



US008956842B2

(12) **United States Patent**  
**Hwang et al.**

(10) **Patent No.:** **US 8,956,842 B2**  
(45) **Date of Patent:** **Feb. 17, 2015**

(54) **PAENIBACILLUS SP. HPL-3 STRAIN PRODUCING XYLANASE HAVING HEAT-RESISTANCE, A WIDE RANGE OF OPTIMUM PH AND HIGH ACTIVITY, A NOVEL XYLANASE SEPARATED FROM THE STRAIN, AND A METHOD FOR MASS-PRODUCTION OF THE SAME USING THE TRANSFORMANT ORIGINATED FROM THE STRAIN**

(75) Inventors: **In Taek Hwang**, Daejeon (KR); **No Joong Park**, Daejeon (KR); **He Kyoung Lim**, Daejeon (KR)

(73) Assignee: **Korea Research Institute of Chemical Technology**, Daejeon (KR)

(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/111,647**

(22) PCT Filed: **Aug. 12, 2011**

(86) PCT No.: **PCT/KR2011/005966**

§ 371 (c)(1),  
(2), (4) Date: **Oct. 14, 2013**

(87) PCT Pub. No.: **WO2013/024909**

PCT Pub. Date: **Feb. 21, 2013**

(65) **Prior Publication Data**

US 2014/0038262 A1 Feb. 6, 2014

(51) **Int. Cl.**  
**C12N 9/12** (2006.01)  
**C12N 15/00** (2006.01)  
**C12N 1/20** (2006.01)  
**C07K 1/00** (2006.01)  
**C12N 9/24** (2006.01)  
**A23K 1/165** (2006.01)  
**A23K 1/18** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **C12N 9/2482** (2013.01); **A23K 1/1653** (2013.01); **A23K 1/1813** (2013.01); **C12N 9/248** (2013.01); **A23K 1/1826** (2013.01); **C12Y 302/01008** (2013.01)  
USPC .... **435/195**; 536/23.2; 435/320.1; 435/252.3; 530/350

(58) **Field of Classification Search**  
USPC ..... 435/195, 320.1, 252.3; 530/350; 536/23.1  
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2008/0248160 A1 10/2008 Steer et al.

FOREIGN PATENT DOCUMENTS

WO 96/02632 A1 2/1996  
WO 97/14803 A1 4/1997  
WO 97/22692 A1 6/1997

OTHER PUBLICATIONS

GenBank Accession No. ADX97440: Xylanase KRICT PX3 [*Paenibacillus terrae* HPL-003]2011.02.23; 2 pages.  
International Search Report; mailed Apr. 20, 2012; PCT/KR2011/005966.

*Primary Examiner* — Maryam Monshipouri  
(74) *Attorney, Agent, or Firm* — Ladas & Parry LLP

(57) **ABSTRACT**

The present invention relates to the novel *Paenibacillus* sp. strain, and the novel protein isolated from the same. More particularly, the present invention relates to the novel *Paenibacillus* sp. strain producing xylanase, and the novel xylanase having high activity at high temperature and in a wide range of pH, and a production method of the same. The *Paenibacillus* sp. HPL-3 strain (KCTC11987BP) and the xylanase of the present invention demonstrates high activity at high temperature or in a wide range of pH to decompose xylan, the major component of various lignocellulosic biomass, so that they can be effectively used for the production or development of bio-fuel, alternative material, performance chemical, bio-polymer, food and feeds, etc.

**6 Claims, 7 Drawing Sheets**

Fig. 1

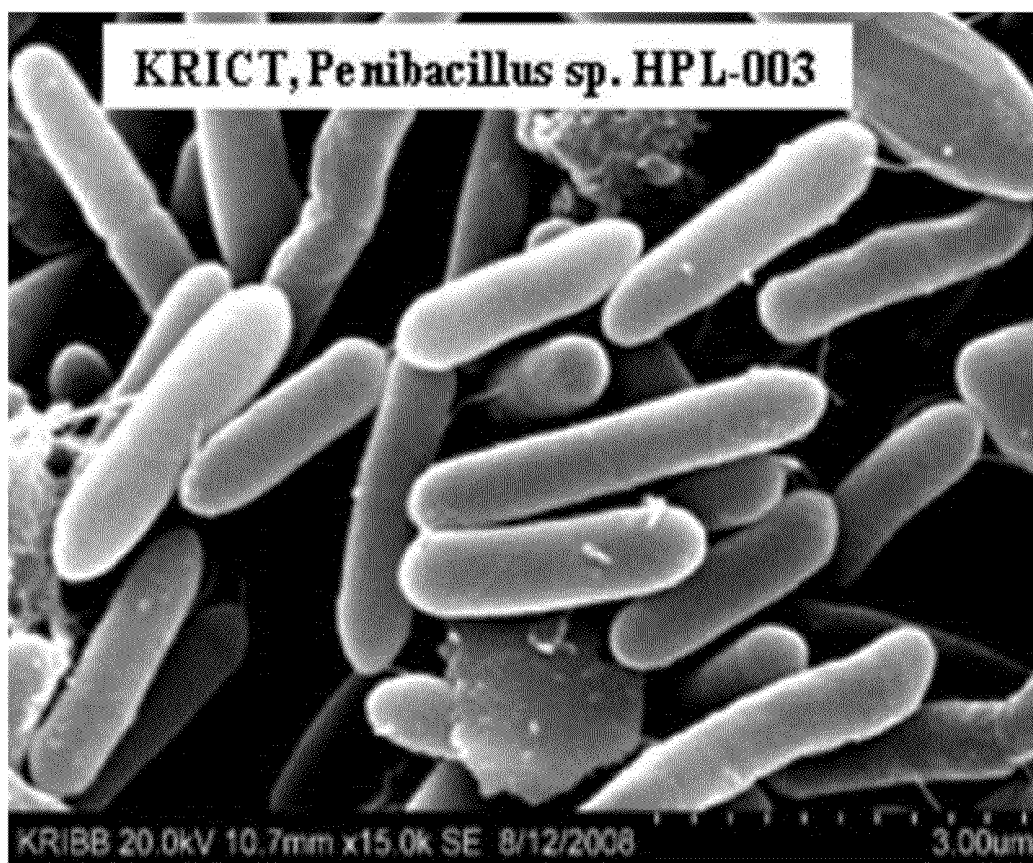


Fig. 2

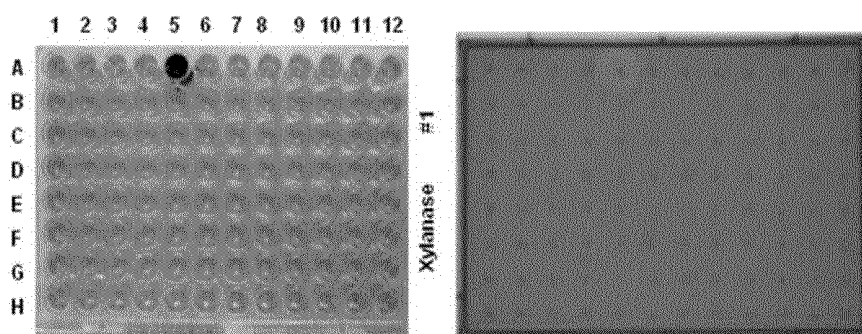
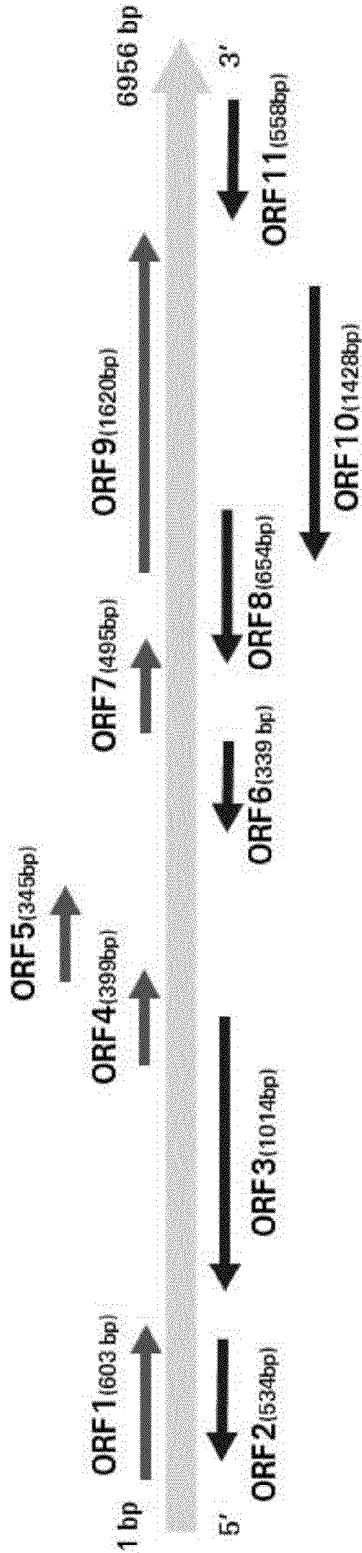
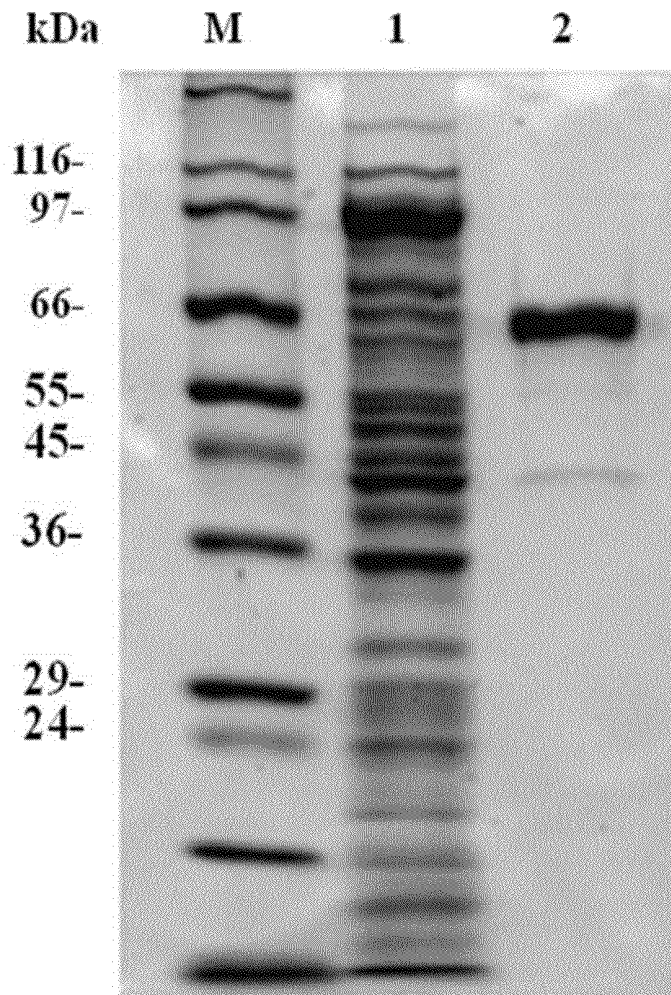


Fig. 3



ORF clone Length ID (aa)	Blast P result	Identities (%)	Ref.
ORF1 200	hypothetical protein [Strongylocentrotus purpuratus]	32	ref XP_001179691.1
ORF2 177	hypothetical protein LOC100189595 [Xenopus laevis]	42	ref NP_081128553.1
ORF3 338	hypothetical protein [Paenibacillus sp.]	31	ref ZP_0485211.1
ORF4 132	hypothetical protein [Robigritalea biformata]	26	gb EAR16711.1
ORF5 144	No significant similarity found.		
ORF6 112	Serine/Threonine protein kinase [Plesiocystis pacifica SIR-1]	42	ref ZP_01910219.1
ORF7 164	binding-protein-dependent transport systems inner membrane component [Geobacillus sp.]	84	ref ZP_03037925.1
ORF8 217	LPX16-motif cell wall anchor domain protein [Lactobacillus reuteri]	32	ref ZP_03073481.1
ORF9 539	endo-1,4-beta-xylanase [Opitutus terrae PB90-1]	48	ref YP_001817989.1
ORF10 475	x-pro dipeptidase [Pyrococcus furiosus]	34	ref NP_578431.1
ORF11 185	6-phospho 3-hexuloisomerase [Geobacillus sp. Y4, IMC1]	64	ref ZP_05371417.1

Fig. 4



SDS-PAGE analysis.

M : Marker,

lane 1 : PX3 cell lysate,

lane 2 : Only PX3

Fig. 5

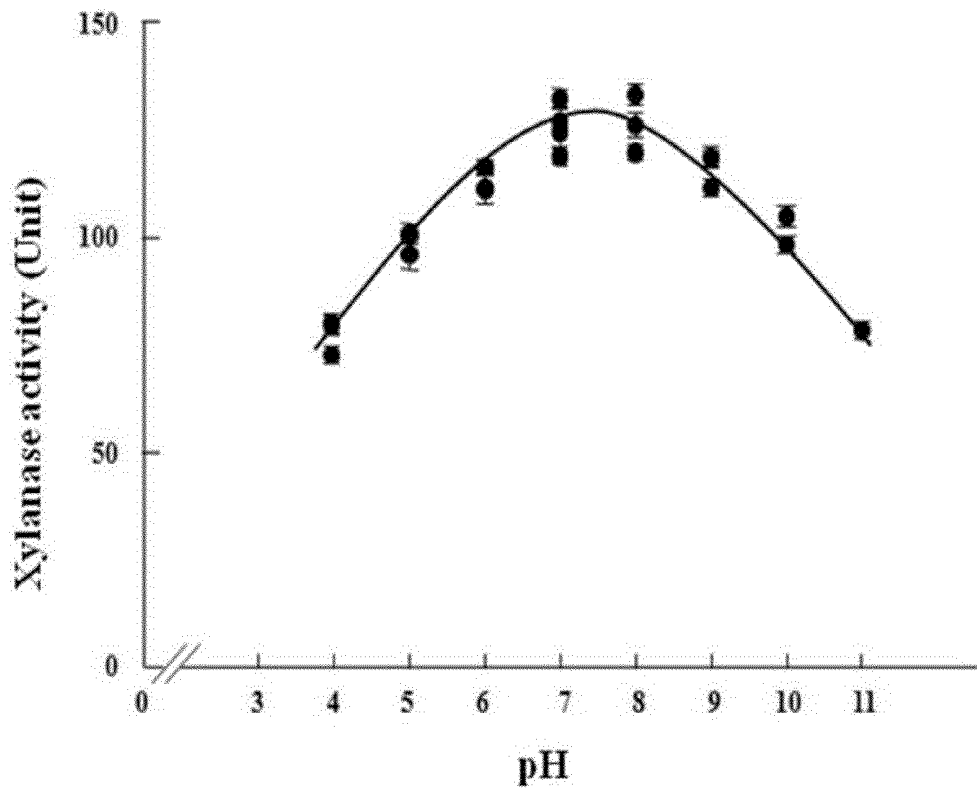


Fig. 6

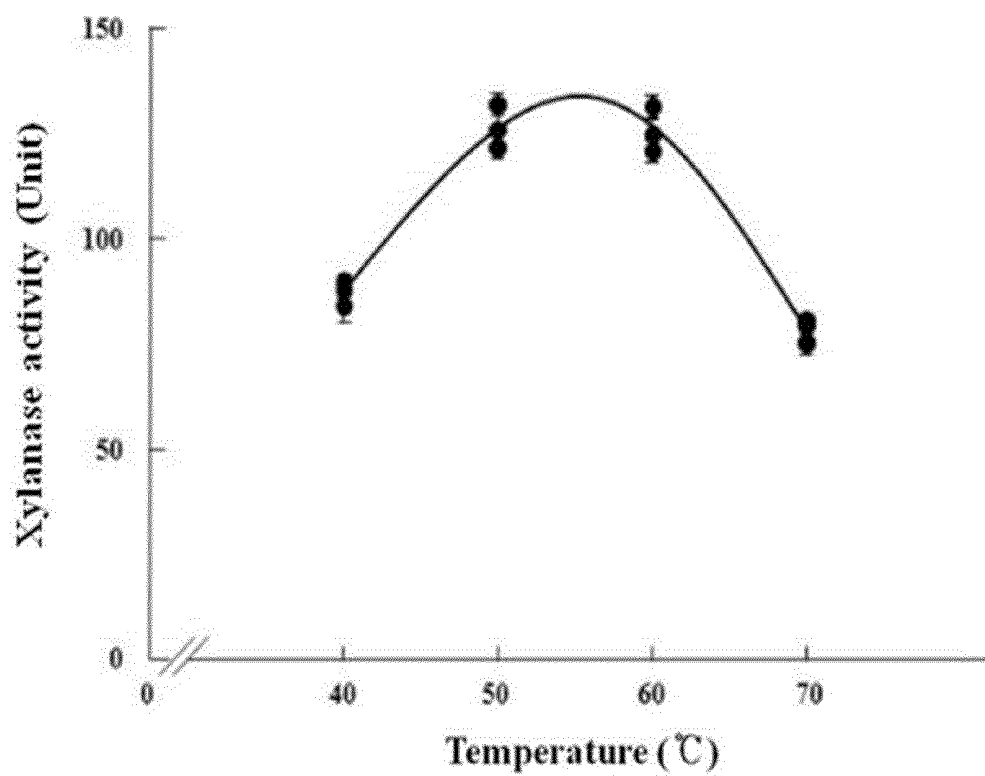
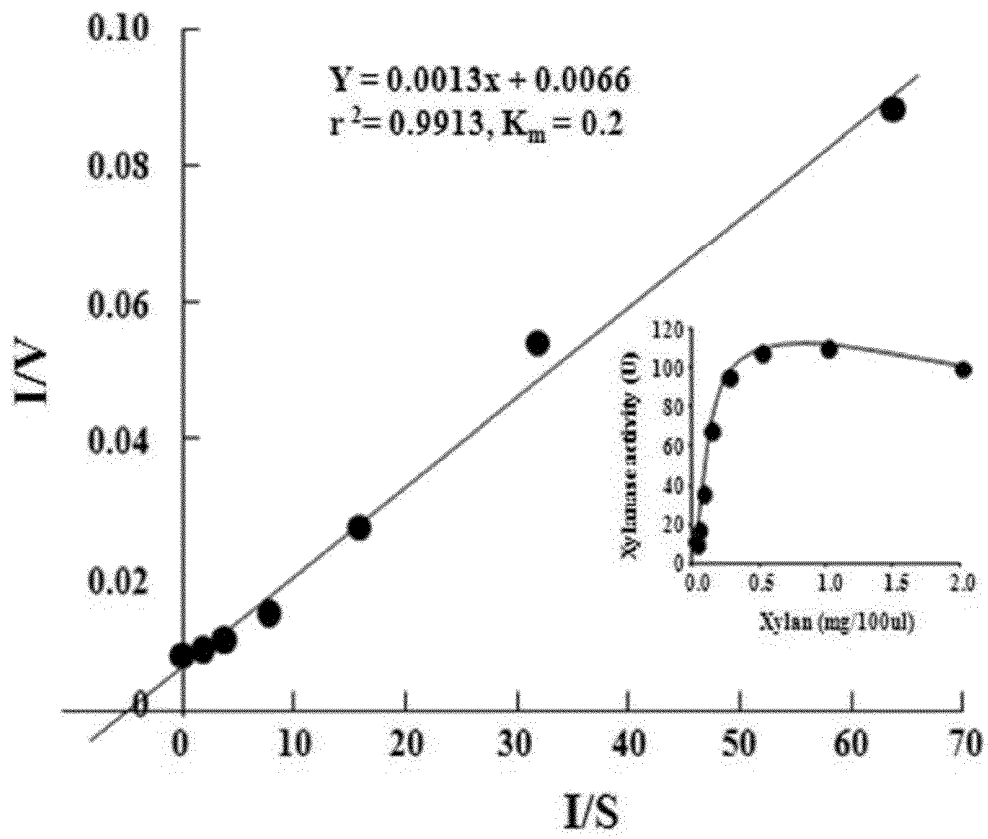


Fig. 7





**PAENIBACILLUS SP. HPL-3 STRAIN  
PRODUCING XYLANASE HAVING  
HEAT-RESISTANCE, A WIDE RANGE OF  
OPTIMUM PH AND HIGH ACTIVITY, A  
NOVEL XYLANASE SEPARATED FROM THE  
STRAIN, AND A METHOD FOR  
MASS-PRODUCTION OF THE SAME USING  
THE TRANSFORMANT ORIGINATED FROM  
THE STRAIN**

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a novel *Paenibacillus* sp. strain producing novel xylanase, a novel xylanase separated from the strain, and a method for mass-production of the same using the transformant of the strain. More precisely, the said novel xylanase exhibits excellent activity of decomposing xylan at high temperature or in a wide range of pH, so that the novel enzyme can be effectively used not only in the fields of feeds, paper and detergent industries, but also in the field of biochemical industry producing bio-fuel, petroleum alternative fuel, performance chemical, or bio-polymer.

2. Description of the Related Art

To keep pace with the changes of international environmental regulations including reduction of carbon dioxide emission, humankind of 21<sup>st</sup> century has the assignment to develop alternative resources of fossil fuel. In preparation of global warming and oil resource depletion, solar energy, wind power, hydropower, atomic power, and biomass have been major targets of research. In the process of biorefinery for the production of bio-fuel and chemical fuel via saccharification of lignocellulosic biomass, it is inevitable to produce the by-product, xylan, that is included in the lignocellulosic biomass by 15-30%. However, it is not possible to use the by-product directly, so most of it are discarded as wastes.

Hydrolysis of xylan has been induced via chemical method so far, which is precisely as follows: sulfuric acid is added to lignocellulosic biomass, followed by decomposing at 130° C. with pressurized steam; leading to the conversion into xylose and xylooligosaccharide. However, in the above process, many impurities are additionally generated by excessive reaction. Therefore, purifying technique is additionally requested. This method has other disadvantages as follows: it not only consumes a massive amount of energy but also requires high priced equipments durable in acid and high temperature condition, and it costs extra money for the treatment of wastes generated during the processes, raising the production cost as well. On the other hand, the biological method for xylan decomposition using xylanase (the enzyme that converts xylan, the major component of hemicellulose, into xylose via saccharification is generally called xylanase) consumes less energy and produces less wastes, compared with the chemical method, suggesting that it has an economical advantage owing to the easy treatment of less wastes.

Xylanase is not only urgently requested in the process of biorefinery (biochemical industry) but also utilized in the process of paper bleaching, for the improvement of feeds efficiency, in the clearing process of fruit beverages, for the production of high quality bread, and in the utilization of agricultural by-products, etc. Xylanase has been produced by using various microorganisms up to date. In particular, alkali-resistant or heat-resistant xylanase was isolated from various bacteria for the use in breaching process of paper industry (Tenkanen, M. et al., *Enzyme. Microb. Technol.* 14, 566-574, 1992). Many xylanase producing microorganisms without cellulase activity have been reported, and attempts to reduce

cellulose loss in the production of paper have been also reported (Khashin, A. et al., *Appl. Environ. Microbiol.* 59, 1725-1730, 1993; Kosugi, A. et al., *J. Bacteriol.* 183, 7037-7043, 2001). Successful cases have been reported to improve quality of bread by treating xylanase (Courtin, C. M. et al., *J. Agric. Food. Chem.*, 47, 1870-1877, 1999), and to introduce  $\beta$ -xylosidase and xylanase genes into yeast that is further used for saccharification of agricultural by-products for a microorganism to use them (La Grange, D. C. et al., *Appl. Environ. Microbiol.* 67, 5512-5519, 2001). In the feeds industry, xylanase came into the market as a feed additive enzyme. So, when the cattle eat grain feeds containing the feed additive enzyme, the enzyme is functioning lower viscosity generated by hemicellulose of the intestines of the cattle, indicating that it is helpful to prevent digestive disease in the cattle and to improve feed efficiency (McCracken, K. J. et al., *Br. Poult. Sci.* 42, 638-642, 2001).

Among the xylanase producing microorganisms reported so far, *Trichoderma* sp. fungal strains have been largely used whose enzyme productivity is superior than other xylanase producing bacteria but the maximum activity is mainly observed in acidic condition (Tenkanen et al., *Enzyme and Microbial Technology* 14(7):566-574, 1992). Xylanase producing bacteria are exemplified by *Aeromonas* sp., *Bacillus* sp., *Clostridium* sp., *Streptomyces* sp., *Aspergillus* sp., etc. The properties of xylanase depend on the bacteria and various genes able to encode xylanase have also been reported.

Status of domestic and international technology involved in xylanase is as follows. *Trichoderma* sp. C-4 strain producing cellulase was identified by Dr. Jung's research team of Kyung Hee University, Korea, however, higher activity is required for the industrialization (Sul et al., *Appl Microbiol Biotechnol.* 66(1):63-70, 2004). *Cephalosporium* sp. RYM-202 strain producing alkali-resistant xylanase was identified by Dr. Kang's research team of Donghae University, Korea, and its usability in pulp processing is being studied (Kang et al., *Korean Journal of Environmental Biology* 17(2):191-198, 1999). *Bacillus subtilis* DB104/pJHKJ4, the recombinant strain producing *Bacillus* originated endoxylanase, was constructed by Dr. Kim's research team of KAIST, Korea (Kim J H et al., *J. Microbiol. Biotechnol.*, 10(4):551-553, 2000). In Taiwan, a case has been reported that alkali-resistance of xylanase genetically replicated from the anaerobic fungus *Neocallimastix patriciarum* was increased by directed enzyme evolution (Yew-Loom Chen et al., *Can. J. Microbiol.* 47(12):10881094, 2001) and recently *Bacillus firmus*, one of the alkali-resistant strains, has been identified in waste water generated from the pulp processing (Pochih Chang, *Biochemical and Biophysical Research Communications* 319: 1017-1025, 2004). This xylanase demonstrates high activity in the wide pH range of 4-11 and heat-resistance as high as maintaining 70% of the original activity even after 16 hour culture at 62° C. Likewise, various strains have been developed and their functions have been improved via directed evolution in many countries.

Patents in relation to xylanase so far are mainly focused on the method for producing xylanase by using a recombinant strain obtained from *E. coli* or using wild-type strain identified as xylanase producing one (International Patent Publication No. 93/08275, International Patent Publication No. 92/01793, International Patent Publication No. 92/17573, Korean Patent Publication No. 10-0072225, Korean Patent Publication No. 10-02211204, Korean Patent Publication No. 10-0411771). Patents in relation to xylanase as a feed additive so far are as follows: Novel *Streptomyces* sp. WL-2 strain producing xylanase (Korean Patent Publication No. 2001-0111986); Recombinant plasmid containing secretion signal

sequence of endoxylanase from *Bacillus subtilis* and expression of foreign proteins using thereof (Korean Patent Publication No. 2000-0034279); and Gene coding xylanase of *Bacillus* sp. AMX-4 strain and recombinant xylanase through transformant thereof (Korean Patent Publication No. 2003-0085679).

Domestic patents in relation to xylanase so far are as follows: Novel *Streptomyces* sp. WL-2 strain producing xylanase (Korean Patent Publication No. 2001-0111986); Recombinant plasmid containing secretion signal sequence of endoxylanase from *Bacillus subtilis* and expression of foreign proteins using thereof (Korean Patent Publication No. 2000-0034279); Gene coding xylanase of *Bacillus* sp. AMX-4 strain and recombinant xylanase through transformant thereof (Korean Patent Publication No. 2003-0085679); and Novel *Paenibacillus* sp. HY-8 strain and xylanase isolated from it (Korean Patent Publication No. 2007-0082329). However, there was no specific explanation about the enzyme activity, neither was reported the cases of using them in domestic industry. Owing to the advanced technology, new methods to polymerize and produce various valuable compounds based on biomass such as high molecular compounds (plastic) have been developed and therefore it is urgently requested to develop xylanase with novel characteristics to match with the above.

For the efficient use of biomass, the development of saccharification process of cellulose using cellulase and the development of saccharification process of hemicellulose using xylanase need to be achieved at the same time. In the enzymatic saccharification process using xylanase, the characteristics of each enzyme required for the process are different according to the pre-treatment method of biomass. For example, in the process of pre-treatment of biomass using acid, acid-resistant saccharifying enzyme is required, while alkali-resistant saccharifying enzyme is required in the process of pre-treatment of biomass using alkali such as in the processes of pulp or paper production. In the meantime, heat-resistant enzyme is required for the simultaneous process of saccharification and fermentation. Most of commercialized xylanases are suitable for acid condition, indicating that novel xylanase demonstrating high activity under alkali condition needs to be developed. It is better to develop such xylanase that shows high activity in both acid and alkali conditions. To use xylanase directly in industry, it is important to secure xylanase gene that is able to maintain high activity under tough conditions such as high temperature and a wide range of pH via screening novel microorganisms and enzyme systems, from which the disadvantages shown in the conventional patents might be overcome.

To avoid those xylanases and those strains producing the same which have already been claimed by other advanced countries, not to infringe intellectual property right, the present inventors tried to develop novel xylanase to meet the domestic and further international need. In the course, the inventors completed this invention by confirming that the xylanase produced from the novel *Paenibacillus* sp. HPL-3 strain demonstrated excellent activity unit (Unit=mM product/mg protein/min), heat-resistance and a wide range of optimum pH, compared with the conventional xylanases, confirmed by solid culture and/or liquid culture enzyme activity measurement method.

#### SUMMARY OF THE INVENTION

It is an object of the present invention to provide xylanase having high activity at high temperature and in a wide range of pH.

It is another object of the present invention to provide a strain producing the said xylanase.

It is further an object of the present invention to provide a polynucleotide encoding the said xylanase.

It is also an object of the present invention to provide a recombinant expression vector operably linked to the said polynucleotide.

It is also an object of the present invention to provide a transformant prepared by introducing the said recombinant expression vector into host cells.

It is also an object of the present invention to provide a production method of xylanase containing the step of obtaining crude enzyme solution by centrifugation after culturing the strain or the transformant above in a medium.

It is also an object of the present invention to provide a xylan decomposer comprising the said xylanase, the said strain, or the said transformant.

It is also an object of the present invention to provide a composition for processing food xylan comprising the said xylanase.

It is also an object of the present invention to provide a feed additive comprising the said xylanase.

It is also an object of the present invention to provide a composition for papermaking process comprising the said xylanase.

It is also an object of the present invention to provide a method for decomposing xylan containing the step of adding the said xylanase, the said strain, or the said transformant to lignocellulosic biomass or xylan containing solution.

It is also an object of the present invention to provide a preparation method of feeds containing the step of adding the said xylanase, the said strain, or the said transformant to animal feed materials.

It is also an object of the present invention to provide the said xylanase, the said strain, or the said transformant for the use as a xylan decomposer.

It is also an object of the present invention to provide the said xylanase for the use as a composition for processing food xylan.

It is also an object of the present invention to provide the xylanase for the use as a feed additive.

In addition, it is an object of the present invention to provide the xylanase for the use as a composition for papermaking process.

To achieve the above objects, the present invention provide the xylanase having the characteristics of (a)-(d):

(a) molecular weight: approximately 65 KDa on SDS-PAGE;

(b) maximum activity in the range of pH 5~pH 11;

(c) maximum activity at the temperature of 50~60° C.; and

(d) xylose production at 50° C., pH 5~pH 11: at least 95 unit/minmg; and xylose production at 60° C., pH 6~pH 9: at least 100 unit/minmg.

The present invention also provides a strain producing the said xylanase.

The present invention also provides a polynucleotide encoding the said xylanase.

The present invention also provides a recombinant expression vector operably linked to the said polynucleotide.

The present invention also provides a transformant prepared by introducing the said recombinant expression vector into host cells.

The present invention also provides a production method of xylanase containing the step of obtaining crude enzyme solution by centrifugation after culturing the strain or the transformant above in a medium.

The present invention also provides a xylan decomposer comprising the said xylanase, the said strain, or the said transformant.

The present invention also provides a composition for processing food xylan comprising the said xylanase.

The present invention also provides a feed additive comprising the said xylanase.

The present invention also provides a composition for papermaking process comprising the said xylanase.

The present invention also provides a method for decomposing xylan containing the step of adding the said xylanase, the said strain, or the said transformant to lignocellulosic biomass or xylan containing solution.

The present invention also provides a preparation method of feeds containing the step of adding the said xylanase, the said strain, or the said transformant to animal feed materials.

The present invention also provides the said xylanase, the said strain, or the said transformant for the use as a xylan decomposer.

The present invention also provides the said xylanase for the use as a composition for processing food xylan.

The present invention also provides the xylanase for the use as a feed additive.

In addition, The present invention provides the xylanase for the use as a composition for papermaking process.

#### Advantageous Effect

As explained hereinbefore, the xylanase separated from *Paenibacillus* sp. HPL-3, the novel strain of the present invention, has excellent heat-resistance at 60° C. and demonstrates excellent xylan decomposing activity in a wide range of pH (4~11), so that this enzyme can be effectively used not only in the fields of feed, paper and detergent industries, but also in the saccharification process of lignocellulosic biomass for the production of raw materials of petroleum alternative material, performance chemical, and bio-polymer.

#### BRIEF DESCRIPTION OF THE DRAWINGS

The application of the preferred embodiments of the present invention is best understood with reference to the accompanying drawings, wherein:

FIG. 1 is a electron micrograph illustrating the selected strain.

FIG. 2 is a diagram illustrating the selection of active clones from 1,248 gDNA library.

FIG. 3 is a diagram illustrating the results of ORF analysis and homology analysis among ORF amino acids.

FIG. 4 is a diagram illustrating the activity of the xylanase separated and purified from the transformant.

FIG. 5 is a graph illustrating the optimum pH range of the xylanase.

FIG. 6 is a graph illustrating the optimum temperature range of the xylanase.

FIG. 7 is a diagram illustrating the kinetics of the separated and purified xylanase.

#### DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, the present invention is described in detail.

The present invention provide the xylanase having the characteristics of (a)~(d):

(a) molecular weight: approximately 65 KDa on SDS-PAGE;

(b) maximum activity in the range of pH 5~pH 11;

(c) maximum activity at the temperature of 50~60° C.; and  
(d) xylose production at 50° C., pH 5~pH 11: at least 95 unit/min mg; and xylose production at 60° C., pH 6~pH 9: at least 100 unit/mining.

The amino acid sequence of the xylanase of the present invention preferably contains one of the following sequences, but not always limited thereto:

a) the amino acid sequence represented by SEQ. ID. NO: 4;

b) the amino acid sequence having at least 70% homology, preferably at least 80%, and more preferably at least 90% homology with the amino acid sequence represented by SEQ. ID. NO: 4;

c) the amino acid sequence encoded by the nucleotide sequence represented by SEQ. ID. NO: 3;

d) the amino acid sequence of the protein composed of the modified amino acid sequence having substitution, deletion, insertion, and/or addition of at least one of amino acids of the sequence represented by SEQ. ID. NO: 4, which is also identical in its function to the protein containing the amino acid sequence represented by SEQ. ID. NO: 4; and,

e) the amino acid sequence encoded by DNA hybridized with the DNA containing the nucleotide sequence represented by SEQ. ID. NO: 3 in the strict condition, which is identical in its function to the protein containing the amino acid sequence represented by SEQ. ID. NO: 3.

The said 'strict condition' is determined in the phase of washing after hybridization. One of the strict conditions is exemplified as follows: washing with 6± SSC, 0.5% SDS at room temperature for 15 minutes, then washing with 2± SSC, 0.5% SDS at 45° C. for 30 minutes, and then washing with 0.2± SSC, 0.5% SDS at 50° C. for 30 minutes twice. More preferable strict condition herein means washing at a higher temperature. That is, washing is performed by the same manner as described above only except that the last washing is performed with 0.2± SSC, 0.5% SDS at 60° C. for 30 minutes twice. Another example of the strict condition of the present invention is set with modification of the above washing process, that is the last two washings are performed with 0.1± SSC, 0.1% SDS at 65° C. Whoever in this field can set up and adjust the conditions to satisfy the strict conditions.

The xylanase of the present invention demonstrates maximum activity in the pH range of 5~11, preferably in the pH range of 6~10, and more preferably in the pH range of 6~9, at 50~60° C., but not always limited thereto.

In a preferred embodiment of the present invention, the strain having excellent xylan decomposing activity was collected from the soil containing waste wood residue left after mushroom cultivation in halfway up the mountain Gara located in Dadae-ri, Nambu-myeon, Geoje-si, Gyeongsangnam-do, Korea.

In a preferred embodiment of the present invention, gDNA library was constructed to separate a gene encoding the enzyme protein having xylanase activity from the said strain, and then xylanase activity was examined. From the experiment, one clone was selected (see FIG. 2), and then nucleotide sequence of the inserted DNA fragment was analyzed. As a result, the size of the DNA fragment was 6,956 bp (SEQ. ID. NO: 2) and 11 ORFs were included in the sequence range of 100 or more amino acids (see FIG. 3). The present inventors investigated homology of those ORF proteins encoded by the gene. Then, *E. coli* was transfected with ORFS (1620 bp, 539 aa) showing 48% homology with endo-1,4-beta-xylanase (GenBank Accession No: YP\_001817989), and xylanase activity was investigated. As a result, excellent xylanase activity was confirmed. Nucleotide sequence of target DNA fragment of the transformant was also investigated, and as a

result ORF of the novel xylanase gene having the nucleotide sequence represented by SEQ. ID. NO: 3 was confirmed.

In a preferred embodiment of the present invention, the transformant over-expressing xylanase was constructed in order to produce the novel xylanase having the amino acid sequence represented by SEQ. ID. NO: 4 in a large scale. Enzyme activity of the novel xylanase with 65 kD (see FIG. 4) which was produced, separated, and purified from the said transformant *E. coli* was investigated. As a result, maximum activity was observed at 50~60° C., in pH range of 4~11 (see FIGS. 5 and 6). Even though the activity was inhibited by 74%, 28%, 12%, and 46%, respectively by 1 mM of Cu+2, Zn+2, Fe+2, and EDTA, among various heavy metal sources, the enzyme activity was hardly affected at the concentration of 100 HM or rather increased by them (see Table 1). Enzyme kinetics was also investigated. As a result, Km, presenting substrate affinity, was 0.2 (see FIG. 7). Hydrolyzed products were largely xylo-oligomer.

From the results of sequencing and activity analysis, it was confirmed that the xylanase produced from the strain identified in this invention was novel one that was different from the conventional xylanase.

The present invention also provides a strain producing the said xylanase.

The said strain can be prokaryotic cells including *E. coli*, or eukaryotic cells including yeast, animal cells and insect cells, but not always limited thereto. The said strain producing xylanase is preferably *Paenibacillus* sp. HPL-3 deposited under the Accession No. of KCTC11987BP, but not always limited thereto, and any strain that is able to produce xylanase can be included in this invention.

In a preferred embodiment of the present invention, the strain having excellent xylan decomposing activity was collected from the soil containing waste wood residue left after mushroom cultivation in halfway up the mountain Gara located in Dadae-ri, Nambu-myeon, Geoje-si, Gyeongsangnam-do, Korea. The collected strain was identified as a Gram-positive, rod type, non-motile *bacillus* without flagellum. The cell size was 1.1 µm and the cell length was 2.5~4 µm (see FIG. 1). The strain had 16S rRNA represented by SEQ. ID. NO: 1. From the rRNA homology analysis, it was confirmed that the strain had 95.0% homology with *Paenibacillus* sp. CSH12-5 (GenBank Accession No. EF694701) and 95.7% homology with *Paenibacillus daejeonensis*(T) (GenBank Accession No. AM141; AF391124). Since no higher homology with any other strain was confirmed, the strain of the present invention was named *Paenibacillus* sp. HPL-3, which was deposited at Korean Research Institute of Bioscience and Biotechnology in Jul. 20, 2011 under the Accession No. KCTC1198BP.

The present invention also provides a polynucleotide encoding the said xylanase.

The polynucleotide encoding the xylanase of the present invention preferably contains one of the following sequences, but not always limited thereto:

- a) the nucleotide sequence represented by SEQ. ID. NO: 3;
- b) the nucleotide sequence having at least 70% homology, preferably at least 80%, and more preferably at least 90% homology with the nucleotide sequence represented by SEQ. ID. NO: 3;
- c) the nucleotide sequence encoding the amino acid sequence represented by SEQ. ID. NO: 4;
- d) the nucleotide sequence encoding the amino acid sequence of the protein with substitution, deletion, insertion, and/or addition of at least one of amino acids of the sequence represented by SEQ. ID. NO: 4, which is also identical in its

function to the protein containing the amino acid sequence represented by SEQ. ID. NO: 4; and,

e) the nucleotide sequence comprising DNA sequence to be hybridized with DNA containing the nucleotide sequence represented by SEQ. ID. NO: 3 under the strict condition and encoding the protein having the same function as the protein comprising the amino acid sequence represented by SEQ. ID. NO: 4.

The present invention also provides a recombinant expression vector operably linked to the said polynucleotide.

In this invention, the nucleotide sequence of the novel gene encoding the xylanase separated from *Paenibacillus* sp. HPL-3 strain was identified, so that a recombinant vector containing the said gene can be constructed by the conventional method known to those in the art. The recombinant vector of the present invention can be a commercialized one, but not always limited thereto, and can be constructed by the conventional method known to those in the art.

The present invention also provides a transformant prepared by introducing the said recombinant expression vector into host cells.

The host cells usable in this invention are not limited, but preferably selected from the group consisting of prokaryotic cells including *E. coli* and bacteria, and eukaryotic cells including yeast, animal cells and insect cells, and more preferably *E. coli*, but not always limited thereto.

The present invention also provides a production method of xylanase containing the step of obtaining crude enzyme solution by centrifugation after culturing the strain or the transformant above in a medium.

The production method of the present invention can additionally include the step of purifying xylanase from the obtained crude enzyme solution.

In the above method, the medium is preferably selected among commercialized media well-known to those in the art that is considered to be appropriate for the culture of *Paenibacillus* sp. HPL-3 (KCTC11987BP) or the transformant of the present invention.

To simplify the purification process and to increase purification efficiency, the present inventors used a specific resin binding vector for column-chromatography for the construction of the transformant. It is preferred to select and separate the enzyme linked to resin in the course of purification. For the strict condition herein, glutathione binding vector, calmodulin binding vector, and maltose binding vector can be used and resin for column filling is determined by considering the vector used. In this invention, the results obtained by using glutathione binding vector and resin are presented, but the invention is not limited thereto.

The present invention also provides a xylan decomposer comprising the said xylanase, the said strain, or the said transformant.

The xylan decomposer of the present invention can be not only the xylanase produced in the strain or the transformant of the invention but also the strain or the transformant itself.

The present invention also provides a composition for processing food xylan comprising the said xylanase.

The present invention also provides a feed additive comprising the said xylanase.

The present invention also provides a composition for papermaking process comprising the said xylanase.

The composition or the feed additive of the present invention can include, in addition to the xylanase, one or more effective ingredients having the same or similar function to the xylanase. The preferable concentration of the xylanase of the present invention is 1~90% by the total composition or feed additive, but not always limited thereto.

Unlike the conventional xylanase, the xylanase of the present invention demonstrates excellent activity in a wide range of pH (5~11) and temperature (50~60° C.) (see FIGS. 5 and 6). Therefore, the xylanase of the present invention can be used as the novel xylanase having high activity in the wide pH range and heat-resistance.

The use of xylanase in the enzyme market is largely divided into food industry, feed industry, and technology field (Bedford and Morgana, World's Poultry Science Journal 52:61-68, 1996). In food industry (fruit and vegetable production, brewing and liquor production, bakery and confectionery), xylanase has been used to improve quality of the product by softening raw materials, improving purification efficiency, reducing viscosity, and increasing extraction/filtration efficiency. In feed industry, xylanase has been used to reduce non-starch carbohydrates in feed for pig, poultry and ruminants, to improve intestinal viscosity, and to increase digestibility of protein and starch (Kuhad and Singh, Crit. Rev. Biotechnol. 13, 151-172, 1993). In addition, in the field of technology, xylanase has been used in papermaking process, precisely for biological whitening, reduction of chlorine decay, saving energy through simplifying mechanical papermaking process, separation of starch and gluten, production of renewable fuel (bio-ethanol), and production of chemical raw materials.

Therefore, it is well understood by those in the art that the novel xylanase of the present invention can be effectively used for the decomposition of xylanase industrially used in papermaking and paper recycling, and in feed and food industry to improve quality of the products. The composition of the present invention can be formulated by the conventional method known to those in the art.

The present invention also provides a method for decomposing xylan containing the step of adding the said xylanase, the said strain, or the said transformant to lignocellulosic biomass or xylan containing solution.

In the above method, the amount of the strain, the transformant, or the novel xylanase produced by the strain or the transformant can be adjusted by those in the art.

The present invention also provides a preparation method of feeds containing the step of adding the said xylanase, the said strain, or the said transformant to animal feed materials.

In the above method, the amount of the strain, the transformant, or the novel xylanase produced by the strain or the transformant can be adjusted by those in the art.

The present invention also provides the said xylanase, the said strain, or the said transformant for the use as a xylan decomposer.

The xylan decomposer of the present invention can be not only the xylanase produced in the strain or the transformant of the invention but also the strain or the transformant itself.

The present invention also provides the said xylanase for the use as a composition for processing food xylan.

The present invention also provides the xylanase for the use as a feed additive.

In addition, The present invention provides the xylanase for the use as a composition for papermaking process.

The said xylanase preferably has the characteristics of (a)-(d), but not always limited thereto:

(a) molecular weight: approximately 65 KDa on SDS-PAGE;

(b) maximum activity in the range of pH 5~pH 11;

(c) maximum activity at the temperature of 50~60° C.; and

(d) xylose production at 50° C., pH 5~pH 11: at least 95 unit/min mg; and xylose production at 60° C., pH 6~pH 9: at least 100 unit/min mg.

The amino acid sequence of the said xylanase preferably contains one of the below sequences, but not always limited thereto:

a) the amino acid sequence represented by SEQ. ID. NO: 4;

b) the amino acid sequence having at least 70% homology, preferably at least 80%, and more preferably at least 90% homology with the amino acid sequence represented by SEQ. ID. NO: 4;

c) the amino acid sequence encoded by the nucleotide sequence represented by SEQ. ID. NO: 3;

d) the amino acid sequence of the protein composed of the modified amino acid sequence having substitution, deletion, insertion, and/or addition of at least one of amino acids of the sequence represented by SEQ. ID. NO: 4, which is also identical in its function to the protein containing the amino acid sequence represented by SEQ. ID. NO: 4; and,

e) the amino acid sequence encoded by DNA hybridized with the DNA containing the nucleotide sequence represented by SEQ. ID. NO: 3 in the strict condition, which is identical in its function to the protein containing the amino acid sequence represented by SEQ. ID. NO: 3.

Unlike the conventional xylanase, the xylanase of the present invention demonstrates excellent activity in a wide range of pH (5~11) and temperature (50~60° C.) (see FIGS. 5 and 6). Therefore, the xylanase of the present invention can be used as the novel xylanase having high activity in the wide pH range and heat-resistance for the composition for processing food xylan, for feed additive, or for papermaking process.

Practical and presently preferred embodiments of the present invention are illustrative as shown in the following Examples, Experimental Examples and Manufacturing Examples.

However, it will be appreciated that those skilled in the art, on consideration of this disclosure, may make modifications and improvements within the spirit and scope of the present invention.

### Example 1

#### Isolation and Selection of Strain

##### <1-1> Isolation of Strain

The strain of the present invention was collected from the soil containing waste wood residue left after mushroom cultivation in halfway up the mountain Gara located in Dadae-ri, Nambu-myeon, Geoje-si, Gyeongsangnam-do, Korea. Soil sample was collected from 2~5 cm under the surface layer, which was dried over wind and filtered with 2 mm sieve. The filtered soil sample (30 g) was loaded in 270 ml of sterilized saline (NaCl 8.0 g/l), followed by shaking in a shaking incubator (37° C., 200 rpm) for 20 minutes. The soil sample stood at room temperature for 30 minutes to precipitate big soil particles and impurities on the bottom. The supernatant was transferred in a sterilized container, leading to the preparation of the first diluted solution. The first diluted solution was stirred well and then 10 ml of the solution was taken and loaded in 90 ml of saline to prepare the second diluted solution (100 ml). The second diluted solution was stirred well and then 10 ml of the solution was taken again and loaded in 90 ml of saline to prepare the third diluted solution (100 ml). Then, the fourth, fifth and sixth diluted solutions were prepared by the same manner as described above. The 3rd, 4th, 5th, and 6th diluted solutions were distributed in TSA (Tryptic Soy Agar, Difco Co.) medium for strain separation, three times by 0.25 ml at a time. The diluted solutions were smeared evenly on the medium and culture was performed in a 37° C. bench-type incubator for 2 days. Then, the formed

microorganism colonies were selected. The selected colonies were separated by shape, size, color, and other relevant factors. The separated colonies were sub-cultured in TSA medium, to isolate pure strains which were stored at  $-70^{\circ}\text{C}$ . for being used as the mother strain.

#### <1-2> Selection of Strain

For the selection of active strain showing xylanase activity among the isolated pure strains, soft agar double medium was prepared by adding birch xylan (Fluka Bio Chemika. Co.) to TSA medium by 0.5~1.0%, to which the isolated strains were inoculated. After overnight culture, those strains forming translucent zone (halo) around the cultured colony and active clones were selected by Congo-red staining method (Theater R M, P J. Wood. *Appl Environ Microbiol* 43, 777-780, 1982; Beguin P. *Analytical Biochemistry*, 131(2):333-336, 1983). Xylan decomposing activity of the selected strain was measured again to confirm reproducibility. Among those strains, the strain demonstrating most excellent xylan decomposing activity was selected finally as the microorganism producing xylanase.

### Example 2

#### Identification of Strain

The present inventors cultured the strain producing xylanase demonstrating the highest activity, isolated in Example 1, at  $30^{\circ}\text{C}$ ., and then performed Gram staining and spore staining. As a result, the strain of the present invention was confirmed to be Gram-positive *bacillus* forming spores. The morphology of the strains was observed under electron microscope. As shown in FIG. 1, the strain was identified as a rod type, non-motile *bacillus* without flagellum. The cell size was  $1.1\ \mu\text{m}$  and the cell length was  $2.5\sim 4\ \mu\text{m}$ . From analysis of 16S rRNA nucleotide sequence of the strain, 1234 bp rDNA represented by SEQ. ID. NO: 1 was obtained, followed by screening with GenBank database. As a result, it was confirmed that the strain had 96.4% homology with *Pantoea agglomerans* ZFJ-15 (GenBank Accession No. EU931554) and 96.3% homology with *Paenibacillus* sp. WPCB158 (GenBank Accession No. FJ006910). Since no higher homology was confirmed, the strain of the present invention was named *Paenibacillus* sp. HPL-3, which was deposited at Korean Research Institute of Bioscience and Biotechnology in Jul. 20, 2011 under the Accession No. of KCTC1198BP.

### Example 3

#### Separation of Novel Xylanase

##### <3-1> Construction of *Paenibacillus* Strain Gene Library and Activity Test

To separate the gene encoding the enzyme protein having xylanase activity from the *Paenibacillus* sp. HPL-3 strain separated and identified in Example 1 and Example 2, genome DNA was first extracted to construct gDNA library containing gene fragments less than 5 kb. To construct the library, the extracted DNA was fragmented into 1~6 kb sized fragments by random digestion, followed by electrophoresis on agarose gel. The fragments were sorted by size and those DNA fragments having approximately 5 kb size were selected. The fragments were inserted in pCB31 plasmid vector, with which *E. coli* DH10B was transfected. Xylanase activity was investigated with 1,248 clones of the constructed library in solid or liquid condition.

##### <3-2> Xylanase Activity Test

The measurement of xylanase activity (xylan decomposing activity) of the isolated strain, active clone, transformant, and isolated/purified enzyme was performed by either or both of the following two methods. The first method was enzyme activity measuring method using solid culture. Particularly, soft agar double medium was prepared by adding birch xylan (Fluka Bio Chemika. Co.) to LB medium by 0.5~1.0%, to which the strain was inoculated, followed by culture for overnight. On the next day, the strain and active clone forming translucent zone (halo) around the cultured colony were selected by Congo-red staining. The second method was enzyme activity measuring method using liquid culture, that is DNS (3,5-dinitrosalicylic acid) quantitative method (Miller G. L. *Anal Chem* 31, 426-428, 1959). Particularly, 50  $\mu\text{l}$  of substrate solution (50 mM Tris-HCl containing birch xylan by 2%, pH 7.0) was added to 50  $\mu\text{l}$  of enzyme solution, followed by reaction at  $50^{\circ}\text{C}$ . for 20 minutes. 200  $\mu\text{l}$  of DNS solution was added thereto, followed by further reaction at  $90^{\circ}\text{C}$ . for 5 minutes. Then,  $\text{OD}_{540}$  was measured. 1 unit of the enzyme was defined as the enzyme activity of 1 mg xylanase to produce 1  $\mu\text{mol}$  of reducing sugar (xylose) per 1 minute. One clone showing the best activity, GM3-SLX1, was selected by liquid culture and solid culture activity test (FIG. 2).

##### <3-3> Selection of Xylanase Active Clone and Gene Assay

Sequencing of the DNA fragment inserted in the clone selected in Example <3-2> was performed. As a result, the size of the DNA fragment inserted in the plasmid was 6,956 bp (SEQ. ID. NO: 2). ORF (Open Reading Frame) was also investigated by using NCBI Blast P or Blast N program (<http://www.ncbi.nlm.nih.gov/>). Among the ORFS analyzed above, 11 ORFS having the size of at least 100 amino acids were named as follows: SLX-O1, SLX-O2, SLX-O3, SLX-O4, SLX-O5, SLX-O6, SLX-O7, SLX-O8, SLX-O9, SLX-O10, and SLX-O11. Among the ORFs, SLX-O9 (SEQ. ID. NO: 3) showing 48% homology with endo-1,4-beta-xylanase (AJ006646) was selected as a target. Based on nucleotide sequence of the target, the primer having the addition of XhoI and BamHI sites was constructed, followed by amplification by PCR. Then, the amplified primer was inserted in pGEM-T-Easy vector (Promega) to construct a recombinant plasmid.

Particularly, 1 ng of GM3-SLX1 template plasmid was mixed with the primer set (10 pmol) composed of the forward primer represented by SEQ. ID. NO: 5 (5'-CTCGAGATG-GATACATTGAAGTTGTATGTG-3') and the reverse primer represented by SEQ. ID. NO: 6 (5'-GGATCCCTATTCGT-TGCTCCCC-3'), followed by PCR using PCR Premix (GenetBio) as follows: predenaturation at  $94^{\circ}\text{C}$ . for 5 minutes, denaturation at  $94^{\circ}\text{C}$ . for 30 seconds, annealing at  $55^{\circ}\text{C}$ . for 30 seconds, extension at  $72^{\circ}\text{C}$ . for 1 minute, 30 cycles from denaturation to extension, and final extension at  $72^{\circ}\text{C}$ . for 7 minutes. Then reaction was terminated at  $4^{\circ}\text{C}$ . The PCR amplified product was purified by using GENCLEAN II Kit (Q-Biogene), and a recombinant DNA was constructed with pGEM-T-easy vector using T4 ligase (RBC). *E. coli* transformant was prepared by transfecting *E. coli* JM109 with the recombinant plasmid. The transformant was cultured in LB liquid medium, and then, plasmid DNA was extracted by using HiYield™ Plasmid Mini Kit (RBC). The extracted plasmid DNA was digested with XhoI (NEB) and BamHI (NEB), followed by electrophoresis to confirm the insertion of the target DNA fragment. Xylanase activity of the said transformant was investigated in the liquid phase as explained in Example <3-2>. As a result, xylanase activity was observed therein.

Nucleotide sequence of the target DNA fragment of the transformant was investigated and as a result ORF of the novel xylanase gene represented by SEQ. ID. NO: 4 was confirmed.

<3-4> Construction of Transformant Over-Expressing Xylanase (pIVEX-GST-PX3)

To construct a transformant over-expressing the novel xylanase, PCR was performed using GM3-SLX1 plasmid as a template with the primer set composed of the sequence represented by SEQ. ID. NO: 5 and the sequence represented by SEQ. ID. NO: 6. PCR reaction mixture and the reaction condition were same as described in Example <3-2>. The amplified product was purified and digested with XhoI (NEB) and BamHI (NEB), which was inserted in pIVEX-GST (Roche), the protein over-expressing vector, to construct the recombinant over-expression plasmid. *E. coli* transformant over-expressing xylanase was prepared by transfecting *E. coli* BL21v (RBC) with the recombinant plasmid. The constructed *E. coli* transformant over-expressing xylanase was cultured and plasmid DNA was extracted. The extracted plasmid DNA was digested with the said restriction enzymes, followed by electrophoresis to confirm that the target DNA and the vector were successfully recombined. The identified strain was cultured in LB liquid medium (supplemented with 100 ampicillin/ml) for 18 hours (37° C., 250 rpm, A600=1.0) and inoculated in fresh LB liquid medium. When OD<sub>600</sub> reached 0.4-0.6, the medium was treated with 1 mM of IPTG, followed by further culture for 3 hours. Then, cells were collected, resuspended and sonicated. The sonicated cell suspension was centrifuged at 10,000 g to separate supernatant and precipitate. The target protein over-expressed in the supernatant was confirmed. Molecular weight of the target protein was approximately 65 kD, which was confirmed by SDS-PAGE (FIG. 4).

<3-5> Condition for Xylanase Activity Expression

In this example, pH, temperature, and metal ion-dependent activity of xylanase over-expressed and isolated from the *E. coli* transformant over-expressing the novel xylanase constructed in Example <3-4> was investigated by the same manner as described in example 3-2. pH of the reaction solution was regulated to pH 4-5 with citric acid buffer, to pH 6-8 with phosphate buffer, to pH 7-9 with Tris/HCl buffer, and to pH 9-11 with glycine/NaOH buffer. To investigate the effect of metal ions on xylanase activity, CaCl<sub>2</sub>, MgCl<sub>2</sub>, MgCl<sub>2</sub>, CuCl<sub>2</sub>, ZnCl<sub>2</sub>, and FeCl<sub>3</sub> were added by 1 mM each. It was further investigated how other salts such as NaCl, LiCl, KCl, NH<sub>4</sub>Cl, EDTA, CsCl<sub>2</sub>, 2-ME (2-Mercaptoethanol), DTT (Dithiothreitol), PMSF (Penylmethylsulfonyl fluoride), acetate, and furfural could affect xylanase activity.

As a result, the novel xylanase demonstrated the maximum activity at the pH range of 4-11 as shown in FIG. 5, and at the temperature range of 50-60° C., as shown in FIG. 6. As shown in Table 1, xylanase activity was inhibited by 74%, 28%, 12%, and 46% respectively by 1 mM of such heavy metal or additive as Cu<sup>+2</sup>, Zn<sup>+2</sup>, Fe<sup>+2</sup>, and EDTA.

TABLE 1

Additive	Relative activity according to conc. of additive (%) 1 mM
Negative Control	100
NaCl	105
LiCl	101
KCl	101
NH <sub>4</sub> Cl	99
CaCl <sub>2</sub>	102

TABLE 1-continued

Additive	Relative activity according to conc. of additive (%) 1 mM
MgCl <sub>2</sub>	93
MnCl <sub>2</sub>	98
CsCl <sub>2</sub>	97
CuSO <sub>4</sub>	26
ZnSO <sub>4</sub>	72
FeCl <sub>3</sub>	88
EDTA	54
2-ME	89
DTT	95
PMSF	95
Acetate	101
Furfural	98

## Example 4

## Mass-Production of the Novel Xylanase

*E. coli* BL21-Gold (DE) (Stratagene, USA) was transfected with pIVEX GST-xylanase recombinant vector (Bioprogen Co., Ltd., Korea) containing the gene (SEQ. ID. NO: 3) encoding the novel xylanase represented by SEQ. ID. NO: 4, which was inoculated in liquid medium (LB 25 g/L) supplemented with ampicillin (50 µg/ml), followed by shaking culture at 37° C. at 150 rpm until OD<sub>603</sub> reached 0.4-0.6. To induce the expression of the target protein in *E. coli* cells, IPTG (isopropyl-D-thiogalactoside) was added to the suspension at the concentration of 1 mM, followed by further culture for 3 hours. The culture solution was centrifuged at 10,000 rpm for 10 minutes and the recovered precipitate was washed with PBS twice. The washed precipitate was re-suspended in PBS and then cell were lysed by using a ultrasonicator (Cosmo Bio Co., LTD). Centrifugation was performed (12,000 rpm, 10 minutes) to obtain supernatant. To isolate xylanase from the supernatant, glutathione S-transferase column (GST binding resin column, Novagen) was used. For xylanase separation, the obtained supernatant was filled in glutathione S-transferase column (GST binding resin column, Novagen) equilibrated with washing buffer (50 mM Tris-HCl, 100 mM NaCl; pH 7.0), followed by treatment of factor Xa protease (NEB) and separation using washing buffer (50 mM Tris-HCl, 100 mM NaCl; pH 7.0). The enzyme activity of xylanase in each sample recovered from the purification stage was investigated. The purification of active fraction showing the enzyme activity was confirmed by SDS-PAGE. Protein content was measured by using Bradford method (Bradford, Sigma Aldrich), and BSA (bovine serum albumin) was used as the standard protein.

As a result, it was confirmed that xylanase was mass-produced easily by glutathione resin column chromatography. Considering the condition of xylanase conjugated onto the resin, it was confirmed that xylanase activity was not changed. Therefore, the novel xylanase could be used for high efficiency conversion process via enzyme immobilization method. The enzyme purified by the above method demonstrated at least 5 times higher activity than before purification. The enzyme activity at 50° C. was 97.37, 124.19, 122.21, 124.61, 122.95, 103.27, and 96.08 units, respectively at pH 5.0, pH 6.0, pH 7.0, pH 8.0, pH 9.0, pH 10.0. and pH 11.0, suggesting that the enzyme activity was guaranteed in a wide range of pH. In the meantime, the enzyme activity at 60° C. was 26.93, 105.19, 123.56, 120.95, 112.25, 29.89, and 22.76 units (µM of xylose produced by 1 mg of enzyme per 1 minute), respectively at pH 5.0, pH 6.0, pH 7.0, pH 8.0. pH

9.0, pH 10.0, and pH 11.0, suggesting that the enzyme had excellent heat-resistance and excellent activity.

### Example 5

#### Characteristics of the Mass-Produced Noble Xylanase

To investigate the characteristics of the enzyme, the purified xylanase was loaded in a test tube, to which 50 mM Tris-HCl (pH 7.0) buffer containing birch xylan at different concentrations was added. The mixture was reacted at 50° C. for 20 minutes to investigate enzymatic reaction rate (Lineweaver-Burk).

As a result, as shown in FIG. 7, affinity  $K_m$  value to xylan substrate was 0.2. Most of the hydrolyzates were xylose and xylo-oligomer. Xylanase activity against other xylans (beech, oats, etc) was similar to that against birch xylan.

#### INDUSTRIAL APPLICABILITY

As explained hereinbefore, unlike the conventional xylanase, the novel xylanase of the present invention shows high activity in a wide range of pH and excellent heat-resistance to decompose xylan, the major component of various lignocellulosic biomass, so that it can not only be used for the preparation and development of a xylan decomposer, a composition for food processing, a feed additive, or a composition for papermaking process, but also contribute to biochemical industry via the application to the development of bio-fuel, alternative material, performance chemical, and bio-polymer.

Those skilled in the art will appreciate that the conceptions and specific embodiments disclosed in the foregoing description may be readily utilized as a basis for modifying or designing other embodiments for carrying out the same purposes of the present invention. Those skilled in the art will also appreciate that such equivalent embodiments do not depart from the spirit and scope of the invention as set forth in the appended Claims.

---

#### SEQUENCE LISTING

<160> NUMBER OF SEQ ID NOS: 6

<210> SEQ ID NO 1

<211> LENGTH: 1393

<212> TYPE: DNA

<213> ORGANISM: Paenibacillus sp.

<400> SEQUENCE: 1

```

ggctcaggac gaacgctggc ggcgctgcta atacatgcaa gtcgagcggg gttatgtaa      60
aagcttgctt ttaacataac ctagcggcgg acgggtgagt aacacgtagg caacctgccc      120
atcagactgg gataactacc ggaaacggta gctaataccg gatacatcct ttcctgcat      180
ggggagagga ggaaagacgg agcaatctgt cactgatgga tgggcctgcg gcgcattagc      240
tagttggtgg ggtgaaggcc taccaaggcg acgatgcgta gccgacctga gagggtgatc      300
ggccacactg ggactgagac acggcccaga ctctacggg aggcagcagt agggaatctt      360
ccgcaatggg cgaaagcctg acggagcaac gccgcgtgag tgatgaaggt ttcggatcg      420
taaagctctg ttgccaggga agaagctctt gtagagtaac tgctacaaga gtgacggtac      480
ctgagaagaa agccccggct aactacgtgc cagcagcgc ggtaatacgt agggggcaag      540
cgtgtccgg aattattggg cgtaaagcgc gcgcaggcgg ctctttaagt ctggtgttta      600
atcccagggc tcaacttcgg gtcgcactgg aaactgggga gcttgagtgc agaagaggag      660
agtgaattc cactgttagc ggtgaaatgc gtagatatgt ggaggaacac cagtggcgaa      720
ggcgactctc tgggctgtaa ctgacgctga ggcgcgaaag cgtggggagc aaacaggatt      780
agataccctg gtatgccacg ccgtaaacga tgaatgctag gtgtagggg tttcgatacc      840
cttggtgccc aagttaaac attaagcatt ccgcctgggg agtacggtcg caagactgaa      900
actcaaagga attgacgggg acccgcaaca gcagtggagt atgtggttta attcgaagca      960
acgcgaagaa ccttaccagg tcttgacatc cctctgatcg gtctagagat agatctttcc      1020
ttcgggacag aggagacagg tgggtgatgg ttgtcgtcag ctcggtcgtg gagatgttg      1080
gtaagtccc gcaacgagcg caacccttat gcttagttgc cagcaggtea agctgggcac      1140
tctaagcaga ctgccgtgta caaacgggag gaagggtggg atgacgtcaa atcatcatgc      1200
cccttatgac ctgggctaca cacgtactac aatggccggg acaacgggaa gcgaaagagc      1260
gatctggagc gaactctaga aaagccggtc tcagttcggg ttgcaggctg caactcgct      1320

```



-continued

---

 gcatgaagtc ggaattgcta gtaatcgccg atcagcatgc ccgcggtgaa tacgttcccc 1380

ggtcttgtag aca 1393

&lt;210&gt; SEQ ID NO 2

&lt;211&gt; LENGTH: 6956

&lt;212&gt; TYPE: DNA

&lt;213&gt; ORGANISM: Paenibacillus sp.

&lt;400&gt; SEQUENCE: 2

catcctctct ataagcttaa cagaagccta gcccaataga caaaagacgg gtataccgtc 60

cccggccccg tcttttctta tcatgaatcg ctgctgtata tggcaggcga gctggaagtg 120

aattgcgctt caaccttatt tcttggttgt tgttactact ttagctgctg cttttggagc 180

tgttttcaact gctgtttttg gagctgtttt taccactggt tttgctggag tcactttttt 240

aacaggagct ttgtgagccg ctttttttagc tacaacatgg tgtgcacgag ttttgtgagc 300

tgttgcttta tgttttactg cataatgtct tttagcatga tgtttaacgg tacggtgctt 360

cgcttttaca gcttttgcct tatgtgccgt ttttttgcca acagcttttt tggcaggagc 420

tttttttagct gttgttactt tatgagctgt tgcagctttt ttaacaggtg ctttcaccac 480

tgggtgtttc gtcgcaggtg cttttactgc tgggtgcttg gtagccgggg tcgtaaccgc 540

cgggtccttc gttgctggtg cagttgtage tggcgttgtt gtcgctgtag cggcgaatgc 600

actgcttgcct cctcccaata cgcttactac ggtcaatacg gctgctgcat ttttagtcca 660

ttttttcatg attgtatcac ctctccttta aagtatcttt agcttatcag gagaattcgg 720

gataattgtg gaacaaatgt gtgaaaagta tatgaaaag cgtgcagccc cgtattcaaa 780

aaatcgtga gctgcacgcg tgtacgtttt acacaattac attcactaac cgatggcaat 840

ccaggaaaaca ataccgtagt tgtgcgcggg ttcggtccat ttggttacta caatcaccgc 900

tccattcggc gctgcgagtt tcagcgtcgc atgaaagaga ggatgggttcg tcatecgtac 960

cagcgtatag tccgggttca taaaaggctc tgcgaatata atgatcactt ccgtctctcc 1020

ttcgtgccc tcaaaagaa acggcgcctc gccaaactgc tgcaatgcgg actgattggc 1080

acaagtacga accgggggtg tgctcagatg ctccgcttc actgcgttca gctccagctc 1140

acgcgagcct acggagcctt ccaccagatg atgcccttca atgctttgct ctgccaagtg 1200

atggctttgt accgcagcgg tctgtagatg ctccgatcct acagcttccg ggctcagcac 1260

ctcgtgtgac accgctgag ctttcagatg gctgcgagat aactatctg cctggagtct 1320

gtcgcactg ataccttct cggcctaaaag ccccgagaga tgaatgtccg tggacaactg 1380

agccagcgtc actgcgcccg gcttcagggt gtgcgcacat atggcttctg ctccaatgtg 1440

tcggccttca atggcttct cagccacatg ctgggactgt accgctccat ttgcaagctt 1500

gccggacgta accgcttctt cttgcaatgt gtcttccgac accacctgcc agcctatatg 1560

ctgcggcttg atggcacctg cttgcagatg ctccgactgg acggaatcca aggcgatatg 1620

ccttgattgc accgcttctt ctgcccagcgc cgattctctg accgccccat cggccagatg 1680

aagggtggtg accgcttctt ccaccagatg tacggagctt acgctggctt cegccaaatt 1740

cgaagcacgc accgcccga ggcgaagctt ctacagatc acgctcccgg cctggagcgc 1800

gtgaacagat acacttcccg gcgcaaatat cggggtcctc actgctgaag cctgcaaatg 1860

gtcagagggt acggcttccg gggccaaatg gctcagattgg atgcctctt ctgccaatg 1920

gttccttgc accgcttctt ccgtaatgtg ceatggctgt accgagtggt cggacagctt 1980

ggccggccgt cacgctctca tccgccagtt tgcggagct aacagactca tctgcaagg 2040

-continued

---

catcggtcga taccgectgt gatgcgatat gctcgcctctg aatggttccg atgtgcagat 2100  
 gatgtggctg gatggactcc ggtgcgatat gcacggactt cactgcccc tctgccagcg 2160  
 ctctgtcctg taccgctcca tctgccagat gccgggggtg tacggcctgc gcagacaaat 2220  
 gtgaagggcc gacgatgcct tccgcgaggt tggtegettg cacggcccga gccgccagct 2280  
 tctccgaggt gacgctttcc gcttgaagcg cacgaccgga tacgctatcc ggggccagat 2340  
 gtctcgtaag caccgcccga gccctgcaaat ggtcagaggt gacggcttcc ggggccaaat 2400  
 ggctcgattg gatcgtttct tctgccaaat ggttcccttg caccgcttcg tccgtaatgt 2460  
 gccatgctg taccgagtga gcggacaact tggcggccgt cacactctca tccgccagtt 2520  
 tgtcagacgt aacagactca tcttcaagc catcggtcga taccgctgt gatgcgatat 2580  
 gctcgcctg aatggttccg atgtgcagat gatgtggctg gatggactcc ggtgcgatat 2640  
 gcacggactt tactgcccct tctgccagcg ctctgtcttg taccgctcca gctgccccat 2700  
 gccgggggtg tacggcctgc gcagacaaat gtgaagggcc gacgctgctt tccgcgagat 2760  
 tctcgtctg caccgagcgt gctgccagct tttccgaggt gatgctttcc gcttgaagcg 2820  
 cacgatcga tacactatcc ggggccagat gtctcgtatg caccgacgaa gactgtaaat 2880  
 gaaccgaggt gaccgcttcg gctgccagat gtgtcgaatc cacagcccgc acagccaggt 2940  
 gactgctttg tacagcttca tctgtaatat gctcggactg cactgcatgg gcagatagct 3000  
 tgatggaggt tacacttcc cccagcagtt gtcggacgta acagactcat tctgcaaacg 3060  
 atcggtcgat atcgcctgtg atgtgatatg ctgcgcctga atggttccga tgtgcagatg 3120  
 gtgcgcttg atagactccg gtcgcatgtg caccgacttc actgccccct ctgccagcgc 3180  
 tctttcctgt accgctccaa ctgctagatg cccgggggtg accgctctgc cagataaatg 3240  
 cggaggacc accgctcctt cccgagaggt cattccttgt accgagcgcg cccagcagct 3300  
 ttccgaggta atgctttctg cttgaaagcg accgaccgat accgctatcc gggccagatg 3360  
 tctcgtaagc accgtggagg cttgtagatg taccgaggtg accgctccg cccagcagatg 3420  
 cgcgcaatc acagccgcca cagccagatg gttgcttctc ctgattctgt agctggggat 3480  
 gcttgaagc tctggtgtg atatcgtgcc tgggctgatc ggggtgttca atgtgattgt 3540  
 aattcgtcc tttattgagg gcttaccgga agggatcttg gagtcggcgc gtatagatgg 3600  
 ggcgggggag tttgcgactt ttatgcgtat cgttttgccg ctatgtgtcc cgggtctggc 3660  
 aacggtgtc ctgttcacgg cagtagcga atggaactcc tggttcgatg tatttttcta 3720  
 caattcgtc tatgagcagt ggagtaccct ccagtatgag ctgatgaaaa tattgcaaaa 3780  
 ttccaacacg tccgtgaacg ctcaggatta tgccagccaa ttcgcagcct cggaaaatct 3840  
 ggcgaaggcg gttactccta cctccattcg tgccacgatg acaattgtgg cgtctgtgcc 3900  
 tattattttg gtctatccat ttttgcaaaa atattttgtg aagggtatga ctttgggcgg 3960  
 tgtcaaggga taagcaagga ccggaatgt gtgaaactcg ctttcttata ttttgaatat 4020  
 atgggcgtag gagggattgc gttgaggtca tttttgtata aatctttggg tctggtgctg 4080  
 gtcggggtgt tgttattgcc agtggggtg tgggggctgt ctgtagcga gccgactcca 4140  
 actgtggaac attcccagtc agttgaggat accgctctgt cgacggggag cgtgaataag 4200  
 accatcggga cgtatggatt tgagcaagc aacgttgagg gctggaagcc tccggggact 4260  
 tatacccaaa tcgcaaccgt ctcagaagct gcatatggcg gcgtacacag cctgaaggta 4320  
 accgctcga cggaggtttg gaacggtgcg gagctggatg tgaagtcgct gttgcagccg 4380

-continued

---

ggtgtggaat atgagattag cggctatgtg aagcaggacg gtaattctac gacgccgagc	4440
gtgattaagt ttacggtgga gcagcagccg acaggcgggg ccacgacatg gaagacggtt	4500
gcgcagacag agacgacgga tacatcgtgg gccaaacttc aagggacata tacattcacc	4560
gggggatgg atacattgaa gttgtatgtg gaaagctcga atcctgcaca ggctattat	4620
ctggatgagg tggaaatcag gcaggtgtcg gagacaccaa ccactcccc aacggagccg	4680
acaagtggta tcgaatccag atttgaagat ggtacggctc aaggctgggt atcccgatg	4740
ggcaccgaga cgggtcaggt gtcgaatgcc gatgcacgaa ccggatcgta cagtctgttg	4800
acgacaggca gacaacaaac atatgccggg ccaaagctgg acgtgactgc tacagtgcaa	4860
aaaggcagcc gttacacggt cagcgtctgg gtaaagctgg caccgggcga gcagcagcct	4920
gccaaagtgc gcctcagcgt acagcgcgat catcaaggtg aaagtacgta tgaactgtg	4980
gtaggcaaca cggccatcac gactggggga tggacgatt tgtacggaac gtatacttc	5040
gcgcatgagg cagacaccgt ctctatgtat ttggaaacgc cagaaggtac ggcttccttt	5100
tacatggatg atttcgagct gtcgcttggg ccgccgttgg ctattgagaa ggacattccc	5160
tctttgcatg gattgtatca gggacagtcc agcatcggta cggctattga agctttccag	5220
acagaagggg cttacgggga gctggtgcag aagcatttta acagcgtcgt cgcggaaaat	5280
gcgatgaagc cgatctcctt gcagccgtcc gaaggacagt tccattggga agaagcagac	5340
cggattgtgc aatttgccca gcagcatggg attgctatcc gtttcatac actggtgtgg	5400
cataaccaga ccggcgattg gatgtttaag gataagaatg gacagccgat gacgccgacc	5460
gcgaaaaata aaaagctttt gctggatcgg ctggagacgc atattcgtgc tgttcagcc	5520
cgtataaaaa atgtaatcac cgattgggat gtggtgaatg aagtcattga tcccgaccag	5580
ccggacggta tgcgccgag caagtggat cagattaccg gcaaggatta tattgacaaa	5640
gcattccgtg tcacgagga agcggcgggt ccgaacgcc ggctgtacat taacgattac	5700
aacacgcatg aaccgaagaa acgggatttt ctgtacaatt tggctcgtga tttactcgt	5760
aaaggcgtac cgatcgatgg cgtaggtcac caatcgcata tccgctgga gttccctgct	5820
attgacgaga tggagcagtc tattgaaaag tttgcttcgc tcggcctgga taatcagatc	5880
acggagctgg atatgggcct gtattctaata gatacagacc actacgaaac gatacctgaa	5940
gccatgctga tccggcagcg tcaccgctat cgggcttgt tcgatatggt tcccgcagac	6000
caggagcata tcagtaatgt gacgatttgg ggtacggatg atgaaaatac gtggtcagt	6060
atgttcccga ttgcccggct ggataagccg ctgctgttcg acgaaacggt aaaggccaaa	6120
tatgctatt gggcgcttgt tgaccctcc aaagtaccgc cgctgccagc ggggagcaac	6180
gaatagcaac ataggtatgg attacacgtg gaaatcattt ctatacaca aaaaggcag	6240
cgcctctga catgccacaa ggacatgcga aggacgatct gccttttact gtaaaataat	6300
acgatctcta ctccagattg gcgtgttgac caaacataga ttcagaagtc agcttgcgta	6360
gctccatcgt tctgagcacc aatgcctcgc catacagcag caaggtttgc tcaaatagtg	6420
aaccatggg ctgaatggtt tggtaatcct tgttgatgg atccttgggt ggcgccgaa	6480
gcctgacgat aatatacagc agcttgccaa tggctgatcc aggggaggtg gtcagaagt	6540
ccagagaagc cccagcctt ttcgtctttt ctgccatcga ggtcaaaact ttggtttcac	6600
cagagcctga accgataatc agcaagtcc cttcgcccaa acctggagtt actgtttccc	6660
cgaccacata agcctgaaca cccatagca tcagccgat cgccagcga cggatcatga	6720
atccagaagc gcctgcgct gcgacgaaca ccttatctgc tgaggtaatg gactggatca	6780

-continued

---

```

gttgctctga ttcctcatca ttgattagct gtggaaccaa ttgcagttcc ttgagcacct 6840
cggataaata ttgagagggt tccattggaa ttaaccttgt ttaatgagct gctgcatttc 6900
ggaagcaacg gcctttttgt cgtcctcacc agtgatcccc ccgccaacaa taacca 6956

```

```

<210> SEQ ID NO 3
<211> LENGTH: 1620
<212> TYPE: DNA
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: SLX-09

```

```

<400> SEQUENCE: 3

```

```

atggatacat tgaagtgtga tgtggaagc tcgaatcctg cacaggccta ttatctggat 60
gaggtggaaa tcaggcaggt gtcggagaca ccaaccactc cccaacgga gccgacaagt 120
ggtatcgaat ccagatttga agatggtacg gctcaaggct gggatcccc tatgggcacc 180
gagacggtgc aggtgtcgaa tgccgatgca cgaaccggat cgtacagtct gttgacgaca 240
ggcagacaac aaacatatgc cgggccaaag ctggacgtga ctgctacagt gcaaaaaggc 300
agccgttaca cggtcagcgc ttgggtaaag ctggcaccgg gcgagcagca gcctgccaaag 360
gtgcgcctca gcgtacagcg cgatcatcaa ggtgaaagta cgtatgaaac tgtggtaggc 420
aacacggcca tcacgactgg gggatggacg catttgtacg gaacgtatac tctcgcgcac 480
gaggcagaca ccgtctctat gtatttggaa acgccagaag gtacggcttc cttttacatg 540
gatgatttcg agctgtcgct tgtgcccgcc ttggctattg agaaggacat tcctctttg 600
catggattgt atcagggaca gttcagcacc ggtacggcta ttgaagcttt ccagacagaa 660
ggggcttacg gggagctggt gcagaagcat ttaacacgcg tcgtcgccgg aatgctgatg 720
aagccgatct ccttgcagcc gtccgaagga cagttccatt ggaagaagc agaccggatt 780
gtgcaatttg ccagcagca tgggattgct atccgtttcc atacactggt gtggcataac 840
cagaccggcg attggatggt taaggataag aatggacagc cgatgacgcc gaccgcggaa 900
aataaaaagc ttttctgga tcggctggag acgcataatc gtgctgttgc agcccgttat 960
aaaaatgtaa tcaccgattg ggatgtggtg aatgaagtca ttgatccoga ccagccggac 1020
ggtatgcgcc gcagcaagtg gtatcagatt accggcaccg attatattga caaagcattc 1080
cgtgtcacga ggaagcggc ggtccgaac gcccgctgt acattaacga ttacaacacg 1140
catgaaccga agaaacggga tttctctgac aatttgggtg gtgatttact cgctaaagc 1200
gtaccgatcg atggcgtagg tcaccaatcg catatccgcc tggagttccc tgctattgac 1260
gagatggagc agtctattga aaagtttgc tgcctcgccc tggataatca gatcacggag 1320
ctggatatgg gcctgtattc taatgataca gaccactacg aaacgatacc tgaagccatg 1380
ctgatccggc aggtccaccg ctatcggggc ttgttcgata tgttttccc acagcaggag 1440
catatcagta atgtgacgat ttgggttacg gatgatggaa atacgtggct cagtatgttc 1500
ccgattgccc ggtcggataa gccctgctg ttcgacgaac ggttaaaggc caaatatgcc 1560
tattgggcgc ttgttgacct gtccaaagta ccgccctgc cagcggggag caacgaatag 1620

```

```

<210> SEQ ID NO 4
<211> LENGTH: 539
<212> TYPE: PRT
<213> ORGANISM: Artificial Sequence
<220> FEATURE:
<223> OTHER INFORMATION: SLX-09 protein sequence

```

-continued

&lt;400&gt; SEQUENCE: 4

Met Asp Thr Leu Lys Leu Tyr Val Glu Ser Ser Asn Pro Ala Gln Ala  
 1 5 10 15  
 Tyr Tyr Leu Asp Glu Val Glu Ile Arg Gln Val Ser Glu Thr Pro Thr  
 20 25 30  
 Thr Pro Pro Thr Glu Pro Thr Ser Gly Ile Glu Ser Arg Phe Glu Asp  
 35 40 45  
 Gly Thr Ala Gln Gly Trp Val Ser Arg Met Gly Thr Glu Thr Val Gln  
 50 55 60  
 Val Ser Asn Ala Asp Ala Arg Thr Gly Ser Tyr Ser Leu Leu Thr Thr  
 65 70 75 80  
 Gly Arg Gln Gln Thr Tyr Ala Gly Pro Lys Leu Asp Val Thr Ala Thr  
 85 90 95  
 Val Gln Lys Gly Ser Arg Tyr Thr Val Ser Ala Trp Val Lys Leu Ala  
 100 105 110  
 Pro Gly Glu Gln Gln Pro Ala Lys Val Arg Leu Ser Val Gln Arg Asp  
 115 120 125  
 His Gln Gly Glu Ser Thr Tyr Glu Thr Val Val Gly Asn Thr Ala Ile  
 130 135 140  
 Thr Thr Gly Gly Trp Thr His Leu Tyr Gly Thr Tyr Thr Leu Ala His  
 145 150 155 160  
 Glu Ala Asp Thr Val Ser Met Tyr Leu Glu Thr Pro Glu Gly Thr Ala  
 165 170 175  
 Ser Phe Tyr Met Asp Asp Phe Glu Leu Ser Leu Val Pro Pro Leu Ala  
 180 185 190  
 Ile Glu Lys Asp Ile Pro Ser Leu His Gly Leu Tyr Gln Gly Gln Phe  
 195 200 205  
 Ser Ile Gly Thr Ala Ile Glu Ala Phe Gln Thr Glu Gly Ala Tyr Gly  
 210 215 220  
 Glu Leu Val Gln Lys His Phe Asn Ser Val Val Ala Gly Asn Ala Met  
 225 230 235 240  
 Lys Pro Ile Ser Leu Gln Pro Ser Glu Gly Gln Phe His Trp Glu Glu  
 245 250 255  
 Ala Asp Arg Ile Val Gln Phe Ala Gln Gln His Gly Ile Ala Ile Arg  
 260 265 270  
 Phe His Thr Leu Val Trp His Asn Gln Thr Gly Asp Trp Met Phe Lys  
 275 280 285  
 Asp Lys Asn Gly Gln Pro Met Thr Pro Thr Ala Glu Asn Lys Lys Leu  
 290 295 300  
 Leu Leu Asp Arg Leu Glu Thr His Ile Arg Ala Val Ala Ala Arg Tyr  
 305 310 315 320  
 Lys Asn Val Ile Thr Asp Trp Asp Val Val Asn Glu Val Ile Asp Pro  
 325 330 335  
 Asp Gln Pro Asp Gly Met Arg Arg Ser Lys Trp Tyr Gln Ile Thr Gly  
 340 345 350  
 Thr Asp Tyr Ile Asp Lys Ala Phe Arg Val Thr Arg Glu Ala Ala Gly  
 355 360 365  
 Pro Asn Ala Arg Leu Tyr Ile Asn Asp Tyr Asn Thr His Glu Pro Lys  
 370 375 380  
 Lys Arg Asp Phe Leu Tyr Asn Leu Val Arg Asp Leu Leu Ala Lys Gly  
 385 390 395 400  
 Val Pro Ile Asp Gly Val Gly His Gln Ser His Ile Arg Leu Glu Phe  
 405 410 415

-continued

Pro Ala Ile Asp Glu Met Glu Gln Ser Ile Glu Lys Phe Ala Ser Leu  
 420 425 430

Gly Leu Asp Asn Gln Ile Thr Glu Leu Asp Met Gly Leu Tyr Ser Asn  
 435 440 445

Asp Thr Asp His Tyr Glu Thr Ile Pro Glu Ala Met Leu Ile Arg Gln  
 450 455 460

Ala His Arg Tyr Arg Ala Leu Phe Asp Met Phe Ser Arg Gln Gln Glu  
 465 470 475 480

His Ile Ser Asn Val Thr Ile Trp Gly Thr Asp Asp Gly Asn Thr Trp  
 485 490 495

Leu Ser Met Phe Pro Ile Ala Arg Leu Asp Lys Pro Leu Leu Phe Asp  
 500 505 510

Glu Arg Leu Lys Ala Lys Tyr Ala Tyr Trp Ala Leu Val Asp Pro Ser  
 515 520 525

Lys Val Pro Pro Leu Pro Ala Gly Ser Asn Glu  
 530 535

<210> SEQ ID NO 5  
 <211> LENGTH: 30  
 <212> TYPE: DNA  
 <213> ORGANISM: Artificial Sequence  
 <220> FEATURE:  
 <223> OTHER INFORMATION: SLX-09 sense primer

<400> SEQUENCE: 5

ctcgagatgg atacattgaa gttgtatgtg

30

<210> SEQ ID NO 6  
 <211> LENGTH: 22  
 <212> TYPE: DNA  
 <213> ORGANISM: Artificial Sequence  
 <220> FEATURE:  
 <223> OTHER INFORMATION: SLX-09 antisense primer

<400> SEQUENCE: 6

ggatccctat tegttgctcc cc

22

What is claimed is:

1. A Xylanase having
  - a) the amino acid sequence set forth as SEQ. ID. NO: 4;
  - b) the amino acid sequence having at least 90% homology with the amino acid sequence set forth as SEQ. ID. NO: 4;
  - c) the amino acid sequence encoded by the nucleotide sequence set forth as SEQ. ID. NO: 3; or
  - d) the amino acid sequence encoded by DNA hybridized with the DNA containing the nucleotide sequence set forth as SEQ. ID. NO: 3 in the strict condition comprising at least two washings in 0.1×SSC, 0.1% SDS at 65° C., which is identical in its function to the protein containing the amino acid sequence set forth as SEQ. ID. NO: 4;
 wherein the xylanase has the characteristics (i)-(iii);
  - (i) molecular weight: approximately 65 KDa on SDS-PAGE;
  - (ii) maximum activity in the range pH 5-pH 11; and
  - (iii) maximum activity at the temperature of 50-60° C.
2. A transformant to which a recombinant expression vector is introduced, in which polynucleotide encoding the xylanase of claim 1 is operably linked to the recombinant expression vector.
3. The transformant according to claim 2, wherein the polynucleotide has one of the following sequences:
  - a) the nucleotide sequence set forth as SEQ. ID. NO: 3;
  - b) the nucleotide sequence having 90% homology with the nucleotide sequence represented by SEQ. ID. NO: 3;
  - c) the nucleotide sequence encoding the amino acid sequence set forth as SEQ. ID. NO: 4; and
  - d) the nucleotide sequence comprising DNA sequence to be hybridized with DNA containing the nucleotide sequence set forth as SEQ. ID. NO: 3 under the strict condition comprising at least two washings in 0.1×SSC, 0.1% SDS at 65° C. and encoding the protein having the same function as the protein comprising the amino acid sequence set forth as SEQ. ID. NO: 4.
4. The production method of xylanase of claim 1 comprising the steps of:
  - a) obtaining crude enzyme solution by centrifugation after culturing *Paenibacillus* sp. HPL-3 strain in a medium; and
  - b) purifying xylanase from the crude enzyme solution of step a).
5. The production method according to claim 4, wherein the strain is *Paenibacillus* sp. HPL-3 deposited under the Accession No. of KCTC11987BP.

6. The production method according to claim 4, wherein the xylanase has one of the following sequences:

- a) the amino acid sequence set forth as SEQ. ID. NO: 3;
- b) the amino acid sequence having 95% homology with the amino acid sequence represented by SEQ. ID. NO: 3; 5
- c) the amino acid sequence encoded by the nucleotide sequence represented by SEQ. ID. NO: 4; and
- d) the amino acid sequence encoded by DNA hybridized with the DNA containing the nucleotide sequence set forth as SEQ. ID. NO: 3 in the strict condition compris- 10  
ing at least two washings in 0.1×SSC, 0.1% SDS at 65°  
C., which is identical in its function to the protein containing the amino acid sequence set forth as SEQ. ID.  
NO: 4.

\* \* \* \* \*