RESEARCH REPORT

Comparative analysis of alfalfa hay variable chamber round baler efficiency

Abstract: The efficiency of a variable chamber round baler is evaluated by its output numbers - that is in tons of baled hay per unit of time. In case of intensive bailing the output rate of a baler is a more significant performance parameter than the cost of the machine. A slight difference in output can either produce a significant cost reduction or drive the cost over the target sale price. Unfortunately, the machinery manufacturers are not able to provide data about the output rates (tons/hour) of their balers due to differences in kinds of grass, moisture level and vegetation stages of grass during baling.

Introduction: Farmers do not have any methods to estimate the efficiency of a variable chamber round baler when they see it at an agricultural show or in showrooms. The efficiency of a certain baler is directly linked to the economy of a farm which is using this or that machine. "ALFA-FEEDS" LLC is a pure forage producer and a marginal saving on a single operation can generate a large scale profit. It is essential to evaluate where in the production process the hay producer can cut his costs. In field dried alfalfa hay production, baling manipulations must be completed within the shortest time possible due to the rain damage threat which may result in significant losses. For "ALFA-FEEDS" LLS farm (Alexin district of Tula region in Russia) rain damage is the main reason for hay loss.

Hay production process is made up of the following technological steps:

1. Mowing (1-2 days after the latest rain, tractors should not damage field surface with wheels);
2. Tedding (2-4 hours after mowing, surface moisture must evaporate from mowed alfalfa to minimize dust attraction from tractor wheels and tedder);
3. Raking (3-6 days after mowing, depending on weather conditions);
4. Baling (mostly immediately after raking, but could be 1-2 days later);
5. Picking up bales, transporting them to storage, stacking on pallets, covering with haystack blanket, fixing haystack blanket with fixation screws.

During alfalfa hay production, if a light rain (but not a heavy rain) sprays over the already mowed and tedded alfalfa – it will only slightly reduce the quality of the hay. Surface moisture evaporates quickly enough so no bacteria or fungus has enough time and moisture to damage the product.

Similarly, in case the hay is already baled, but not picked up from the field, light to mild rain would not dramatically damage it. Rain water does not penetrate deep into the bale as well as many raindrops slide down from tight round sides. Bales do not get moisture from the soil either since they were formed after a long dry period. After 1-3 days the hay is perfectly dry again, sometimes even less damp than during baling due to days of exposure to the sun and wind.

If alfalfa is already raked and then gets under even a mild rain, almost certainly the hay will be dramatically damaged. There is an option of tedding the wet windrows, but it is only possible after the field gets moderately dry (not to damage the soil/stand) so it takes at least 24 hours after the rain to start the tedding. In any case the farmer faces dramatic decrease of hay quality or even a complete loss due to fungus and mold damage. Sometimes such hay is not usable even for bedding (due to plenty of fungus spores and dust).

It is important to keep in mind that raked hay, when it gets fatally rain damaged, does not disappear from the field by itself, it should be taken away, or it will be collected with the next cut (with all its fungus and mold) and will seriously damage the stand. So to avoid it, the 'bad' hay must be dried, baled and thrown away. And all these operations take up the time while good hay could be baled and collected.

If a farmer does not have enough machinery capacity to bale hay within the shortest time possible, rain damage not only cuts down a possible income (yield) but adds operational costs that convert into a pure loss.

In this case a baler with the highest possible functional output is the only reasonable choice for a farmer who wants to produce a high quality product and not face significant loss in the process of hay production.

TASC of Testing and Research:

To determine the most efficient round bale press with variable chamber for alfalfa hay baling.

Efficiency parameters:

Hay baler efficiency is calculated on the basis of its output and cost parameters (baler itself and its use).

Primary performance indicators include:
- time required to produce one bale of hay (cycle = pressing time + drop off time);
- mass of hay bale of specific diameter (bale density);
- baler output in tons of hay per hour (combined parameter);
- price of the baler (price according to the dealer's price list).

Testing conditions:

The testing was carried out on August 21, 2020 in Aleksinsky district of the Tula region (Russian Federation) on a field of Artemis alfalfa (BARENBRUG seeding - May 2017). Third cut yield estimated approximately 2.5 tons of hay per hectare with an average moisture content of 15% to 18%. The Alfalfa vegetation phase was in the beginning of bloom. Its height was at 40 to 50 cm. The mowing height stood at 12 to 14 cm from the surface of the field. The swath was formed with CLAAS LINER 3100 swather with a working width of 9 m. The yield of hay in the specified swath was about 2.25 kg per meter of the swath.

The following four balers got into the testing:
- McHale V6740 (price = 54.904 Euro);
- CLAAS VARIANT 450 (price = 37.500 Euro);
- John Deere V461M (price = 53.500 Euro);
- KRONE Comprima F125 (price = 53.500 Euro), the baler tested outside of the set, because it has a fixed belt-and-slat bale chamber.

All balers were coupled with a Massey Ferguson 6713 tractor with a maximum power of 132 hp. The Massey Ferguson 6713 tractor with relatively low power was chosen on purpose, to keep the total cost of a tractor + baler under 120.000 Euro.

METHODOLOGY.

Method for determining average minimum pressing time of one bale:

The hay baling cycle consists of two phases:

- "start-stop" - from the start of pressing to stopping the machine (the cycle includes picking up the hay from the swath and pressing/forming a bale of maximum density for a given diameter);

- "stop-start" - from stopping the press to a new start of the next pressing cycle (wrapping the bale with net, opening the press chamber, dropping off the bale, closing the chamber).

During the testing all balers produced at least 10 bales of a given diameter (125 cm and 150 cm). Each pressing cycle was measured with a stopwatch and the data was recorded into a journal.

To establish the average minimum bale pressing time in the start-stop phase we chose not to take into account:

- the first cycle (as it is the longest);
- cycles with u-turns or any turning maneuvers;
- the shortest cycle;
- the longest cycle.

Only cycles of straight sections of the windrow were taken into account; the average time was calculated by summing up all relevant cycles and dividing the result by the number of the cycles taken into account.

To establish the average minimum bale pressing time in the stop-start phase we did not take into account the first cycle, the last cycle, the shortest and the longest cycles. The rest of the cycles were summed up and divided by the number of the cycles to calculate the average cycle time.

Method for determining average bale weight:

Each bale, after it was dropped off from the baler, was marked with paint of a corresponding color. The assigned colors were:

- McHale V6740 - orange;
- CLAAS VARIANT 450 - blue;
- John Deere V461M - red;
- KRONE Comprima F125 - purple.

After baling, the hay got loaded onto RMZ-11 bale trailers and transported to the storage area.

Each bale was unloaded from the bale trailer with a telescopic loader CLAAS Scorpion 7044 and a McHale R5 bale handler. Each hay bale was then placed onto the platform scales SKALE 2SKP-1515 with a weighing capacity of up to 2000 kg and +/- 0.5 kg accuracy. The weight of each bale was recorded into the journal according to the color of its marking.

To calculate the average weight of a hay bale of a given diameter produced by a particular baler, the mass of all bales in the category got summed up and divided by the number of bales counted.

Method for determining average density of hay bales (kilograms of hay per cubic meter of a bale of a given diameter).

Bale density kg/m3 was determined by the formula = average bale mass / $((\pi * D^2)/4) * H$, where:

- π - number Pi (the ratio of a circle's circumference to its diameter);
- D - bale diameter (set by the press setting 1.25 or 1.5 meters);
- H - bale height (the distance between the flat sides of the bale, the standard is 1.2 m).

Method for calculating the theoretical maximum output of a baler in TONS of hay for a given bale diameter under test conditions:

With continuous hourly operation at the theoretical maximum speed under experimental conditions, it is possible to determine the productivity of the baler in tons per hour.

The output of a baler in tons per hour can be calculated by the formula = ((60sec * 60min) / (cycle time "Start-Stop" + "Stop-Start" sec)) * (average weight of one bale of a given diameter/1000kg).

<u>RESULTS of TESTING for 125 diameter bales.</u>

Minimum time needed to press one bale of hay of 125 cm diameter.

McHale V6740 baler is the leader in this category with an average start-stop cycle time of 30.51 seconds, an average stop-start cycle time of 18.9 seconds and an overall average time to produce one bale with a diameter of 125 cm - **49.41 seconds.**

Second place goes to **John Deere V461M** with an average start-stop cycle time of 26.17 seconds, an average stop-start cycle time of 23.5 seconds and a total average time spent on production of one bale with a diameter of 125 cm - **49.67 seconds.**

Third place belongs to **KRONE Comprima F125** with an average start-stop cycle time of 23.87 seconds, an average stop-start cycle time of 26.93 seconds and a total average time to produce one bale with a diameter of 125 cm - **50.8 seconds.**

In fourth place is **CLAAS VARIANT 450** with an average start-stop cycle time of 25.97 seconds, an average stop-start cycle time of 25.23 seconds and an overall average time to produce one bale of 125 cm diameter - **51.2 seconds.**

Average weight of a hay bale of 125 cm diameter.

The leader in this category is **McHale V6740** which produced 13 bales of hay weighing respectively: 281, 281, 287, 289, 298, 300, 305, 308, 310, 310, 311, 312, 348 kg. Thus, the average weight of a hay bale was **303 kg**. Maximum deviation of bale mass from the average was -22 kg (or -7.3%) and +45 kg (or +14.8%).

In second place is the **John Deere V461M** that produced 11 hay bales weighing respectively 263, 268, 272, 274, 274, 277, 278, 280, 280, 281, 287 kg. The average hay bale weight was **276 kg**. Maximum deviation of bale mass from the average was -13 kg (or -4.6%) and +11 kg (or +4.1%).

In third place is the **KRONE Comprima F125** with its 27 hay bales weighing respectively 234, 237, 239, 241, 241, 241, 242, 243, 245, 248, 248, 249, 249, 252, 254, 254, 255, 257, 258, 259, 262, 271, 272, 273, 274, 275, 306 kg. The average weight of a hay bale was **255 kg**. Maximum deviation of bale mass from the average was -21 kg (or -8.2%) and +51 kg (or +20.1%).

In fourth place is the **CLAAS VARIANT 450** baler which produced 18 bales of hay weighing respectively 219, 219, 231, 232, 232, 233, 234, 234, 235, 235, 239, 246, 248, 252, 259, 269, 270 kg. The average weight of a hay bale was **242 kg**. Maximum deviation of bale mass from the average was -23 kg (or -9.4%) and +28 kg (or +11.7%).

Average density of hay in a bale of 125 cm diameter.
The leader in this category is **McHale V6740** with bale density of **206 kg/m^3**;
In second place is **John Deere V461M** with bale density of **187 kg/m^3**;
In third place is **KRONE Comprima F125** with bale density of **173 kg/m^3**;
In fourth place is **CLAAS VARIANT 450** with bale density of **164 kg/m^3**.

Balers' output in tons per hour with a bale diameter of 125 cm.
The leader in this category is **McHale V6740** with output of **22.08 tons per hour**.
In second place is **John Deere V461M** with output of **19.99 tons per hour**.
In third place is **KRONE Comprima F125** with output of **18.06 tons per hour**.
In fourth place is **CLAAS VARIANT 450** with output of **17 tons per hour**.

RESULTS of TESTING for 150 diameter bales.

Minimum amount of time needed to produce one 150 cm hay bale.

McHale V6740 is the leader in this category with an average start-stop cycle time of 34.73 seconds, an average stop-start cycle time of 22.85 seconds and a total average production time for one 150 cm diameter hay bale **- 57.58 seconds.**

In second place is the **CLAAS VARIANT 450** baler with an average start-stop cycle time of 34.23 seconds, an average stop-start cycle time of 23.42 seconds and a total average time to produce one 150 cm bale - **57.65 seconds.**

In third place is the **John Deere V461M** baler with an average start-stop time of 40.8 seconds, an average stop-start cycle time of 25.17 seconds and a total average cycle time needed for one 150 cm hay bale - **65.97 seconds.**

Average weight of a 150 cm hay bale.

In this category **McHale V6740** baler is the leader, having produced 16 bales of hay weighing respectively 396, 396, 398, 404, 405, 409, 410, 411, 413, 413, 418, 421, 424, 431, 437 kg. Average hay bale weight was **412 kg**. Maximum deviation of the bale mass from the average was -16 kg (or -3.9%) and +41 kg (or +5.6%).

Second place went to **John Deere V461M** baler with 11 bales of hay weighing respectively 386, 390, 396, 405, 407, 407, 409, 413, 414, 426, 428 kg. Average hay bale weight was **407 kg**. Maximum deviation of the bale mass from the average was -21 kg (or -5.2%) and +42 kg (or +10.3%).

Third place belongs to **CLAAS VARIANT 450** baler with 11 hay bales weighing respectively 276, 281, 282, 284, 284, 285, 287, 288, 289, 289, 297 kg. Average hay bale weight was **286 kg**. Maximum deviation of the bale mass from the average was -10 kg (or -3.4%) and +11 kg (or +4%).

Average hay density in 150 cm bales.

The leader in this category is **McHale V6740** with bale density of **194 kg/m^3** (-5.61% compared to 125 cm bale).

Second place goes to **John Deere V461M** with bale density of **192 kg/m^3** (+ 2.56% compared to 125 cm bale).

In third place is **CLAAS VARIANT 450** with bale density of **135 kg/m^3** (-17.94% compared to 125 cm bale).

Output in tons per hour for 150 cm bales.

The leader in this category is **McHale V6740** with output of **25.76 tons per hour**.

Second place goes to **John Deere V461M** with output of **22.23 tons per hour**.

Third comes **CLAAS VARIANT 450** with output of **17.84 tons per hour**.

SUMMING UP

In the conducted testing **McHale V6740** baler proved to be the winner in all categories.

John Deere V461M took second place with very impressive results in terms of maximum output. However, its output in tons per hour is **9.47%** less than that of McHale when it comes to 125 cm bales and **13.68%** less for 150 cm bales. When we compare the purchase price of the two machines, John Deere is only 2.56% less expensive than McHale.

Third place in the category of 125 cm hay bales goes to **KRONE Comprima F125**, with an output of **18.23%** tons per hour less than the leader. The price difference between a KRONE and a McHale is the same as with a John Deere press - 2.56%.

Last place is taken by **CLAAS VARIANT 450** with the worst performance in comparison with the leader - **23.02%** less tons of 125 cm hay bales and **30.74%** less tons of 150 cm hay bales. CLAAS baler price is 31,7% less than that of the McHale machine, which all in all corresponds to its extremely poor performance.

It is extremely important to understand that the key parameter that reflects the economic efficiency of a baler is its output measured in tons of baled hay per hour. Highest density bale needs the same amount of effort from the farmer as the lowest density bale, while spreading the cost of picking up, transporting, unloading, stacking, covering, etc. on reduced hay mass.

Addition

During the experiment, the following additional observations have been made (which cannot be numerically calculated):

- **McHale V6740** baler had the least apparent dust trail from the loss of alfalfa leaves during baling (the difference with other balers not possible to estimate in numbers) as well as it effectively picked up hay from the windrow even at speeds up to 14.5 km/h. The single-belt compression chamber clearly had less leaf spillage than competitors with 5-6 belts. The thickness of all metal parts, the body and the frame, of the McHale baler significantly exceeds that of the competitors', the press is heavier and made with a larger safety margin;

- **John Deere V461M** baler missed hay from the windrow when it was working at high speed (flaws), most likely due to the incorrect setting of the pick-up device. After reducing the gap between the pick-up device and the surface of the field, as well as slowing down the pulling tractor, hay picking got normalized. John Deere dealer's representatives ("Ekoniva-Tekhnika" LLC) assured that John Deere produces a more "advanced" picking device for this baler, which is an option for an extra cost. John Deere baler has an extensive system of thick oil flow supply to the bearings of the majority of rotating parts of the machine and a solid motor chain similar to one in McHale baler, although the sheet metal of the frame is considerably thinner than that of McHale;

- **KRONE Comprima F125** baler with a belt-and-slat pressing chamber left the most noticeable dusting trail (the loss of alfalfa leaves after picking and baling). In addition to the ground dust, a big cloud of green dust was constantly blown from the top of the press (over the open part of the chamber). There were also problems with getting bales of hay into the net wraps properly (the wrapping was performed with a shift so part of the bale was not wrapped). All efforts to fix the wrapping performance failed. This machine must only be suitable for baling grass hay, and not alfalfa hay;

- **CLAAS VARIANT 450** baler had severe flaws in picking up hay mass from the swath, dusting trail was similar to that of the John Deere V461M baler.

CONCLUSION

McHale V6740 variable chamber baling press has the highest output rate among all balers tested during the experiment. For a farmer who is focused on high output production, McHale baler would be the best choice, and in comparison with it even the good John Deere V461M machine shows a significant lack of performance.

John Deere V461M showed impressive results and looked well-built overall.

KRONE Comprima F125 is not appropriate for alfalfa hay baling but could be suitable for grass hay production. This particular machine seems to be heavily overpriced and a bit weak for a serious job.

CLAAS VARIANT 450 baler is a weak and cheap baler suitable only for farmers who produce 500 to 1000 tons of hay per year.

It is essential to make an economic modelling of alfalfa hay production from baling to hay stacking to get a clear picture of each baler performance, since differences in % do not reflect overall efficiency clearly enough.

Trials, calculations and modelling undertaken by
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Economic efficiency analysis of variable chamber round balers from different suppliers for baling alfalfa hay.

To determine the actual cost-effectiveness of using a particular baler, it is worth considering its operation within the framework of real field conditions and a specific task.

The most important indicator of efficiency of a baler is its output measured in tons of products per unit of time.

As a result of testing, carried out on August 21, 2020 over McHale V6740, John Deere V461M, KRONE Comprima F125, CLAAS VARIANT 450 balers, McHale baler showed maximum output rate, higher than:

- John Deere for 125 cm bales by 9.47% and for bales with 150 cm diameter - by 13.68%;
- KRONE for bales with 125 cm diameter - by 18.23%;
- CLAAS for 125 cm bales by 23.74% and for 150 cm bales by 30.74%.

Due to the fact that the percentage numbers obtained as the result of the experiment are not very informative (or illustrative), it makes sense to make economic calculations for harvesting alfalfa hay for each of the tested balers separately.

The purpose of building a calculated economic model is to figure out the maximum amount of hay that can be harvested in a limited time, see the costs of hay production in case of each baler and to estimate the overall economic result when we use a certain set of hay harvesting equipment along with the specific baler.

Assumptions for calculating economic efficiency of baler performance:

1. The economic model has been calculated on the basis of a baler performance together with its servicing equipment from the moment of the start of pressing to the moment the hay is stored (costs of baler + tractor, two self-loading bale trailers with tractors and a telehandler); other operations (field cultivation, fertilization, sowing, mowing, tedding and raking) are not taken into account in this calculation since they do not have a direct impact on the economy of the process under consideration.

2. The costs are considered only within the technological cycle related to the baler - baling, picking up the bales, delivery to the storage site, offloading, stacking, covering of hay, as well as fuels and lubricants, repairs and spare parts, wages of workers within this cycle, machinery depreciation and downtime, etc.

3. The main limiting factor is the time. The actual time taken into consideration is the total number of hours of hay baling that was available to our company in the 2020 season - that is 245 hours.

4. The actual production field output rate for all balers has been set at 55% of the maximum theoretical output rate. This number was obtained empirically while exploiting the McHale V6740, CLAAS VARIANT 450, CLAAS Rollant 455 RC UNIWRAP balers. Production output rate (the number of bales per season divided by the hours of bailing per season) usually appear between 50% to 60% of the maximum theoretical speed (highest possible output on a straight windrow).

Output rate for hay bales of 125 cm in diameter - in tons per hour - 55% of the maximum.

- McHale V6740 with the capacity of 12.14 tons per hour.
- John Deere V461M with the capacity of 11 tons per hour.
- KRONE Comprima F125 with the capacity of 9.9 tons per hour.
- CLAAS VARIANT 450 with the capacity of 9.35 tons per hour.

Output rate for hay bales of 150 cm diameter - in tons per hour - 55% of the maximum.

- McHale V6740 with the capacity of 14.17 tons per hour.

- V461M with the capacity of 12.23 tons per hour.
- CLAAS VARIANT 450 with the capacity of 9.81 tons per hour.

McHale V6740			John Deere V461M			CLAAS VARIANT 450			KRONE Comprima F125	
Bale D. - 125 cm		Bale D - 150 cm	Bale D. - 125 cm		Bale D - 150 cm	Bale D. - 125 cm		Bale D - 150 cm	Bale Diameter - 125 cm	
Production output speed (55% output from maximum theoretical)										
Seconds per bale	89,84	104,69	Seconds per bale	90,31	119,94	Seconds per bale	93,09	104,81	Seconds per bale	92,36
Production output per hour (bales per hour or tons per hour)										
Bales	40,07	34,39	Bales	39,86	30,02	Bales	38,67	34,35	Bales	38,98
Tons	12,14	14,17	Tons	10,99	12,23	Tons	9,35	9,81	Tons	9,93
Output for the season (bales or tons of baled hay per season of 245 hours of bailing)										
Bales	9 817	8 425	Bales	9 766	7 354	Bales	9 475	8 415	Bales	9 549
Tons	2 974	3 471	Tons	2 694	2 996	Tons	2 290	2 404	Tons	2 433
Baler output comparison (leader - McHale VS followers)										
In comparison with McHale total decrease in output (%)			John Deere V461M	-9.5%	-13.7%	CLAAS VARIANT 450	-23%	-30.7%	KRONE Comprima F125	-18.2%
In comparison with McHale total decrease in output tons per hour				-1,15	-1,94		-2,8	-4,35		-2,21
In comparison with McHale total decrease in output tons per season				-280	-475		-684	-1067		-541

5. The data on the lifespan of a baler or the maximum number of bales it is capable of producing during its total life cycle has been collected from various sources (from manufacturers, dealers or farmers). The fundamental factor that signals that a baler cannot be used any more would be an irreparable deterioration or breakage of the frame (body), i.e. the main part of the machine, all other parts are considered replaceable. Thus, for example, the actual lifespan of the CLAAS Rollant 455 UNIWRAP RC balers with proper and timely maintenance in our company reached 61,000 and 66,000 bales, respectively. Although the machines can still be operated, we have defined the maximum lifespan of the CLAAS Rollant 455 UNIWRAP RC baler at 60,000 bales, since from 60,000 bales we spend more time on welding and repairing jobs rather than on the baling in the field. The difference in lifespan of the baler that produces 125 cm bales and 150 cm bales is considered insignificant.

For hay presses with a round variable bale chamber, we have established a following lifespan:

- McHale V6740 - 100,000 bales (according to a representative of McHale in the European Union, there have been several V6740 balers known to have produced more than 100,000 bales. They are still in active operation, and the owners do not plan a replacement. We also know of a McHale Fusion I baler manufactured in 2005 that operates at “Rozhdestvo” LLC farm in the Vladimir Region (Russia). This exact baler has produced more than 140,000 bales and the owners do not plan to replace it. McHale is considered the best machine on the farm in comparison with John Deere and Kverneland presses that they also own {Fusion and V6740 are made from same materials and have similar rigidity of construction});
- John Deere V461M - 60,000 bales (according to the data from “ZARECHNOE” LLC, Voronezh Region, Russia - its actual production volume is about 60,000 bales when the baler would need to be replaced due to critical wear);
- KRONE Comprima F125 - 50,000 bales (according to the dealer of KRONE in Russia - "Kuznitsa" LLC, their customer had produced around 50,000 bales and the baler was critically worn out and had to be replaced);
- CLAAS VARIANT 450 - 40,000 bales (neither CLAAS dealers in Russia, nor the headquarters in Germany could indicate the lifespan of the baler, although in terms of overall quality of

workmanship, metal thickness, structural rigidity, etc., the machine is unlikely to survive in our conditions of intense operation for more than 30,000 bales).

COST of hay baling directly linked to the baler McHale 6740					COST of hay baling directly linked to the baler John Deere V461M				
Operation	Bale D – 125 cm		Bale D – 150 cm		Operation	Bale D – 125 cm		Bale D – 150 cm	
	per bale	per ton	per bale	per ton		per bale	per ton	per bale	per ton
Baler amortization and repair costs	0,74 €	2,45 €	0,74 €	1,80 €	Baler amortization and repair costs	1,20 €	4,36 €	1,20 €	2,95 €
Net wrap cost	0,63 €	2,07 €	0,75 €	1,83 €	Net wrap cost	0,63 €	2,28 €	0,75 €	1,85 €
Pallets for hay stacking (5 pallets for 15 bales)	0,57 €	1,89 €	0,57 €	1,39 €	Pallets for hay stacking (5 pallets for 15 bales)	0,57 €	2,07 €	0,57 €	1,40 €
Haystack cover blanket	0,53 €	1,74 €	0,65 €	1,58 €	Haystack cover blanket	0,53 €	1,92 €	0,65 €	1,60 €
Haystack cover blanket screw	0,04 €	0,12 €	0,04 €	0,09 €	Haystack cover blanket screw	0,04 €	0,13 €	0,04 €	0,09 €
Haystacking support personnel	0,05 €	0,16 €	0,05 €	0,12 €	Haystacking support personnel	0,05 €	0,18 €	0,05 €	0,12 €
Subtotal cost	2,55 €	8,43 €	2,80 €	6,80 €	**Subtotal cost**	3,02 €	10,94 €	3,26 €	8,01 €
In comparison with McHale V6740 - total increase of production cost in %					**John Deere V461M**	18%	30%	17%	18%
In comparison with McHale V6740 - total increase of production cost in Euro						-0,46 €	**-2,51 €**	-0,46 €	**-1,21 €**

COST of hay baling directly linked to the baler CLAAS 450 VARIANT					COST of hay baling directly linked to the baler KRONE Comprima F125		
Operation	Bale D – 125 cm		Bale D – 150 cm		Operation	Bale D – 125 cm	
	per bale	per ton	per bale	per ton		per bale	per ton
Baler amortization and repair costs	1,27 €	5,24 €	1,27 €	4,43 €	Baler amortization and repair costs	1,44 €	5,67 €
Net wrap cost	0,63 €	2,60 €	0,75 €	2,64 €	Net wrap cost	0,63 €	2,46 €
Pallets for hay stacking (5 pallets for 15 bales)	0,57 €	2,37 €	0,57 €	2,00 €	Pallets for hay stacking (5 pallets for 15 bales)	0,57 €	2,24 €
Haystack cover blanket	0,53 €	2,19 €	0,65 €	2,28 €	Haystack cover blanket	0,53 €	2,08 €
Haystack cover blanket screw	0,04 €	0,15 €	0,04 €	0,12 €	Haystack cover blanket screw	0,04 €	0,14 €
Hay stacking support personnel	0,05 €	0,20 €	0,05 €	0,17 €	Hay stacking support personnel	0,05 €	0,19 €
Subtotal cost	3,08 €	12,74 €	3,33 €	11,65 €	**Subtotal cost**	3,26 €	12,79 €
CLAAS VARIANT 450	21%	51%	19%	71%	**KRONE Comprima F125**	28%	52%
	-0,52 €	**-4,31 €**	-0,52 €	**-4,84 €**		-0,70 €	**-4,36 €**

6. Hay that was not harvested in time is considered lost earnings in the calculation model, although, in fact, the amount of unharvested or irreparably damaged hay must be called a net loss.

- when hay gets rained on before it's raked - it's a loss of quality;
- if a baled hay gets rained over it is not a problem since the rain does not go deep into the bale and surface moisture (2-3 cm) is blown away by the wind in a day or two;
- raked hay caught in the rain - a total spoilage not suitable for feeding.

Additionally, it is worth noting that unharvested hay that got destroyed by the rain must also be dried, baled and removed from the field in order not to disrupt the stand, and all these operations have the same cost as for good hay to be harvested and they need to be carried out at the same time period when good hay could have been baled.

Thus, unharvested and damaged hay would not mean just unearned money, but would signify a double loss that can hardly be even partially compensated.

7. Euro/Ruble exchange rate for the date of testing was at 87.43 Rubles for a Euro.

8. All balers are coupled with a 132 hp Massey Ferguson 6713 tractor priced at 60.000 Euro (5.245.566 Rubles) on the given date with a fuel consumption of 12 l/h at a price of 0.51 Euro/liter (45 Rubles/liter).

9. Pick-up, transporting to storage and offloading the bales gets carried out by self-loading bale trailers Anderson TRB-20 priced at about 25.163 Euro (2.200.000 Rubles), coupled with Massey Ferguson 6713 tractors and delivering 20 bales of hay per hour to the storage facility from an averagely remote field. Each baler requires two bale trailers to deliver hay bales to the storage area in time.

10. Stacking at the storage site is carried out by JCB 535-95AG telehandler worth 96.196 Euro (8.410.391 Rubles), with a fuel consumption of 8 l/h at a price of 0.51 Euro/liter (45 Rubles/liter). One JCB 535-95AG telehandler is capable of servicing an average of 4 Anderson TRB-20 bale trailers (or capable of stacking roughly up to 80 bales/hour).

11. At the storage facility, the hay is piled into stacks of 15 bales each (5 bales at the base of the pyramid +4, +3, +2, +1 on top). Lowest 5 bales are placed on pallets that cost 1.72 Euro each (150 Rubles), 15 bales require 5 pallets. Further, the stack is covered with a haystack blanket with a price of 0.46 Euro/m^2 (40 Rubles) and fixed with plastic haystack blanket fixation screws – 20 screws per blanket with a price of 0.08 Euro/screw or 1.6 Euro for 20 pieces (7 Rubles/screw).

12. For calculation purposes based on actual operational experience with such equipment, the following data is taken into consideration:

- depreciation (lifespan of machinery in operating hours);
- average repair costs at the rate of 35% of the cost of equipment for the period of its lifespan;
- fuel and lubricants - company statistics for the last few years;
- wage fund of machinists = 3.03 Euro/hour * 1.432 (tax coefficient) * 2.5 (actual work coefficient) * number of machines used.

Additionally, the transport coefficient is taken into account (ride to the field, return, refueling, lunch, cleaning, blowing, washing, injection, acceptance, etc.) = 1.3

Costs for supporting machinery to bale hay, load on trailer, deliver to storage facility, offload and stack.									
№	Unit of equipment	№ of units	Purchase price	Lifespan hours	Ammortiz. per hour	Repair cost/hour	Fuel cost/hour	Salary cost/hour	TOTAL per hour
1	Tractor for the baler - Massey Ferguson 6713	1	60 000 €	6 000	10,00 €	3,50 €	6,18 €	10,85 €	**39,69 €**
2	Bal trailer tractor – Massey Ferguson 6713	2	120 000 €	6 000	20,00 €	7,00 €	12,35 €	21,70 €	**79,37 €**
3	Self-loading bale trailer Anderson TRB-20	2	50 328 €	6 000	8,39 €	2,94 €	0,00 €	0,00 €	**14,72 €**
4	Telehandler JCB 535-95AG for stacking	1	96 200 €	10 000	9,62 €	3,37 €	4,12 €	10,85 €	**36,34 €**
Total price paid for machinery (except the baler):			326 528 €	Per hour:	48,01 €	16,80 €	22,65 €	43,41 €	170,12 €

One baler supporting machinery operating cost per year = 170,12 €*245 hours of work = 41.680,30 € (3.643.946 Rubles).

13. Selling price of hay (low average) = 51,47 Euro per ton (4,500 Rubles per ton).

14. "Economic parameters of the process" and "PROFIT" are considered comparative indicators only, not absolute, and they show total cost overruns when choosing a baler with a lower capacity solely for the selected operations (only from baling to stacking – not for seeding, fertilization, mowing, tedding, raking, etc.).

CALCULATIONS.

I. Economic efficiency of operating a set of equipment with a specific baler for harvesting alfalfa hay calculation (from baling to stacking).

McHale V6740			John Deere V461M		
Bale diameter – 125 cm		Bale diameter – 150 cm	Bale diameter – 125 cm		Bale diameter – 150 cm
Output for the season (bales or tons of baled hay per season of 245 hours of bailing)					
Bales	9 817	8 425	Bales	9 766	7 354
Tons	2 975	3 471	Tons	2 694	2 996
Season cost linked to baler					
Euro	25 077 €	23 606 €	**Euro**	29 463 €	24 006 €
Season cost linked to support machinery					
Euro	41 680 €	41 680 €	**Euro**	41 680 €	41 680 €
Total season cost of production (cost of operations from baling to stacking)					
Euro	**66 757 €**	**65 286 €**	**Euro**	**71 143 €**	**65 686 €**
Total cost per bale					
Euro	6,80 €	7,75 €	**Euro**	7,28 €	8,93 €
Total cost per ton of hay					
Euro	**22,44 €**	**18,81 €**	**Euro**	**26,41 €**	**21,93 €**
Difference in cost of production per one ton of hay					
Total increase in cost - Euro				**-3,97 €**	**-3,12 €**
Total increase in cost - %				-18%	-17%

CLAAS 450 VARIANT			KRONE Comprima F125	
Bale diameter – 125 cm		Bale diameter – 150 cm	Bale diameter – 125 cm	
Output for the season (bales or tons of baled hay per season of 245 hours of bailing)				
Bales	**9 475**	**8 415**	Bales	**9 549**
Tons	**2 290**	**2 404**	Tons	**2 433**
Season cost linked to baler				
Euro	29 171 €	27 992 €	**Euro**	31 108 €
Season cost linked to support machinery				
Euro	41 680 €	41 680 €	**Euro**	41 680 €
Total season cost of production (cost of operations from bailing to stacking)				
Euro	**70 852 €**	**69 672 €**	**Euro**	**72 788 €**
Total cost per bale				
Euro	7,48 €	8,28 €	**Euro**	7,62 €
Total cost per ton of hay				
Euro	**30,93 €**	**28,99 €**	**Euro**	**29,92 €**
Difference in cost of production per one ton of hay				
Total increase in cost - Euro	**-8,50 €**	**-10,17 €**	Total increase in cost - Euro	**-7,48 €**
Total increase in cost - %	-32%	-46%	Total increase in cost - %	-24%

II. With a given selling price of hay at the level of 51,47 Euro per ton (4,500 Rubles per ton), conditional revenue and profit will be.

BALING PRESS	Revenue D=125 cm bale	Profit D=125 cm bale	Revenue D=150 cm bale	Profit D=150 cm bale
McHale V6740	153 151 €	86 394 €	178 638 €	113 351 €
John Deere V461M	138 650 €	67 506 €	154 191 €	88 505 €
CLAAS VARIANT 450	117 889 €	47 037 €	123 724 €	54 052 €
KRONE Comprima F125	125 228 €	52 440 €	-	-

III. If case of choosing a baler with a lower output compared to McHale V6740, the manufacturer will annually suffer losses due to increased cost of harvesting per ton of hay and due to the fact that they would not bale additional volume of hay (with an expected selling price of 51,47 Euro per ton).

BALING PRESS	Baling hay in bales with 125 cm diameter		Baling hay in bales with 150 cm diameter	
	cost overrun for the season	lost "conditional profit"	cost overrun for the season	lost "conditional profit"
John Deere V461M	-10 707 €	-8 180 €	-9 334 €	-15 512 €
CLAAS VARIANT 450	-19 465 €	-19 892 €	-24 455 €	-34 845 €
KRONE Comprima F125	-18 202 €	-15 752 €	-	-

IV. With a given selling price of hay at the level of 51,47 Euro per ton, it is possible to calculate the annual loss from using a baler with lower output (cost overruns during production together with unbaled hay).

BALING PRESS	Loss when pressing bales with diameter 125 cm	Loss when pressing bales with diameter 150 cm
John Deere V461M	- 18 887 €	- 24 846 €
CLAAS VARIANT 450	- 39 357 €	- 59 300 €
KRONE Comprima F125	- 33 954 €	-

V. Following is the comparison of total annual losses in case of harvesting hay with a less efficient baler to the purchase price of a new McHale V6740 baler (Price in 2020 = 54,904 Euros or 4,800,043 Rubles at the exchange rate for testing date August 21, 2020).

BALING PRESS	Annual loss in comparison to purchase price of the new McHale V6740 D = 125 cm	Annual loss in comparison to purchase price of the new McHale V6740 D = 150 cm
John Deere V461M	34,4 %	45,3 %
CLAAS VARIANT 450	71,7 %	108,0 %
KRONE Comprima F125	61,8 %	-

Trials, calculations and modelling undertaken by
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The conclusions of “ALFA-FEEDS” LLC on the results of McHale, John Deere, KRONE and CLAAS variable chamber baler testing, considering economic efficiency analysis of their operation while baling alfalfa hay.

It is quite obvious that technically similar machines from different manufacturers have different performance characteristics. In our understanding, the main indicator of the efficiency of a baler is the productivity measured in tons of baled hay per unit of time, considering the price, maintainability and lifespan.

We have repeatedly asked dealers and manufacturer representatives about the performance of this or that baler, but we could not get any satisfactory answer, because under different operating conditions machines perform differently and produce different results.

Machinery testing was carried out on August 21, 2020 in controlled and generally equal conditions (as much as it was possible) with the purpose of obtaining reliable comparative data (which can be easily extrapolated for similar tasks later on). Pure figures of output for each baler in seconds or percentage, obtained during the testing, are not very illustrative, therefore, an economic model was calculated for the operational performance of each baler plus supporting equipment (other machinery), within the estimated harvesting season (in our case it's the 2020 season - 245 hours of baling).

It was impossible to predict volumes of direct loss and potentially unearned funds on a farm engaged in intensive hay production with a baler with output rate (tons of baled hay per unit of time) different from the leader.

McHale V6740 has proved to be an undisputed leader showing strong advantages over other balers. McHale has the heaviest construction and drive (its metal thickness is 1.5-2 times higher than that of the competitors when it comes to almost all parts), as well as its lifespan statistics are 1.5-2.5 times greater than those of other machines.

The John Deere V461M baling press is a great machine that has been intensively modernized quite recently, it shows excellent baling density and generally good performance, but the economy, as always, is defined by numbers.

In spite of the fact that John Deere V461M output rate is so close to McHale V6740 – seasonal production cost overrun is quite significant due to a shorter actual lifespan (amortization) and a lower density of bales. For bales of 125 cm diameter seasonal overrun of funds will be 10.707 Euro (936.106 Rubles) and for bales of 150 cm seasonal overrun of funds will be 9.334 Euro (816.042 Rubles).

Additionally, under the given conditions, due to the lower output of John Deere V461M, the operating organization will fail to press 280 tons of bales with 125 cm diameter and about 480 tons of bales with 150 cm diameter, and this will lead to a direct loss of about 8.180 Euro (715,154 Rubles) and 15.512 Euro (1,356,147 Rubles), respectively (at the sale price hay 51,47 €/ton). Total seasonal losses will be around 18.887 Euro (1,651,260 Rubles) when harvesting hay bales of 125 cm diameter and 24.846 Euro (2,172,188 Rubles) when harvesting hay bales of 150 cm diameter.

To better understand the scale of losses, these numbers can be compared to a purchase price of a new McHale V6740 baler machine at 54.904 Euro (4,800,043 Rubles for 21 of August 2020). Thus, when harvesting hay with a John Deere press in 125 cm bales, the seasonal cost overruns will be 34.4% of the purchase price of a new McHale press, and in production of 150 cm bales - 45.3%. So, a purchase of a more productive McHale V6740 baler will be spent over a period of two to three seasons of operation with a less productive John Deere V461M baler.

KRONE Comprima F125 baler, due to its characteristics and design, is not suitable for alfalfa hay baling, its belt-slat bale chamber loses a considerable amount of alfalfa leaves during baling (both from the top and the bottom of the pressing chamber). It is very difficult to estimate losses, but visually the baler is driving in a cloud of green dust.

Due to the fact that the Krone press was tested only in the category of 125 cm bales and has an “almost” fixed chamber (pressing of a bale starts from 50% of the final diameter), we can evaluate it only in one category.

Because of the low lifespan (amortization) and a lower bale density, cost overruns for hay baling per season on the KRONE Comprima F125 baler in comparison with the McHale baler will achieve 18.202 Euro (1.591.358 Rubles) and, due to the lower output of the press, an operating organization will fail to produce additional 381 tons of hay, which will make direct loss of about 15.752 Euro (1.377.097 Rubles). Total loss will be about 33.954 Euro (2.968.455 Rubles) per season.

Compared to the purchase price of a new McHale baler, for 125 cm bales with a Krone baler, the seasonal cost overrun and underproduction is 61.8% of the purchase price of a new McHale baler, i.e. a purchase of the more productive McHale V6740 baler will be spent in less than two seasons of Krone baler operation.

It should also be noted that relatively low bale density of hay produced with Krone press (173 kg/m^3 versus McHale's 206 kg/m^3 in the same bale diameter) is not typical for balers with fixed bale chamber (from our experience, a bale chamber press CLAAS ROLLANT 455 Uniwrap RC makes bales of average hay density of about 180-190 kg/m^3), perhaps this is due to the belt-slat chamber structure and the characteristics of the Krone Comprima balers in general. In addition, during testing, we encountered problems with poor net wrapping of bales. The net wrapped the bales with a side shift of about 10-15 cm and while one side of the bale was covered with net, the other was lacking wrapping and the hay was sticking out. The wrapping problem could not be fixed either during the testing or even later (when the dealer was trying to solve the issue). Krone dealer noted that KRONE balers work well with Krone hay net wrapping, but we consider it an additional disadvantage and customer limitation (at least in terms of price for the net wrap).

The CLAAS VARIANT 450 baler most likely belongs to a different category of machinery (of a lower league) and can only be used on farms where hay is harvested in limited quantities. If a farm needs to bale 500-1000 tons of hay per year and no one is interested in the economics of the process, this may be a way out, because the price of the machine is 31% lower than that of competitors. We believe though, that the price is too high for a performance like this. In our calculation model, the lifespan of this baler is estimated at 40,000 bales, but it seemed that this exact machine would not survive more than 30,000 bales. For the test like ours this was a frankly flimsy and weak machine.

Due to small expected service lifespan (amortization) and the very low bale density (especially on 150 cm diameter bales - only 135 kg/m^3), the cost overrun for hay harvesting per season with a CLAAS baler compared to McHale baler would reach 19.465 Euro (1.701.755 Rubles) when making 125 cm diameter bales and 24.455 Euro (2.138.017 Rubles) when pressing 150 cm bales. Due to the lower output of the press, an operating organization will fail to bale additional 377 tons of hay in 125 cm bales, which will make a direct loss of about 19.892 Euro (1.739.039 Rubles) and 423 tons of 150 cm bales, which be a direct loss of about 34.845 Euro (3.046.341 Rubles). The total loss will be about 39.357 Euro (3.440.794 Rubles) for 125 cm bales production and 59.300 Euro (5.184.358 Rubles) for 150 cm diameter bales.

Compared to the purchase price of a new McHale V6740 baler, when harvesting 125 cm bales with a CLAAS baler, the loss will amount to 71.7% of the purchase price of a new McHale baler per season, and for 150 cm bales - 108%, i.e. the purchase of the more productive McHale V6740 baler will be spent in one or less than two seasons of CLAAS baler operation.

The field testing and the economic analysis of the received data have proved that the choice of baling machinery must be approached with extreme care.

Trials, calculations and modelling undertaken by
the Head of R&D department of "ALFA-FEEDS" LLC

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