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Weight and green density of birch pulpwood harvested from the selected stands of Kaczory Forest Inspectorate

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Abstract: *Weight and green density of birch pulpwoodharvested from the selected stands of Kaczory Forest Inspectorate.* The paper presents the results of a pilot study which was organized in the Kaczory Forest Inspectorate area. The aim of the study was to define the actual weight and green density of birch pulpwood. According to the applied methodology, the actual weight of the material is the total weight of the timber, water contained in the timber, and bark weight. In total 19,91 m^3 of the material was obtained (log volume measured in the bark – without bark 17,67 m^3); the total weight of the material equaled 19 181,5 kg. As per 1 m^3 the actual weight of the material was approximately 963 kg. Wood material weight increases as the log volume increases, since the increase of the log volume is related to the increase of size. In this case we would look at the size of the diameter. The increase of weigh in relation to log volume without bark is even more dynamic. The increase of the material's weight is lower due to the increasing role of the bark. The timber of considerable weight and wide diameter is obtained from butt end of the trunk, in which thick layers of outer bark are located. The opposite was observed about density when the log volume increased. It appeared that the timberof smaller diameter could be of nearly double density than the thicker material of higher log volume. Probably, the influence of bark on this phenomenon is insignificant, it is rather related to selected timber properties which can be seen in the longitudinal trunk cross-section. Similar to other tree species, the weight of the birch tree timber in relation to the log volume decreases, i.e. we observe an increase in porosity. High density of the material obtained from the top part of the trunk is related to the moisture content.

Keywords: mass, green wood, green density, Betula sp.

INTRODUCTION

The actual weight of the freshly harvestedtimber is a total weight of bark, timber and water contained therein. Timber weight is mostly influenced by porosity and wood density which is directly related to the former parameter. Wagenführ (1996) states that birch wood density is around 850 kg/m^3, whereas Möttönen et al. (2004) states that for trees aged 27 – 35 it is around 452 kg/m^3. According to Stener et al. (2003), the value of the analyzed characteristic (for trees 15 years of age) was approximately 429 kg/m^3. Trendelenburg (1939) writes that in Austria birch wood density (q_0) is on average 671 kg/m^3, in Germany 628 kg/m^3, and in south Finland it is 600 kg/m^3. For the European white birch, the area of the cross-section around the circumference according to the analyses of Pavlovičs et al. (2006) is characterized by the density equaling 650 kg/m^3 (q_{12}). Dunham et al. (1999) compared birch timber of various ages, but also different growth dynamics expressed in theaverage width of the annual rings. Trees with low growth dynamics (130 years old) had higher density in comparison to quickly growing trees(48 years old). Despite similar breast height diameter, the density difference was statistically at 61 kg/m^3.

Bark, being the second constituent of the round timber weight, accounts for around 15% of the general log volume according to Prosiński (1984). Similar value, although for general over ground timber biomass, equaling from 11 to 13%, is provided by Niemistö (2013). Birch is a type of tree where the bark at the bottom part of the trunk becomes thick and crackedwith age, whereas in the middle part and on top of the tree it is thin and peeling off in pieces. The cross-section shows that depending on the bark's structure it can be divided into the inner layer and outer layer (outer bark). Bhat (1982) states that European white birch tree bark density is 559,3 kg/m^3, and its double layer is 16,6 mm (average for values obtained from along the tree trunk aged from 65 to 95 years old). Repola (2008), on the other hand, estimates double bark thickness at breast height diameter at 9 mm (trees aged from 11 to 97 years old – 47 years on average).

Taking into account the share of bark in general log volume of the trunk and its density, it is possible calculate volume and actual weight. Add around 0,10 – 0,15 m^3 of the bark per 1m^3 of material without bark, and add around 50 – 55 kg to the timber weight estimated valuewhen using the material density table for road transportation as published in the Polish Journal of Laws of 2012 (item 536). The variability of wood density makesestimation of the actual timber weight difficult. Additional difficulty also stems for seasonal changes in timber moisture. The difference in timber moisture between the summer and winter season can be up to several dozen percent (Wanin 1953).The paper presents the results of a pilot study carried out in the area of Kaczory Forest Inspectorate. The aim of the study was to define actual weight and green density of birch pulpwood. The actual weight of the material according to the assumed methodology equals the total weight of the wood, water contained therein and weight of the bark.

STUDY METHODOLOGY

The study was carried out in two forest stands, where some forest maintenance work had been planned. At the same time, the selected forest stands had to be of similar age and have identical forest site productivity indicator (table 1).

Table 1. Characteristic of stands

Symbol	Site	Age	DBH [cm]	Height [m]	Index of stocking	Stand density
P_1	LMśw	52	26	24	1,1	medium
P_2	Lśw	49	25	21	1,0	medium

Legend: LMśw–fresh mixed broadleaved forest; Lśw – fresh broadleaved forest

The first stage of on-site work was to define dendrometric characteristics of the trees to be cut down, i.e.: maximum and minimum breast height diameter in bark and height.

The breast height diameter measurements were averaged out to 0,5 cm, whereas height measurements were made with0,1 m accuracy. In the next step the trees were divided into groups according to thickness, each group different by 2 cm. From among the measured trees, i.e. intended to be cut down as part of the planned forest maintenance (late thinning), 36 trees were selected by Draudt dendrometric method in areas P_1 and 26 trees in area P_2, in total 62 trees. From the trunks of the cut down trees,specimens of 2,5 m long trunks were selected. The weight of each round timber (in bark) was checked using hook scale, then minimum and maximum diameter was measured (with and without bark), the bottom and top ends. Diameter was measured with0,1 cm accuracy[1].

Statistical analysis was carried out using Statistica 12 software (StatSoft Inc.). The analysis covered preparation of the general statistical characteristics and testing of normal data distribution. Due to the rejection of the null hypothesis in normal distribution of data and assuming an alternative hypothesis, the analysis of the relation and testing of the differences was made using a nonparametric test. The equation was prepared using two general prediction models: simple regression and multiple regression.

[1]Tree felling and preparation of the specimens was carried out in both areas onMay 15, 2015. Checking of the weight was done on the following day, i.e. May 16, 2015. Air temperature at the moment when measuring began was 6ºC (7 a.m.) and increased during the day to 19ºC (around 2 p.m.). There was no rainfall. Relative air humidity was 69%at the beginning of measurement (7 a.m.) and declined to 43% at the end of the measuring.

RESULTS

In the studied forest stands, the average weight of one 2,5 m long birch round timber was 49,7 kg, with log volume in bark 0,052 m^3 (0,046 m^3 without bark). Considerable differences were noted between minimum and maximum values of the studied timber characteristics; high variability was observedregarding weight and log volume with and without bark. Large discrepancy was also noted between the minimum and maximum density of the timber with bark; however, in this case the coefficient of variation was relatively low (16,2%), whereas the median was close to the arithmetic average. Considerable differences between the arithmetic average and median of the weight and log volume are the effect of a small amount of round timbers with large diameter, log volume and weight which were present in the studied sample (Table 2).

A number of statistically significant relations was observedfor the studied characteristics. The relation between weight and log volume and diameter is much stronger than between weight and density. The correlation coefficient between weight and log volume and diameter was between 0,9 and 1,0, and a had positive value. The value of correlation coefficient between the density of the material with bark, log volume and diameter was between 0,5 to 0,7 and had a negative value (Table 3).

Table 2. Basic measures of location and dispersion of the selected timber characteristics (n=386)

Variable	Mean	SD	VC [%]	Minimum	Maximum	Q25	Median	Q75
m [kg]	49,7	29,2	58,8	14,5	194,0	28,0	42,3	62,5
Vwk [m^3]	0,052	0,038	73,9	0,011	0,215	0,025	0,040	0,063
Vbk [m^3]	0,046	0,034	73,6	0,009	0,194	0,022	0,036	0,057
Ø↑wk [cm]	13,6	4,2	30,8	6,8	27,5	10,3	13,1	16,3
Ø↑bk [cm]	12,8	4,1	31,9	6,2	26,5	9,6	12,3	15,5
Ø↓wk [cm]	16,7	6,4	38,3	8,3	38,6	12,2	15,2	19,1
Ø↓bk [cm]	15,7	6,0	37,9	7,6	36,2	11,5	14,3	18,2
Qwk [kg/m^3]	1049	170	16,2	591	1533	986	1067	1139

Legend: m – weight, Vwk – volume measured in the bark, Vbk – volume measured without bark, Ø↑wk – diameter at the small end measured in the bark, Ø↑bk – diameter at the small end measured without bark, Ø↓wk – diameter at butt end measured in the bark, Ø↓bk – diameter at butt end measured without bark, Qwk – density measured in the bark

Table 3. Results according to Spearman's rank correlation coefficient

Variable	m [kg]	Vwk [m^3]	Vbk [m^3]	Ø↑wk [cm]	Ø↑bk [cm]	Ø↓wk [cm]	Ø↓bk [cm]	Qwk [kg/m^3]
m [kg]								
Vwk [m^3]	**0,977020**							
Vbk [m^3]	**0,978602**	**0,998985**						
Ø↑wk [cm]	**0,976291**	**0,964375**	**0,966891**					
Ø↑bk [cm]	**0,975461**	**0,963648**	**0,966744**	**0,999465**				
Ø↓wk [cm]	**0,957353**	**0,990932**	**0,989102**	**0,924993**	**0,924230**			
Ø↓bk [cm]	**0,959482**	**0,990753**	**0,990843**	**0,927874**	**0,927495**	**0,998732**		
Qwk [kg/m^3]	**-0,529447**	**-0,676132**	**-0,672902**	**-0,591421**	**-0,592257**	**-0,688455**	**-0,685734**	

Marked effect are significant with p<0,01
Symbols as in the Table 2

The increase of log volume in bark or without bark means the increase of weight and decrease of material density. More dynamic changes are characteristic for the weight and density of the timber without bark. The differences between the weight and density of the material with and without bark increase as the material's log volume increases (Fig. 1a, 1b). Log volume increases along with the share of bark in total weight, the density of which being lower than the density of wood. The average difference between the log volume of a round timber with and without bark was 0,006 m^3 which means that bark constitutes around 12% of the material volume.

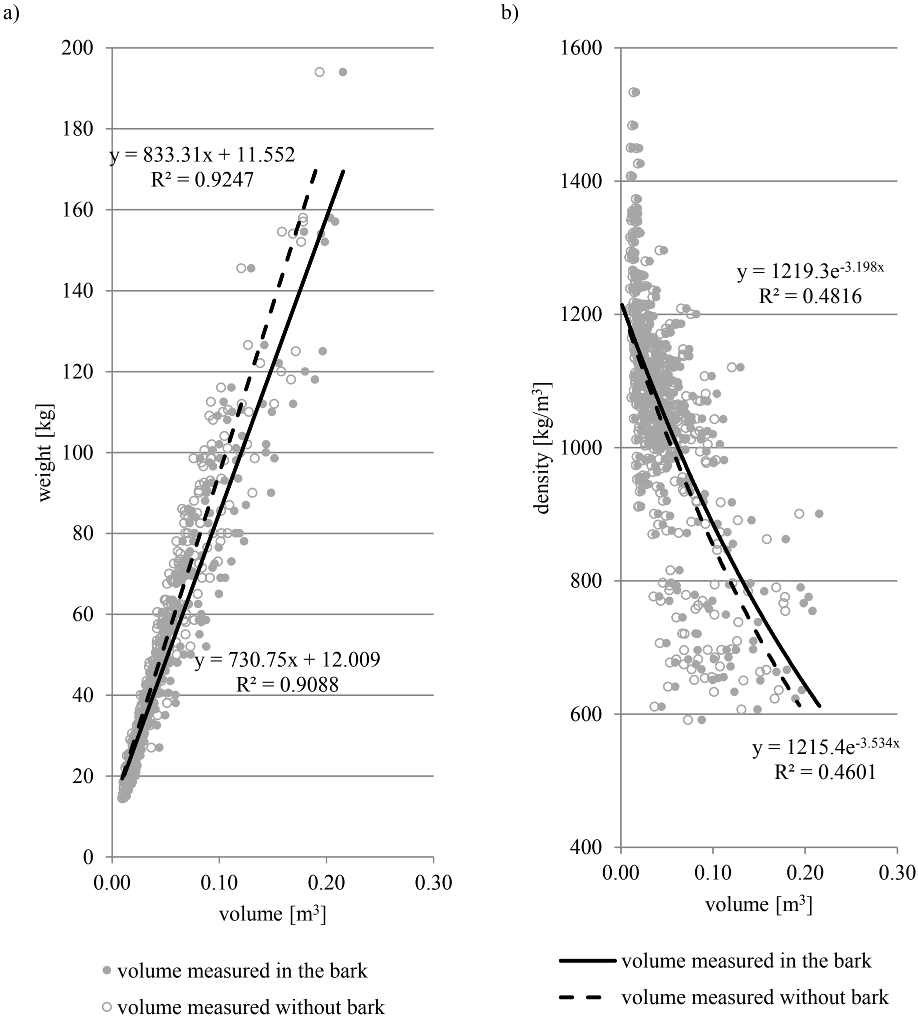

Figure 1 a-b. The correlation between the log volume of the material, with and without bark, and its weight (a) and density (b)

SUMMARY

The aim of the study was to define the actual weight of the fresh birch pulpwood. In total, 19,91 m^3 of timber was harvested (log volume measured with bark – without bark 17,67 m^3) at the total weight of 19 181,5 kg. The actual weight of the timber was approximately 963 kgper 1 m^3. The obtained value is higher than the one provided by Wanin (1953), according to whom 1 m^3 of freshly cut timberweights 878 kg. The achieved value is also higher by approximately 153 kg than the weightestimate from the industrial and construction grade wood density table for road transport (Polish Journal of Laws 2012, item 536). The table does not take into account the weight of the bark due to the fact that before sale the log volume of the bark is deducted from the total timber log volume. Taking into account the calculated share of bark at around 12% material log volume as well as timber density given by Bhat (1982), we can estimate the weight of the bark at approximately 60 kg per 1 m^3. The difference between the calculated actual value and table values could have been influenced by a number of factors. The calculation of the weight has to be done in the most simple way possible; hence, the values in the table do not take into account a number of variables. The calculations only provide an average value withone of the main variablesbeing wood density. When studying selected birch timber properties Lachowicz (2011) noted that wood density is influenced by the thickness of the tree expressed in the average width of the annual ring. This is a very important notion since before that it had been assumed that there is no relation between the width of the annual ring and wood properties for diffuse-porous species. When studying birch wood density it was also noted that this the density is influenced by geographical position and age of the trees (Lachowicz 2010; 2012), as well as the forest site (Lachowicz et al. 2014).

Statistically significant relations were noted between the studied characteristics. Much stronger relation than in the case of density was noted between the weight and log volume and material thickness. It is possible to simulate actual weight on the basis of material properties which are easy to measure, such as the diameter. In such case the model would be the following (diameters in bark, material length 2,5m):

$$weight = -38,10554+4,29014*Ø\uparrow_{in\ bark}+1,760621*Ø\downarrow_{in\ bark} \quad (1)$$

or diameters without bark

$$weight = -35,83233+4,15665*Ø\uparrow_{no\ bark}+2,04656*Ø\downarrow_{no\ bark} \quad (2)$$

Practitioners usually opt for the log volume without bark ($V_{no\ bark}$). It takes into account not only the diameter of the material but also its length. In such case the model would be the following:

$$weight = 11,55182+833,30569*V_{no\ bark} \quad (3)$$

The distribution values of the estimated weight in comparison to the observed weight values indicates that the model is quite accurate for the material with smaller dimensions and log volume and lower weight. When actual weight is higher, the estimated values are lower (Fig. 2).

Wood material weight increases along with log volume, since the increase of the log volume is related to the increase of dimensions. In the analyzed example, it is the diameter. The increase of weigh in relation to log volume without bark is even more dynamic. The increase of the material's weight is lower due to the increasing role of the bark. The material of considerable weight and wide diameter is obtained from butt end of the trunk, which is a place with thick layers of the outer bark.

The opposite relation was observed for density when the log volume increased. It was found out that the lower diametertimber could be characterized by nearly the double density of the thicker material with higher log volume. It is probable that the influence of bark on this phenomenon is insignificant, rather it being related to the selected wood properties which can be seen in the longitudinal trunk cross-section. Repola (2006) presented a model of changing birch wood density and proved that the density decreases from the butt end of the tree towards the top. However, in this study it was demonstrated that the density of the material increases.

Repola (2006) provides accepted density values, that is the relation of the dry matter weight per unit volume of green wood.

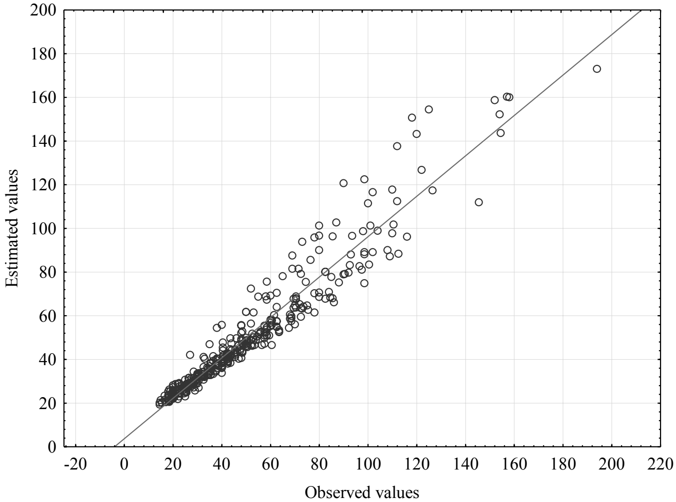

Figure 2. Distribution of the estimated values compared to observed values

When it comes to birch as well as other tree species (Tomczak et al. 2013; Tomczak, Jelonek 2014), the longitudinal cross-section of the trunk shows a decrease of weight in relation to log volume, i.e. the porosity increases. High density of timber obtained from the top part of the trunk is rather related to moisture content because water weight per volume unit is considerably higher than the density of the xylem.

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Streszczenie: *Masa i gęstość średniowymiarowego surowca brzozowego pozyskanego z wybranych drzewostanów nadleśnictwa Kaczory.* W pracy zaprezentowano wyniki badań pilotażowych, przeprowadzonych na terenie Nadleśnictwa Kaczory. Ich celem było określenie rzeczywistej masy i gęstości, świeżo pozyskanego, średniowymiarowego surowca brzozowego. Masa rzeczywista surowca to według przyjętych założeń metodycznych łączna masa drewna, wody w nim zawartej oraz masa kory. W sumie pozyskano 19,91 m^3 surowca (miąższość mierzona w korze – bez kory 17,67 m^3), o łącznej masie 19 181,5 kg. W przeliczeniu na 1 m^3 rzeczywista masa surowca wynosiła około 963 kg. Masa surowca drzewnego rośnie wraz ze wzrostem miąższości, ponieważ wzrost miąższości związany jest ze wzrostem wymiarów. W analizowanym przypadku średnic. Wyższą dynamiką wzrostu charakteryzuje się przyrost masy względem miąższości bez kory. Przyrost masy surowca w korze jest niższy ze względu na wzrastający udział kory. Surowiec o stosunkowo dużych średnicach i masie pozyskiwany jest z odziomkowych części pnia, czyli w miejscu występowania grubych warstw martwicy korkowej. Odwrotną tendencję zmian w stosunku do przyrostu miąższości wykazywała gęstość. Okazało się, że surowiec o niewielkich średnicach charakteryzować się może niemal dwukrotnie wyższą gęstością niż surowiec grubszy, o wyższej miąższości. Prawdopodobnie wpływ kory na to zjawisko jest niewielki, należy wiązać je raczej ze zmianami wybranych właściwości drewna jakie zachodzą na przekroju podłużnym pnia. U brzozy, podobnie jak u innych gatunków drzew, na przekroju podłużnym pnia masa drewna w stosunku do objętości maleje, czyli rośnie porowatość. Wysokie wartości gęstości surowca pozyskanego z wierzchołkowych części pni należy raczej wiązać z wilgotnością.

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