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Still special? Harvesting procedures for industrial hemp

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A multitude of different harvesting procedures is available after the re-approval of hemp growing in Germany about 20 years ago. Established, but as well recent machine developments enable the supply of raw materials for further processing or as food and feed materials. The necessary specialization level results in high but, compared to other established crops, not exceeding procedural costs. In this study, harvesting procedures and technologies are analyzed that are currently used under Northern European cultivation conditions. However, technological enhancements are still needed in order to improve the competitiveness of fibre hemp in the crop rotation as well as of hemp-based semi-finished and finished products.

Keywords
Fibre hemp, harvest, procedures, technologies, assessment

From the year 1996, the reintroduction of hemp growing in Germany was characterized by a quick growth of cropping areas and the establishment of a multitude of fibre processing lines. However, the sector underwent an unsteady development following this euphoric initial stage until the first decade of the new millennium. A mid- to long-term introduction of respective products into sustainable industrial applications as well as technological problems along the value added chain led to a virtual cessation of growing and processing of fibre crops (Brückner and Steger 2013).

On the other hand, an increasing interest in natural fibres for different purposes, like in composite industries – basically independent from origin and kind of raw materials, can be observed in the past 30 years. For example, the amount of natural fibre raw materials used in the European automotive industry increased by almost 40% up to 30.000 t a^{-1} from 2005 to 2012 (Dammer et al. 2013). As the interest in domestic raw materials is increasing and new commercialization possibilities of additional components of the hemp crop are arising, the status and prospects of process technological solutions for harvest and supply of hemp crop based raw materials are to be assessed critically.

Status quo

Traditionally, the technical accouterment of farms or agricultural contractors was aimed at harvesting hemp as whole stems for the further processing in the apparel industry.

Although the interest in unshortened stems decreased due to the relocation of the related textile industries to Asia, several agro-technical solutions were developed within different R&D projects in order to offer modern machines for this supply chain (Figure 1 and 2).

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Figure 1: Prototype of a harvesting machine of the IWNIRZ for mowing and separate simultaneous recovery of flowers/panicles (Photo: R. Kaniewski)

Figure 2: Harvesting machine prototype of the company Kranemann for mowing and and cross-parallel laying of hemp stems (Photo: H.-H. Kranemann)

Between the end of the 90s and 2007, the Polish Institute of Natural Fibres & Medicinal Plants (IWNIRZ) in Poznan (Figure 1) (Pari et al. 2015) as well as the German special purpose machinery manufacturer Kranemann GmbH (Klocksin/Blücherhof) (Figure 2) developed and tested harvesting machines for cross-parallel laying of mowed hemp stems on the field ground. A subsequent baling of dried and retted plant stems in the given arrangement enables further textile-technological processing by scutching (Amaducci and Gusovius 2010). Within the schematic drawing of process sequences for industrial hemp (Figure 3), this procedure is to be ranged in the process steps 14 to 17 or 6, respectively. A market and request for such machine developments is to be expected as the interest in a revitalization of the textile production based on domestic bast fibre crops is rising in Europe.

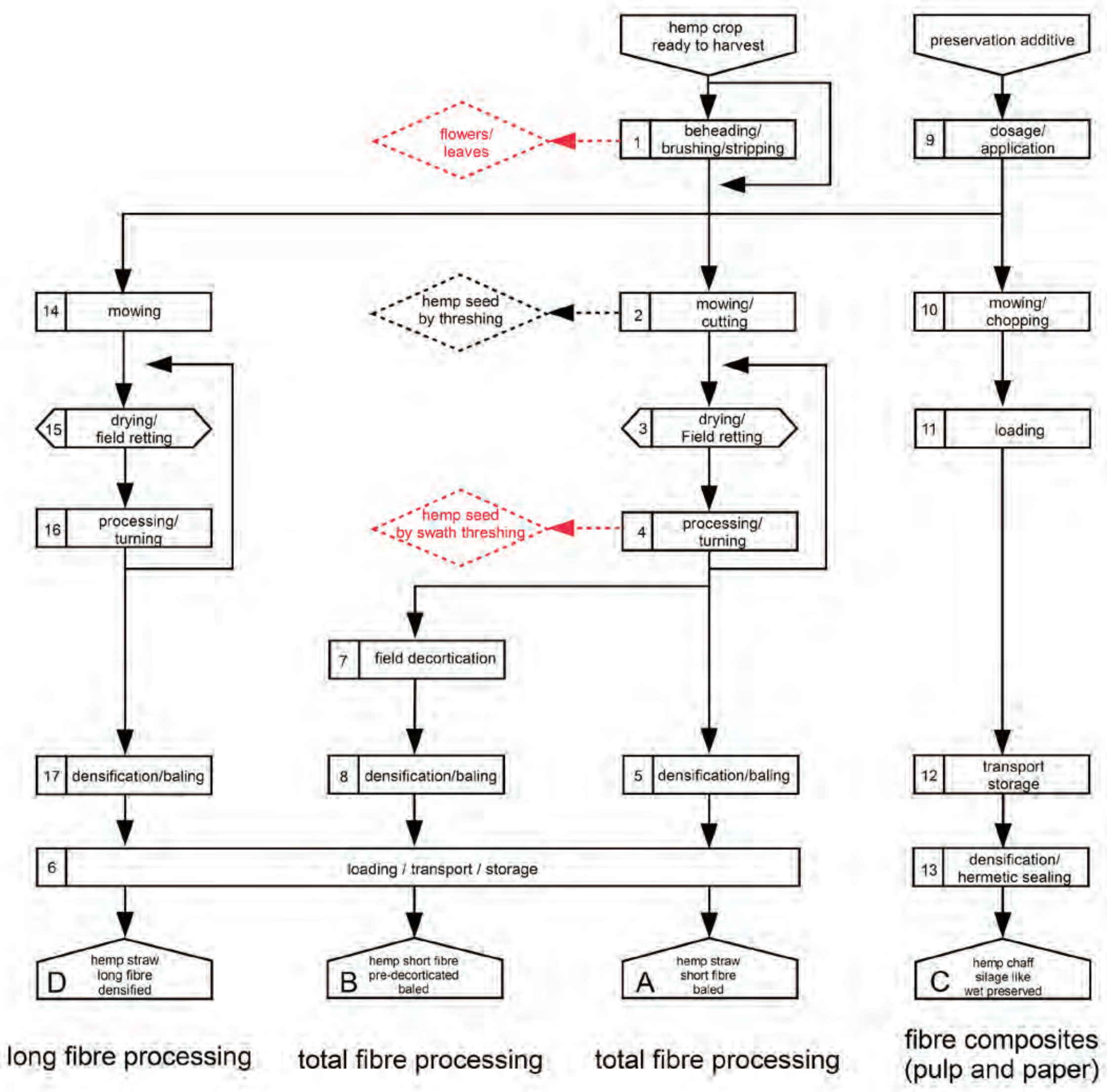

Figure 3: Process sequences for the harvest of industrial hemp

Harvesting systems for exclusive stem utilization

In the past years, growing and harvesting procedures enabling the supply of fibrous raw materials for technical products were developed preferentially. In these markets an enormous pricing pressure has to be recognized. Therefore, technological developments, especially for harvesting machines, oriented on high area output and low procedural costs. Basically, these developments are characterized by the need to cut the particularly very long stems to shorter sections by additional cuts. This is the main prerequisite for a trouble-free subsequent turning and swathing as well as baling of the hemp straw. In order to achieve this goal, several machine systems with different technical principles were already developed in the mid-90s (Figure 3, process steps 2–6) (Amaducci and Gusovius 2010).

The machine system „HempCut", realizing working width of 3.0 or 4.5 m, respectively, was developed in the 90s in the Netherlands. At present, it is regarded as the most widely used system for harvesting hemp but as well for kenaf. The system is manufactured and distributed by the company

Wittrock (Rhede-Brual). It is based on a row-independent mower header in combination with a modified chopper drum equipped with only a single knife (Amaducci and Gusovius 2010). A Claas forage harvester 492/493 is commonly used as bearing vehicle where the original cutterhead is replaced by the mentioned module including the Kemper mower header. The variable drive control of the drum allows the cutting of fibre crop stems into lengths from 150 to 600 mm. The bearing vehicle basically remains in its original condition and can be used in all harvest operations for other field crops, too. Thus, high yearly machine hours are achieved and allocated machine costs can be reduced.

The machine system „Blücher“of the company Kranemann (Klocksin-Blücherhof) is based on a completely different concept. Mowing as well as the stem length reduction by additional cutting in up to 80 cm long pieces by vertically installed cutter discs are realized in the original upright position of the hemp plant (Amaducci and Gusovius 2010). Both sub-processes are realized simultaneously before eccentric steered conveyor elements convey the biomass behind the cutter header module. Swaths with a width of 80 to 110 mm are deposited on the field ground by both harvesting systems. Taking into account the comparably high biomass yield of hemp, one to several times of turning and swathing operations are necessary in order to enable a uniform field drying and retting of the entire material.

A further technological approach is focusing on the application of the scissor-type principle for the harvest of hemp as it is known from fodder or cereals cutting. A two to four level vertical arrangement of several cutter bars enables the requested shortening of the hemp stems. In 2007, the Czech company Tebeco launched a three level harvesting system to market which is based on cutter bars with steel double fingers (Gebr. Schumacher GmbH, Eichelhard) (Pari et al. 2015). Similar developments are known from England and Germany. The demand on such mowers was increasing especially in the first decade after the re-admission of hemp growing in Germany and was attended by e. g. Saxon machine manufacturers with the „HMG Hanf-Mäh-Gerät“ (Gusovius and Paulitz 2009).

Specific advantages of such harvesting system are the comparable low power requirement of 2,5 kW m^{-1} working width and per cutter bar level (Wenner et al. 1986, Gusovius and Paulitz 2009) and the swath-less deposition of the crop on the field ground. Positive effects on field drying and retting are proven (Gusovius 2002) and are confirmed by practitioners. Nevertheless, it has to be stated that harvesting machines based on finger or double knife cutter bars have not made any appreciable progress on the market yet. The renunciation is based on the fact that the mowed and shortened biomass deposited on the stubbles is overrun due to the functional principle of the machine arrangement and thus very often contaminated by soil particles. Additionally, the knifes have to be sharpened respectively the cutter bars have to be changed from time to time in order to enable a proper cutting.

Harvesting systems for dual purposes

The harvesting systems mentioned above were or are used in northern regions preferably, as the (additional) gathering of seeds is problematic under northern climatic conditions. Economic compulsions at the customer level and the proceeding competition for growing area led to an increase of the dual utilization (stem/fibre and seed) of hemp – even outside the traditional growing areas. Therefore, an adaption of existing special harvesting technologies and the development of new ones, respectively, was necessary.

Conventional combine harvesters with axial flow principles are used for threshing of seed and propagation material in the traditional growing areas in France. This is a part of a two-phase harvesting system where only the plant tops of hemp are cut and threshed with the combine. The remaining stems are mowed afterwards with double knife cutter bars (Desanlis et al. 2013).

At the beginning of the new millennium the harvesting system „Hanfvollernter“ (hemp total harvester) was developed by the companies Götz (Bühl/Moos), Bafa (Malsch) and Deutz-Fahr (Lauingen). It is technically based on a combine with straw walkers in combination with a mowing and two-knife chopping module and was developed in order to simplify the process (one-phase, shortening of the stems) (Mastel 2002). An obvious disadvantage of this principle is the passage of the whole harvested biomass trough the threshing and straw cleaning units of the combine. In particular, a reduction of the area efficiency of the machine caused by a lower working speed and huge loads at the respective machine components are to be expected at biomass yields of 20 t ha^{-1} and more. A partial decortication (disintegration of the natural bond between bast and woody core) of the hemp stems while passing the threshing system of the combine is resulting in a slightly lower straw yield but can have positive effects on subsequent field drying and retting (Gusovius 2002). But, already the first comprehensive machine tests it turned out, however, that mowing with row-independent Kemper header can result in considerable seed losses due to the shaking (Mastel 2002). Regardless of the technical evaluation and previous tests about 15 of these machine systems were sold and are in use all across Europe.

Following some French predevelopments the new concept „Double-Cut Combine“was presented recently by a Dutch farm machinery company (Profi 2014). In cooperation with the Dutch fibre processor Hempflax (Oude Pekela) a combine was modified in order to cut only the plant tops using a special high-cut arrangement of a common cereal header (Figure 4). The application of load to the integrated threshing and cleaning unit is reduced because the remaining stems are mowed, shortened and deposited on the field ground by means of the approved „HempCut“ module underneath the cutter header. Seed losses are assumed to be minimized by conveying the plant tops (panicle with seeds) directly into the cutter header trough.

Figure 4: Double-Cut Combine (Photo: M. Reinders)

The development of the Dutch natural fibre processor DunAgro (Oude Pekela) in cooperation with the company Wittrock (Rhede-Brual) is aiming at the selective detachment of flowers and leaves (as well as seeds if already developed) by a special stripper header in front of the bearing machine (Figure 3, process steps 1–6). The increased risk accompanying seed harvest due to late ripening is avoided by the high added value for the leave/flower material. Further advantages arise from the improved field retting and drying of the remaining stems mowed and cut with a „HempCut“ module (Figure 5).

Figure 5: Claas Xerion with hemp stripper (Photo: A. Dun)

A new approach to harvest hemp seeds during swath turning is under investigation as part of the ongoing EU-FP project „MultiHemp“(Ref. 311849). In general, at least one swath turning is necessary in order to enable a uniform drying and retting of hemp straw. Thus the basic idea of the new process technology for seed gathering is that an additional and more uniform post ripening can be realized in the swath, even if the crop is mowed and laid down on the field ground at an earlier date than common for seed harvesting (Figure 3, process steps 1–3, 4, 5–6). Hence, an increased yield, a more uniform ripening as well as a better quality of seeds are to be expected. Comparable procedures are known from the harvest of specific summer varieties or seed propagation material. In France such procedures were applied for the production of hemp seed propagation qualities in earlier times, too (Thouminout 2015, personal communication).

In order to implement the new approach a novel machine concept will be manufactured in the near future. This machine can take up the hemp straw swath gently with a belt conveyor, shake out the seeds by means of an oscillating sieve and finally lay down the material turned to the field ground (Figure 6). The operation of cost intensive special machines for combined harvesting of straw and seeds can thereby be avoided. In addition, higher yield and quality of the seeds are expected.

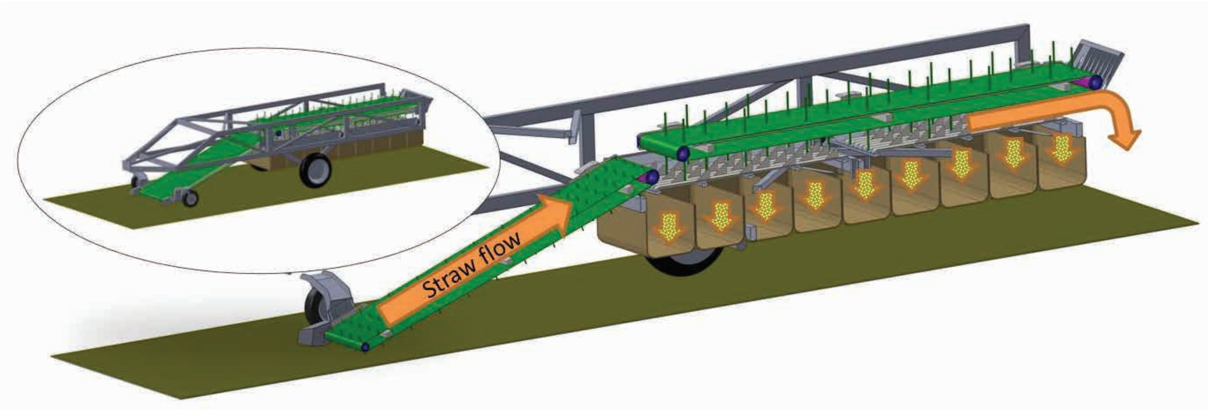

Figure 6: Schematic drawing of a machine for seed gathering from swath deposited hemp crops

This machine is currently under development and manufacturing in cooperation between the Institute for Agricultural Engineering Potsdam-Bornim (ATB) and the company Kranemann. First experiences and results on costs, capacity as well as quality of the process and the products are expected from the harvest 2016.

Harvesting systems for whole crop utilization

Already for some years a novel supply and processing procedure for whole hemp crops by means of wet preservation is under investigation at the ATB (Pecenka et al. 2007, Idler et al. 2011). Common machines as available at almost every farm or contractor's vehicle fleet and used for e. g. maize harvest can be deployed for the respective hemp harvest (Figure 3, process steps 9–13). Mowing, e. g. with a row-independent Kemper header as well as conveying to and chopping with a common cutterhead are able without significant malfunction (Figure 7).

Figure 7: Hemp harvest for wet preservation (Photo: R. Pecenka)

The operation of a chopper-baler unit is known from agricultural practice in the Netherlands. Hemp plants taken up from swath are chopped into pieces of up to 50 mm and directly conveyed into the pressing unit of the baler (Figure 8). Subsequently, the square bales are wrapped with silage films. This silage can be utilized e. g. as part of feed rations for dairy cattle. Except for the driving unit for the bale's press, no further changes or modification at the machines are necessary.

Figure 8: Swath chopping with attached baler (Photo: H.-J. Gusovius)

Process-technological assessment approach

From the available data no comprehensive capacity, functional and expenditures assessment can be carried out. But an attempt to compare capacity and expenditure analysis will be undertaken by use of manufacturers data as well as informations from agricultural practice and own measurement data. Further process steps like transport and storage are not included. Informations on investment costs, fixed and variable machine costs, salaries as well as working capacities are available from own measurements and interviews as well as from standardized data sets (KTBL 2014, KTBL 2015). The assessment is neither comparing nor including the revenues as the arrangements and agreements are very specific and can not be generalized.

Bearing vehicles, like self-propelled system tractors or choppers, are commonly used for more than the hemp harvest only. Partially very high investment costs up to 600.000 € are spread on a larger number of area or time units and thus help to reduce the procedural costs. In the case of the two combine systems „Hanfvollernter“ and „Double-Cut Combine“ it is assumed that the base machine can be used for the harvest of other crops as well. Therefore, the working times as well as the depreciation rates as recommended by the KTBL are used to calculate the machine costs (KTBL 2014). The procedural costs are related to the working area in order to enable a better comparability to other KTBL-standardized procedures. These are comparable with their so called thresholds (AS). Salaries are calculated with 17.50 € h^{-1}.

An assessment of the harvesting systems for textile oriented parallel deposition of hemp stems as well as for the novel machine for swath-deseeding is not possible as these devices are not (yet) manufactured in series. Information on investment costs and working capacities are therefore not available.

A drawing vehicle providing the necessary engine power class was considered for the harvesting systems based on cutter bars. The same is valid for „Blücher 03“ and „HempCut 4500“ where self-propelled forage harvesters are commonly used.

The working width as well as the working speed have significant influence on the working time but also on the procedural costs (Figure 9). Advancements in machine design and development, e. g. for double knife cutters „HMG“ (working width HMG 4-240: 2.4 m, HMG 4-5000: 5.0 m) enable a reduction of the expenditures from 68 to 56 € ha^{-1}. The highest procedural costs are identified for the combine-based harvesting systems with 146 € ha^{-1} (Double-Cut Combine) or 155 € ha^{-1} (Hanfvollernter), respectively. Despite working widths of up to 4.55 m, it is expected that the working speed is comparably low due to high mass flows. Considering the whole value added chain, machine systems for dual use of hemp plants can generate an additional revenue of 50 % from the seeds (900–1,500 € t^{-1}) depending on yield (0.7–1.5 t ha^{-1}) and quality.

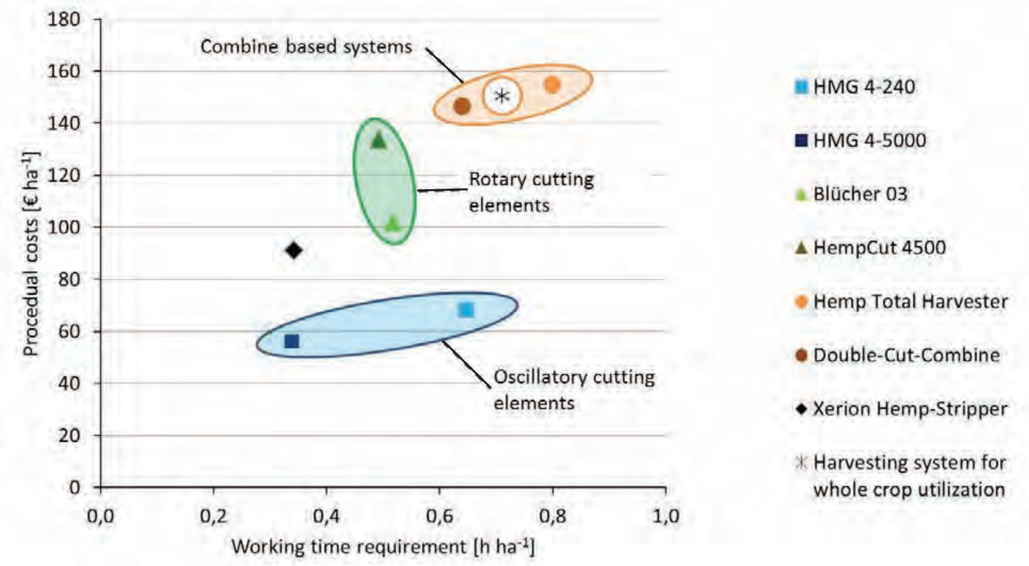

Figure 9: Working time requirement and procedural costs of different harvesting systems (incl. categorized working principles)

The harvesting system based on the Claas Xerion 400 with working width up to 6 m s obtains the highest working capacities (2.9 ha h^{-1}; 0.34 h ha^{-1}). Our time studies and interviews with the machine owner and operators have shown that a working speed up to 9 km h^{-1} is possible. This requires certain prerequisites on the choice and preparation of the fields as well as a high degree of automation of the several components of the machine.

Further technological improvements are required in the supply system for wet preserved whole crop material. High biomass yields of up to 20 t ha^{-1} as well as particle sizes recommended for a successful preservation are leading to low working capacities of 0.71 h ha^{-1} as well as to high procedural costs.

Conclusions

Most of the known harvesting systems for industrial hemp are still characterized by a high degree of specialization. Even if standard machines at farm or contractors level are used, certain modifications or device couplings are still necessary due to the specific characteristics of the crop. Especially the fact that long pieces from the hemp stem or even loosened fibres can cause wrappings and by that, considerable damages at rotating machine components, suitable proactive measures have to be carried out. High biomass yields, as well as the specific mechanical characteristics of the crop, are applying huge loads to the respective machine elements. Lower working capacities as well as abrasion related higher service costs and a lower serviceable life of machines or at least their components have to be taken into account as well. Nevertheless, neither working capacities nor procedural costs are differing much compared to respective parameters of other procedures like cereals threshing (115 € ha^{-1}) or maize chopping (140 € ha^{-1}) (KTBL 2015).

References

Amaducci, S.; Gusovius, H. (2010): Hemp-Cultivation, Extraction and Processing. In: Müssig, J.; Stevens, C. (eds.): Industrial Applications of Natural Fibres Structure, Properties and Technical Applications. John Wiley & Sons, Ltd, Chichester, West Sussex, United Kingdom, pp. 109–134

Brückner, T.; Steger, J. (2013): Quantitative und qualitative Bedarfsanalyse für Naturfasern und Optionen zur regionalen Sicherung der Rohstoffbereitstellung in Deutschland. Abschlussbericht zum FNR-Fördervorhaben 22034311, Waldenburg, Gülzow

Dammer, L.; Carus, M.; Raschka, A.; Scholz, L. (2013): Market Developments of and Opportunities for bio-based products and chemicals. Report for Agentschap NL, nova-Institute for Ecology and Innovation, Hürth

Desanlis, F.; Cerruti, N.; Warner, P. (2013): Hemp agronomics and cultivation. In: Bouloc, P.; Allegret, S.; Arnaud, L. (eds.): Hemp: industrial production and uses. Cabi Publishing Wallingford, Oxfordshire, United Kingdom, pp. 98–124

Gusovius, H.-J. (2002): Stoffwandlungen und Umwelteinflüsse in Verfahrensketten für Faserhanf., Dissertation, Humboldt-Universität zu Berlin, Cuvillier-Verlag, Göttingen

Gusovius, H.; Paulitz, J. (2009): Current developments for efficient raw material supply procedures enforcing cost-effective bast fibre production in Europe. Journal of Biobased Materials and Bioenergy 3, pp. 262–264, DOI: http://dx.doi.org/10.1166/jbmb.2009.1031

Idler, C.; Pecenka, R.; Fürll, C.; Gusovius, H. (2011): Wet Processing of Hemp: An Overview. Journal of Natural Fibers 8(2), pp. 59–80, DOI: http://dx.doi.org/10.1080/15440478.2011.576089

KTBL (2014): Datensammlung Betriebsplanung Landwirtschaft 2014/15. Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V., Darmstadt

KTBL (2015): Verfahrensrechner Pflanze. http://www.ktbl.de, accessed on 16 July 2015

Mastel, K. (2002): Prüfung des Prototyps einer Maschine zur Ernte von Hanfstroh und Hanfkörnern. In: Informationen für die Pflanzenproduktion – Sonderheft 2/2002, LAP Forchheim

Pari, L.; Baraniecki, P.; Kaniewski, R.; Scarfone, A. (2015): Harvesting strategies of bast fiber crops in Europe and in China. Industrial Crops and Products 68, pp. 90–96, DOI: http://dx.doi.org/10.1016/j.indcrop.2014.09.010

Pecenka, R.; Idler, C.; Grundmann, P.; Fürll, C.; Gusovius, H. (2007): Tube ensiling of hemp – Initial practical experience. Agrartechnische Forschung (Agricultural Engineering Research) 13(1), pp. 15–26

Profi (2014): Two headers for Dutch combine harvester. Profi - Magazin für Agrartechnik, Online-Newsletter vom 2.9.2014, https://www.profi.com/news/Two-headers-for-Dutch-combine-harvester-1530620.html, accessed on 26 May 2015

Wenner, H.-L. (1986): Die Landwirtschaft, Band 3: Landtechnik Bauwesen. BLV Verlagsgesellschaft mbH, München, 8. Aufl.

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