Change in Mass, Volume and Density of Common hornbeam (*Carpinus betulus* L.) in short sawn and splitted firewood due to air drying

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Introduction

- Firewood in the traditional form of one-meter split wood and round wood, most commonly produced by self-production, is still the most important energy source for the production of heat energy in rural areas of the Republic of Croatia,
- In addition to the traditional way of production, sale and use of one-meter and longer than one-meter firewood, in recent years, an increasing number of companies started production of short sawn and split firewood, mainly for export, mostly in Italy, Slovenia, Hungary and Austria,
- When placing firewood on the market, it is possible to measure it by volume or mass. Measuring wood by mass is influenced by the current moisture content, and most commonly is used when dispatching firewood,
- As there are few months from felling and production to selling of firewood, there is a loss due to the shrinkage.

Aim of research

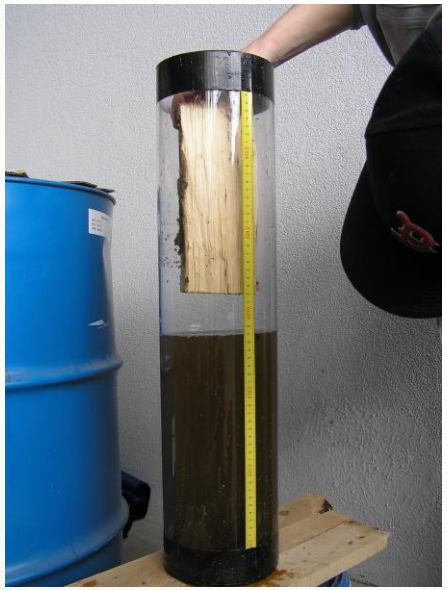
- The influence of moisture, mass, volume and density of firewood is of crucial importance to transport, quantity and price of firewood in commercial businesses,
- The aim of the paper is to experimentally and theoretically explore the changes that occur in the course of air drying of Common hornbeam (*Carpinus betulus* L.) short sawn and splitted firewood,
- The results of this research should give the answers to how much have this firewood lost in mass, volume, moisture and density during air drying over a given period of time.

Materials and methods

- 440 pieces of 25 cm long split firewood marked by numbers were selected, and their mass, volume and moisture in the green and air dried condition were measured.
- Air drying was conducted on well-ventilated and sheltered company area from 05. May. 2016. to 06. October. 2016.

Materials and methods

- The percentage of the firewood mass, volume and density reduction due to air drying is calculated according to the expressions:



$$\Delta(m)_{rel} = \frac{m_{green} - m_{dry}}{m_{green}} \cdot 100$$

$\Delta(m)_{rel}$ – relative change in sample mass, %,
m_{green} – sample mass in green condition, kg,
m_{dry} – sample mass in air dried condition, kg.

$$\Delta(V)_{rel} = \frac{V_{green} - V_{dry}}{V_{green}} \cdot 100$$

$\Delta(V)_{rel}$ – relative change in sample volume, %,
V_{gren} – sample volume in green condition, m^3,
V_{dry} – sample volume in air dried condition, m^3.

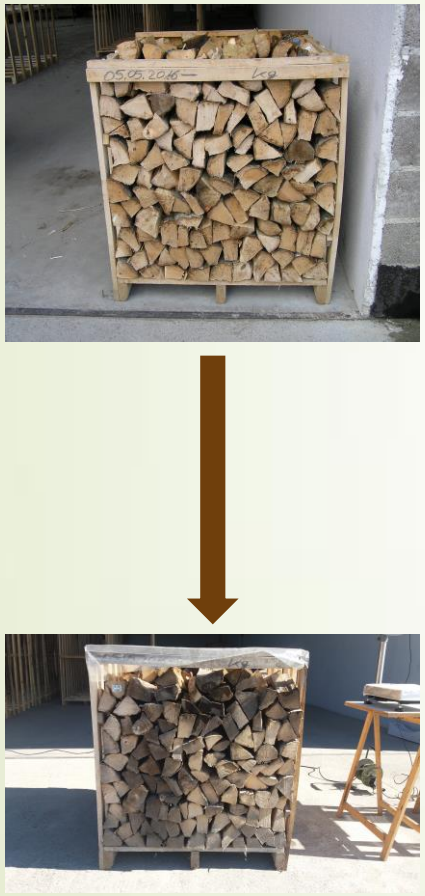
$$\Delta(\rho)_{rel} = \frac{\rho_{green} - \rho_{dry}}{\rho_{green}} \cdot 100$$

$\Delta(\rho)_{rel}$ – relative desity change of the sample, %,
ρ_{green} – sample density in green condition, kg/m^3,
ρ_{dry} – sample density in air dried condition, kg/m^3.

Materials and methods

Figure 1. Overview of the production process and measuring of firewood following the arrows: the stack of the round wood longer than 1 metre in log yard; cross-cutting of round wood longer than one metre and production of one-metre round wood by a motor chainsaw; splitting one-metre round wood; cross-cutting of one-metre split wood with a band saw to the final length and additional splitting; measuring in green condition; disposing on pallets and air drying; measuring in dry condition

Results



Firewood size	Short split firewood (L = 25 cm)						
	Size	N	Min.	Median	Max.	Average	Std. dev.
U_{green}	%	46	50.50	61.28	73.47	61.81	5.53
U_{dry}	%	46	10.57	11.51	12.62	11.54	0.40

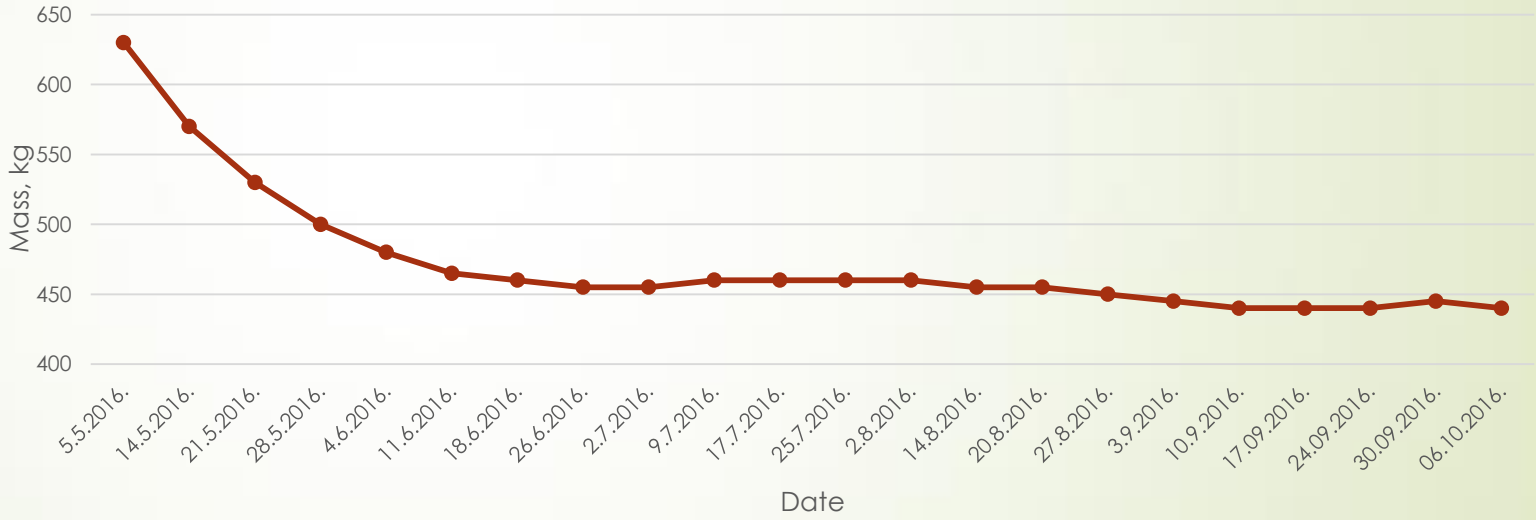
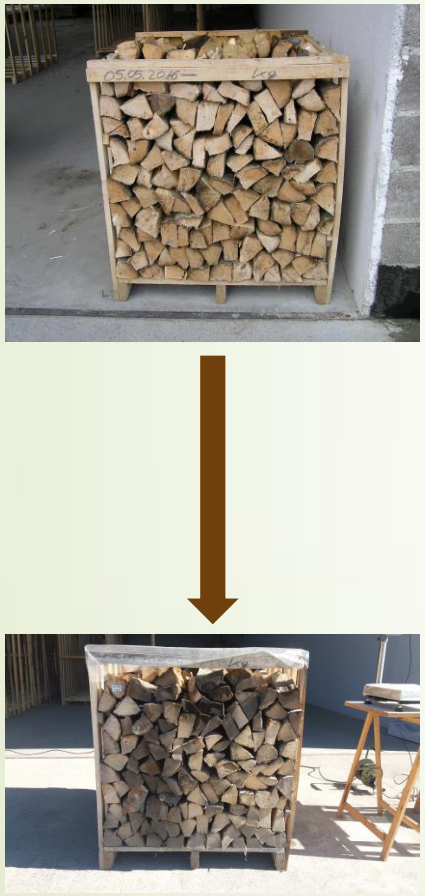


Figure 2. Graphic representation of the mass loss of dry short split firewood bulk due to air drying

Results



Firewood size	Short split firewood (L = 25 cm)						
	Size	N	Min.	Median	Max.	Average	Std. dev.
m_{green}	kg	440	0.6450	1.3350	2.1850	1.3417	0.3164
m_{dry}	kg	440	0.4400	0.9250	1.5600	0.9274	0.2173
$\Delta(m)_{rel}$	%	440	21.28	30.75	38.39	30.78	2.72

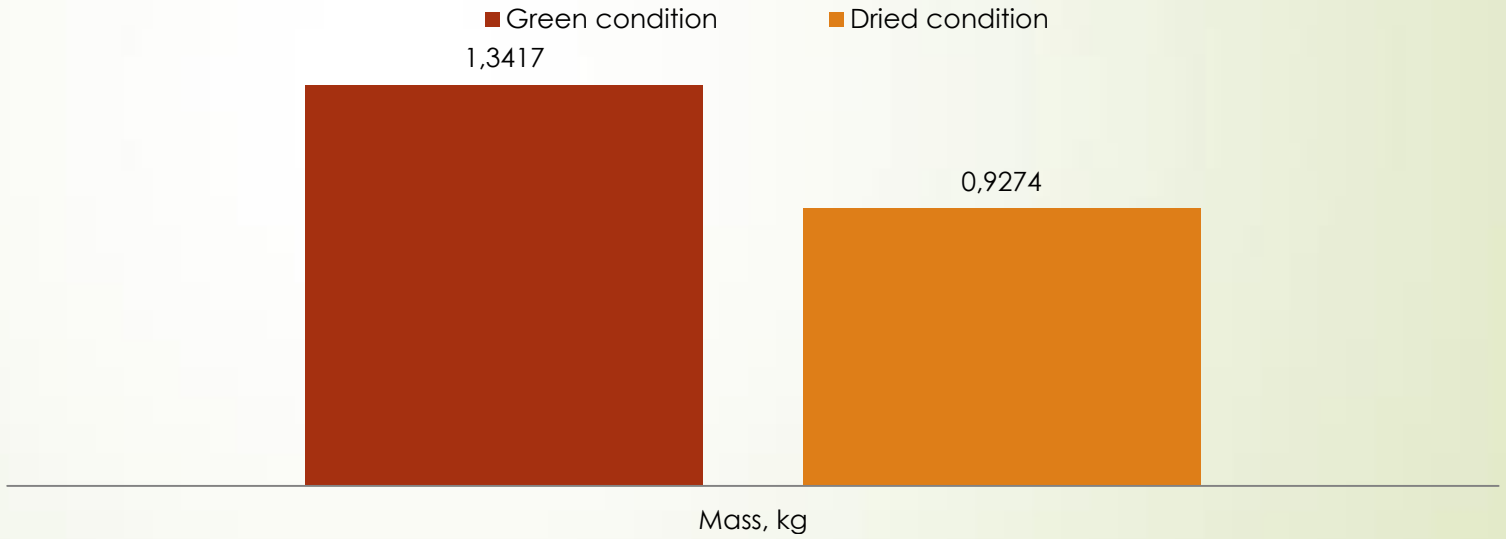
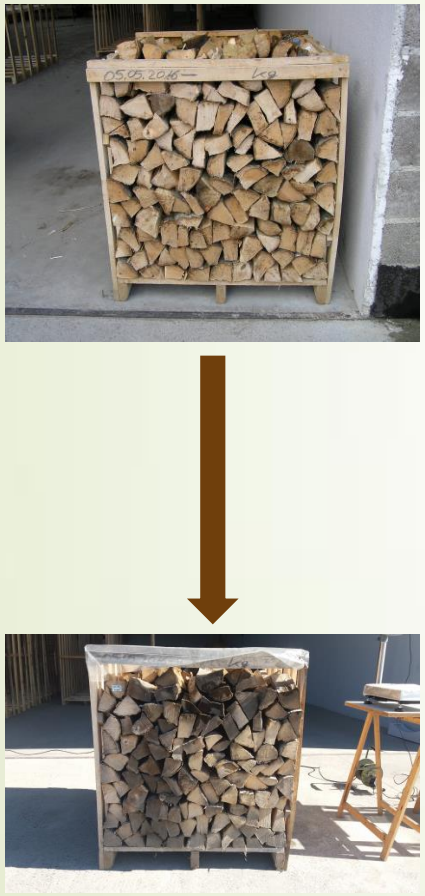


Figure 3. Change in the mass of firewood due to air drying

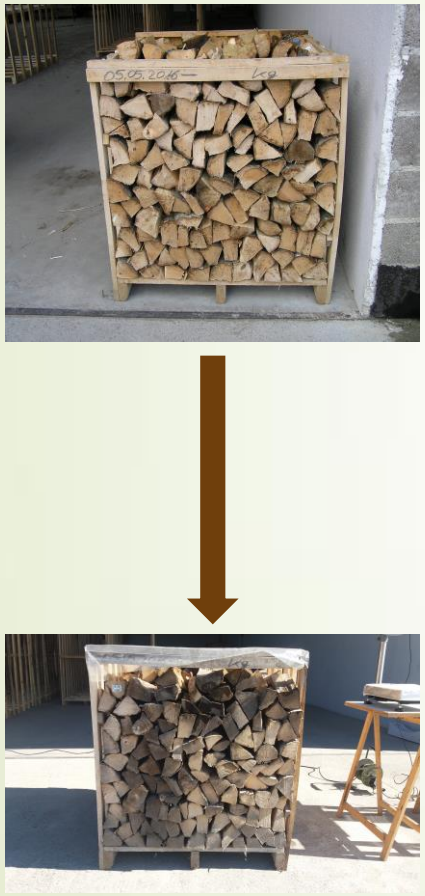
Results



Firewood size	Short split firewood (L = 25 cm)						
	Size	N	Min.	Median	Max.	Average	Std. dev.
V_{green}	m^3	440	0.00062	0.00131	0.00207	0.00130	0.00030
V_{dry}	m^3	440	0.00053	0.00115	0.00184	0.00115	0.00027
$\Delta(V)_{rel}$	%	440	4.08	11.43	23.00	11.66	3.34

Figure 4. Change in the volume of firewood due to air drying

Results



Firewood size	Short split firewood (L = 25 cm)						
	Size	N	Min.	Median	Max.	Average	Std. dev.
ρ_{green}	kg/m^3	440	894.81	1036.34	1158.08	1033.34	45.81
ρ_{dry}	kg/m^3	440	704.42	807.93	899.21	809.94	43.64
$\Delta(\rho)_{rel}$	%	440	10.410	21.499	32.686	21.551	4.057

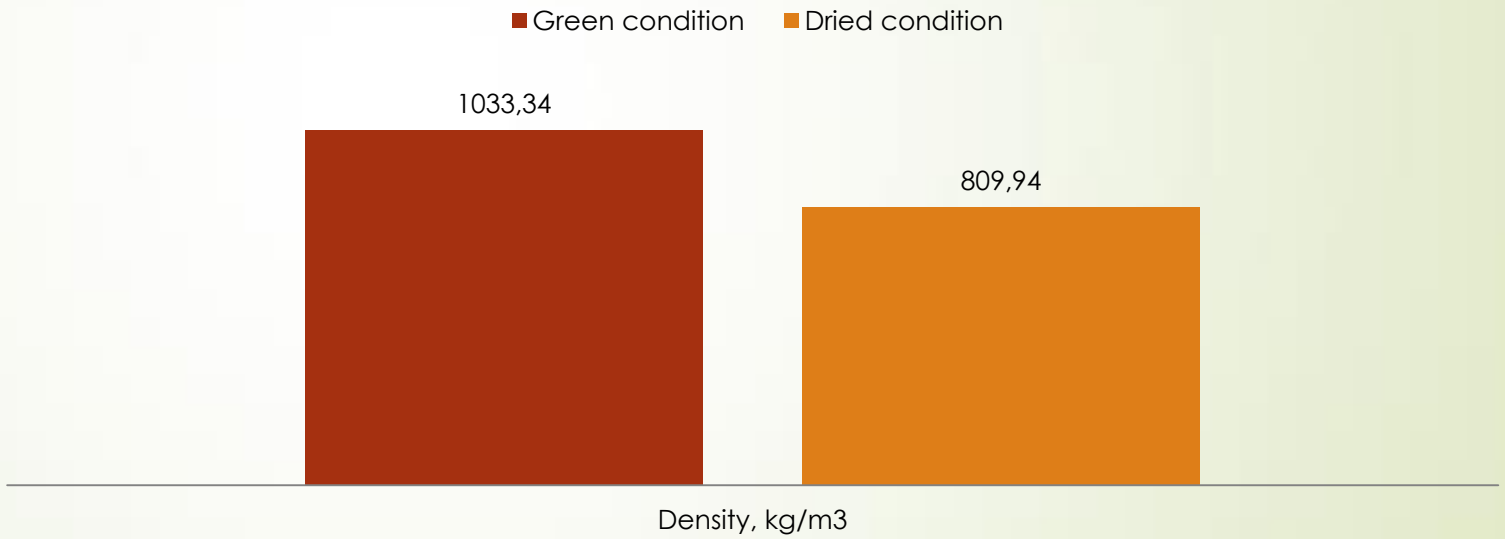


Figure 5. Change in the density of firewood due to air drying

Conclusion

- Air drying reduced mass, volume and density regardless of the shape of the Common hornbeam short split firewood,
- The moisture of short split firewood with air drying was reduced from 61.81 % to 11.54 %,
- The mass firewood has decreased after the air drying process. The average mass reduction was 0.4143 kg per split firewood, while this amount for the entire palette was 190 kg. Expressed in percentages, this would mean a 30.88 % mass reduction in terms of the green state,
- By air drying, there was also a reduction in the volume of short split firewoods. On average, the reduction was amounted to 0.000150131 m^3 per single split firewood. If it were to show that in percentages the value would be 11.66 % less due to the green state,
- The density was reduced in average of 223.40 kg/m^3, or in percent it would amount to 21.551 % considering the green state.