Industrial Crops & Products 118 (2018) 81–94

Contents lists available at ScienceDirect

Industrial Crops & Products

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

Comparative investigations of fibreboards resulting from selected hemp varieties

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ARTICLE INFO

Keywords:
Wet preserved hemp
Fibre crop processing
Fibreboards
Material properties

ABSTRACT

Two hemp varieties have been processed by different process technologies. The resulting fibrous intermediate has been characterized by particle analysis prior the manufacture of fibreboards. The results of comprehensive tests of respective product samples are used to describe the influence of raw material, processing method and target density on selected product properties. It has been shown that the intended respectively realized density of the fibre boards has the greatest influence on their physical and mechanical properties. Comparing values within the same density range both raw material (variety) choice as well as the number of processing steps lead to partially different results. A processing with a disc mill additional to a single step extruding is increasing the ratio of finer particles which applies to one hemp variety to a greater extent than to the other hemp variety. Close relations to respective properties of the fibre boards are identified and presented in the paper.

1. Introduction

The wood-based materials industry is representing a large sector of the German economy with a turnover of approximately 4.8 billion Euro and about 13,500 employees (indirectly about 300,000) (Sauerwein, 2014; VHI, 2017). For 2015 a total production volume of 10.5 million m^3 was recorded in which particle boards represented 5.5 million m^3, fibre boards 3.6 million m^3 and Oriented Strand Boards (OSB) 1.2 million m^3 (VHI, 2017).

Due to different reasons, the wood-based materials industry has undergone an intensive consolidation process in the last 10 years (Sauerwein, 2014). However, after a remarkable decline of production volumes in the second half of last decade recent statistics show an improvement of the situation (2013–2016: +2% for particle boards; +4% for fibre boards).

The ratio of demand to available raw materials for such products is a subject of both public as well as of industry-sector-specific discussions already for a long time. The use of wood is increasingly being discussed as the future demand might exceed the possible supply from forest as well as alternative resources (Pauls et al., 2008; Mantau et al., 2010; Sauerwein, 2014). Among others, the determining factors in this context are capacity extension in particular in the pellet and paper industry entailing an increase in costs for wood based raw materials (Dörschel, 2014; Sam-Brew and Smith, 2017).

Non wood based raw materials as being available from e.g. agriculture can be used as an alternative for the production of respective applications. Thus, materials like cereal straw and fibre crops as a whole or components thereof have been subject of research and development already for a long period (Sheperd, 1932; Oman, 1995; Klauditz et al., 1958; Groner and Barbour, 1971; Deppe and Stashevski, 1974; Atchison and Collins, 1976; Hesch, 1978; Heller, 1980; Allin, 2005; Kymäläinen and Sjöberg, 2008; Barros et al., 2011; de Lima Mesquita et al., 2018). For example, it could be shown that with a proportionate admixture of hemp shives to wood partially improved mechanical and technological properties of particle boards were achieved respectively new product properties of pure hemp shive boards (Nonninger et al., 2010; Pecenka et al., 2010). Furthermore industrial activities led to the market launch of several hemp based products. The German building company STEICO AG presented insulating materials from fibres as well from shives with suitable material properties (Gahle, 2007). Particularly of interest is also the production of hemp or flax shive boards as construction materials, similar to commercially available particle boards made of wood. Hemp shive boards have been offered on the market by various manufacturers. Pfleiderer Holzwerkstoffe GmbH presented a panel coated with HPL (High Pressure Laminate) under the name “Hemp fibre composite” (Thermopal, 2010). In cooperation with Resopal GmbH, the Kosche Group launched a light furniture board “Hemp” with a low raw density (Kosche-Group, 2005; Pauls et al., 2008). However, hemp based product offered for sale in the long term have not been successful in the

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https://doi.org/10.1016/j.indcrop.2018.03.031
Received 1 November 2017; Received in revised form 5 March 2018; Accepted 15 March 2018

market. The requirements for the production of such products are on the one hand competitive raw material costs on the other hand a high quality as well as a high availability of cleaned shives. Both could not be realized on a requested level (Pauls et al., 2008; Lühr, 2017). In contrast, tens of thousands of tonnes flax shives are used by manufacturers in France, Belgium and the Netherlands for the production of respective boards (Pauls et al., 2008; van Dam, 2014; Grow2Build, 2015).

Beside the traditional way to separate fibre crop stems and use its structural main components fibres and shives the whole crop utilization of flax and hemp became of interest since few years. For example, the processing and application of such materials in natural reinforced composites have been investigated in a large national collaborative project (Gusovius et al., 2016). The described supply chain for wet preserved hemp raw materials is based on long term research activities at Leibniz Institute of Agricultural Engineering and Bioeconomy (ATB) in Potsdam (Germany) (Pecenka et al., 2009; Radosavljević, 2010; Idler et al., 2011; Wallot et al., 2012). Furthermore, special attention has been given to applications for board production and respective insulating properties (Kirilovs et al., 2012; Kirilovs et al., 2015).

The intention of the present study was to investigate the influence of variety choice, type of processing and product density on selected quality parameters of intermediates and resulting medium density fibreboards (MDF).

2. Material and methods

2.1. Raw material supply and particle disintegration

Hemp (*Cannabis sativa* L.) was grown at the experimental plot of ATB in course of research and demonstration activities of the collaborative EU-FP7 project “Multipurpose hemp for industrial bioproducts and biomass” (MultiHemp) in 2014. Two varieties with contrasting properties, Polish Bialobrzeskie (owner: Institute of Natural Fibres & Medicinal Plants, Poznan) and French Futura 75 (owner Fédération Nationale des Producteurs de Chanvre, Le Mans), have been chosen from a variety trail covered in MultiHemp's workspace 3 (“Optimisation of hemp cultivation and crop modelling”). Among other European locations they have been cultivated under agricultural conditions as well in Potsdam (52.4°N; 13.0°E). The site conditions are characterized by a loamy-sand with an average soil quality (“Ackerzahl”) of 30 … 40. Sowing took place at April, 17th, 2014 and an additional ration of 60 kg ha^{-1} N-fertilizer (calcium ammonium nitrate) was applied at May, 15th. Weather conditions in course of growing season for Potsdam have been GDD = 2809; mean temperature = 18.0 °C; T_{min} = 6.5 °C and T_{max} = 38.3 °C; amount of rainfall = 286 mm.

The harvest was carried out September, 23rd 2014 by means of a forage harvester (chopper) mounted to a tractor (Fig. 1 left). Thereby the crop is cut into smaller particles (approximately 50 mm) which enable a proper densification of the harvested material. This procedure is necessary to guarantee the absence of oxygen in course of the following wet preservation.

Thus, spoilage and the unwanted degradation of cellulose are avoided when the densified biomass is sealed with a silage film immediately after baling (Fig. 1, right). The biomass yields were calculated with 23 t ha^{-1} (7.8 t ha^{-1} dry matter) for the French variety respectively 19.9 t ha^{-1} (6.8 t ha^{-1} dry matter) for the Polish variety. In this experiment Bialobrzeskie as a continental, medium late variety yielded approximately 13% lower than the maritime, late variety Futura. This is comparable to the results of MultiHemp‘s demonstration activities carried out simultaneously in Oude Pekela (The Netherlands; 53.6°N; 7.0°E) but remarkable lower than the French location Aulnoy (48.5°N; 3.5°E) (MultiHemp, 2017).

The bales have been stored under ambient conditions for 530 days before the subsequent processing (Fig. 2). A silage typical odour but no noticeable degradation and have been noticed after removal of the wrapping from the bales.

The processing of the wet preserved hemp into a fibrous intermediate was carried out by means of a so called dry/half-dry procedure which consists of similar process steps known from the wood fibre industry (Pecenka et al., 2009; Idler et al., 2011). The experimental trials have been conducted at the pilot plant of the ATB. Two main procedure steps and machines therefore are of specific interest for the resulting intermediate quality (Fig. 3).

The processing of the wet preserved raw material was proceeded at following parameters:

- Extruder: screw dimensions: d_{in}/d_{out} = 150/220 mm, l = 1235 mm, outlet gap at 16 mm, RPM: 48 min^{-1}, throughput: 420 … 480 kg h^{-1} fresh matter (FM)
- Disc mill: disc diameters: 500 mm with a grinding area of 830 cm^2, RPM 2000 min^{-1} (33 Hz), gap distance of the discs: 0.2 mm
- Particle disintegration at its original moisture content (59.2 … 61.6%)
- Subsequent drying: at 160 °C to < 10% moisture content

Following types of fibrous intermediates have been produced for the further processing into fibre boards: (Fig. 4):

- Bialobrzeskie, extruded (Bialo E)
- Bialobrzeskie, extruded and milled (Bialo E + S)
- Futura, extruded (Fut E)
- Futura, extruded and milled (Fut E + S)

A RETSCH sieve shaker was used to determine the particle size distribution of the resulting fibrous intermediate. Sieving time was set

Fig. 1. Harvest of hemp with a field chopper (left) and densification as well as wet preservation of the chopped harvest material (right).