Research Article

Design of Competitive Processing Plants for Hemp Fibre Production

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Despite an annually growing demand for natural fibres accompanied by worldwide increasing fibre prices as well as long tradition and experience in fibre processing, the production facilities for hemp and flax fibres are very limited in Europe. At present, the lack of modern harvesting and economic processing technologies seem to be the greatest obstacles for hemp fibre producers under the changing conditions of international raw material markets. Therefore, detailed investigations of all process stages of hemp fibre processing have been carried out at the Leibniz Institute for Agricultural Engineering (ATB). A novel hemp processing line has been developed, installed, and tested at industrial scale in the last 3 years. Investigations regarding optimum plant layout have shown that a straw throughput of approximately 4 t h$^{-1}$ is required for economic fibre production for all new processing lines at currently high straw prices of more than 150 € t$^{-1}$. Throughputs in the range from 4 to 6 t h$^{-1}$ showed a favourable relation between profit and investment cost. At throughputs higher than 6 t h$^{-1}$, the profit per ton processed straw can be further increased. But investment and straw logistic cost increase at these high-throughput levels often much faster.

1. Current Situation and Purpose of Research

Resulting from limited fossil resources, global warming, and increasing competition for arable land, there is an increasing demand for renewable raw material from agriculture. Automotive and building industries are traditional customers for the agricultural processing plants supplying high-quality hemp and flax fibres. Presently, more than 23000 t of natural fibres are used annually in the European automotive industry alone. Typically, fibres are used for indoor applications such as seat coverings, door panels, and insulation materials [1]. Future applications of natural fibres will highly depend on the costs of agricultural production and the costs of fibre straw processing. Efficient technologies are already employed for cultivation of hemp and flax in agriculture [2, 3] and in the fibre fleece and composite industry. But there is a substantial need for powerful technologies for fibre straw processing to ensure a reliable resourcing of high-quality fibres from agriculture. Therefore, a complete new machine line has been developed and tested at the Leibniz Institute for Agricultural Engineering (ATB) [4].

2. New Technology for Fibre Straw Processing

A pilot plant for bast fibre processing with a capacity of up to 3 t h$^{-1}$ hemp straw has been developed and evaluated with partners from industry at the ATB (Figures 1 and 2). In this plant innovative technologies have been applied for bale opening, decortication, fibre cleaning, and hurd cleaning [4]. With the same technology, retted and unretted fibre straw from hemp, flax, and oilseed flax can be processed to high-quality fibres for technical applications. Experiments with hemp and flax have shown that the excellent decortication quality achieved by this technology essentially simplifies the cleaning process. Thus, a reduction of the cleaning line to a 2-staged process is feasible (hurd content approx. 2% ATB line, traditional lines > 7%).

In existing plants, long processing lines are related to high investment cost, low mass flows and a high susceptibility to operational problems (Figure 2(a)). The new decortication machine developed at the ATB using impact stress to brake the connection between fibres and hurds is the key to solving operational problems encountered in existing processing lines [5]; see Figure 2(b).
(1) Bale feeder  
(2) Bale/straw cutter  
(3) Straw opener  
(4) Decortication  
(5) Dust separation  
(6) Fibre cleaning  
(7) Fibre baler  
(8) Hurd/shive cleaning  
(9) Air cleaning

**Figure 1:** ATB pilot plant for hemp and flax processing.

**Figure 2:** Industrial processing lines for short fibres from hemp and flax.
Table 1: Model parameters for the calculation of profitability of fibre processing plants (subset of main parameters).

<table>
<thead>
<tr>
<th>Technical data</th>
<th>Economic data</th>
<th>Investment</th>
<th>Financing</th>
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<tbody>
<tr>
<td>1–8 t h⁻¹ d.m.</td>
<td>140–170 € t⁻¹ d.m.</td>
<td>550,000 € t⁻¹ h⁻¹</td>
<td>50%</td>
</tr>
<tr>
<td>Hemp straw throughput</td>
<td>Straw price for hemp</td>
<td>Equipment costs per ton straw throughput</td>
<td>Financed from credit</td>
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<tr>
<td>25% Fibre yield</td>
<td>0.15 € kWh⁻¹ Energy price</td>
<td>(average at 5 t h⁻¹ throughput)</td>
<td>4% Interest rate</td>
</tr>
<tr>
<td>55% Hurd yield</td>
<td>0.55 € kg⁻¹ Fibre price</td>
<td>(10 years duration of the credit)</td>
<td></td>
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<tr>
<td>80% Running time</td>
<td>0.15–0.28 € kg⁻¹ Hurd price</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5–8 Employees for two shifts</td>
<td>390,000–820,000 € p.a. Labour costs</td>
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<td></td>
<td>0.75 € t⁻¹ km⁻¹ Specific straw transport cost</td>
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3. Development of a Model for the Evaluation of Fibre Processing Plants

Long-term praxis experiences with the ATB-hemp processing line between the years 2008 and 2011 as well as information from other hemp processors have been used to evaluate the economy of hemp fibre production. Using the detailed information about all process stages of the entire hemp processing line, an economic feasibility study was carried out applying the European economic conditions [6]. An overview of the most important input factors of this economic study is given in Table 1. On the basis of technical, performance, and financial data, the profit per ton processed hemp straw has been calculated for different plant sizes and variable straw prices.

Earlier studies have shown that profitable fibre production on the basis of hemp straw prices from 90 to 110 € t⁻¹ needs a straw throughput of more than 2.5 t h⁻¹ fibre straw [7]. Currently, for quality hemp straw prices ranging from 140 to 160 € t⁻¹ have to be paid to the farmers because of increased prices of main crops such as grain, rape seed, and maize.

Because raw material price is one of the most important input variables, a comprehensive investigation of the agricultural process chain of hemp straw production, storage, and transport has been carried out. Hemp cropping is still a niche branch in agriculture, and special knowledge as well as special machinery is required [8]. In the last 20 years praxis experiences have shown that a close cooperation of hemp processors with the local farmers is a prerequisite for success in the long-term. Straw processors need a reliable supply of high-quality straw to fulfil attractive long term contracts with, for example, the automotive industry. On the other hand, farmers need reliable industrial straw purchasers to invest in special equipment for economic straw production. Without the regional cooperation of both partners, the niche character of hemp fibre production cannot be overcome and transport cost stay an important cost factor. The dependence of transport distances and the allocated share of crop land for hemp straw production in the region of a hemp processing plant...
4. Results and Conclusions

On the basis of the specific straw transport costs (Table 1), an average straw yield of 7 t ha$^{-1}$ [2, 3] and the modelled average transport distances typical cost for straw transport can be calculated. Figure 5 illustrates the transport costs in dependence to the required acreage for continuous supply of a hemp processing plant.

Beside the demands on product quality, a processing capacity of more than 2.5 t h$^{-1}$ fibre straw and a high operational availability are essential requirements for profitable fibre production (Figure 6, A: break even). According to the results of the economic feasibility study, modern processing plants with capacities of 5 t h$^{-1}$ could generate a profit of approx. 40 € per ton processed hemp straw at straw prices of 155 € t$^{-1}$ and costs for straw transport from 7 to 13 € t$^{-1}$. Bigger processing plants with capacities up to 8 t h$^{-1}$ can increase their profit to approx. 55 € t$^{-1}$. However, also the required investment increases up to more than 4.5 million Euro. For the supply of such bigger processing plants, almost the double hemp cultivation area is required and higher transport costs often have to be accepted (Figure 5).

To reduce this disadvantage the close cooperation with farmers is of highest importance for the economic success. Otherwise, the higher profit will be easily used up by higher transport cost at calculated levels of 17 to 29 € h$^{-1}$ and more.

Finally, a straw throughput of more than 4 t h$^{-1}$ is the basis for economic fibre production for all new processing lines at current straw prices of more than 150 € t$^{-1}$. As a consequence of the results shown in Figures 5 and 6, the design of a hemp processing line made for a straw throughput of approx. 5 t h$^{-1}$ will be the target for next machine developments in cooperation with partners from industry.

References


