \, X - 248.29 \)         |
| 2. | 1.0  | 1.00  | 0.000530 | 1887.000 | \( K_m = 7.83 \, \text{mg/ml} \)       |
| 3. | 1.5  | 0.67  | 0.000930 | 1075.500 | \( V_{max} = 4.03 \, \mu \text{g/h} \) |
| 4. | 2.0  | 0.50  | 0.001739 | 575.000  |                                       |

[S]: Substrate concentration  
Vi: reaction velocity

Acknowledgment

This research was funded by The Ministry of Research and Technology Republic of Indonesia under The Incentive Research Program, 2007-2009 of Prof. Sebastian Margino, Ph.D.

References

Abdul-Rouf U. M. 1990. Studies of proteolytic bacteria isolated from certain localities in Aswan city. A thesis (MSc.), Botany and Microbiology Department, Faculty of Science, Al-Azhar University, Cairo.

Ammar M. S., 1975. Studies on thermophilic bacteria. Ph.D., Thesis, Botany Department, Faculty Science, Al-Azhar University, Cairo, Egypt.

Anonymous, 2010. Control of potato cyst nematodes. Official control program for sampled units recorded as infested. Guidance for growers and landowners. Science and Advise for Scottis Agriculture. The Scottish Goverment.

Asker, M.S., M.G. Mahmoud, K.E. Shebwy and M.S. Abd el Aziz., 2013. Purification and characterization of two thermostable protease fraction from Bacillus megaterium. J. of Gen. Engineer. and Biotechnol., (in press MMS. Asker etal., http://dx.doi.org)

Bradford, M.M., 1976. A Rapid and Sensitive Method for Quantification of Microgram Quantities of Protein Utilizing the Principle of Protein-Dy Binding. Anal. Biochem., 72, 248-254
Beg, Q.K., V. Sahai and R. Gupta, 2003. Statistical media optimization and alkaline protease production from *Bacillus mojavensis* in bioreactor. *Process Biochem.*, 39, 203-209.

Darah, I. and C.O. Ibrahim, 1996. Effect of agitation on production of lignin degrading enzymes by Phanerochaete chrysosporium grown in shake-flask cultures. *As. Pac. J Mol. Biol. Biotechnol.*, 4, 174-182.

Duncon, L.W., 1991. Current Options for Nematode Management. *Annu. Rev. Phytopathol.*, 29, 469-490.

El-Safey, E.M., U.M. Abdul-Raouf. (2004) Production, Purification and Characterization of Protease Enzyme from *Bacillus subtilis*. Botany and Microbiology Departement, Faculty of Science, Al-Azhar University, EGYPT.

Ghafoor, A. and S. Hasnain, 2010. Purification and characterization of an extracellular protease from *Bacillus subtilis* EAG-2 strain isolated from ornamental plant nursery. *Polish J. of Microbiol.*, 59 (2), 107-112.

Gupta, R., Beeq QK, Loranz P., 2002a. Bacterial alkaline proteases: molecular approaches and industrial applications. *Appl. Microbiol. Biotechnol.*, 59 (1), 15-32.

Gupta, R., Beeq Q. K.; Khan S. And Chauhan, B., 2002b. An overview on fermentation, downstream processing and properties of microbial alkaline proteases. *Appl. Microbiol. Biotechnol.*, 60 (4), 381-395.

Harris, E.L.V. and S. Anggal. (1990) *Protein purification Method*. Oxford University Press. New York.

Harman, G.E., C.K. Hayes, M. Lorito, R.M. Broadway, A. Di Pietro, C. Peterbauer and A. Tronsmo., 1993. Chitolytic enzymes of *Trichoderma harzianum*; Purification of Chitobiosidase and Endochitinase. *Phytopathology*, 83, 313-318.

Jewll, S.N., 2000. Purification and characterization of a novel protease from *Burkholderia* strain 2.2N. Thesis Faculty of Virginia Polytechnic Institute and State University. Blacksburg, Virginia.

Josephine, F.S., V.S. Ramya, N. Devi, S.B Ganapa, K.G. Siddalingeshwara, N. Venugopal and T. Vishwanatha., 2012. Isolation, production and characterization of protease from Bacillus sp. isolated from soil sample. *J. of Microbiol. and Biotechnol. Res.*, 2(1), 163-168.

Kumar, C.G. and H. Takagi, 1999. Research review paper: microbial alkaline proteases: from a biindustrial viewpoint. *Biotechnol. Adv.*, 17, 561-94.

Kohlmann K. L.: Nielsen S. S; Stenson L.R and Ladisch M. R., 1991. Production of proteases by psychrotrophic microorganisms. *J. Dairy Sci.*, 74, 3275-3283.

Laemmli, U.K., 1970. Cleavage of Structural Proteins during the assembly of the head of bacteriophage T4. *Nature*, 227, 680-685.

Liao, C.H. and D.E. McCallus., 1997. Biochemical and genetic characterization of an extracellular protease from *Pseudomonas fluorescens* CY091. *Appl. Environ. Microbiol.*, 64, 914-921.

Lowry, O.H., N.J. Rosebrough, A.L. Farr, R.L. Randall., 1951. Protein Measurement with the Folin Phenol Reagent. *J. Biol. Chemis.*, 193: 265-273.

Margino, S., Mulyadi, T.K. Pronoand B. Rahayu. 2009. Report of Research Project. Biological control of potato cyst nematodes (*Globodera rostochiensis*) integratedly. Ministry of Research and Technology. Indonesia.

Margino, S.,A. J. Nugroho and W. Asmara., 2010. Purification and characterization of *Streptomyces* sp. IK chitinase. *Indonesian J. of Biotechnol.*, 15(1), 29-36.

Margino, S., C. Behar and W. Asmara., 2012. Isolation and purification of chitinase Bacillus sp. D2 isolated from potato rhizosfer. *Indonesian J. of Biotechnol.*, 17(1), 69-78.

Padmapriya, M and C.Williams. 2012. Purification and characterization of chitination of neutral protease enzyme from Bacillus subtilis. *J. Microbiol. Biotechnol. Res.*, 2(4), 612-618.
Padmapriya, B., T. Rajeswari, R. Nandita and F. Raj., 2012. Production and purification of alkaline serine protease from marine Bacillus species and its application in detergent industry. European J. Appl. Sci., 4(1), 21-26
Qadar, S.A.U., E. Shireen, S. Iqbal, A. Anwar. 2009. Optimization of Protease Production from Newly Isolated Strain of Bacillus sp. PCSIR EA-3. Institute of Sustainable Halophite Utilization and Dept of Biochemistry University of Karachi, Pakistan.
Rahman RNZR, Basri M, Salleh AB., 2003. Thermostable alkaline protease from Bacillus stearothermophilus FI; nutritional factors affecting protease production. Ann Microbiol., 53, 199-210.
Rahman, R.N.Z.A., L.P. Geok, M. Basri, A.B. Salleh, 2005. Physical factors affecting the production of organic solvent-tolerant protease by Pseudomonas aeruginosa strain K. Biores. Technol., 96, 429-436.
Singh, J., R.M. Vohra and D.K. Sahoo., 1999. Alkaline protease from new obligate alkalophilic isolate of Bacillus sphaericus. Biochemical Engineering Research and Process Development Center, Institute of Microbial Technology, Sector 39A, Chardigard 160036, India.
Sambrook J, Russel D. (2001) Molecular cloning: a laboratory manual, 3rd ed. Cold Spring Harbor, NY.
Secades, P and J. A. Guijarro. (1999) Purification and Characterization of Extracellular Protease from the Fish Pathogen Yersinia ruckeri and Effect of Culture Conditions on Production. IUBA, University de Oviedo. Spain.
Scopes, R.K. (1994) Protein Purification, Principle and Practice. Third edition. Springer-Verlag. New York.
Sharmin, S., Md. Towhid Houssain and M.N. Anwar. 2005. Isolation and Characterization of Protease Producing Bacteria Bacillus amovivorus and Optimization of Some Factors of Culture Conditions for Protease Production. Dept of Microbiology, University of Chittagong-4331, Bangladesh.
Shafee, N., S.N. Aris, R.N.Z. Abd Rahman, M. Basri, A.B. Shalleh. 2005. Optimization of Environmental and Nutritional Condition for the Production of Alkaline Protease by a Newly Isolated Bacterium Bacillus cereus strain 146. Dept of Microbiology, Dept of Biochemistry, Faculty of Biotechnology and Biomolecular Sciences, Universiti Putra Malaysia.
Shumi, W., M.T. Hossain and M.N. Anwar, 2004. Proteolytic activity of a bacterial isolate Bacillus fastidiosus den Dooren de Jong. J. Biol. Sci., 4, 370-374.
Towatan, H., N., A. Painupong and P. Suntinanalert.1999. Purification and characterization of an extracellular protease from alkalophilic and thermophilic Bacillus sp. PS719. J. of Bioso and Bioeng, vol. 87 (5), 581-587.
Tian, B., J. Yang and K.Q. Zhang. 2007. Bacteria used in the biological control of plant-parasitic nematodes: population, mechanisms of action, and future prospects. Review. FEMS Microbial. Ecol., 61, 197-213
Wilson, K. and J. Walker. (2005) Practical Biochemistry: Principles and Techniques. Fifth edition. Cambridge University Press. Cambridge.
Zhou, X.S., H.K. Kaya, K. Heungens, and G.B. Heidi., 2002. Response of Ants to Deterrent Factor(s) Produced by the Simbiotic Bacteria of Entomopathogenic Nematode. Appl. Environ. Microbiol., 68, 6202-6209.
Yang, J.K., I.L. Shih, Y.M. Tzeng and S.L. Wang. 2000. Production and purification of protease from a Bacillus subtilis that can deproteinize wastes. Enzyme and Microbial Tech, 26, 406-413