PAPERMAKING POTENTIAL OF NEW LINES OF POPLAR TREES

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Abstract

The scientific description is a part of broader study on papermaking potential of different market available papermaking fibrous materials. This study focuses on structural and tensile properties of paper obtained from pulps produced from new lines of poplar, which seems to be one of new emerging fibrous resources for paper industry. Papermaking potential of poplar (Populus tremula) is adopted as a benchmark for detailed investigation of pulp and paper properties.

Key words: *paper, pulp, poplar pulps, new lines of poplar, properties of paper*

The main factor in the further development of the paper industry is to ensure adequate resource base. Paper industry, like other industries, according to the existing formal and legal standards is guided by the principles of "sustainable development". According to this concept, paper industry should be incorporated into the constant cycle of change of the environment. This involves balancing growth and consumption of natural plant fiber material and a maximum reduction of consumption of raw materials and fuels. Since the primary natural source for paper is wood, pulp and paper industry is trying to the maximum extent possible to protect their resource base in the form of forests, as well as to increase yield of timber from plantations of fast-growing trees , etc. (Forsström, 2006) (Przybysz, 2014).

Currently in tropical and subtropical regions, there are already huge plantations of eucalyptus and acacia, where the annual increase in weight of wood per hectare is more than 20 m^3. In Europe, there are also undertaken intensive efforts towards the establishment of plantations for paper industry, among others, different varieties of poplars. These plantations due to worse climatic conditions show much lower efficiency, but the obtained timber is processed at existing pulp plants and converted to paper, which is used by the absorbent European market (EC Report, 2012) (Avo, 2009).

The study presents just a part of the results of research carried out under the research grant (N N309 706340, Examination of the chemical composition, morphology and the papermaking potential of fibers of new varieties of genetically modified poplar") for comparison of papermaking potential of pulp from poplar wood and papermaking cellulose pulps obtained from the basic varieties of wood used in Poland. This research is further continued within project PBS1/A8/16/2013 “Application of poplar lines characterized by increased biomass growth and improved chemical composition of wood for papermaking and energetic purposes” financially supported by The National Center for Research and Development in Poland.

RESEARCH GOAL

The aim of this paper is to compare the papermaking potential of pulps obtained from lines of poplar such as:

- ✓ Populus tremula,
- ✓ Populus trichocarpa and
- ✓ Populus Maximowiczii.

RESEARCH METHODOLOGY

Wood harvested from these varieties has been shredded manually into cubes with dimensions of approximately 8x16x25mm. The obtained material was further cooked by sulfate method in a laboratory digester under the conditions shown in table 1.

Wood species	Amount of dosed alkali A_{cz} [%]	Maximum temperature during digestion T_{max} [°C]	Effective alkali after digestion [g/dm^3]	Yield of pulp after digestion	Kappa number [-]
Populus tremula	19	160	2,61	57,9	24,2
	26	160	7,81	53,1	15,4
Populus trichocarpa	19	160	2,06	56,2	29,3
	26	160	6,77	51,8	15,7
Populus Maximowiczii	19	160	2,56	54	29
	26	160	9,98	49,5	18,1

Table 1. Digestion parameters of pulps obtained from different poplar lines

Individual pulps were refined in a PFI mill in standard conditions (load 3,4 kg), afterwards laboratory sheets of paper were formed in Rapid Koethen type device.

The following properties of obtained cellulose pulps were investigated:

- ✓ freeness,
- ✓ water retention value (WRV)
- ✓ average weighted fiber length,
- ✓ fines content.

The following properties of paper were investigated:

- ✓ density of paper,
- ✓ breaking length
- ✓ tear resistence.

RESULTS

The papermaking potential of pulp is dependent on properties of pulp and the conditions and degree of refining. During the refining process there is an increase in structural and tensile properties of the obtained paper and simultaneously increase in freeness takes place. For virgin pulps a standard freeness value is assumed to be 30°SR. Comparison of tensile and structural properties is performed at this value of freeness.

Refining process is a very energy-intensive one; therefore an important criterion for assessing properties of pulp is its susceptibility to refining. This parameter is defined as the specific energy required to refine pulp up to freeness of 30°SR. In the case of comparative studies relative relation of time so as to achieve freeness equal to 30°SR is investigated (Przybysz, 1975).

The figure 1 shows the course of changes in freeness of studied pulp as a function of refining time in PFI mill.

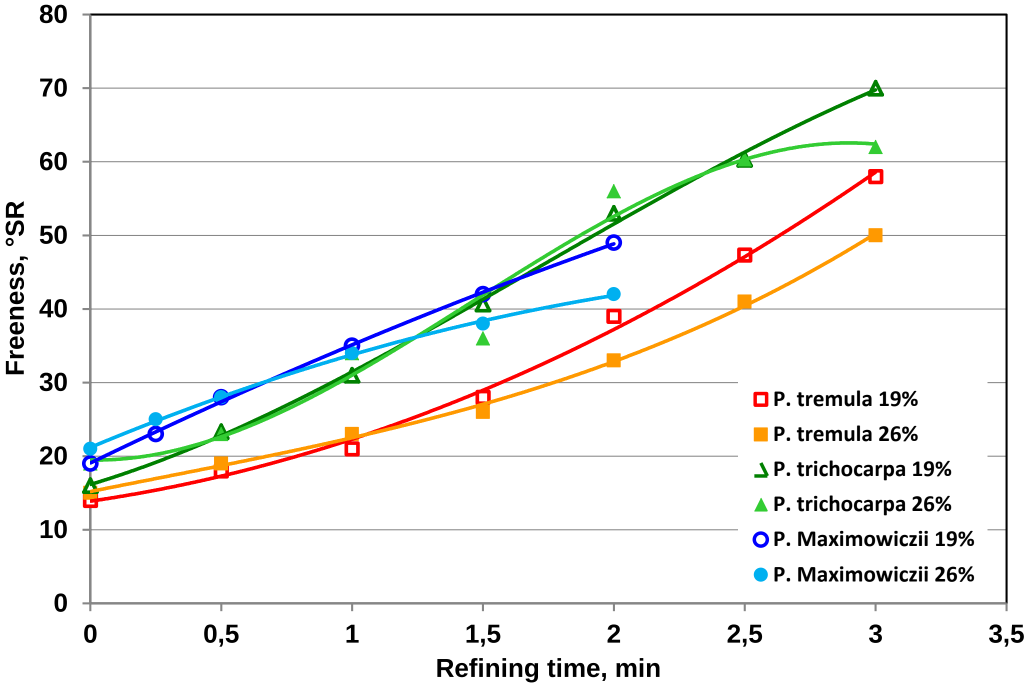

Figure 1. The course of changes in freeness of studied pulps as function of refining time in PFI mill

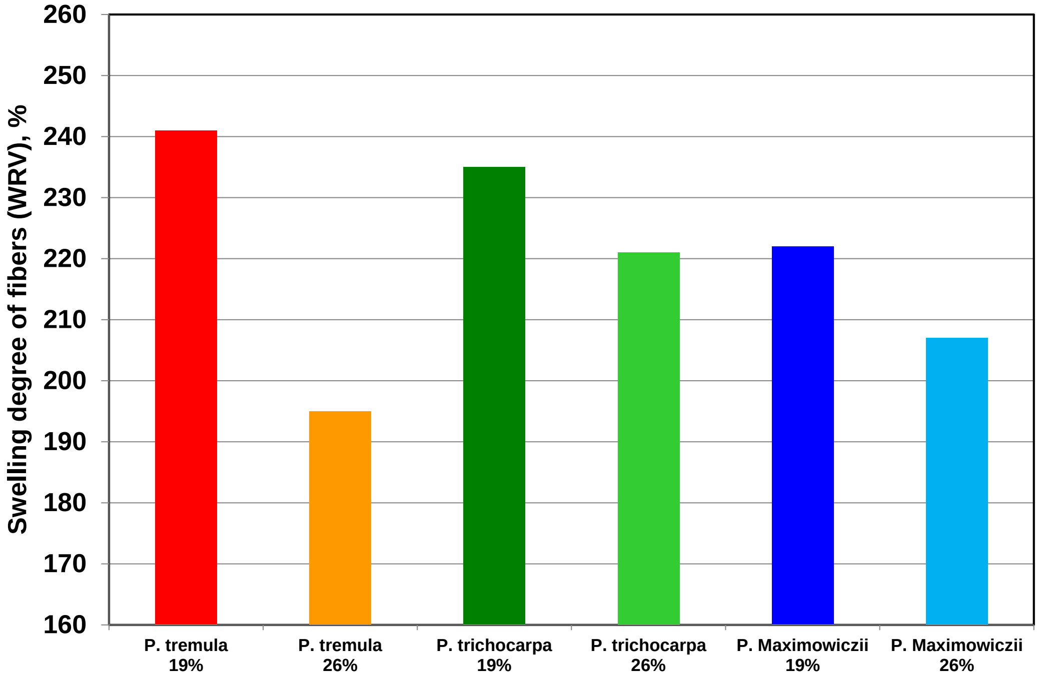

Figure 2. Comparison of the swelling degree of investigated pulps after refining to freeness of 30°SR

The figure above shows that poplar pulp obtained from Populus tremula reaches 30°SR freeness after 90 seconds of refining. In comparison, pulps produced from Populus trichocarpa and Populus Maximowiczii reach freeness equal to 30°SR within 60 seconds. This means that new poplar lines shows 30% higher susceptibility to refining.

Investigating basic pulp properties after refining to 30°SR freeness, it can be stated that fiber swelling degree expressed by WRV is in range from 195 to 241% (Figure 2). In the lower range of this interval there is pulp obtained from *Populus tremula* with alkali dosage of 26%. In contrast, the highest value of swelling degree is obtained for the pulp from the same line of poplar, however with alkali dosage of 19%. Pulps produced from new investigated pulps have shown WRV between these two extreme values. On the basis of these results it can be concluded that the investigated pulps, produced from new poplar lines, refined to the freeness of 30°SR were characterized by quite similar degree of swelling.

In contrast to the swelling degree, standard poplar pulps obtained from *Populus tremula* after refining to freeness of 30°SR was characterized by the weighted average fiber length of about 0,75 mm (Figure 3). These results are twice higher than for other pulps and indicates that for papermaking reasons new lines may not be as suitable as pulps from *Populus tremula*. It has to be underline that pulps from new line of poplar show average weighted fiber length just around 0,5 mm.

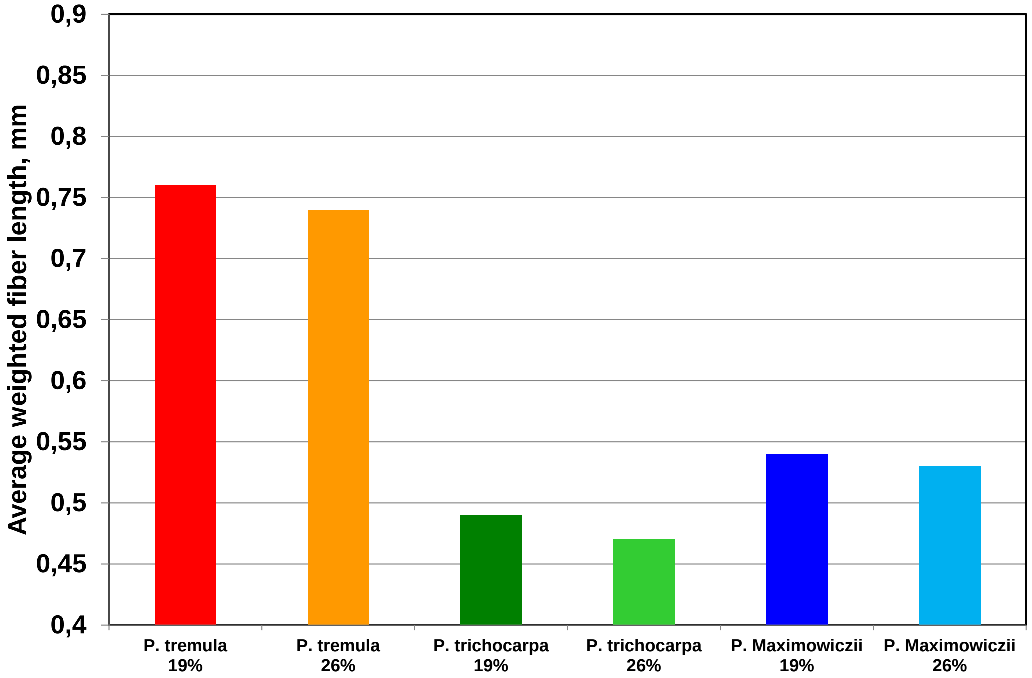

Figure 3. Comparison of the average weighted fiber length of pulps after refining to freeness of 30°SR

The fines fraction of the pulp is fraction permeating through a wire number 120 that corresponds to a particle size below 0.2 mm. In this case pulps produced from *Populus tremula*, shows typical fines content, and this value is very similar as for other hardwood pulps (10÷11,5%). However, fines content in two other investigated lines is around twice higher (Figure 4). Such significant fines content is an additional argument suggesting that papermaking potential of new lines of poplar may be not high enough to apply these pulps in industrial practice.

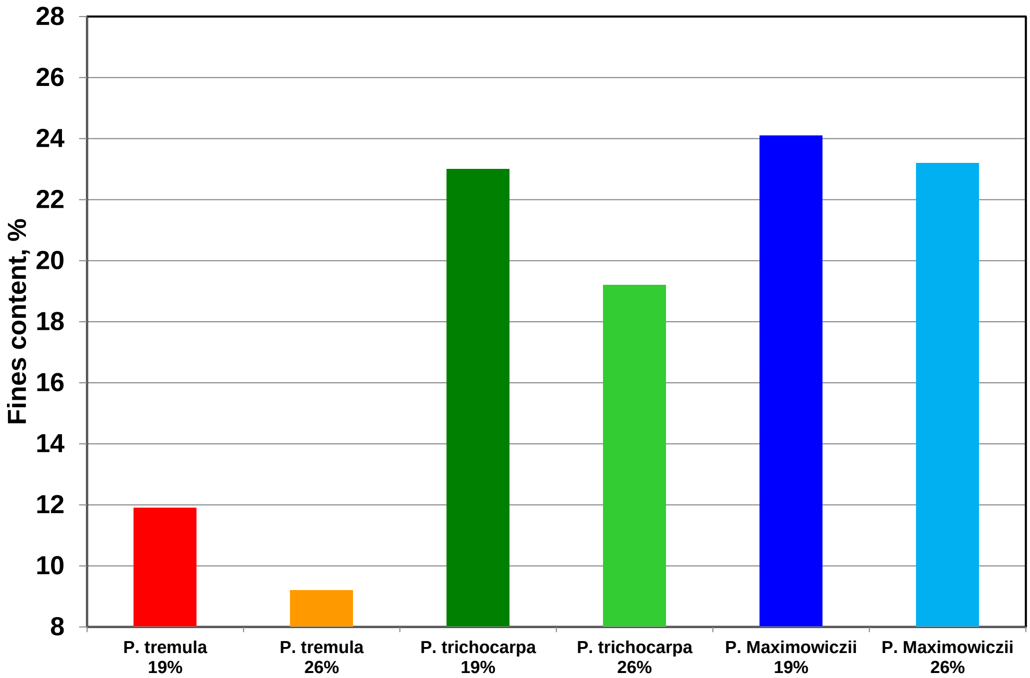

Figure 4. Comparison of the fines content in the investigated pulps after refining to freeness of 30°SR

Changes during refining of pulps have a significant impact on the properties of paper produced from these pulps.

Volumetric mass is one of fundamental structural properties that characterize the compactness of the structure of paper. The figure 5 shows a comparison of the volumetric mass of paper made from investigated pulps refined to freeness of 30°SR.

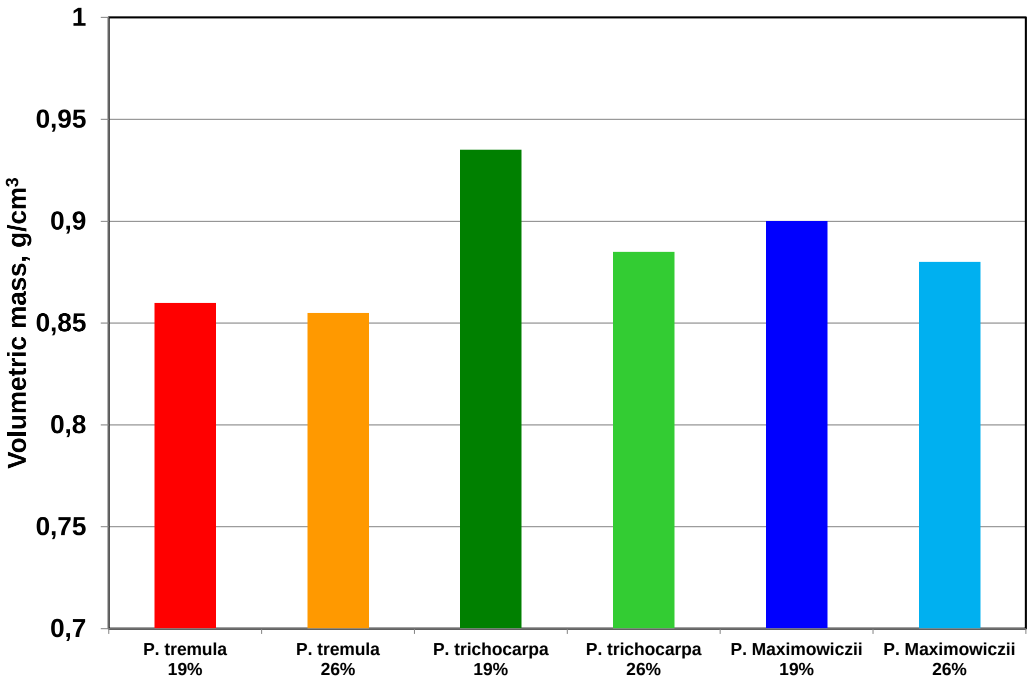

Figure 5. Comparison of the volumetric mass of the investigated paper obtained from pulp after refining to freeness of 30°SR

The degree of swelling of fibers (WRV) and the content of fines has the greatest impact on volumetric mass of paper. In investigated case, due to shorter fibers and higher fines content paper produced from new lines of populous show about 10÷15% higher volumetric mass. There is no significant difference between these pulps, however all these values are much higher in comparison with paper produced from other hardwood pulp.

Breaking length is one the basic static tensile properties of paper. The figure 6 shows a comparison of breaking length of paper made from investigated pulps after refining to freeness of 30°SR.

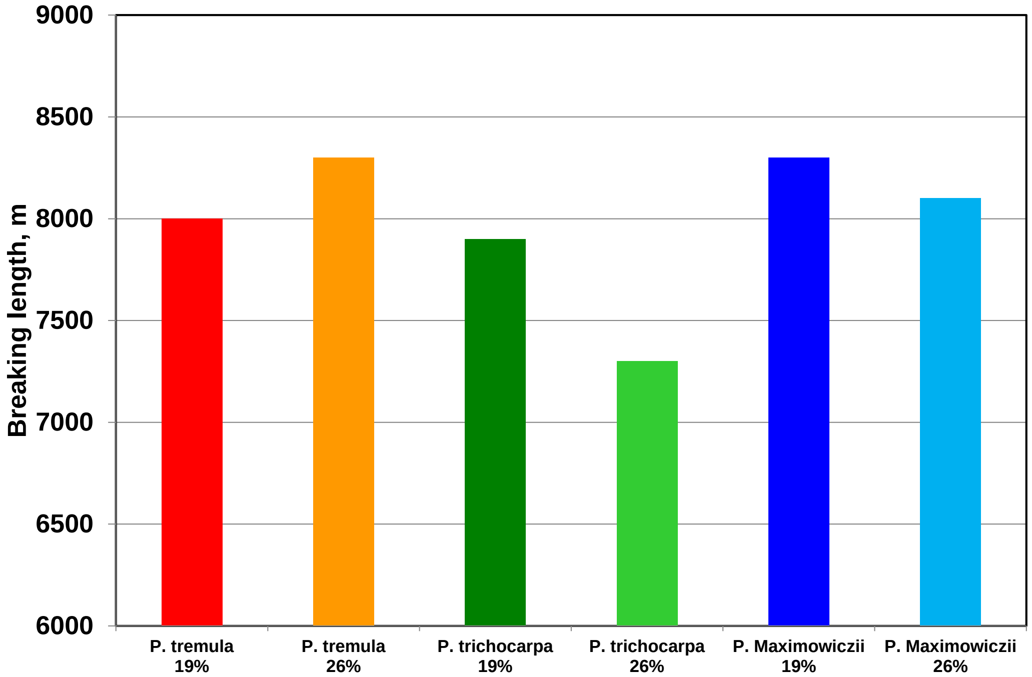

Figure 6. Comparison of breaking length of paper made from investigated pulps after refining to freeness of 30°SR

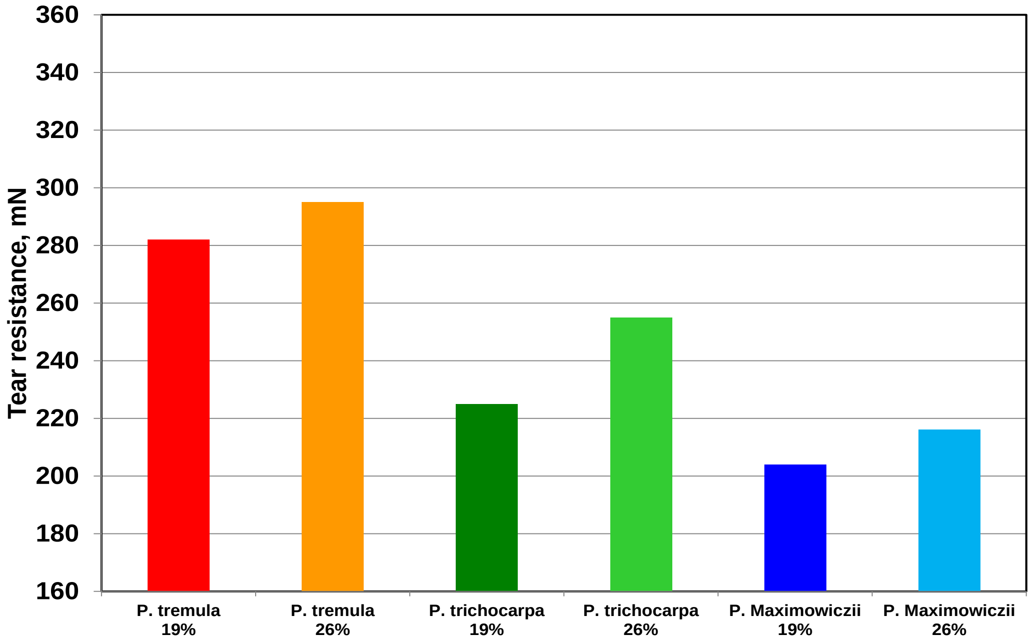

Figure 7. Comparison of tear resistance of paper made from investigated pulps after refining to freeness of 30°SR

Paper produced from any of the investigated pulps shows similar values of breaking length. The lowest value equal to 7300m is obtained for *Populus trichocarpa* digested with alkali dosage of 26%. There is no simple explanation for this situation, and probably such low value is caused by inaccuracy in braking length measurement.

Tear resistance is one of the fundamental dynamic tensile properties of paper. The figure 6 shows a comparison of tear resistance of paper obtained from investigated pulps after refining to freeness of 30°SR.

Average fiber length and density of paper (volumetric mass) has decisive impact on formation of tear resistance. Pulps from *Populus tremula* has shown higher average fiber length and similar volumetric mass in comparison with other investigated pulps. Hence it was predictable that tear resistance for this pulp should be also much higher. The data strictly confirm this assumption. Tear resistance for paper produced from new poplar lines is 30% lower than for "standard" poplar – *Populus tremula*.

An extremely important criterion for assessing the tensile properties of paper is relation between of static and dynamic tensile properties of paper. The figure 8 presents the tear resistance of paper produced from the investigated pulps in relation to breaking length of paper.

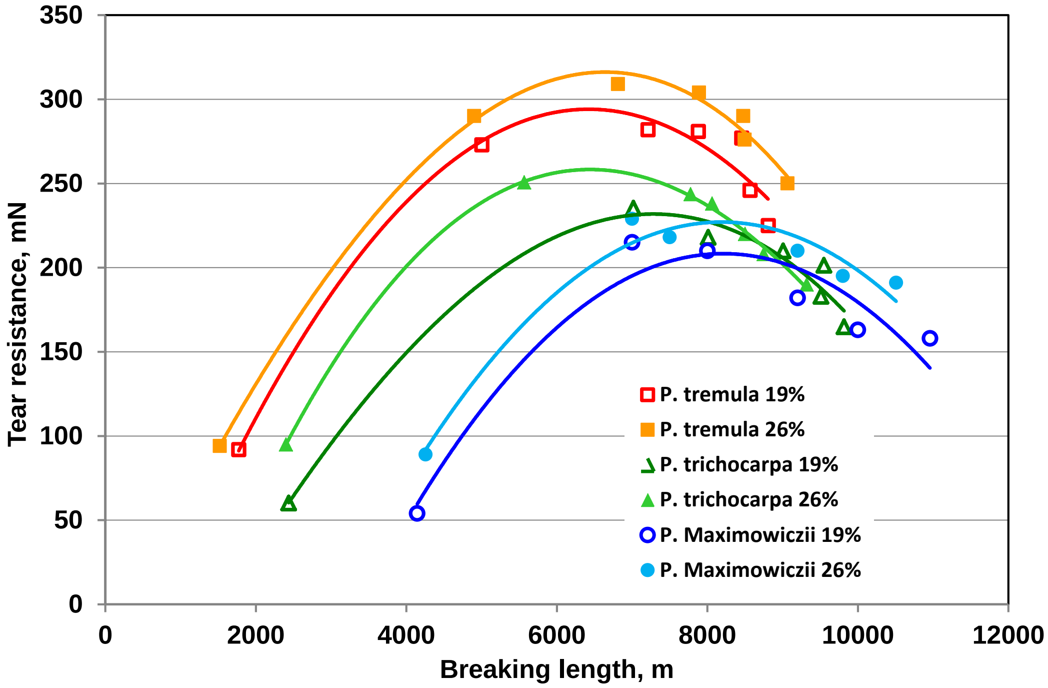

Figure 8. Changes in tear resistance as a function of breaking length for papers obtained from investigated pulps

The figure above shows that pulps produced from *Populus tremula* exhibits higher dynamic tensile properties (tear resistance) and lowest static tensile properties (breaking length). Contrary, paper produced from pulps obtained from *Populus Maximowiczii* presents much lower dynamic tensile properties, however static tensile properties are the highest from all investigated pulps.

CONCLUSION

The article compares the basic properties of pulps obtained from different lines of poplar investigated within governmentally funded research program. Characteristics of tested pulps after refining to freeness of 30°SR are also presented.

The following conclusions can be withdrawn on the basis of the performed research:

1. The average weighted fiber length for pulps produced from *Populus tremula* was about 0.75 mm and was more 50% higher of other pulps, which was about 0.5 mm.
2. The degree of swelling of fibers (WRV) contained in the range 195 ÷ 241 % and was generally not very diverse.
3. The fines content of investigated pulps ranged from 9 to 24%. In the case of pulps made from *Populus tremula* this value was much lower than for all other investigated pulps.
4. Volumetric mass of paper made from investigated pulps ranged from 0.86 ÷ 0.93 g/cm^3. It can be stated that there are no significant differences in this property between all investigated pulps.
5. Breaking length of paper pulp of poplar to lies within range 7300 up to 8300. These values are comparable with data of other hardwood pulps.
6. Tear resistance of paper pulps derived from all poplar pulps is very low (below 300mN). However the highest value of this parameter was obtained for *Populus tremula*.
7. Pulps from *Populus Maximowiczii* presents lower resistance to tearing and higher breaking length compared to *Populus tremula*. Nonetheless, these differences are not very significant.

The investigation of tensile properties of poplar paper is just a part of the general characteristics of the paper products. However, all new investigated poplar lines do not have sufficiently high tensile properties so as to be competitive with typical poplar pulps produced from *Populus tremula*. Therefore, new lines should be investigated to find fast-growing fibrous resource suitable for production of paper.

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