EXPERIMENTAL RESEARCH ON THE KNIFE BLADES USED TO CUTTING AND SHREDDING FIBROUS FODDER

CERCETĂRI EXPERIMENTALE ASUPRA ORGANELOR DE TĂIERE-MĂRUNŢIRE A FURAJELOR FIBROASE

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ABSTRACT

In the process of harvesting fibrous fodder an important and negligible requirement is the appropriate shredding of the fiber feed directly or indirectly into the composition of animal feed, whether it be fresh fodder, high moisture or fodder feed or even dried. The degree of comminution of feeding stuffs decisively influences the speed of assimilation by animals of the administered feed, implicitly their weight gain, the profitability of the respective cattle farm and not only. In the paper are presented the possibilities of technically obtaining a finest shredding of fibrous fodder, especially by using multirow knives in the feed channel of self-loading hay trailer. However, these technical solutions also have certain disadvantages in the daily operation of such machines.

REZUMAT

În procesul de recoltare a furajelor fibroase o cerinţă importantă şi de loc de neglijat este mărunţirea corespunzătoare a furajelor fibroase care intră direct sau indirect în componenţa hranei animalelor, indiferent dacă este vorba de furaje fibroase proaspete, cu un grad de umiditate ridicat sau despre furaje vestejite sau chiar uscate. Gradul de mărunţire a furajelor influenţează în mod hotărâtor viteza de asimilare de către animale a nutreţului administrat, implicit sporul în greutate al acestora, rentabilitatea de funcţionare a fermei respective de bovine şi nu numai. În lucrare se prezintă posibilităţile de a obţine tehnic o mărunţire cât mai bună a furajelor fibroase, cu precădere prin utilizarea a cuţitelor multiple aşezate pe mai multe rânduri în canalul de alimentare ale remorcilor autoîncărcătoare fân. Aceste soluţii tehnice însă prezintă şi anumite dezavantaje în exploatare de zi cu zi ale utilajelor de acest gen.

INTRODUCTION

In order to counteract all these shortcomings presented above, we carried out some theoretical research, resulting in a universal knife profile, which has the advantage of general usability.

Its profile is thus conceived from the design stage to meet the requirements of cutting - shredding of all types of green fodder feed used in animal feed in zootechnics, regardless of their degree of humidity.

In the experimental researches we performed a series of cutting - shredding tests on different types and kinds of fibrous feeds in order to establish the correctness regarding the results of the experimental research and the actual shape of the knife obtained from the researches.

For this purpose, we designed and executed a cutting bench at the laboratory, where we used different forms of knives to determine the specific energy needed to cut different types of fibrous feed (*Caba I., 2006; Babinszky L., Halas V., 2019).*

MATERIALS AND METHODS

In order to carry out experimental laboratory tests to ascertain the usefulness and viability of the projected knife profile, it was necessary to design and execute a test stand where successive, repeated cuts with different shapes and sharpening angles could be performed, where the section of the test samples fodder feed remained constant and measurable at all times (*Ciocârdia C., 1999; Dănilă I., 1981; Neculăiasa V., Dănilă I., 1995*). The actual operation scheme is shown in Figure 1.

Another requirement was ease, simplicity and last but not least the safety of clamping of different shapes of their edges. The basic element of the experimental laboratory tests was the Charpy pendulum (*Dutton A. and Mines R., 2002; Truşculescu M., 2016*), for which we designed and built a special support device for easy gripping of the knives and samples. This support allowed the knives to snap and loosen easily and ensured that they were hardened during the laboratory experiment. The clamping-fastening device of the knife is made up of a metal plate identical in shape to the pendulum profile. Stiffening of this plate (the knife holder) to the pendulum profile was accomplished by the application of four fastening heels welded to the surface of the plate. On the surface of the disc, I have reinforced with electric arc welding four clamping clamps, which serve to stiffen the cutting and grinding blade during the measurements, but also allow for a slight change of the clamp.

Balancing the accessories applied to the surface of the pendulum profile was done with great care, while recording these values. The weight of the initial hammer arm of 2074 g was reached after the knife fastening device was mounted at 2530 g, but the balancing was so carefully chosen that it did not significantly change the center of gravity of the knife.

Another urgent necessity has also been to provide a certain distance between the knife and the hammer, failure to meet this requirement, and the removal of the detached part by cutting from the length of the specimen automatically led to the locking of the cutting knife in the feed material used as the test samples. In order to achieve a proper grip of the feed material specimen and to ensure a constant cutting section throughout the measurements, we designed and made a simple clamping vice, with three rigid walls and a fourth movable. Thus, we ensured a cross section of the constant and measurable specimen. The vise movable wall was operated with a press screw, and the vise supply was possible by completely detaching the movable wall and its support bracket into stiffening screws.

The drawings of the Charpy hammer pendulum are shown in Figure 2, which allows us to easily determine the specific energy consumed in the cutting of the fibrous feed specimen and the technical data related to this device used in the experimental determinations made in the laboratory are as follows:

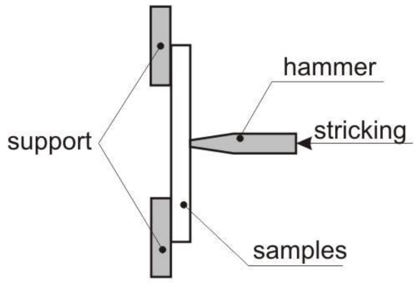

Fig. 1 - The principle of the test

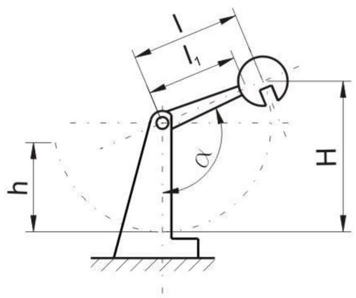

Fig. 2 - Scheme of Charpy hammer operation

where:

l - the distance from the axis of rotation - the suspension at the cutting center of the knife blades, in this case l = 0.380 m;

l_1 - distance from rotation axis - suspension at the center of gravity, having the following value l_1 = 0.335 m;

d - angle of hammer launch, in the present case α = 130^0;

β - the angle of maximum hammer position after cutting of the specimen, read on the graduated screen of the appliance;

H - the hammer launch height;

h - the height at which the hammer is lifted after cutting the specimen

In the case mentioned above for the equilibrium position of the pendulum hammer, the condition is that:

$$Gl \neq G_1 l_1 \tag{1}$$

where: G_1 - the weight of the hammer;

G - the weight of the hammer reduced in the percussion center.

The energy consumed when cutting a fiber feed specimen is determined by calculating the difference between potential potentials of the Charpy pendulum hammer in the initial and final position.

By calculating the heights H and h we obtain:

$$H = l_1 + l_1 \sin(\alpha - 90^0) = l_1 (1 - \cos \alpha) \tag{2}$$

$$h = l_1 - l_1 \cos \beta = l_1 (1 - \cos \beta) \tag{3}$$

of these two relationships, the value of the energy W consumed at the cutting of the fibrous feed specimen results:

$$W = G_1 l_1 (\cos \beta - \cos \alpha) \tag{4}$$

With this cut-off energy calculated with the above relationship, we can easily determine the value of the specific energy used to cut the surface unit:

$$W_S = W/S_O \tag{5}$$

where: S_O - surface area of the fibrous feed material specimen.

Knowing the angular values, the hammer weight and the length from the axis of rotation to the cutting center (values determined in the laboratory experiments), we can obtain the specific energy and cutting energy values for each cut. These calculated and tilted values can also be graphical.

The working procedure in the Charpy hammer-pendulum experiments and the fibrous feed samples were practically carried out as follows:

1. place the indicator needle at zero on the dial with the hammer left in the static equilibrium position;
2. raise the hammer and fasten it to the heel, place the knife in the holder;
3. place the test samples of the fibrous feed material on the support of the apparatus so that one end of it is locked in the vise and the other end is free, measure the dimensions of the samples by means of a caliper, make adjustments with the central screw if it is applicable;
4. the fall occurs;
5. after cutting the samples, stop the hammer and read the values indicated by the needle from the dial;
6. collect the comminuted feed material by repeated cuts into the capsules to determine the moisture content of the samples used.

These tests have been repeatedly carried out for cutters having the cutting angle between 0^0, 20^0, 25^0 and 30^0 and the cutting edge angle of 20^0. The sliding cutting angle represents the angular cutting tangent and had the values k = 0.57 for $\alpha = 30^0$; k = 0.46 for $\alpha = 25^0$ and k = 0.36 for $\alpha = 20^0$ (*Krasznicsenko A., 1965; Letoşnev M., 1969*).

The laboratory experiment was performed on samples of fibrous feed material, which is used mainly in livestock breeding for livestock feed. S_o we used lucerne, in the two versions available at the moment, corn - stalk, sunflower and freshly harvested lolium pasture grass and we also made some attempts on dried wheat straw. After each cut, we collected the detached material and proceeded to determine the moisture content of the specimen (*Nosov V., 1988; Szendro P., 2000; Bellus Z., Fenyvesi L., 2016*).

The fibrous feed material, detached by cutting the knife, was placed in crucibles, weighed, dried in the oven, and then weighed again (*Zaman A., Sagar M., 2018*). The data thus obtained were tabulated. Also in these tables are the values indicated by the needle on the graduated dial, whenever cuts are made. Several determinations were made with each knife profile, precisely to ensure accuracy in the processing and interpretation of the results obtained from experimental laboratory tests.

RESULTS

Following experimental laboratory determinations carried out using the Charpy hammer pendulum simulating the actual cutting of the fibrous feeds made by the grinding knives of the furrow-gathering machines during its exploitation, we find that an almost perfect simulation of the phenomena what is happening in reality.

Here, I refer to the grinding process - cutting which is made by knives, existing in a larger or smaller number, inside the feed channel, constructive part of self-loading hay trailers, cutting knives of different types, in function the type of feed, the way of feeding the feed furnace at the moment of penetration into the feed channel, its degree of humidity, the way of laying the knives in the groove, the profile of their cutting line, the angle of sharpening, the material used to make the knife, the frequency sharpening, s.o. Keeping the sharpening angle at 20^0, we try blades with different angles of bend in order to determine the specific energy when cutting (*Csulak A. and Stoica A., 1968; Gainov N.S., 1985*).

These experimental laboratory tests should indicate the ideal profile of a knife that if we have correctly calculated it should be similar to the one we obtained from the calculations.The fodder materials used for the test specimens are as follows: freshly harvested lucerne; semy dry lucerne; lolium; dry wheat straw; corn stalk; sunflower stem.The results obtained are shown in the tables as follows:

Table 1

Cutting the fresh lucerne samples. Cutting angle knife 0^0, sharpening angle 20^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
1	27*27	117	1.57	0.58	Tip of the stem with leaves
2	27*27	117	1.57	0.58	
3	27*27	116	1.70	0.63	
4	27*27	114	1.96	0.73	Rods and leaves
5	27*27	112	2.23	0.82	
6	27*27	113	2.09	0.78	
7	27*27	113	2.09	0.78	Rods at the harvesting level
8	27*27	109	2.64	0.98	
9	27*27	109	2.64	0.98	

Table 2

Cutting the fresh lucerne samples. Cutting angle knife 0^0, sharpening angle 25^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	112	2.23	0.82	Tip of the stem with leaves
27*27	112	2.23	0.82	
27*27	111	2.36	0.87	
27*27	110	2.50	0.93	Rods and leaves
27*27	110	2.50	0.93	
27*27	109	2.64	0.98	
27*27	105	3.19	1.18	Rods at the harvesting level
27*27	103	3.47	1.29	
27*27	101	3.76	1.31	

Table 3

Cutting the fresh lucerne samples. Cutting angle knife 0^0, angle of sharpening 30^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	104	3.33	1.23	Tip of the stem with leaves
2	27*27	103	3.47	1.29	
3	27*27	103	3.47	1.29	
4	27*27	99	4.04	1.50	Rods and leaves
5	27*27	97	4.33	1.60	
6	27*27	95	4.62	1.71	
7	27*27	94	4.62	1.76	Rods at the harvesting level
8	27*27	94	4.62	1.76	
9	27*27	92	5.05	1.87	

Table 4

Cutting the lucerne lucerne samples. Cutting angle knife 0^0, sharpening angle 20^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	105	3.19	1.18	Tip with leaves
27*27	104	3.33	1.23	
27*27	104	3.33	1.23	
27*27	101	3.76	1.39	Rods and leaves
27*27	101	3.76	1.39	
27*27	100	3.90	1.44	
27*27	98	4.19	1.55	Rods at the harvesting level
27*27	98	4.19	1.55	
27*27	96	4.19	1.66	

Table 5

Cutting the semy dry lucerne samples. Cutting angle knife 0^0, sharpening angle 25^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	100	3.90	1.44	Tip with leaves
2	27*27	98	4.19	1.55	
3	27*27	99	4.04	1.50	
4	27*27	95	4.62	1.71	Strains with leaves
5	27*27	95	4.62	1.71	
6	27*27	93	4.90	1.82	
7	27*27	92	5.05	1.87	Rods at the harvesting level
8	27*27	90	5.34	1.98	
9	27*27	89	5.49	2.03	

Table 6

Cutting the semy dry lucerne samples. Cutting angle knife 0^0, angle of sharpening 30^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	94	4.76	1.76	Tip with leaves
27*27	93	4.90	1.82	
27*27	93	4.90	1.82	
27*27	92	5.05	1.87	Strains with leaves
27*27	90	5.34	1.98	
27*27	90	5.34	1.98	
27*27	88	5.63	2.09	Rods at the harvesting level
27*27	88	5.63	2.09	
27*27	88	5.63	2.09	

Table 7

Cutting the wheat straw samples. Cutting angle knife 0^0, sharpening angle 20^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	90	5.34	1.98	Rods
2	27*27	89	5.49	2.03	
3	27*27	89	5.49	2.03	
4	27*27	87	5.78	2.14	Rods
5	27*27	85	6.07	2.25	
6	27*27	86	5.92	2.19	
7	27*27	84	6.21	2.30	Rods
8	27*27	84	6.21	2.30	
9	27*27	82	6.50	2.41	

Table 8

Cutting the wheat straw samples. Cutting angle knife 0^0, sharpening angle 25^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	88	5.63	2.09	Rods
27*27	86	5.92	2.19	
27*27	86	5.92	2.19	
27*27	83	6.36	2.35	Rods
27*27	82	6.50	2.41	
27*27	80	6.79	2.51	
27*27	79	6.93	2.57	Rods
27*27	79	6.93	2.57	
27*27	79	6.93	2.57	

Table 9

Cutting the wheat straw samples. Cutting angle knife 0^0, angle of sharpening 30^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	83	6.36	2.35	Rods
2	27*27	82	6.50	2.41	
3	27*27	83	6.36	2.35	
4	27*27	81	6.64	2.46	Rods
5	27*27	80	6.69	2.51	
6	27*27	79	6.93	2.57	
7	27*27	79	6.93	2.57	Rods
8	27*27	75	7.50	2.78	
9	27*27	75	7.50	2.78	

Table 10

Cutting the lolium samples. Cutting angle knife 0^o, sharpening angle 20^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	98	4.19	1.55	Strains and leaves
27*27	97	4.33	1.60	
27*27	96	4.47	1.66	
27*27	95	4.62	1.71	Strains and leaves
27*27	93	4.90	1.82	
27*27	91	5.20	1.92	
27*27	89	5.49	2.03	Strains and leaves
27*27	89	5.49	2.03	
27*27	88	5.63	2.09	

Table 11

Cutting the lolium samples. Cutting angle knife 0^0, sharpening angle 25^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	27*27	5.20	1.92	Strains and leaves
2	27*27	27*27	5.49	2.03	
3	27*27	27*27	5.49	2.03	
4	27*27	27*27	5.78	2.14	Strains and leaves
5	27*27	27*27	5.78	2.14	
6	27*27	27*27	5.78	2.14	
7	27*27	27*27	5.92	2.19	Strains and leaves
8	27*27	27*27	5.92	2.19	
9	27*27	27*27	6.07	2.25	

Table 12

Cutting the lolium samples. Cutting angle knife 0^0, angle of sharpening 30^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	87	5.78	2.14	Rods and leaves
27*27	85	6.07	2.25	
27*27	86	5.92	2.19	
27*27	84	6.21	2.30	Rods and leaves
27*27	84	6.21	2.30	
27*27	83	6.36	2.35	
27*27	82	6.50	2.41	Rods and leaves
27*27	82	6.50	2.41	
27*27	82	6.50	2.41	

Table 13

Cutting the fresh corn stalk samples. Cutting angle knife 0^0, sharpening angle 20^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
1	27*27	109	2.64	0.98	Rods and leaves
2	27*27	108	2.77	1.03	
3	27*27	108	2.77	1.03	
4	27*27	106	3.05	1.13	Rods and leaves
5	27*27	105	3.19	1.18	
6	27*27	105	3.19	1.18	
7	27*27	101	3.76	1.39	Rods and leaves
8	27*27	100	3.90	1.44	
9	27*27	99	4.04	1.50	

Table 14

Cutting the fresh corn stalk samples. Cutting angle knife 0^0, sharpening angle 25^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	102	3.61	1.34	Rods and leaves
27*27	101	3.77	1.39	
27*27	101	3.77	1.39	
27*27	99	4.04	1.50	Rods and leaves
27*27	98	4.19	1.55	
27*27	99	4.04	1.50	
27*27	98	4.19	1.55	Rods and leaves
27*27	97	4.33	1.60	
27*27	97	4.33	1.60	

Table 15

Cutting the fresh corn stalk samples. Cutting angle knife 0^0, angle of sharpening 30^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
1	27*27	101	3.76	1.39	Rods and leaves
2	27*27	99	4.04	1.50	
3	27*27	99	4.04	1.50	
4	27*27	97	4.33	1.60	Rods and leaves
5	27*27	96	4.47	1.66	
6	27*27	96	4.47	1.66	
7	27*27	93	4.90	1.82	Rods and leaves
8	27*27	94	4.76	1.76	
9	27*27	93	4.90	1.82	

Table 16

Cutting the fresh sunflower samples. Cutting angle knife 0^0, sharpening angle 20^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	105	3.19	1.82	Especially rods and sloppy leaves
27*27	103	3.47	1.29	
27*27	104	3.33	1.23	
27*27	100	3.90	1.44	Especially rods and sloppy leaves
27*27	100	3.90	1.44	
27*27	99	4.04	1.50	
27*27	98	4.19	1.55	Especially rods and sloppy leaves
27*27	98	4.19	1.55	
27*27	95	4.62	1.71	

Table 17

Cutting the fresh sunflower samples. Cutting angle knife 0^0, sharpening angle 25^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator(^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
1	27*27	97	4.33	1.60	Especially rods and sloppy leaves
2	27*27	95	4.62	1.71	
3	27*27	96	4.47	1.66	
4	27*27	95	4.62	1.71	Especially rods and sloppy leaves
5	27*27	94	4.76	1.76	
6	27*27	93	4.90	1.82	
7	27*27	94	4.76	1.76	Especially rods and sloppy leaves
8	27*27	93	4.90	1.82	
9	27*27	91	5.20	1.92	

Table 18

Cutting the fresh sunflower samples. Cutting angle knife 0^0, angle of sharpening 30^0

Test-bar size (mm /mm)	Angle indicator(^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	93	4.90	1.82	Especially rods and sloppy leaves
27*27	92	5.05	1.87	
27*27	92	5.05	1.87	
27*27	89	5.49	2.03	Especially rods and sloppy leaves
27*27	88	5.63	2.09	
27*27	86	5.92	2.19	
27*27	87	5.78	2.14	Especially rods and sloppy leaves
27*27	87	5.78	2.14	
27*27	85	6.07	2.25	

From the above, it appears that the best results in terms of energy consumption required for the cutting of the fibrous feed samples were made using the blades with a sharpening angle of 20^0, and in cases where we increased the angle of sharpening at 25^0 and 30^0, respectively, we had business with a significant increase in energy consumption when cutting samples.

Next, we retain the most convenient sharpening value obtained by the laboratory tests, the sharpen angle remains at 20^0, and alter the tilting angle of the knife so as to achieve a truly sliding cutting process. In the same manner as before, we will proceed to the cutting of samples from fibrous feed materials, with the difference that the angle of inclination of the cutting knife changes, taking successive values of 20^0, 25^0 or 30^0. Applying the above, we obtain the following experimental values:

Table 19

Cutting the fresh lucerne samples. Knife with cutting angle 20^0, sharpening angle 20^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator(^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	116	1.70	0.63	Tip of the stem with leaves
2	27*27	114	1.96	0.73	
3	27*27	114	1.96	0.73	
4	27*27	110	2.50	0.93	Rods and leaves
5	27*27	109	2.64	0.98	
6	27*27	104	3.33	1.23	
7	27*27	102	3.61	1.34	Rods at the harvesting level
8	27*27	98	4.19	1.55	
9	27*27	97	4.33	1.60	

Table 20

Cutting the fresh lucerne samples. Cutting angle knife 25^0, sharpening angle 20^0

Test-bar size (mm /mm)	Angle indicator(^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	117	1.57	0.58	Tip of the stem with leaves
27*27	116	1.70	0.63	
27*27	116	1.70	0.63	
27*27	111	2.36	0.87	Rods and leaves
27*27	112	2.23	0.82	
27*27	110	2.50	0.93	
27*27	109	2.64	0.98	Rods at the harvesting level
27*27	107	2.91	1.08	
27*27	107	2.91	1.08	

Table 21

Cutting the fresh lucerne samples. Knife with cutting angle 30^0, sharpening angle 20^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator(^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	119	1.31	0.49	Tip of the stem with leaves
2	27*27	118	1.44	0.53	
3	27*27	116	1.70	0.63	
4	27*27	115	1.83	0.68	Rods and leaves
5	27*27	115	1.83	0.68	
6	27*27	112	2.23	0.82	
7	27*27	111	2.36	0.87	Rods at the harvesting level
8	27*27	109	2.64	0.98	
9	27*27	109	2.64	0.98	

Table 22

Cutting the lucerne lucerne samples. Knife with cutting angle 20^0, sharpening angle 20^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	106	3.05	1.13	Tip of the stem with leaves
27*27	105	3.19	1.18	
27*27	103	3.47	1.29	
27*27	102	3.61	1.34	Rods and leaves
27*27	102	3.61	1.34	
27*27	99	4.04	1.50	
27*27	98	4.19	1.55	Rods at the harvesting level
27*27	99	4.04	1.50	
27*27	98	4.19	1.55	

Table 23

Cutting the lucerne lucerne samples. Cutting angle knife 25^0, sharpening angle 20^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator(^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	108	2.77	1.03	Tip of the stem with leaves
2	27*27	107	2.91	1.08	
3	27*27	106	3.05	1.13	
4	27*27	105	3.19	1.18	Rods and leaves
5	27*27	103	3.47	1.29	
6	27*27	102	3.61	1.34	
7	27*27	100	3.90	1.44	Rods at the harvesting level
8	27*27	98	4.19	1.55	
9	27*27	98	4.19	1.55	

Table 24

Cutting the lucerne lucerne samples. Knife with cutting angle 30^0, sharpening angle 20^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	110	2.50	0.93	Tip of the stem with leaves
27*27	110	2.50	0.93	
27*27	108	2.77	1.03	
27*27	107	2.77	1.08	Rods and leaves
27*27	104	3.33	1.23	
27*27	104	3.33	1.23	
27*27	102	3.61	1.34	Rods at the harvesting level
27*27	99	4.04	1.50	
27*27	99	4.04	1.50	

Table 25

Cutting the wheat straw samples. Knife with cutting angle 20^0, sharpening angle 20^0

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	95	4.62	1.71	Rods
2	27*27	94	4.76	1.76	
3	27*27	91	5.20	1.92	
4	27*27	92	5.05	1.87	Rods
5	27*27	90	5.34	1.98	
6	27*27	88	5.63	2.09	
7	27*27	87	5.78	2.14	Rods
8	27*27	87	5.78	2.14	
9	27*27	87	5.78	2.14	

Table 26

Cutting the wheat straw samples. Cutting angle knife 25^0, sharpening angle 20^0

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	97	4.33	1.60	Rods
27*27	97	4.33	1.60	
27*27	95	4.62	1.71	
27*27	94	4.76	1.76	Rods
27*27	94	4.76	1.76	
27*27	93	4.90	1.82	
27*27	90	5.34	1.98	Rods
27*27	91	5.20	1.92	
27*27	90	5.34	1.98	

Table 27

Cutting the wheat straw samples. Knife with cutting angle 30⁰, sharpening angle 20⁰

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (⁰)	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
1	27*27	99	4.04	1.50	Rods
2	27*27	98	4.19	1.55	
3	27*27	97	4.33	1.60	
4	27*27	97	4.33	1.60	Rods
5	27*27	94	4.76	1.76	
6	27*27	94	4.76	1.76	
7	27*27	93	4.90	1.82	Rods
8	27*27	92	5.05	1.87	
9	27*27	92	5.05	1.87	

Table 28

Cutting the fresh corn stalk samples. Knife with cutting angle 20⁰, sharpening angle 20⁰

Test-bar size (mm /mm)	Angle indicator (⁰)	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Obser-vation
27*27	110	2.50	0.93	Rods and leaves
27*27	109	2.63	0.98	
27*27	108	2.77	1.03	
27*27	108	2.77	1.03	Rods and leaves
27*27	105	3.19	1.18	
27*27	102	3.61	1.34	
27*27	100	3.90	1.44	Rods and leaves
27*27	99	4.04	1.50	
27*27	97	4.33	1.60	

Table 29

Cutting the fresh corn stalk samples. Cutting angle knife 25⁰, sharpening angle 20⁰

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (⁰)	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
1	27*27	111	2.36	0.87	Rods and leaves
2	27*27	110	2.50	0.93	
3	27*27	109	2.63	0.98	
4	27*27	109	2.63	0.98	Rods and leaves
5	27*27	107	2.91	1.08	
6	27*27	106	3.05	1.13	
7	27*27	103	3.47	1.29	Rods and leaves
8	27*27	100	3.90	1.44	
9	27*27	99	4.04	1.50	

Table 30

Cutting the fresh corn stalk samples. Knife with cutting angle 30⁰, sharpening angle 20⁰

Test-bar size (mm /mm)	Angle indicator (⁰)	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	116	1.70	0.63	Rods and leaves
27*27	114	1.96	0.73	
27*27	114	1.96	0.73	
27*27	112	2.23	0.82	Rods and leaves
27*27	111	2.36	0.87	
27*27	107	2.91	1.08	
27*27	105	3.19	1.18	Rods and leaves
27*27	101	3.76	1.39	
27*27	100	3.90	1.44	

Table 31

Cutting the fresh sunflower samples. Knife with cutting angle 20⁰, sharpening angle 20⁰

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (⁰)	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
1	27*27	107	2.91	1.08	Especially rods and sloppy leaves
2	27*27	105	3.19	1.18	
3	27*27	103	3.47	1.29	
4	27*27	101	3.76	1.39	Especially rods and sloppy leaves
5	27*27	100	3.90	1.44	
6	27*27	97	4.33	1.60	
7	27*27	97	4.33	1.60	Especially rods and sloppy leaves
8	27*27	95	4.62	1.71	
9	27*27	94	4.76	1.76	

Table 32

Cutting the fresh sunflower samples. Cutting angle knife 25⁰, sharpening angle 20⁰

Test-bar size (mm /mm)	Angle indicator (⁰)	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	110	2.50	0.93	Especially rods and sloppy leaves
27*27	108	2.77	1.03	
27*27	109	2.63	0.97	
27*27	106	3.05	1.13	Especially rods and sloppy leaves
27*27	105	3.19	1.18	
27*27	103	3.47	1.29	
27*27	102	3.61	1.34	Especially rods and sloppy leaves
27*27	99	4.04	1.50	
27*27	96	4.47	1.66	

Table 33

Cutting the fresh sunflower samples. Knife with cutting angle 20⁰, sharpening angle 20⁰

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
1	27*27	112	2.23	0.82	Especially rods and sloppy leaves
2	27*27	110	2.50	0.93	
3	27*27	109	2.63	0.98	
4	27*27	109	2.63	0.98	Especially rods and sloppy leaves
5	27*27	106	3.05	1.13	
6	27*27	104	3.33	1.23	
7	27*27	101	3.76	1.39	Especially rods and sloppy leaves
8	27*27	99	4.04	1.50	
9	27*27	99	4.04	1.50	

Table 34

Cutting the fresh sunflower samples. Cutting angle knife 25⁰, sharpening angle 20⁰

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	104	3.33	1.23	Strains and leaves
27*27	103	3.47	1.29	
27*27	102	3.61	1.34	
27*27	102	3.61	1.34	Strains and leaves
27*27	99	4.04	1.50	
27*27	99	4.04	1.50	
27*27	98	4.19	1.55	Strains and leaves
27*27	97	4.33	1.60	
27*27	95	4.62	1.71	

Table 35

Cutting the lolium samples. Cutting angle knife 25⁰, sharpening angle 20⁰

Nr. crt.	Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
1	27*27	107	2.91	1.08	Strains and leaves
2	27*27	105	3.19	1.18	
3	27*27	105	3.19	1.18	
4	27*27	104	3.33	1.23	Strains and leaves
5	27*27	103	3.47	1.29	
6	27*27	100	3.90	1.44	
7	27*27	100	3.90	1.44	Strains and leaves
8	27*27	99	4.04	1.50	
9	27*27	98	4.19	1.55	

Table 36

Cutting the lolium samples. Knife with cutting angle 30⁰, sharpening angle 20⁰

Test-bar size (mm /mm)	Angle indicator (^{0})	Energy needed to cut (J)	Specific energy to cut (J/cm^2)	Observation
27*27	109	2.64	0.98	Strains and leaves
27*27	109	2.64	0.98	
27*27	107	2.91	1.08	
27*27	106	3.05	1.13	Strains and leaves
27*27	105	3.19	1.18	
27*27	103	3.47	1.29	
27*27	103	3.47	1.29	Strains and leaves
27*27	101	3.76	1.39	
27*27	100	3.90	1.44	

After a simple analysis, it can be noticed that the specific cutting energy values vary not only depending on the humidity or origin and type of the feed material samples used during the experimental laboratory determinations, but also according to the place where the cutting along the rod the knife sharpening angle, and the degree of inclination of the knife used for cutting, as well as a number of other factors that are not considered in this research phase.

There is a decrease, in some cases even significant, of the value of the specific cutting energy, starting from the base of the stem, to the tip of the stem. This is represented in the graphs below, grouping the values of the specific cutting energy into three value groups, while taking into account the constructive angles of the knife.

The first group is the specific energy values for cutting in the upper area of the feed material rods used as test samples, where the rods are mostly thin, with many leaves, the relative humidity of this part is higher and, last but not least, the rods contain tissues young, soft. In this first group, we can analyze a constructive variant, which is the straight knife variant, where only the angle of sharpening i_c changes, but the angle of inclination of the alpha knife is equal to zero; $\alpha = 0$. Under these conditions, we obtain according to Figure 3. a slow increase in the specific cutting energy values due to the gradual increase in sharpen angle values. In fact, this phenomenon occurs when using uncut knives, blunted due to a high workload. There is also a well-known phenomenon, namely the increase of the specific energy in the cutting of fodder materials with a low humidity, such as the grinding of wheat straw, where the humidity determined during the laboratory experiments did not exceed 6%.

At high relative humidity levels of plants, in the case of semy dry lucerne or corn and sunflower, the cutting-specific energy gets lower values, cuts can be made easier, and hence a number of functional exploitation advantages, lower costs accounted for per kg of harvested forage.

We must also remember that it is very important to choose the material from which the knife is made. Good materials, quality steels are more expensive but resist over time, keep the angle of sharpening longer, their wear is reduced. Poor quality steels cost less, but their use is limited precisely because of repeated regrinding and their premature exit from use (*Caba I. 2006*).

These losses also have to be added to the losses suffered by the company through the non-use, the stagnation of the machinery, mostly due to the increased working capacity with these knives.

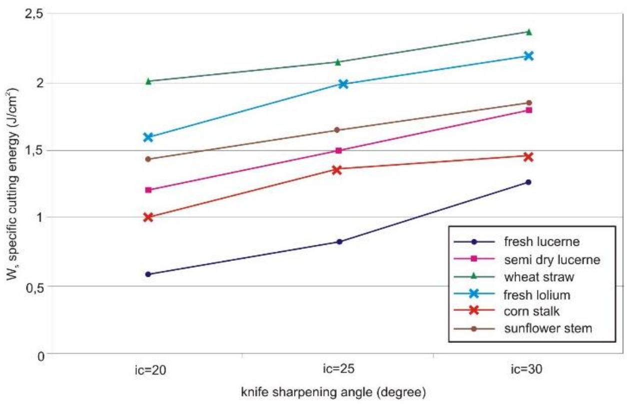

Fig. 3 - Variation of the specific cutting energy according to the angle of the knife sharpening. The samples contain leaves and rods at the top

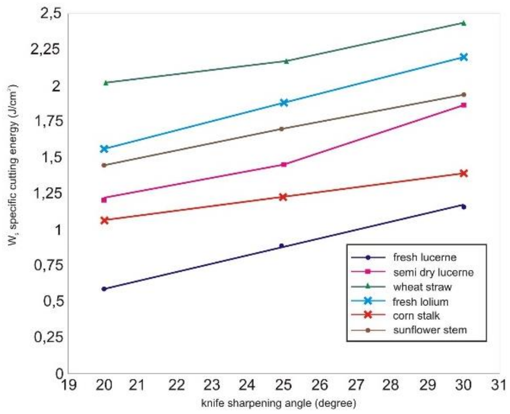

Fig. 4 - Variation of the specific cutting energy processed according to the angle of the knife sharpening. The samples contain leaves and rods at the top

Processing the experimental data represented graphically in Figure 3. obtained in laboratory conditions, using the statistics applied in mathematics, we traced the real curves, obtaining some straight lines related to the cuts made on the fodder samples made from different feeds, according to the legend of the Figure 4, with strictly linear variations, has confirmed the initial assumption, that is, the increase in the sharpness values of the cutting-chopping knife, entails increasing the values of the specific energies at cutting, resulting in extreme cases at forces so large that no cutting actually takes place, breaking the samples material, or even stopping the knife in the material of the test specimen used.

The second group, represented by Figure 5, signifies the specific cutting energy values from the middle of the length of the samples, the area where the fiber feed samples has, besides many rods and leaves, in most cases this ratio is substantially equal.

There is a noticeable increase in the specific energy required to cut samples from feed materials to the values recorded at the cutting of samples formed from foliage and stems at the tip of the plants.

This increase is due to the decrease of the foliage and the increase in the number of rods, which have a more pronounced lignin structure in this area of plants. The increase in specific cutting energy expressed as a percentage represents approximately 10-15%, copying the percentage increase expressed as a sharp increase in the knife sharpening angle.

Applying identically, as in the previous case, the statistical processing of the experimental values obtained in the laboratory determinations on fodder samples and graphs, a linear variation, represented in Figure 6 was also obtained. And in the third group, represented by Figure 7. the values of the specific cutting energy in the lower area of the plants near the harvest area, which have been used as cutting material, are found.

This area is rich in lignite, aging, and low-moisture tissue, with a marked lack of leaves. Rods are ubiquitous in this type of samples, the cross section of the stems is much higher compared to the cross section of the stems at the tips, they are characterized by the high resistance to penetration of the knife blade.

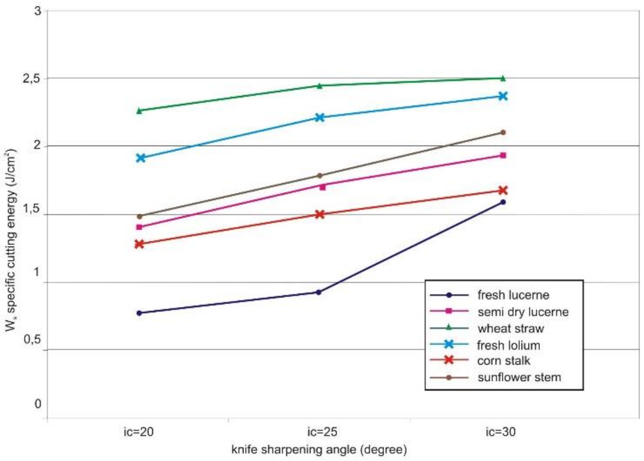

Fig. 5 - The specific cutting energy variation according to the angle of the knife sharpening. The samples contain leaves and rods at the top

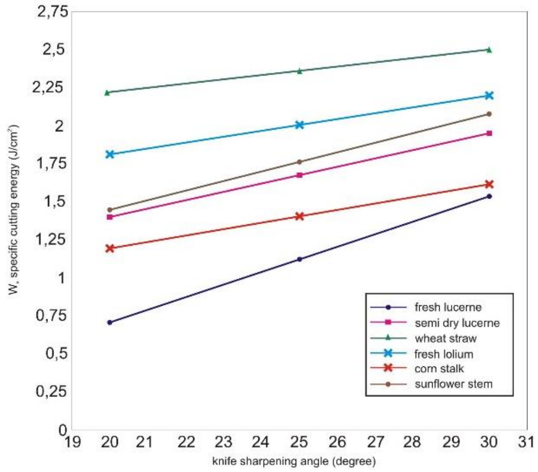

Fig. 6 - The specific cutting energy variation processed statisticaly according to angle of the knife sharpening. The samples contain leaves and rods at the top

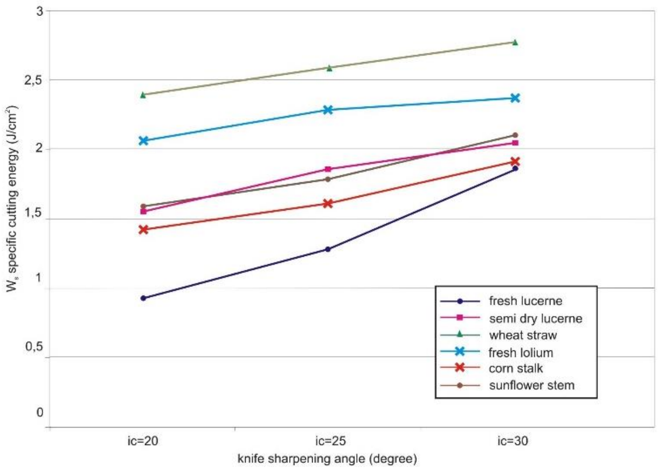

Fig. 7 - The specific cutting energy variation according to the angle of the knife sharpening. The samples contain leaves and rods at the top

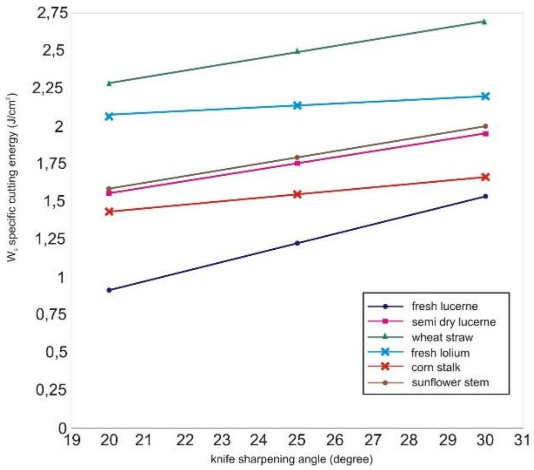

Fig. 8 - The specific cutting energy variation processed according to the angle of the knife sharpening. The samples contain leaves and rods at the top

After the statistical processing of the values obtained in the laboratory tests at the cutting of samples from feed materials, we obtain, according to expectations, also a linear variation, but with higher values than in the other two studied cases, phenomenon explained by taking into account the increased resistance of the strains aged, ligninous, with a relatively lower moisture content as compared to the stem tips.

The sharpening and tilting angles of the knife also play an important role in modifying the specific cutting energy values, their correct choice depending on the material of the samples, its moisture content and other factors, may lead to a a significant decrease in the specific energy consumed in the cutting of the feed material used to make the daily feed of livestock from zootechnical farms.

This also results from the laboratory determinations performed on feed specimen specimens, where we modified only the angle of inclination alpha of the knife, while keeping the most convenient angle of sharpening, determined by the experimental tests performed, being $i_c = 20^0$. The specimen in this case, it mostly contains leaves and thin rods from the tip of the forage plant, from which it can be concluded that the cutting is carried out with a lower energy effort, according to Figure 9, we have values that gradually decrease with increasing the angle of inclination of the knife .

This decrease is not very spectacular and cannot be achieved to extreme values because of some conditions of exploitation and design of the shape of the knife and its resistance to daily exploitation. An inclination of more than 30^0 of the cutting-grinding knife in the laboratory experiment has made it technically impossible for the knife to be executed and used with the projector.

After performing the statistical processing of the obtained experimental data, we can see that this time a linear variation of the specific cutting energies was obtained, according to Figure 10.

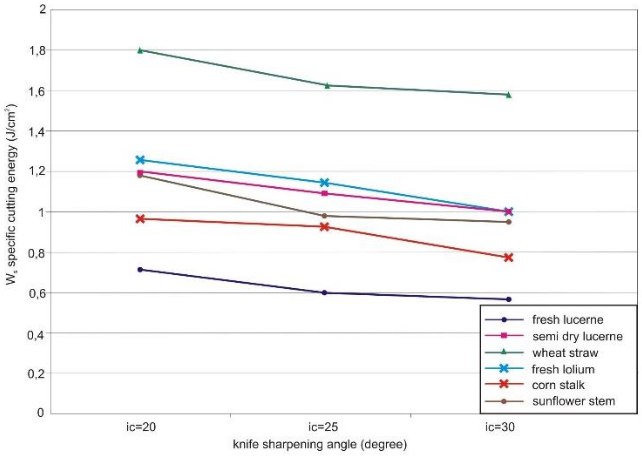

Fig. 9 - Specific energy variation when cutting the feed material samples from leaves and rods at the plant tip according to the angle of the knife sharpen at 20⁰

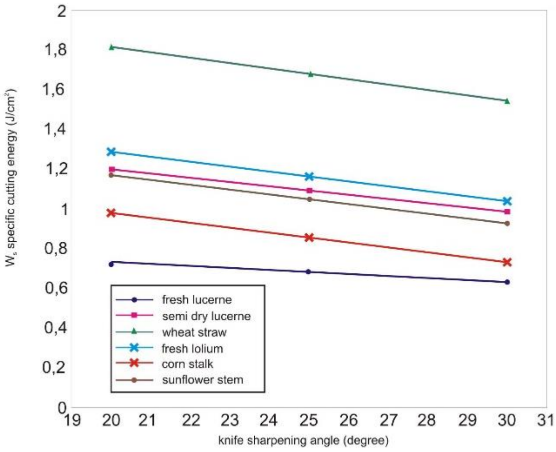

Fig. 10 - Specific energy variation processed statisticaly when cutting the feed material samples from leaves and rods at the plant tip according to the angle of the knife sharpen at 20^0

If the angle of sharpening of the knife $i_c = 20^0$ is maintained, but we vary the angle of inclination, using high-feed feed samples in rods and leaves harvested from the middle of the forage plants where the ratio of rods and leaves is substantially equal, values represented in Figure 11.

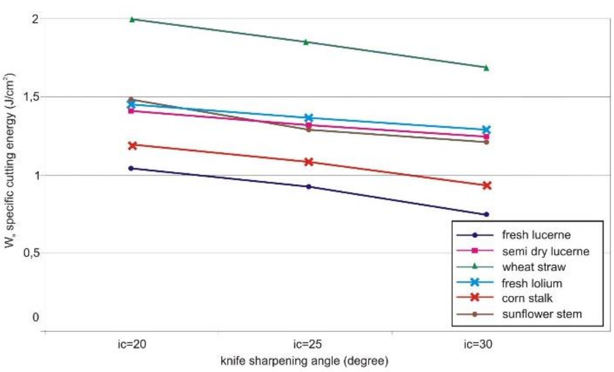

Fig. 11 - Specific energy variation when cutting the samples feed material with a rod content and leaves in the middle of the plant according to the inclination of the knife 20^0

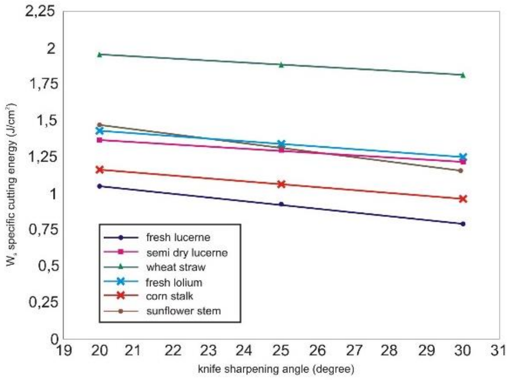

Fig. 12 - Specific energy variation processed statisticaly when cutting the samples feed material with a rod content and leaves in the middle of the plant according to the inclination of the knife 20^0

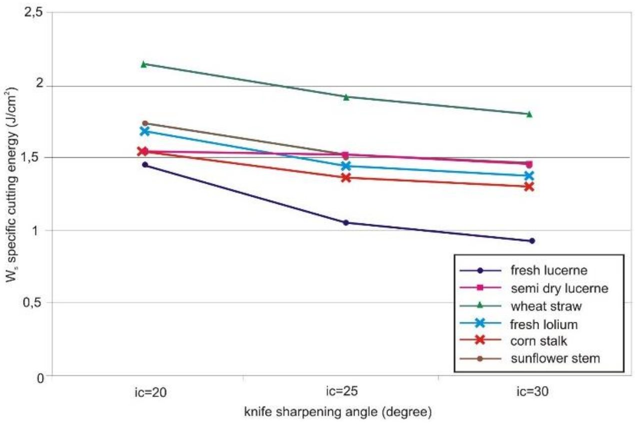

Fig. 13 - The specific energy variation when cutting the feed material specimen with a high rod content, depending on the inclination of the knife 20^0

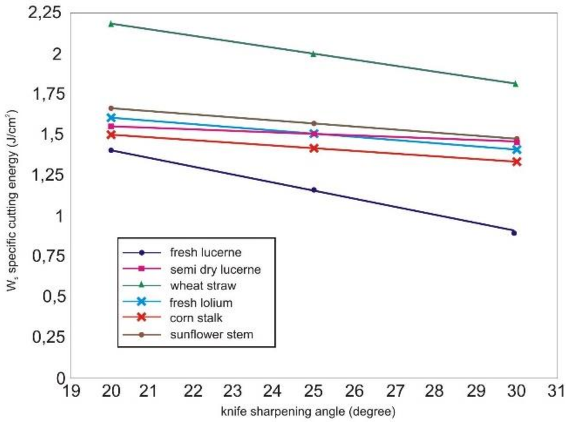

Fig. 14 - The specific energy variation processed statisticaly when cutting the feed material specimen with a high rod content, depending on the inclination of the knife 20^0

As can be seen, a linear decrease in the specific energy required to perform the cutting of the samples was obtained in this case, which is shown in Figure 12.

The last evaluation of the specific cutting energy represented by Figure 13. which is carried out in the case of cuts made on samples of feed materials mainly made of rods with a high content of hard tissues, and in these determinations the value of the angle of sharpening the knife at i_c = 20^0, but altering the tilting of the knife, alpha, in those three previously known steps, previously described.

After the statistical processing of the experimental data obtained from the cutting of samples of feed materials with a high content of rods and this time a linear variation of the values of the specific cutting energies according to Figure 14 was obtained. There is a relative increase of these values compared to those obtained in the experiments performed on specimens with high leaf or mixed samples (leaves and rods) but after a realistic analysis it was found that this increase is justified by changing the structure of the stems, which are lighter, less water content, and last but not least we notice the total absence or low presence of leaves.

CONCLUSIONS

Starting from the experimental results obtained from the laboratory research on the fibrous fodder organs, we obtained conclusive results which, after their processing, proved the veracity of the theory presented in the above chapters regarding the design of a cutting knife that is universally usable to the cutting-off of a variety of assortment of fibrous feed, irrespective of the maturity status or the time elapsed since harvesting.

In the first part of the experiments, straight knives were used and we only varied their angles of sharpening, from 20^0 to 25^0 or 30^0, thus obtaining a permanent increase in the specific cutting energy (*Neculăiasa V., Dănilă I. 1995*). In the second part of the experiments carried out in the research laboratory, the angle of the most convenient knife sharpening angle of 20^0 was chosen, at which the specific cutting energy values were the lowest and we varied this time the angle of inclination of the knife 20^0, 25^0 and 30^0 to the corresponding cutting factor k = 0,36; k = 0.46 and k = 0.57.

Conclusions on the results obtained are as follows:

1) plant humidity significantly influences the consumption of the specific energy of cutting fodder plants;

2) specific cutting energy consumption varies according to the place where the cutting is done, higher at the base of the plants and gradually decreases towards the top of the plant;

3) the angle of sharpening of the knives has an important role in establishing the energy balance at the cutting-shredding of the plants, a small angle of sharpening leads to a specific consumption of low cutting energy, and if the angle of rotation increases, we have a significant increase in the specific energy of cutting;

4) sharpen angle of less than 20^0 leads to rapid knife cut, resulting in an increase in cutting-specific energy, knife rewind stops, machine productivity decreases, increases operating cost;

5) a solution to this problem is the use of knives made of special materials which do not require repeated re-drilling, but the cost of the special knives would be too high and their equally fragile, which would lead to their frequent change with repeated stops, the loss of precious harvest time;

6) the sharpening angle of more than 30^0 causes an excessive energy consumption of excessive cutting, especially in the case of drier fodders, because the actual cutting is partially replaced by the breaking of the fibrous feed material, vibrations occur during the cutting and even the clogging of the cutter;

7) a specific energy consumption of balanced cutting and at the same time a minimal wear of the blade cutting edge during the work we obtained at the angle of sharpening of the knife 25^0, even with a material not recommended for making the knife;

8) while keeping the knife sharpening angle at 20^0, where the specific cutting energy values were the smallest, we varied the tilting angle of the knife by which we obtained the sliding cut, the cutter energy values gradually decreasing with the increase of the inclination angle knife;

9) the highest cut-off energy values were recorded for the cutting angle 20^0 and the tilting angle of the knife 20^0 as well, and the lowest specific cutting energy values for the sharpen angle of 20^0 and the angle of inclination of the knife of 30^0;

10) passing over these values causes some knife execution problems, and in extreme cases slipping the material on the cut.

REFERENCES

[1] Babinszky L., Halas V., (2019), Innovative feeding, (Innovatív takarmányozás), *Academic Publisher Budapest, Hungary, Online Publication,* ISBN (13) 978-963-454-057-1;

[2] Bellus Z., Fenyvesi L., (2016), *Fodder Production Procedures and Equipment, (A takarmánygyártás eljárásai és berendezései)*, year LVII, nr.2, pp 30-33, Hungary Agricultural Engineering, NAIK MGI, Gödöllő/Hungary;

[3] Caba I., (2006), *Research regarding the improvement of the constructive and functional parameters of the working organs of the self-loading machines of tight and transported fibrous fodder*, Brumar Publishing House, Timişoara / Romania, ISBN (13) 978-976-602-233-3;

[4] Ciocârdia C., (1999), *Basis of experimental research in machine building technology; (Bazele cercetării experimentale în tehnologia construcţiilor de maşini)*, Technique and Pedagogical Pub. House Bucharest /Romania;

[5] Csulak A., Stoica A., (1968), *Contributions to the study of cutting machines with straight drum and knives; (Contribuţii la studiul aparatelor de tocare cu tobă şi cuţite drepte),* Studies and Research of Agricultural Mechanics, Scientific publication, Bucharest/Romania;

[6] Dănilă I., (1981), *Contributions to the analysis of the working process of two-knife cutters (Contribuţii la analiza procesului de lucru al aparatelor de tăiere cu două cuţite),* Scientific publication I. P. Timişoara/Romania*;*

[7] Dutton A., Mines R., (2002), *Analysis of the Hopkinson presure bar loaded instrumeted Charpy test using an inertial modelling tehnique*, A. S. T. M., Philadelphia/USA;

[8] Gainov N.S., (1985), *Determination of elasticity properties of agricultural plants (Determinarea proprietăţilor de elasticitate a plantelor agricole)*, Meh. Ielek. Sot. Sel. P. H. nr.6, Moskow/Russia;

[9] Krasznicsenko A., (1965), *Manual of the of agricultural machinery manufacturer; (Mezogazdasagi gepszerkesztok kezikonyve),* (translation from Russian), Akademiai Publishing House, Budapest /Hungary*;*

[10] Letoşnev M., (1969), *Agricultural machinery, (Maşini agricole),* Agrosilvică P. H. Bucharest/Romania;

[11] Neculăiasa V., Dănilă I., (1995), *Working processes and agricultural machinery for harvesting, (Procese de lucru şi maşini agricole de recoltat)*, A92 Publishing House Iaşi/Romania;

[12] Nosov V., (1988), Researching the working process of thick stem plants (Cercetarea procesului de tăiere a tulpinelor groase), *Traktor i selhozmasinie nr.9. Publishing House, Moskow/Russia*;

[13] Szendro P., (2000), *The examination of the process of chopping, based on the analysis of the slag length distribution (Apritasi folyamat vizsgalata, a szecskahosszusag eloszlasanak elemzese alapjan*), Szent Istvan Agricultural University Publishing House, Godollo/Hungary;

[14] Truşculescu M., (2016), *Study materials. Analyzes and researches. (Studiul materialelor. Analize şi cercetări)*, Litografia Publishing House U. P. Timişoara / Romania.

[15] Zaman A., Sagar M. (2018), *Cutting Edge Technology for Agricultural Sustainability*, New India Publishing Agency- NIPA/India, ISBN-(13) 978-938-797-328-2.