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The Fifth International Symposium on Agricultural Engineering

ISAE 2021

Belgrade, Serbia

30.September - 2.October 2021

The Fifth International Symposium on
Agricultural Engineering
ISAE-2021

30th September-2nd October 2021, Belgrade – Zemun, SERBIA
http://www.isae.agrif.bg.ac.rs

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Support:
– Association for Medicinal and Aromatic Plants of Southeast European Countries – AMAPSEEC
– Balkan Environmental Association – BENA
– Research Network on Resource Economics and Bioeconomy Association – RebResNet

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Acknowledgements:	This publication is published with the financial support of the Ministry of Education, Science and Technological Development, Republic of Serbia
Published by:	University of Belgrade, Faculty of Agriculture, The Institute for Agricultural Engineering, Nemanjina 6, 11080 Belgrade, Serbia
Editors:	Prof. Dr. Aleksandra Dimitrijević Prof. Dr. Ivan Zlatanović
Technical editor:	Msc. Mitar Davidović
Printed by:	University of Belgrade, Faculty of Agriculture, Beograd
Published:	2021
Circulation:	100 copies

ISBN 978-86-7834-386-5

CIP - Каталогизација у публикацији
Народна библиотека Србије, Београд

631.3(082)(0.034.2)
631.17(082)(0.034.2)

INTERNATIONAL Symposium on Agricultural Engineering (5 ; 2021 ; Beograd)
Proceedings [Elektronski izvor] / The Fifth International Symposium on Agricultural Engineering ISAE-2021, 30. September-2. October 2021, Belgrade, SERBIA ; [organizer] University of Belgrade, Faculty of Agriculture, The Institute for Agricurtural Engineering, Belgrade, Serbia ; co-organizers University of Basilicata, School for Agricultural, Forestry, food and Environmental Sciences, Potenza, Italy ... [etc.] ; [editors Aleksandra Dimitrijević, Ivan Zlatanović]. - Belgrade : University, Faculty of Agriculture, The Institute for Agricurtural Engineering, 2021 (Beograd : University, Faculty of Agriculture). - 1 elektronski optički disk (CD-ROM) ; 12 cm

Sistemski zahtevi: Nisu navedeni. - Nasl. sa naslovne strane dokumenta. - Tiraž 100. - Bibliografija uz svaki rad.

ISBN 978-86-7834-386-5

а) Пољопривредне машине -- Зборници б) Пољопривреда -- Механизација -- Зборници

COBISS.SR-ID 51949065

REDUCTION OF PLANT WEIGHT LOSS IN THE PROCESS OF HAY BALING USING WATER STEAM

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Abstract: *Hay is a bulky part of the meal that is most often used in the winter period of the year in all types of ruminants, while the role of hay in the meal of high-milk cows is invaluable. The most common way to produce hay is to dry the cut grass on the surface of the land in the field, using the energy of the sun. In the process of hay production, there is a reduction of nutrients in relation to the green mass, where the achieved yield and quality of hay largely depends on the technological operations that are performed during storage. In the baling process, the dried mass is exposed to the mechanical treatment of the working elements of the press, as a result of which the leaf mass decreases. Loss of leaf mass, which contains a large amount of nutrients, can greatly affect the achieved yield and quality of the obtained hay. One of the possibilities to reduce losses is the application of "DewPoint" technology, which involves the use of water vapor in the baling process. The steam produced by the device is injected into the mass-hay after lifting by the pickup device and further until the mass enters the pressing chamber. Mass treatment is achieved by injecting steam through a series of nozzles located inside the press. Water vapor is an extremely efficient medium for the controlled hydration of hay during the baling process, where approximately 450 l of water vapor can be produced from 1 l of water. By applying this technology, water consumption is 5-7 l per 1 t of hay, producing 2250-3150 l of water vapor. This amount of steam enables efficient treatment of individual plants (tree, leaf) in a mass of 1t to the desired humidity level.*

Keywords: *: hay quality, baling, losses, water vapor, hydration*.

1 INTRODUCTION

In the total livestock production, special importance is given to the production of so-called bulky fodder (green mass, hay, haylage - silage, by-products of industrial food processing, etc.). Adequate amount of quality bulk fodder is one of the important factors that greatly affect the stability and productivity of modern livestock production [15,17,5]. Quality hay is an almost irreplaceable bulky food in the winter for all types of ruminants as well as horses [33,30]. The nutritional value of the plant mass depends on the type of plants and the phenophase in which the plant is at the time of harvest, while the yield and quality of the obtained hay largely depends on the process during hay storage and applied agrotechnical measures [8,4,1,31] .

In the process of preparing hay, the main goal is to preserve as tender parts of the plant as possible, such as leaves, flower buds. The reason for this is certainly the content of nutrients that are most abundant in these parts [32,3]. Alfalfa hay contains about 70% protein and about 90% carotene in the leaves, which fall off very easily in the dry state [33,12]. In the process of hay production, the most critical phase is in the period when the moisture content of the plant mass falls below 40%, after which there is a loss of mass with falling leaves, and thus a decrease in nutritional value [29,27,14,6].

Hay in a loose state is difficult to transport and store with the inevitable occurrence of losses. At the same time, hay has a small bulk density, so the utilization coefficient of means of transport is quite low with a simultaneous increase in transport costs. It should also be emphasized that the procedure of hay manipulation is significantly more difficult. In order to overcome these shortcomings, the process of hay production involves the implementation of agro-technical measures of baling, which increases the bulk density of hay and significantly facilitates manipulation procedures [16,17,7].

The process of hay production implies the application of different types of machines with the aim of performing the necessary technological operations (mowing, kneading, conditioning, collecting, pressing, transport) in the shortest possible time [2,20,32,9]. The technological phase of hay baling is an operation in which the possibility of losses is greatest. At the moment of baling, the moisture content within the mowed mass is 18–20% [15,28]. With such a moisture content, individual plants within the mowed mass become very brittle, and leaves and flowers can easily fall off [18]. The baling process implies lifting the mass from the surface of the soil using a pick-up device whereby the metal fingers capture the dried mass which is further transported to the chamber in which the pressing is performed. Due to the mechanical treatment during the capture of the mass, there is a drop of leaves that end on the surface of the plot, which creates direct losses [17,19,21].

Reduction of losses in the baling process can be performed by returning a certain percentage of moisture to the dried mass, which reduces the possibility of leaf and flower loss [22,19]. In practice, this meant that the baling procedure was performed in the early morning hours when we had the appearance of "perfect natural dew" on the plot. However, in real production conditions, perfect natural dew for specific localities (plots) occurs rarely, lasts for a very short time or is completely absent. Hay producers in arid climates usually do not have enough moisture due to dew for optimal wetting of hay, while in humid climates this moisture content is often higher than optimal [19,24,11].

One of the possibilities for reducing plant mass losses in the hay baling process is the application of the "DewPoint Hay Steamer" dew simulation system [22,23,24,10]. The application of this system involves the controlled addition of water vapor (rehydration) to the dried material during the baling process [26,28]. The main purpose of adding water vapor is to increase the moisture in dry hay in order to prevent mechanical damage to the hay during the baling process. The application of this system enables the baling procedure to be performed throughout the day, regardless of the appearance of dew and with minimal losses [26,21].

2. THE ROLE OF THE "DEWPOINT" SYSTEM FOR STEAM PRODUCTION

The application of "DewPoint" technology involves the rehydration of dried plant material (hay) by applying water vapor during the hay bale process. Water vapor is an extremely effective medium for moistening the material and controlled hydration of hay. Hay treatment means that water vapor is injected into the material from the moment the mass separates from the soil surface, ie. from the moment the mass is captured by the pick-up device until the mass enters the pressing chamber. Water vapor is injected into the material through a number of special injectors that are additionally installed in the pick-up device of the press which bales the hay. During the rehydration process, the current moisture of the hay is continuously monitored and the injection rate and the amount of water vapor are adjusted depending on the current values of the material moisture. In this way, it is possible to maintain optimal humidity values of the material to be baled at all times. The production of a sufficient amount of water vapor necessary for the controlled hydration of hay on the plot itself is ensured by adding a dedicated device for the production of water vapor [26].

The device for the production of water vapor is in the form of a towed attachment machine which is added to the standard tractor-press unit. The device is aggregated for the tractor from the rear over the drawbar and placed between the tractor and the press Fig.1.

Figure 1. Position of water vapor production device between tractor and press

Figure 2. Appearance of the device pulley and PTO shaft connection

The construction of the device enables the aggregation of presses of different types, manufacturers and constructions from its rear side (Fig. 2), which achieves the universality of the application of this device. Along the device, from the front to the rear end, there is a through cardan shaft at the ends of which there are standard connections. By placing the PTO shafts between the tractor and the device and the device and the press, the torque is transferred from the tractor to the press. In this way, the operation of the press elements during the baling procedure is enabled [23].

3. CONSTRUCTION OF "DEWPOINT" SYSTEM FOR STEAM PRODUCTION

The device for production of water vapor, which is applied together with the process of baling hay, consists of support wheels and frame construction on which different types of mechanical, electrical and electronic components of the system are housed as one unit. Shown in Figure 3 [23].

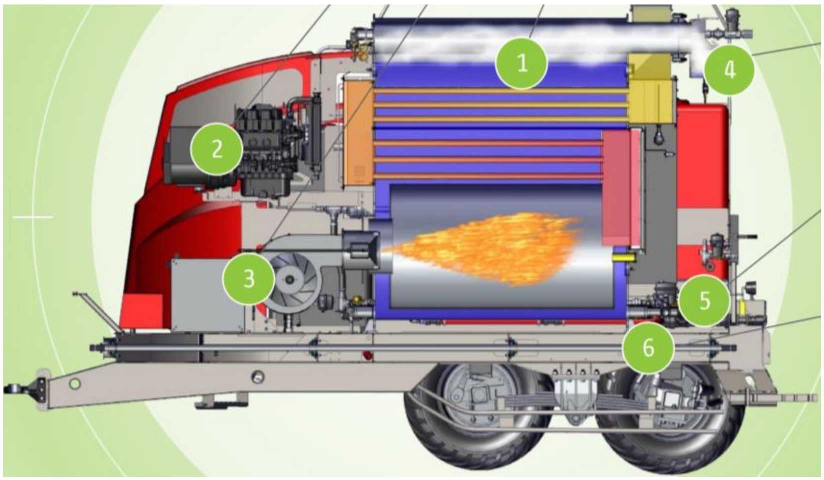

Figure 3. Scheme of a device for the production of water vapor: 1- Boiler :, 2- Generator, 3- Burner, 4- Steam valves, 5- Feed water system, 6- PTO Shaft, 7 - Tires, 8 - Fuel Tanks, 9 - Water Tanks [26]

The basis of the device for steam production is the boiler (fig. 3 position 1). The boiler is designed and adjusted so that it enables maximum efficiency of heat utilization at low pressure. Exhaust gases that occur as a product of burner combustion are directed towards the steel pipes through which the water moves. The flow of combustion products over the surface of the pipe heats the water. The water is heated up to the temperature when the physical state changes from liquid to gaseous, as a result of which the water turns into steam.

Generator (fig. 3, position 2), is an electrical device that converts the mechanical energy into electrical energy that is used to power all the electrical components of the machine. The generator is powered by a separate internal combustion diesel engine.

The burner (fig. 3, position 3) represents a heat source that leads to heating of water and transition to water vapor. The most commonly used burner is diesel fuel burner. In this type of burner the combustion of a mixture of diesel fuel and air is performed in a special chamber, which releases heat, which is then used to heat water.

Steam valves (fig. 3, position 4) are located on the lines located at the outlet of the boiler from where the steam is further delivered to the pick-up device. Solenoid valves are connected by electrical lines to the control unit located in the tractor cab. The action of the valve controls the flow and selects the position of application of water vapor produced in the boiler.

The water supply system (fig.. 3, position 5) allows a constant water pressure inside the boiler system. With the production of water vapor and its application in the process of hay rehydration, a part of the liquid (water) inside the heating system (boiler) is consumed and disappears. Continuous production of water vapor in the system requires the addition of a certain amount of new liquid in order to keep the set pressure inside the system constant.

Cardan shaft (fig. 3, position 6) is placed along the device for the production of water vapor. At the ends are standard PTO shaft connections. The task was to transfer the torque from the tractor to the press, which enabled the drive of the working elements of press and the baling procedure.

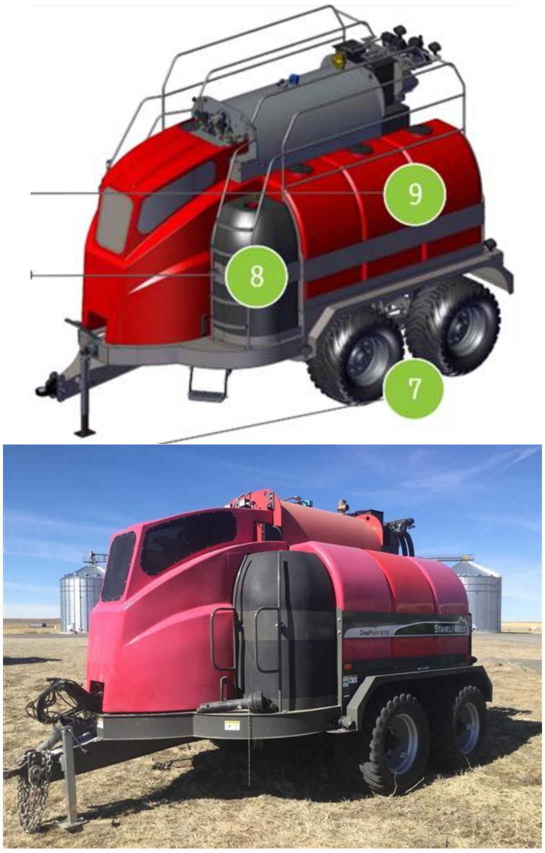

Figure 4. Water vapor production device: 7 - Transport system; 8 - Diesel fuel tank; 9 - Water tanks [26]

Considering that the device for the production of water vapor is in the form of a towed tractor attachment, the role of the transport system in figure 4, position 7, allows the device to move during operation. A system of double axles was applied in combination with specially designed radial flotation tires, which reduced plant damage and soil compaction. On the front of the device is a tank (fig. 4, position 8) for diesel fuel which is necessary for burner operation and water heating. Consumption of diesel fuel in average operating conditions is 1.9 l per ton of baled hay. The water used as a medium for the production of water vapor is placed in a separate tank (fig. 4, position 9). Depending on the crop yield, the amount of steam produced and the specific conditions in the field, the operator can bale between 0.8-1.2 ha with a water consumption of 3600 l [23].

Inside the tractor cab, there is a control unit that is connected to the electronic components of the device via electrical lines. The control unit enables continuous monitoring of operating parameters as well as control of system operation. The system of management and control of operating parameters is based on PLC technology [25].

Figure 5. Control unit installed in the tractor cab

The screen of the control unit is touch-sensitive, which allows the operator complete control and adjustment of operating parameters during operation. A large number of operating parameters can be monitored on the screen of the control unit at the same time, which simplifies the control of the entire process.

4. WATER VAPOR DISTRIBUTION IN THE HAY REHYDRATION PROCESS

The steam treatment of the material is performed from the moment of capture and lifting of the mass by the pick-up device until the mass enters the pressing chamber. Within the pick-up device of the press, it is necessary to make a modification, adding dividers through which water vapor is injected into the material, etc. 6. Water vapor obtained by heating water in the boiler of the device is transmitted by elastic lines (fig. 2) to the distributor in the press where further distribution performed. There is a valve on each of the steam lines. The main task of the valve is the continuous regulation of the amount of water vapor that is delivered to the individual distributors during operation. With the command from the tractor cab, the operator controls the operation of the valve by adjusting the amount of water vapor that passes through each of the distributors. The operation of each of the valves is independent, which enables the adjustment of the amount and zone of action of water vapor on the material in specific operating conditions [26].

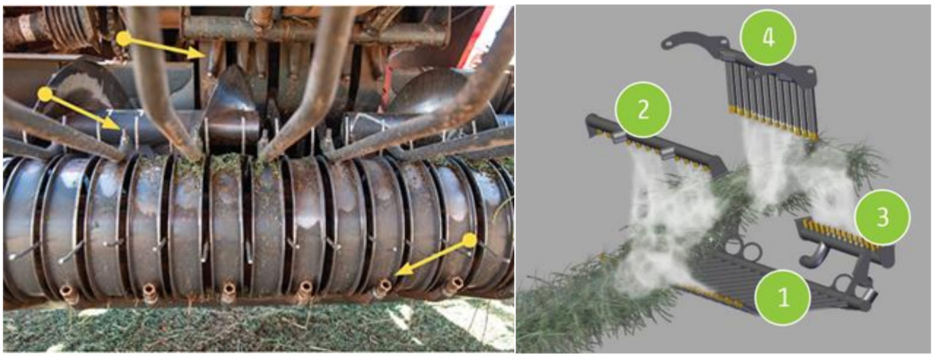

Figure 6. Position of the water vapor distributors [26].

In order to improve the quality of work of the device for rehydration of hay and adaptation to specific conditions, which may differ from plot to plot, a device for measuring moisture can be added to the existing system (fig. 7). The basic function of this device is to continuously monitor the moisture content of the material during the baling process and to provide additional information to the operator. In this way, it is possible for the operator to adjust the speed and amount of water vapor injection during operation in order to maintain optimal moisture conditions in the material at all times.

Figure 7. "Gazeeka" Device for measuring the humidity of the material installed on the press [34].

The non-contact device for measuring the humidity of the manufacturer "Gazeek" is installed at the outlet of the chamber in which the hay is compacted and the bale is formed. The device consists of transmitters and receivers that are installed on opposite sides of the chamber. The transmitter generates and sends a beam of microwave energy through the formed bale to the receiver of the device. Microwaves are sent through the bale 50 times per second. The water molecules in the hay slow down the speed of microwaves and absorb some of the energy sent. The receiver on the opposite side collects microwave energy that the bale has not absorbed. This information is compared with the amount of energy that is emitted. Based on the obtained information on the transfer rate and the absorbed amount of energy, the device determines the value of the moisture content of the material with an accuracy of 0.5% [34].

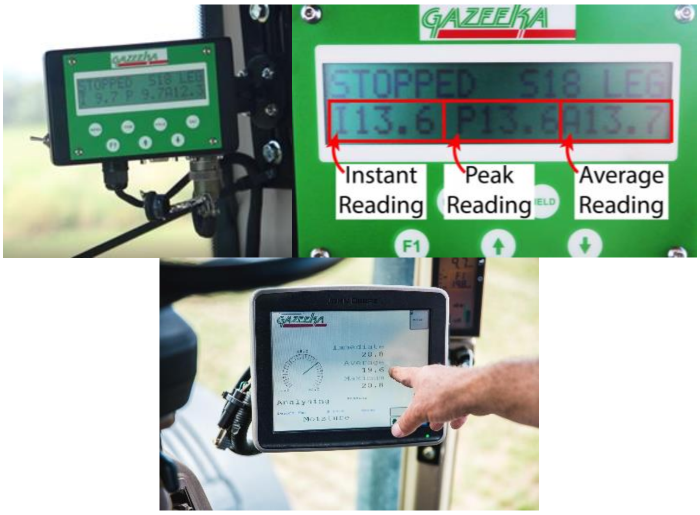

Figure 8. Gazeeka device display [34].

An additional display of the "Gazeek" device is placed inside the tractor cab, on which the value of the humidity of the material passing through the press can be read at any time. The device displays values that are read at 5 second intervals. In addition to the read current value, the device has the ability to simultaneously display the maximum and average values of moisture read in the material to be pressed (fig. 8). The humidity of the bale is continuously monitored and based on the read values. Operator is given the opportunity to precisely adjust the operating parameters of the device for rehydration of hay and maintain optimal humidity. In addition to the visual display of values, the device has the possibility of an audible warning if the humidity value is above or below the set value [34].

5. CONCLUSION

For decades, hay producers have been facing the problem of large losses of plant mass, especially leaves in the process of baling hay. Returning a small amount of water to the dried mass can greatly reduce losses. Some producers perform the baling process until the mass is completely dry (humidity above 20%), while other baling procedures are performed in the early morning hours when there is dew in the field. Baling a mass with a higher water content is risky, while the appearance of dew in nature is often absent during the summer. One of the possibilities for reducing losses is the application of "DevPoint" technology, which involves the use of water vapor in the process of baling hay. The application of this technology allows producers to bale hay at any part of the day whenever the mass is dry enough, without having to wait for the appearance of natural dew. Studies have shown that controlled steam application in the baling process can reduce leaf loss by 58% compared to baling performed when the hay moisture content is below 18%. By reducing leaf losses, the achieved yield and the quality of the obtained mass are greatly affected.

Acknowledgement: *The work is granted by the Ministry of Education, Science and Technological Development of the Republic of Serbia - project number TR 31051: "Improvement of biological processes in the function of rational use of energy, increase of productivity and quality of agricultural products", within the framework of the contract for the realization and financing of scientific research work in 2021 between the Faculty of Agriculture in Belgrade and the Ministry, contract registration number: 451-03-9/2021-14/200116. Present study has not received any additional specific grant from funding agencies in the public, commercial, or not-for-profit sectors.*

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