Biochemical Engineering Journal 71 (2013) 11–18

Contents lists available at SciVerse ScienceDirect

Biochemical Engineering Journal

journal homepage: www.elsevier.com/locate/bej

Regular article

Construction of a pilot plant for producing fine linen fibers for textiles

A.G. Valladares Juárez[a], G. Rost[b], U. Heitmann[b], E. Heger[c], R. Müller[a,*]

[a] Technische Universität Hamburg-Harburg, Institut für Technische Biokatalyse, Denickestraße 15, D-21073 Hamburg, Germany
[b] Institut für Textil- und Verfahrenstechnik (ITV), Körschtalstraße 26, D-73770 Denkendorf, Germany
[c] Heger.Hulda Natural Fibre Consultants, Bornwischen 17, D-23795 Bad Segeberg, Germany

ARTICLE INFO

Article history:
Received 13 December 2011
Received in revised form 16 August 2012
Accepted 19 November 2012
Available online 27 November 2012

Keywords:
Flax
Retting
Pilot plant
Alkaline pectinases
Geobacillus thermoglucosidasius
Textiles

ABSTRACT

A newly built 200-L-pilot plant was used for testing a novel chemo-enzymatic process for producing fine flax fibers without the weather-associated risks of dew retting. Raw, green and decorticated flax fibers were placed inside trays in the tempered main tank of the pilot plant, where a vertically acting mechanism gently moved the parallel fiber bundles. The fibers were incubated in an alkaline bath, in a pectinolytic culture of *Geobacillus thermoglucosidasius* PB94A and in a peroxide-softener bath. Finally the fibers were dried, combed and hackled into a sliver that is ready for wet-spinning of linen yarns. A total of 140 kg of raw fibers were treated in 40 different experiments in the pilot plant. The resolution of the raw fibers improved from 7.3 to 2.7 ± 0.3 after the treatment. The fineness was enhanced from 37.4 dtex to 11.1 ± 1.2 dtex. The proposed pilot-plant process produced constant-quality fibers and could be easily up-scaled.

1. Introduction

Flax, *Linum usitatissimum* is an annual herb cultivated since antiquity for its useful textile fibers (linen). The fibrous cells, localized in the periphery of the stem, form bundles of overlapping fibers from 30 to 90 cm in length. The fibers are glued together by pectic material and account for only 30% of the flax plant. As the pectic material is degraded, the fibers divide during retting, carding and spinning. Short, broken fibers (tow) are used to make coarse fabrics and cordage, while long fibers, the most valuable part of the plant, are used for strong threads and fine linen [1].

The traditional methods used to extract the fibers from the stem are dew and water retting. In both procedures microorganisms (bacteria and fungi) break down the woody tissues and dissolve the pectic substances binding the fibers. In water retting the stems are submerged in water for some days. This method produces the highest quality fibers, but the waste liquors are highly polluting. In dew retting the fibers are spread out on the field and exposed to dew and sun for several weeks. Nowadays dew retting is common practice in the flax industry in Western Europe [1–3]. Dew retting is highly weather dependent. A wet weather produces weak and degraded fibers or even the loss of the entire crop. A dry weather produces under-retted coarse fibers with contaminating shives. In both cases the quality of the fibers is negatively influenced [4]. After dew or water retting the stems are dried and scutched to separate the fibers from the rest of the stem. The remaining nonfibrous matter is removed by hackling [1].

Recently we described a laboratory-scale process for refining the flax fibers using the pectinolytic strain *Geobacillus thermoglucosidasius* PB94A (DSM 21625). This strain degraded selectively hemp and flax pectin at high temperatures in alkaline environments (60 °C and pH 8.5) [5]. An advantage of using a process with a thermophilic strain, is that the temperature of 60 °C, serves as a barrier against mesophilic cellulolytic contaminating microorganisms that damage the flax fibers.

In contrast to some commercial pectinases, the enzymes excreted by *G. thermoglucosidasius* PB94A were free of cellulolytic side-activity that could damage the cellulose of the flax fibers. Moreover, using a whole cell system instead of the crude enzyme supernatant or a commercial pectinase preparation allows to use the treatment liquor more than once. This is positive for the environment and helps to decrease the costs.

Pilot or industrial scale facilities to test if this new process is a technically feasible alternative to dew and water retting do not exist but were needed. Existing processes for treating flax use the whole plant [6], this is not suitable for our new process that uses green decorticated fibers, because the fibers would bend and tangle. Using decorticated fibers for the new process has the advantage that they are only 30% of the weight of the flax plant, this allows to save resources. Therefore, a pilot plant for the testing the new process on a technical scale was designed and built.

* Corresponding author. Tel.: +49 40 428783118; fax: +49 40 428782127.
E-mail address: ru.mueller@tu-harburg.de (R. Müller).

1369-703X/$ – see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.bej.2012.11.010

2. Materials and methods

Chemicals were purchased from Merck (Darmstad, Germany), Fluka (Neu-Ulm, Germany), Sigma–Aldrich (Munich, Germany), Roth (Karlsruhe, Germany). Adulcinol BUN was a gift from Zschimmer & Schwarz Mohsdorf GmbH & Co KG (Burgstädt, Germany).

The flax plants used for this work were grown in 2004 in Mielsdorf, Germany. The plants were decorticated green and the fibers were baled and stored for using in the experiments.

The water used for the analysis and the media preparation was HPLC-grade. For the fiber treatment tap water was used.

2.1. Cultivation of pectin degrading microorganisms

The thermoalkaliphilic, pectinolytic strain *G. thermoglucosidasius* PB94A (DSM 21625) was used in this work [7].

The pectin medium, equipment and the conditions for cultivating the strain *G. thermoglucosidasius* PB94A were described previously [5].

2.2. Denaturing gradient gel electrophoresis

Denaturing gradient gel electrophoresis (DGGE), a method that detects differences in the 16S rDNA of bacteria, was used to verify the identity of *G. thermoglucosidasius* PB94A and to observe bacterial population changes during the treatment of the fibers.

The bacteria-specific colony-PCR was done according to Muyzer et al. [8], with some slight modifications in the protocol. The amplification products were loaded in polyacrylamide-bis-acrylamide gels (37.5:1) with a denaturing gradient of urea-formamide (20–80%). The gels were cast according to the D-Code universal mutation detection system instruction manual, Bio-rad (CA, USA). Finally the gels were stained with Sybr Green and observed on a UV transillumination table and documented. The gels presented in this work are color-inverted to ease visualization. The detailed protocol was described in a previous publication [5].

2.3. Determination of pectin lyase activity and the cell density of the cultures

The pectin lyase activity was determined by measuring the β-eliminative cleavage of the pectin substrate according to a modified procedure of Collmer et al. [9]. The detailed method was previously described [5].

The cell density of the culture of *G. thermoglucosidasius* PB94A was determined with a light microscope using a Neubauer counting chamber.

2.4. Fiber quality determination

The fiber quality was determined at the Institut für Textil- und Verfahrenstechnik Denkendorf (ITV-Denkendorf) as described before [5]. The determined parameters were fineness, resolution and tenacity.

2.5. Hydrogen peroxide detection with the active oxygen method

The determination of the hydrogen peroxide concentration was done according to the procedure described by Solvay Chemicals [10].

2.6. Chemical oxygen demand (COD) determination

The determination of the COD was done with a Dr. Lange kit LCK 514 using the Dr. Lange photometer and thermostat according to the manufacturer's instructions and following the classic COD

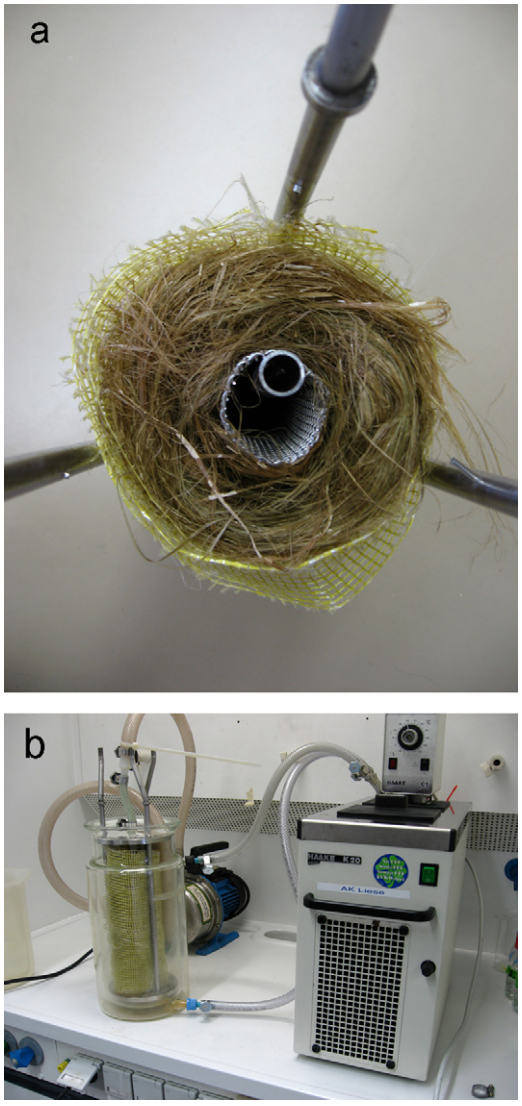

Fig. 1. Packed bed of flax fibers (a) before being placed in the 6.5 L jacketed reactor used for flax fiber treatment (b). Fluid is pumped through the axial tube at the center of the bed of fibers.

Fig. 2. 200-L pilot plant tank where the cut flax fibers were placed next to the housed-propeller that moved the fibers up and down.