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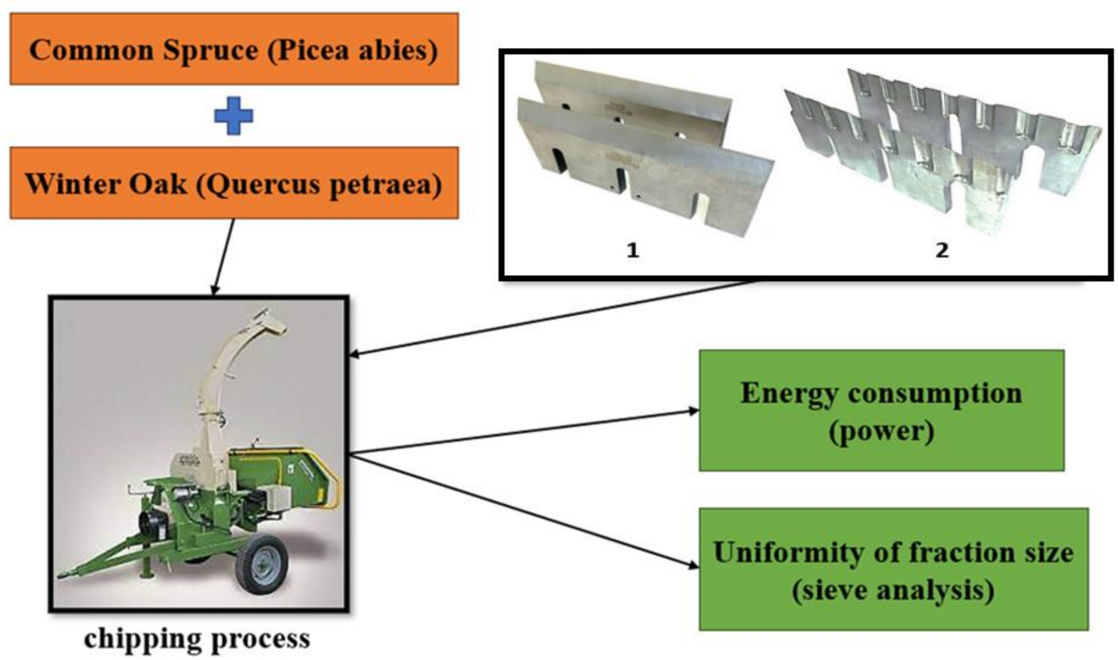
GRAPHICAL ABSTRACT



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The paper is focused on the research of chipper knives with a straight and modified cutting edge in order to determine the energy consumption of the chipping process and the uniformity of the size of the fractions of the designed chipper knife for the production of dimensionally uniform chips. The research took place on two different tree species where the representative of the coniferous tree was the common spruce (*Picea abies*) and the deciduous tree was the winter oak (*Quercus petraea*). The research took place on a PTO-powered (power take off) disc chipping machine where it was not modified for research purposes. The results showed that a knife with a modified cutting edge is higher in terms of energy consumption than chipper knives with a straight cutting edge. From the evaluation of the sieve analysis for a chipper knife with a modified cutting edge, the energy chip of uniform granulometric composition is a homogeneous bulk material.

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Keywords: Chipper knives; Modified cutting edge; Small-sized chips; Energy consumption

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INTRODUCTION

The generation of energy from biomass plays an important role in current international strategies to mitigate climate change and to enhance energy security (Kühmaier and Erber 2018). Wood is widely regarded as a suitable fuel as a natural renewable resource. Wood has been used since time immemorial as a source of heat, and as long as there is vegetation on Earth, this possibility will continue to exist. The global forest cover is listed as 4,058,931,000 ha (Global Forest Resources Assessment 2020). The forest economy is the main source of dendromass (wood products) in the Slovak Republic. Forest cover, as a percentage of the area of forest land in the total area of the Slovak Republic (4.903 million ha, including water areas), was 41.3% in 2020. Deliveries of forest fuel chips decreased by 35 thousand tons in the Slovak Republic. This decrease in supply in the Slovak republic is mainly due to the stagnation of domestic consumption. Also there is less competitiveness of forest fuel wood chips against wood chips produced in the wood processing and non-forest land sectors due to higher production costs as well as the change in the structure of wood fuel consumption in favour of the wood processing industry where they use their own wood residues (Green Report 2021). The pursuit of improved processing technology – with an emphasis on minimizing ecological harm – has led to the development of chipping machines that process wood waste. The advantage of forest waste is its low cost and high availability (Bożym *et al*. 2021). Crushing and chipping wood waste is regarded as being economically advantageous, as well as environmentally (Gendek *et al*. 2018). Waste material converted into wood chips can be further used as a substitute for wood fuel. The chips also can be used in the wood industry for production of fiberboards and chipboards, and in the chemical wood processing (for example cellulose production), or for composting. In order for the production process to be as efficient, high-quality, and economical as possible, the most suitable machines and production technologies must be selected. Today, chipping wood on chipping machines is one of the most common ways of disintegrating residual wood worldwide. This is one of the reasons why the demand for chipping machines is very high today and their development is advancing rapidly.

An important aspect of chipping machines is the quality of the chips. Therefore, research and development are moving in this direction as well. The quality of the chips as well as the chipper knives, is closely linked to the quality of the chips. In terms of performance, the machine always works at maximum power, such that it can do the most work, *i.e.*, cut the most wood material. There is also high consumption of electricity or fuel (depending on the drive of the chipping machine) at high power. Fuel consumption is closely linked to the power requirements of the adapter as well as the operator supplying the wood to the gutter. In the event of incorrect supply, fuel consumption may also change (Spinelli *et al*. 2011). Spinelli *et al*. (2009; 2011) state that fuel consumption depends on the type of wood and increases with increasing diameter of the chipped wood. The performance of the machine is also significantly affected by the downtime when manually feeding the wood into the gutter. Spinneli and Visser (2009) claim that these issues can affect up to 50% of working time. Specific working conditions and ongoing gathering of the material for chipping from standing trees have an impact on performance and productivity (Kormanek 2020). According to Krilek and Kováč (2013), the basic factors that affect the chipping process, in addition to the chipping machine's technical parameters, are the type, moisture, and quality of wood, gutter and cutting edge angle, contact angle, cutting speed, exhaust pipe, cut-out length, and feeding rate of wood substance during chipping. The mentioned factors influencing the chipping process can be summarized in two areas, namely the parameters of the chipping process and the input raw material. According to Warguła *et al*. (2022), current research shows that the efficiency of chipping machines is affected by the size of individual parts of the chipped tree (trunk or branches), wood species (soft or hard wood), wood moisture (fresh or dry), wood condition (fresh, stored, dried or frozen), cutting edge wear, sieve size adjustment or type of cutting mechanism. Research shows that wear and tear on the cutting edge increases the energy requirements of wood disintegration. The size of the sieve used for segregation and chip separation has a similar effect on wood size reduction processes. Sieves with smaller openings contribute to the smaller chip size, leading to a more energy-efficient wood disintegration process.

Currently produced chipping knives have a straight cutting edge. A possible solution would be to modify the shape of the cutting edge or the surface treatment of the tool. By such means it may be possible to produce high-quality wood chips, which we can use as fuel for very simple combustion boilers or boilers designed to burn pellets.

The aim of the work was to implement an experimental evaluation of a dendromass chipping machine with chipper knives both with a straight and with a modified cutting edge (Krilek 2013), to determine the energy intensity of the chipping process and uniformity of fractions of the designed chipper knife for production of dimensionally uniform chips. Based on the designed and manufactured chipper knife, an experimental measurement was performed to determine the size and course of torque (speed and power) when changing the cutting edge of the chipper knife, followed by obtaining the same size (least different fractions) and high-quality chips. A Pezzolato chipping machine was used for the experimental measurement, where the Zetor 5341 was used as the drive unit, the description of which is given in the papers by Krilek *et al*. (2009) and Kováč *et al*. (2011). The chipping machine was not modified for practical measurement. The feed of the input material was 0.2 m.s^{-1}, the distance and the exchange of knives were set according to the manual. The cutting disc speed was approximately 1100 rpm. The distance of the chipping knife was set to 10 mm for both types of chipping knives (Fig. 1). The distance was determined based on the pellet sizes for the pellet boilers.

EXPERIMENTAL

Two species of wood plants were chosen for the experiment: the selected representative of coniferous and soft wood was common spruce (*Picea abies*, density 430 kg.m^{-3}), and the selected representative of deciduous and hard wood was winter oak (*Quercus petraea*, density 765 kg.m^{-3}). One type of assortment was used for the measurement, *i.e*., log at the diameter of 0.20 m and at the length of 2 m. The chipping samples were freshly cut from pre-harvesting of wood. The moisture content of the wood was determined by the weight method, where the moisture content was above the fiber saturation point (above 30%). At the collection point, wood chips produced by the two types of chipping knives were stored in two separate piles. Moisture content was determined by collecting six samples of approximately 400 g from each heap.

The measurement itself was performed by recording (sampling rate of 100 Hz) the torque and speed of the PTO shaft using the HBM T10 FN sensor with output to the SPIDER 8 converter and recorded on the computer's hard drive using the Conmes Spider program.

Table 1. Technical Parameters of the Mower Pezzolato H 780/200

Item	Unit	Specification
Hopper opening	mm	860x630
Disc diameter	mm	780
Number of knives	pcs	3
Max. the number of revolutions of the disc	min^{-1}	1000
Chip length	mm	6-18
Diameter of the sliding rollers	mm	200
Max. hole	mm	230
Required power	kW	30
Shaft speed	min^{-1}	540
Engine power	kW	37
Hourly output of the machine	$m^3.h^{-1}$	10-15

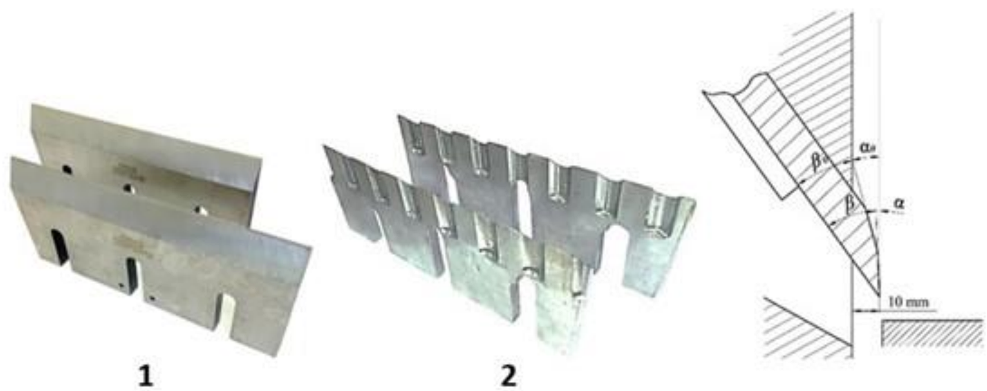

Fig. 1. Chipper knives; 1 – with a straight cutting edge, 2 – with a modified cutting edge

Chipping knives (Fig. 1, part 1), which were the subject of the experiment, are tools used for ordinary wood processing. Chipping knives were purchased from the manufacturer PILANA Group a.s., Hulín (CZ). According to information from the manufacturer, the knives are made of the material X48CrMoV8-1-1 (1.260). For the research, chipping knives with a bent back were used, which is defined by the angles β and β_0 (Fig. 1), where the angles of the cutting wedge were β = 35° and β_0= 25 °.

The basic particle size analysis of the energy chips was performed by sieving analysis. When cutting with straight and modified knives, the size of the fraction of chips produced in spruce and oak was assumed to be in the range of 1 to 10 mm. For this reason, specific sieves with hole sizes were used: 35, 10, 5, 2, 1, 0.5 mm, and bottom for t = 5 min on an automatic vibrating sieving machine AS 200 from RETSCH. The weights of the sieve fractions were determined on RADWAG WPS 510/c/2 laboratory scales with a weighing accuracy of 0.001 g. Analyses of energy chip granularity are presented in the table form as well as in the form of distribution curves. Sampling took place in the same way as when determining moisture.

RESULTS AND DISCUSSION

Evaluation of Energy Consumption

For the evaluation of Energy Consumption, we used the power, which is calculated using the relationship from the measured revolutions and the torque in Eq 1,

$$P = \frac{M \cdot n}{9554} \quad [kW] \tag{1}$$

where P is the resulting power input (kW), M is the measured torque (Nm), and n is the measured revolutions (min^{-1}).

For each variation of the levels of the two factors A and B (2 wood species, 2 knives = 4 variations), a representative range of samples of the investigated physical quantity (P) was created. For the physical power input, the results were statistically evaluated by two-factor analysis of variance. The mathematical model of two-factor analysis of variance has the form (Eq. 2),

$$x_{ijp} = \mu + a_i + b_j + c_{ij} + e_{ijp} \tag{2}$$

where μ is virtual total mean of all levels of the two examined factors, a_i is single effect of i-th level of examined factor A, b_j is single effect of j-th level of examined factor B, c_{ij} is effect of interaction between i-th level of examined factor A and j-th level of examined factor B and e_{ijp} is error (random deviation) of p-th repeated measurement on i-th level of the factor A and j-th level of the factor B, i is wood type (spruce, oak), and j is type of chipper knife (straight, modified).

The main objective of two-factor ANOVA experiment is to determine significance of influence of two factors A, B, and their interaction on values of studied property X. In order to solve these three questions, there are three null hypotheses formulated (Eq. 2, Eq. 3, and Eq. 4) (Schmidtová and Vacek 2013).

For factor A (factor A singly do not influence on values of X):

$$H_{0A}: a_1 = a_2 \dots = a_i = \cdots = a_k = 0 \tag{3}$$

For factor B (factor B singly do not influence on values of X):

$$H_{0B}: b_1 = b_2 \dots = b_j = \cdots = b_l = 0 \tag{4}$$

For interaction of two factors A, B (interaction between two factors A, B is not present in their influence on values of X):

$$H_{0AB}: c_{11} = \cdots = c_{k1} = \cdots = c_{l1} = \cdots = c_{kl} = 0 \tag{5}$$

Table 2. Basic Table of Two-Factor Analysis of Power Variance P per Wood and Type of Chipper Knife

Monitored factor	Sum of Squares	Degree of Freedom	Sample variance	Fisher F test	Sign. level (p-value)
Intercept	595146.207	1	595146.207	18929.320	0.000
Type of wood	29764.5261	1	29764.5261	946.695	0.000
Type of chipper knife	8028.95975	1	8028.95975	255.370	0.000

Type of wood*type of chipper knife	6840.68701	1	6840.68701	217.576	0.000
Error	9935.1799	316	31.4404427		

The first row in Table 2 indicates the probability that the total average power value is zero. The total average value of P for all wood and types of knives is zero, H_0 applies.

Similarly, it can be argued with 100% reliability that there is also a significant difference between the wood and the type of chipper knives. Also, all two-factor interactions are statistically significant.

A wood type and then a knife model had the most statistically significant impact of the two monitored factors.

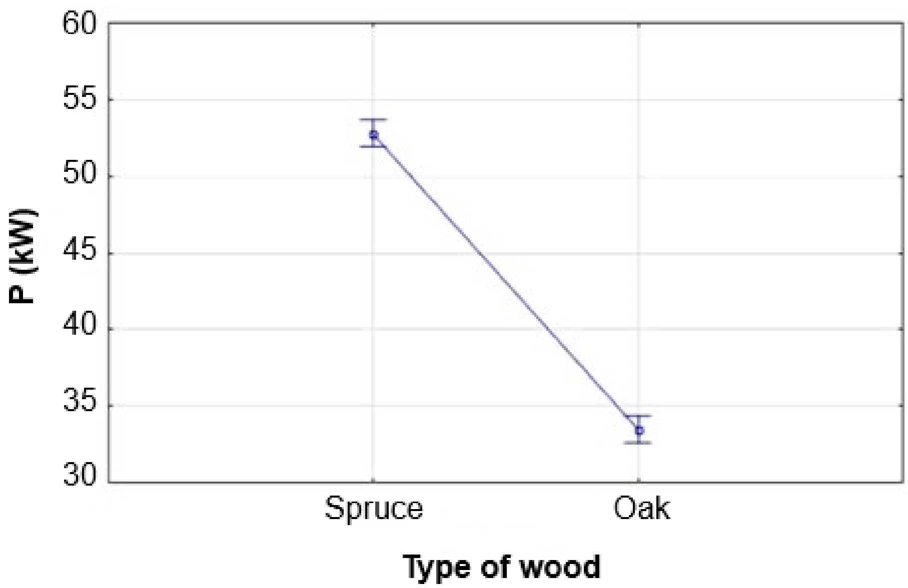

Fig. 2. Influence of the wood type on the power value

The wood-power diagram in Fig. 2 shows that the power in spruce measurement was statistically significantly higher than in oak measurement. This means that the sum of all power averages from the measurements was higher for spruce measurement than for oak one.

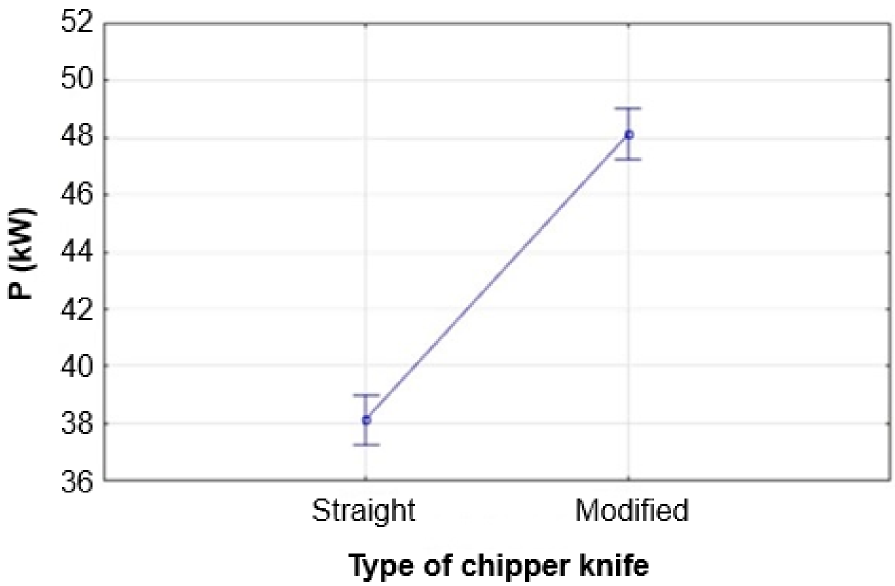

Fig. 3. Influence of the chipper knife model on the power value

It is clear from the diagram shown in Fig. 3 that the interaction of the modified knives was higher in terms of power input than with the knives with a straight cutting edge. This complexity is attributable mainly to the design of the chipper knife.

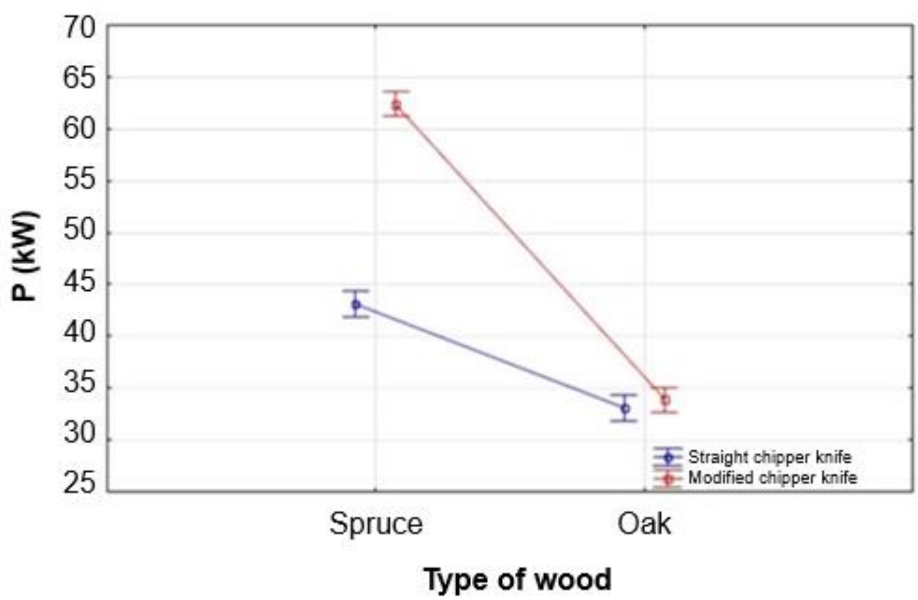

Fig. 4. Influence of the wood type and chipper knife model on power value

It is clear from Fig. 4 that the interaction of the knives with modified cutting edge was higher in power input than in the case of conventional knives with a straight cutting edge. This complexity is caused mainly by the design of the chipper knife. The knives did not prove to be significantly unsuitable in the chipping process of oak wood, which was also confirmed by Duncan’s test for power input (Table 3). The results show the difference in power averages for spruce wood. Effects were mainly due to the cutting time (longer time) of the assortment, where the amount of measured data for one assortment was higher and thus reduced the average power input P. This also implies that the wood was problematic with high demands on the chipping process, which was caused mainly by the structure of the wood and its properties above the point of fiber saturation where coniferous trees were characterized by high toughness. In the case of knives with modified cutting edge, it is necessary to solve the shape of the chipper knife as well as the geometry because the interaction of knives with modified cutting edge was considerably high in terms of power input. With oak, there was no change in input power during the chopping process because it had less resistance to the penetration of the tool than when chipping spruce.

The average power values, such as energy means (tractor), were not suitable for the given type of the chipping machine, as the power input for spruce wood for knives with modified cutting edge was 62.6 kW. This fact can be mainly attributed to a change in the length of the cutting edge and a change in the cutting model.

Table 3. Duncan´s Test for Power Value P

Type of wood	Type of the chipper knife	{1} 43.138	{2} 62.403	{3} 33.096	{4} 33.867
Spruce	1		0.000009	0.000011	0.000009
Spruce	2	0.000009		0.000003	0.000011
Oak	1	0.000011	0.000003		0.384509
Oak	2	0.000009	0.000011	0.384509	

The influence of knives and wood is included among the random factors; therefore, the confidence intervals overlap (Fig. 4). However, as shown in Table 3, the two-factor analysis of variance, the impact of the type of chipper knife in oak was statistically significant.

Evaluation of Sieve Analysis

The first point of the evaluation was to express the impact of the change in the shape of the cutting edge on the size and impurities of the particles. When the modified chipper knives with modified cutting edge were used, the chips were uniform over the entire length of the cut log and the fractions did not change, which was not the case when using conventional chipper knives with straight cutting edge.

The results of the sieve analysis of the energy wood chip of oak and spruce wood produced by the chipping machine showed that the wood chip consisted mainly of fractions with dimensions below 10 mm (Tables 4 and 5). The share of the coarser fractions with dimensions of greater than 35 mm represented 0% for both chipped wood types.

Table 4. Evaluation of Sieve Analysis for Spruce Wood Chips (Average Values)

Sieve size (mm)	Sieve weight (g)	Sample weight (g)		Sample share (%)	
		Knives 1	Knives 2	Knives 1	Knives 2
35 <	413.15	0	0	0	0
10.0 - 35.0	436.07	38.12	18.62	9.35	4.75
5.0 - 10.0	404.91	148	64.81	36.32	16.52
2.0 - 5.0	338.18	162.8	250.42	39.95	63.82
1.0 - 2.0	337.49	48.17	43.39	11.82	11.06
0.5 - 1.0	309.11	8.2	12.38	2.01	3.16
< 0.5	360.21	2.21	2.77	0.54	0.71
Total weight of the wood chips		407.5	392.39	100.00	100.00

Table 5. Evaluation of Sieve Analysis for Oak Wood Chips (Average Values)

Sieve size (mm)	Sieve weight (g)	Sample weight (g)		Sample share (%)	
		Knives 1	Knives 2	Knives 1	Knives 2
35 <	413.15	0	0	0	0
10.0 - 35.0	436.07	14.12	1.06	4.55	0.28
5.0 - 10.0	404.91	118.01	17.12	38.06	4.45
2.0 - 5.0	338.18	139.48	254.32	44.98	66.04
1.0 - 2.0	337.49	29.45	79.03	9.49	20.52
0.5 - 1.0	309.11	6.1	25.06	1.97	6.51
< 0.5	360.21	2.94	8.49	0.95	2.20
Total weight of the wood chips		310.10	385.08	100.00	100.00

The wood chip of a given particle size distribution is a homogeneous bulk material suitable also as an alternative fuel for pellet boilers. The results confirmed that the given modification of the chipper knives with modified cutting edge is suitable for production of small-sized chips that are suitable for combustion in pellet boilers or to produce pellets. The sieve analysis values are represented by the following graphs (Figs. 5 and 6).

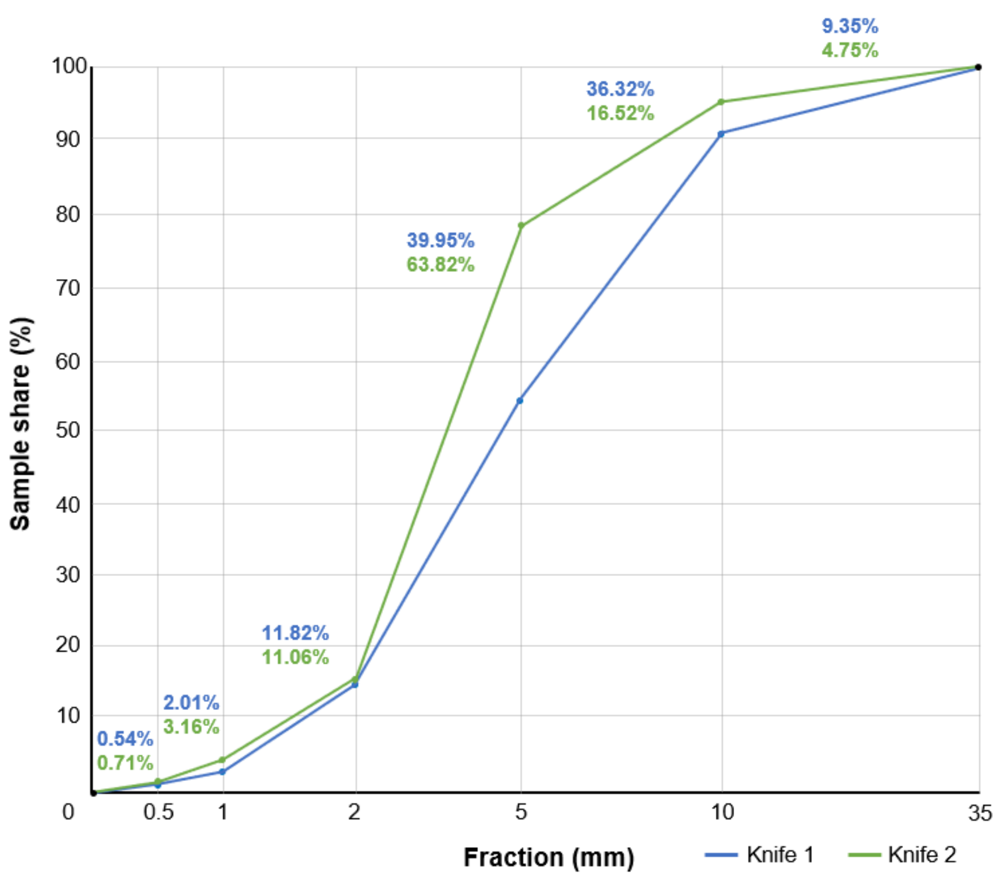

Fig. 5. Percentage representation of wood chip fractions from spruce

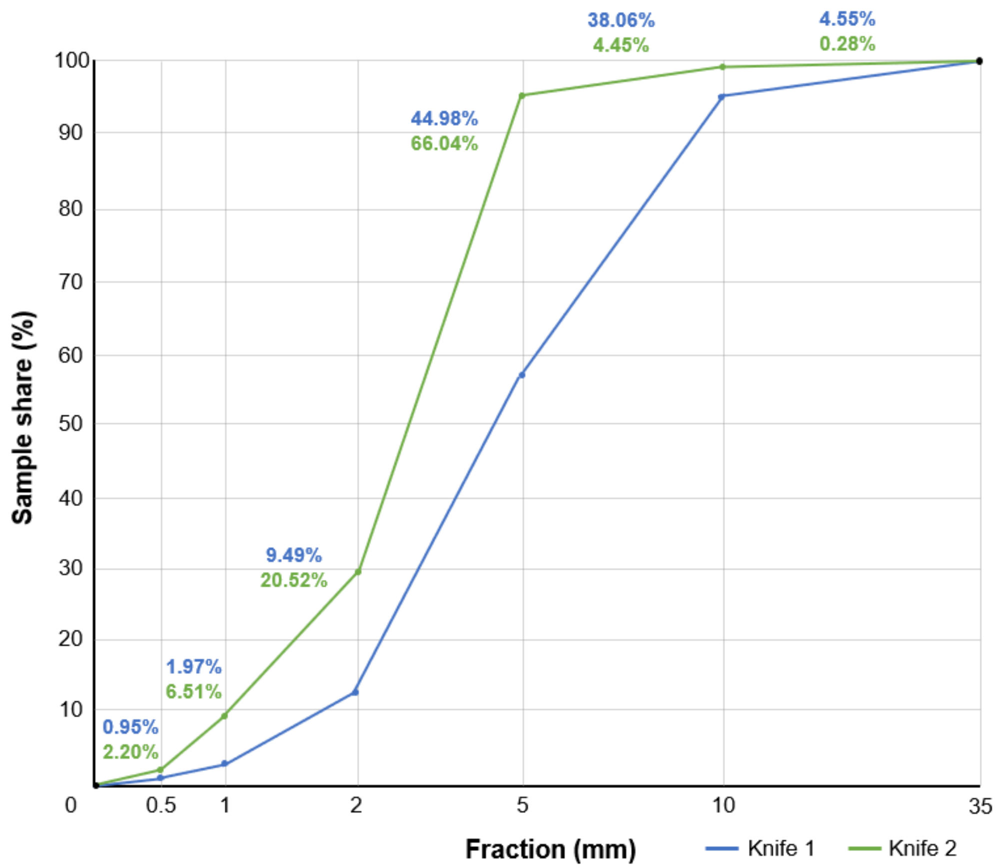

Fig. 6. Percentage representation of wood chip fractions from oak

From the results of the sieve analysis of the sample obtained from spruce wood chips, it can be concluded that the fraction in the range from 2.0 to 5.0 mm had the largest percentage representation in the sample for both types of knives. With knives with straight cutting edge, the percentage fraction was 40.0% and with knife with modified cutting edge 63.8%. Interestingly, the percentage fraction between 5.0 and 10.0 mm for knife with straight cutting edge was only 3.63% lower, while for knives with modified cutting edge it was 47.3%. The percentage fractions between 0 and 2.0 mm were comparable for both types of knives. The fraction in the range from 10.0 to 35.0 mm represented a percentage of less than 10% for both types of knives. Knives with a straight cutting edge produced chips of fraction 1-10 mm in a percentage range of 88.1% and knives with a modified cutting edge produced chips of fraction 1-10 mm in a percentage range of 91.4%.

From the results of the sieve analysis of the sample obtained from oak wood chips, it can be concluded that the fraction in the range from 2.0 to 5.0 mm had the largest percentage representation in the sample for both types of knives. With knives with straight cutting edge, the percentage fraction was 45.0% and with knives with modified cutting edge 66.0%. Interestingly, the percentage fraction between 5.0 and 10.0 mm for knife with straight cutting edge was 6.9% lower, while for knives with modified cutting edge it was as much as 61.6%. The percentage fraction between 0.5 and 1.0 mm was 4.5% lower with knives with straight cutting edge than with knives with modified cutting edge, and the fraction between 1.0 and 2.0 mm was 11.0% lower with knives with straight cutting edge as with knives with modified cutting edge. The fraction in the range from 10.0 to 35.0 mm represented a percentage of less than 5% for both types of knives, in the case of knives with modified cutting edge only 0.3%. Knives with a straight cutting edge produced chips of fraction 1-10 mm in a percentage range of 92.5% and knives with a modified cutting edge produced chips of fraction 1-10 mm in a percentage range of 91.0%.

Based on the results, it can be assessed that knives with a modified cutting edge produced chips of the 2-5 mm fraction in a percentage of more than 60% in both spruce and oak, while knives with a straight cutting edge produced chips of a fraction of 2-5 mm in a percentage of more as 40% for both spruce and oak. In the production of wood composites, chips of fraction 0.25-4 mm are most often used, which means that knives with a modified cutting edge would be more suitable for the production of wood composites. If a larger fraction is needed, for example 5-10 mm, according to the results, knives with a straight cutting edge are more suitable.

Experimental measurements with the designed chipper knives with modified cutting edge were performed on two types of wood. Power parameters were determined depending on the type of wood and the shape of the cutting edge of the chipper knife, where the aim was to determine the impact of the change of the cutting edge of the chipper knife on the chipping process. A partial result of the experiment was the confirmation of the suitability of the proposed solution of the chipper knife.

In the examined case, it was found on the sample that the material used for production of chipper knives was suitable for the construction of tools (Krilek *et al*. 2021). Based on the above, the issue of tools for the production and processing of wood provides many opportunities for further improvement and development using new knowledge as well as materials that were primarily intended for other purposes. This will enable the improvement of the tool properties and machines regarding to economic and ergonomic indicators.

The quality of fraction and chip sizes have important implications for pulp properties, pulp production and pulp quality, especially sulphate pulping. Therefore, industrial factories try to produce homogeneous chips of shape and size. One of the parameters that is crucial for production of wood chips in adequate quality is the length of the wood chips. Chip length is an important parameter for determining chip thickness (Hartler and Stade 1979; Uhmeier 1995; Twaddle 1997). The chip thickness is given by the chip length ratio, usually ranging from 1:4 to 1:10 (Hartler and Stade 1979). The energy efficiency of wood chip combustion is significantly affected by their quality parameters, i.e., the distribution of size fractions, as well as the ash and moisture content. In general, wood chips should be characterized by a low proportion of fine particles (Moskalik and Gendek 2019).

The mentioned shortcomings of the size and quality of the chip are largely eliminated by the proposed solution of the cutting edge of the chipper knife. The basis lies in the shape of the cutting edge, *i.e.*, that there are grooves on the back of the chipper knife that change the shape and size of the chips. The grooves are formed in a semicircular shape determined by technical parameters, namely spacing, radius, depth, and length of the groove. The grooves are evenly spaced along the entire length of the cutting edge of the knives so that the first groove is in the axis of the groove of the first chipper knife and on the second chipper knife it is in the spacing axis. Width – the distance between the grooves – is the same as the width of the groove. The solution is suitable for disc and drum chipping machines.

Within a particular tree species, there are different factors affecting chip length, such as wood feed angle (ε), cutting edge angle (β), knife back angle (α), and cutting blade speed or chipper knife speed (the most important parameter), which can be adjusted so that there is an optimal relationship between the length and thickness of the chips. Such uniformity of the chip thickness depends to a large extent on the precise setting (extension) of the chipper knives around the circumference of the chipper disc (Reczulski 2015).

From the power evaluation, the chipper knives with a modified cutting edge did not prove to be energetically better than the chipper knives with a straight cutting edge. This fact is mainly due to the shape of the grooves on the chipper knife, which extended the length of the cutting edge. The team of Spinelli *et al*. (2012), where a tubular knife is patented instead of chipper knives, also dealt with the idea of producing a small-sized homogeneous chips. From experimental measurements, they managed to reduce energy requirements compared to chipper knives with a straight cutting edge. In the evaluation of power input, the influence of wood proved to be statistically significant. Krilek *et al*. (2009; 2011; 2013; 2023), Spinelli *et al*. (2012), Papworth and Erickson (1966), Röser *et al*. (2012), and Mola-Yudego *et al*. (2015), argue that the influence of wood species on the chipping process has a great impact. The dendromass chipping process is affected by various operating parameters such as wood, assortment, speed, and chipper knife geometry (Uhmeier 1995; Twaddle 1997; Smith and Javid 1999; Hellström *et al*. 2008; Abdallah *et al*. 2011; Kováč *et al.* 2011; Spinelli *et al.* 2013). However, it should be noted that different wood fractions are produced to reduce the size of the wood (chipping), and it is known that a greater degree of fragmentation requires higher energy consumption (Warguła *et al*. 2022; Krilek *et al*. 2024). Choi *et al*. (2019) showed that doubling the size of the drum chipping machine produced (from 40 mm to 80 mm) was characterized by 30% increase in productivity. This means that the relationship is not directly proportional. The type of cutting mechanism must always be taken into consideration.

The analysis of the chip is intended to express the effect of the change in the shape of the cutting edge on the size and impurities of the particles. Based on the evaluation of the sieve analysis, it was found that the wood chip of the given particle size distribution is a homogeneous bulk material. Based on the achieved results, the design of the modified chipper knife is protected by a utility model at the Patent Office of the Slovak Republic (Krilek 2013). Similar results were obtained by Spinelli *et al*. (2012), where the chips were homogeneous without fractions, where they claim that slicing and not chipping occurs.

The proposed solution has several advantages. The first advantage of this solution is that by changing the technical parameters (width, radius, spacing) of the groove, it is possible to change the size and shape of the chip according to the need for chips. This means so that a set of knives according to the chip size would suffice. Another advantage of the solution is that the cutting-edge adjustment can be solved with all commonly produced chipper knives, such that production costs are low. The third advantage of this solution is that a conventional sharpener for sharpening chipper knives is used for sharpening.

CONCLUSIONS

1. The resulting power values based on spruce measurements were higher than in the case of oak measurements. The output was approximately 53 kW for spruce and approximately 34 kW for oak. Interaction of the modified knives was higher in terms of power input than with the knives with a straight cutting edge. This complexity was mainly a result of the design of the chipper knife. For the modified knife, the average power value was about 48 kW, and for the knife with a straight cutting edge, about

38 kW.

2. Through statistical evaluation, the effects on power that were evaluated in the chipping process were determined. Higher performance values were shown when chipping spruce. With knives, the performance was significantly higher when using a knife with a modified cutting edge, especially when chipping spruce.

3. Based on the evaluation of the sieve analysis, it was found that the wood chip of a given particle size distribution is a homogeneous bulk material, *i.e.*, the given modification of the chipper knives is suitable for the production of a homogeneous chip, and by changing the size of the cutting edge, it is possible to change the size of the chip. The results of the sieve analysis of the energy wood chip of oak and spruce wood produced by the chipping machine show that the wood chip consisted mainly of fractions with dimensions below 5 mm. It was 78.7% below 5 mm for spruce wood chips (Table 4) and 98.7% below 5 mm for oak wood chips (Table 5); the share of the coarser fraction with dimensions of 35 < mm represents 0% for both chipped wood types.

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