BALING, TRANSPORTATION, AND STORAGE OF STRAW

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Summary

Straw as a byproduct of the harvest of cereal crops is suitable for many agricultural and industrial applications. Mostly it is saved as fodder or bedding in animal production or for energy utilization.

Both quality assurance and the minimization of supply costs require an optimization of the entire logistic chain from the field where it is harvested to the store. Due to the bulkiness of straw, an appropriate level of compaction is particularly important to reduce the feed and storage space requirements.

With normal compaction systems, the density spectrum ranges from 80 to 160 $kg\,m^{-3}$. These procedures are described as related to harvesting machines as well as to transport, handling and storage equipment.

Procedures are also presented as related to the high pressure compaction of straw, which are favorable for large transport distances and in logistic chains for the supply of fibrous bio-fuels. Criteria for the evaluation and selection of such procedures are presented as well as future trends, which can be expected in straw handling.

1. Introduction

Straw as a lignocellulosic biomass is considered as a byproduct of plant production. Straw is still burned in fields despite the associated environmental damage. A further proportion remains on the field surface after harvest for the improvement of soil characteristics and nutrient contribution. The handling procedures for straw depend on the intended purpose. Main use targets are in animal production (feeding and bedding), in thermal use and in utilization as an industrial raw material. Conflicting aims focus on a tendency to minimize the costs of handling the byproduct straw and on the other hand to harvest a high-quality straw in time for storage. These requirements demand among other things:

- fast removal from the field to avoid degradation in substance and quality;
- a low moisture content of the straw to avoid quality-loss effects when stored;
- an appropiate storage with effective protection from rehumidification.

The weather process during the time the crop is lying in the field influences the sensorily ascertainable modifications of the straw characteristics. In addition, color fading, modification of smell as well as fungal growth can also occur.

Due to the bulkiness of straw, an appropriate level of compaction is particularly important, to reduce the transport and space requirements. The span of density from 50 to 300 kg m^{-3} depends upon the handling and compaction procedures. The highest density (up to 500 kg $m^{-3)}$ is achieved by forming pellets or briquettes. These are preferred for long transport distances as well as in logistic chains for the supply of fibrous bio-fuel. This article provides an overview of presently available procedures for compacting, transporting and storing of straw. Criteria for the evaluation and selection procedures are presented. Trends which can be expected in the future are discussed.

2. Baling

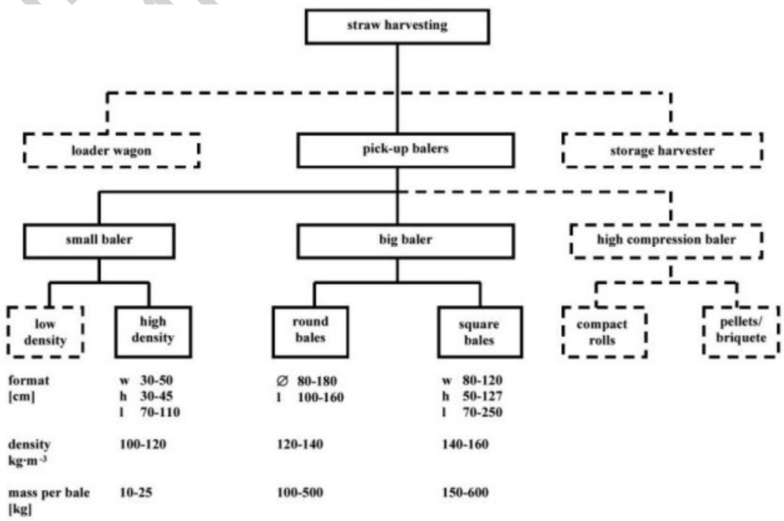

Figure 1. Outline of procedures for straw harvesting.

For straw harvesting baling presses are predominantly used (Figure 1). Loader wagons or forage harvesters with trailers or stack balers are rarely used because (due to the lower density) an elevated volume of feed and stockroom occurs for each mass or energy unit. For chopped straw in relation to big bales, twice the space is needed while in relation to pellets, nine times more feed and stockroom is required (Table 1).

Form of compaction	**Storage room requirement $m^3\ GJ^{-1}$**
straw chop	1.0–1.1
small bales (high density)	0.6–0.7
round bales	0.5–0.6
square bales	0.4–0.5
pellets	0.1–0.15

Table 1. Specific storage room requirement for straw as a source of energy (moisture content 15 percent, energy content 16 MJ kg^{-1}).

Despite the density advantage of pellets, mobile systems for high pressure compaction of straw (and whole-crops) are still at an early stage of development.

Pickup balers are tractor-drawn or self-propelled machines for the pickup and compaction of straw and other dry crops. They form bales of different size, form and mass. The performance of presses depends on their design and throughtput ability, the type of straw and on the swath-mass. The swath-mass depends on the straw yield and the cutterbar width of the combine harvester. Modern large baling presses need high swath masses in order to maximize their performance potential. The moisture content of the straw should be under 18% when pressing. The bale density is also influenced by the straw-chopper of the combine harvester. More strongly cut-up straw from axial or multidrum combines permits higher bale density. Straw chopping aimed at higher press densities and a better dissolution of the bale is attainable also by cutting mechanisms in the press.

2.1 Conventional Balers

Conventional balers in the form of high-pressure small bale presses are very common (Figure 2).

The straw is gathered by a pickup reel, carried by a conveyor rake to the press chamber where it is compressed by a sliding or rolling plunger at 70 to 110 strokes per minute. The bales are bound by needle and knotter. Afterwards they are stored in the field or loaded directly by bale throwers or a bale slide onto trailers. Tractors with 40 to 60 kW of engine power are required.

2.2 Roundbalers

With roundbalers the straw is also gathered by a pickup reel out of the swath, conveyed by a rake to a round or multi-angular chamber and formed there by radial compression into cylindrical bales.

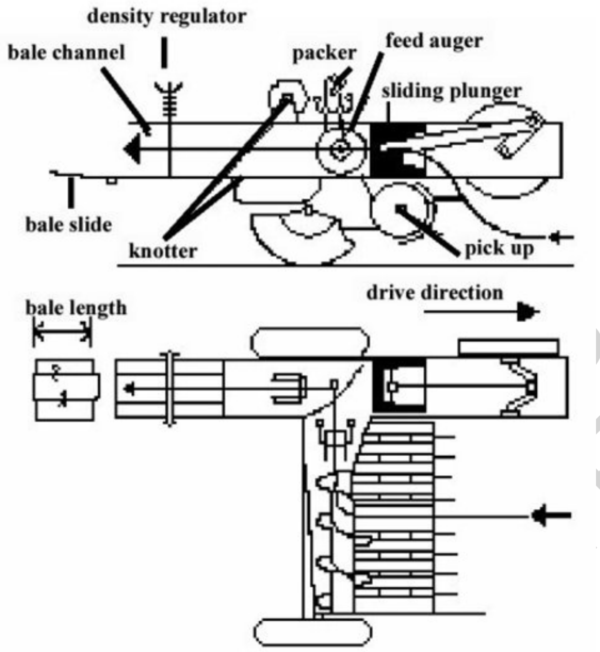

Figure 2. Functional principle of the high-pressure small baler; (source: Eichhorn, H. (1999) *Landtechnik*, Eugen Ulmer, Stuttgart, p. 390)

The bale chamber is limited in its scope by rolls, circulating belts or rod link chains. According to the mode of action, roundbalers can be classified in two main categories: balers with a constant or a variable bale chamber (Figure 3).

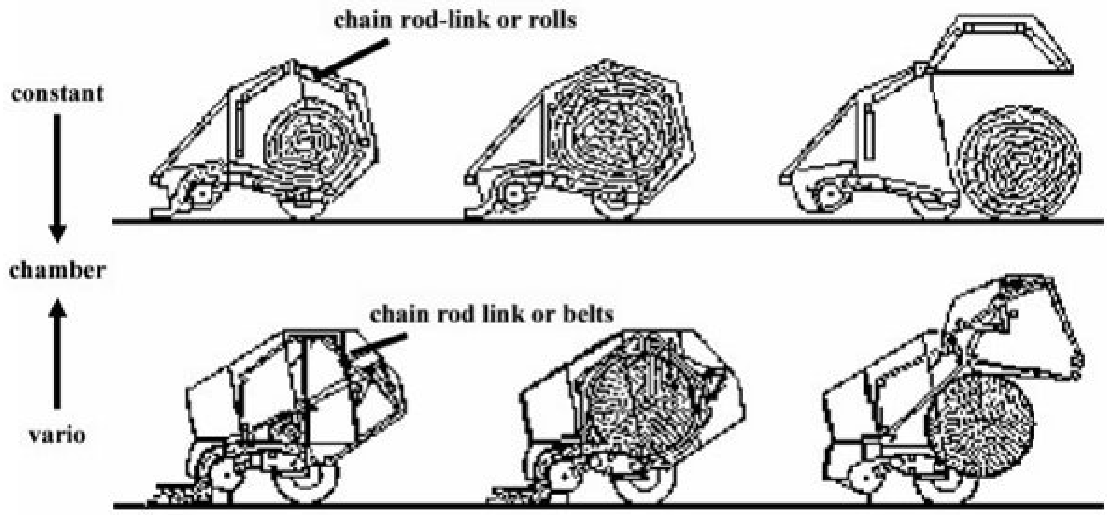

Figure 3. Functional principle of round balers; (source: Eichhorn, H. (1999) *Landtechnik*, Eugen Ulmer, Stuttgart, p. 390).

Constant chamber presses produce bales with a loose core and a compact outer layer. The diameter is constant. If the bale is formed in a "Variopress" from the inside outward by an endless belt system or a rod-link chain system, it results in a compact core. In so-called hybrid-roundbalers the advantages of both versions are combined.

As soon as the bale in the press chamber achieves the desired size and density, the mass flow is interrupted, the bale automatically tied with binding yarn or a wrapping net and ejected by opening the rear door. The interruption of the mass flow is normally connected with the inactivation of the press. With non-stop-round balers these performance-reducing dead times are avoided. A rotor conveys the gathered material to a pre-chamber during the binding and ejection, which is emptied thereafter into the press chamber. For pulling the round balers, tractors with 50 to 70 kW of engine power are necessary. Constant chamber presses have a tendency to a higher power requirement, since towards the end of the compaction process considerable peaks in power requirement occur.

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Bibliography

Eichhorn H., ed. (1999). *Landtechnik-Landwirtschaftliches Lehrbuch 4*, 7th. ed., 688 pp. Eugen Ulmer, Stuttgart, Germany; ISBN 3-8001-108-5. [Textbook of agricultural engineering.]

Hahn J. and Fürll C. (1995). Logistik optimieren-Bewertung logistischer Ketten für halmgutartige Biobrennstoffe, *Landtechnik*, **50**(3), 130–131. [Optimizing logistics-Evaluation of logistic chains for fibrous biofuels.]

Handbook of Agricultural Engineering (1999), edited by CIGR— The International Commission of Agricultural Engineering; Published by ASAE—American Society of Agricultural Engineers, Five-Volume Series on CD-ROM, St. Joseph, Michigan.

Hartmann H. and Strehler A. (1995). Die Stellung der Biomasse im Vergleich zu anderen erneuerbaren Energieträgern aus ökologischer, ökonomischer und technischer Sicht. *Schriftenreihe "Nachwachsende Rohstoffe" der Fachagentur für Nachwachsende Rohstoffe* (ed.), Bd. 3, Landwirtschaftsverlag Münster-Hiltrup, 397 pp. [The status of biomass compared with other renewable sources of energy from an ecological, economic and technical view.]

Herrmann A. (1999). *Modellierung verfahrenstechnischer Bewertungskriterien bei unterschiedlicher Verknüpfung von Ernte- und Transportarbeitsgängen*, 167 pp. Habilitationsschrift, Martin-Luther-Universität Halle-Wittenberg. Forschungsbericht Agrartechnik 335 der Max-Eyth-Gesellschaft Agrartechnik im VDI. [Modeling of process engineering rating criteria in different situations of harvest and transport processes.]

Matthies H. J. (1991). Die Compactrollenpresse, *Landtechnik*, **46**(5), 225–229 [The "Compact roll baler."]

Proceedings of the International CIGR-Workshop on Agricultural Transport, October 4–6, 1999, University Giessen, Germany, 333 pp., ed. by G. Weise.

Biographical Sketches

Jürgen Hahn was born December the 9th 1943 at Schönlage. Enrolment at Technical Faculty at the University Rostock; 1966: Diploma on Agricultural Engineering at the University Rostock; 1966–78: Head of the Department for Transportation and Conveying at the Central Testing Board for Agricultural Engineering at Potsdam-Bornim; 1978–85: Academic Chief Assistant at the Department of Technology, Section Crop Siences, Humboldt-University Berlin; 1981: Doctorate to “Dr. agr.” on the field “Technology in Crop Production”, Humboldt-University Berlin; 1985: University lecturing qualification (PhD) and call as university lecturer at the Humboldt-University Berlin for the field of “Technology in Crop Production”; 1988: Call as professor on a special contract for the field “Technology in Crop Production,” Humboldt-University Berlin; 1991–93: Head of the Institute of Agricultural Engineering at Humboldt-University Berlin; since 1993: Full Professor for “Basics in Agricultural Engineering/Process Engineering in Crop Production”, Faculty of Agriculture and Horticulture at Humboldt-University Berlin

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