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EVALUATION OF SELECTED ENERGY AND TRANSPORT PROPERTIES OF SEED EXTRACTION REMAINS

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Introduction - forest biomass

In Poland, wood biomass is obtained primarily from small-sized wood or wood waste. The primary method of forest biomass processing is chipping.

Empty cones remaining after the seeds extraction process can provide an excellent base for production of refined fuels and satisfy the demand of the local market for thermal energy.

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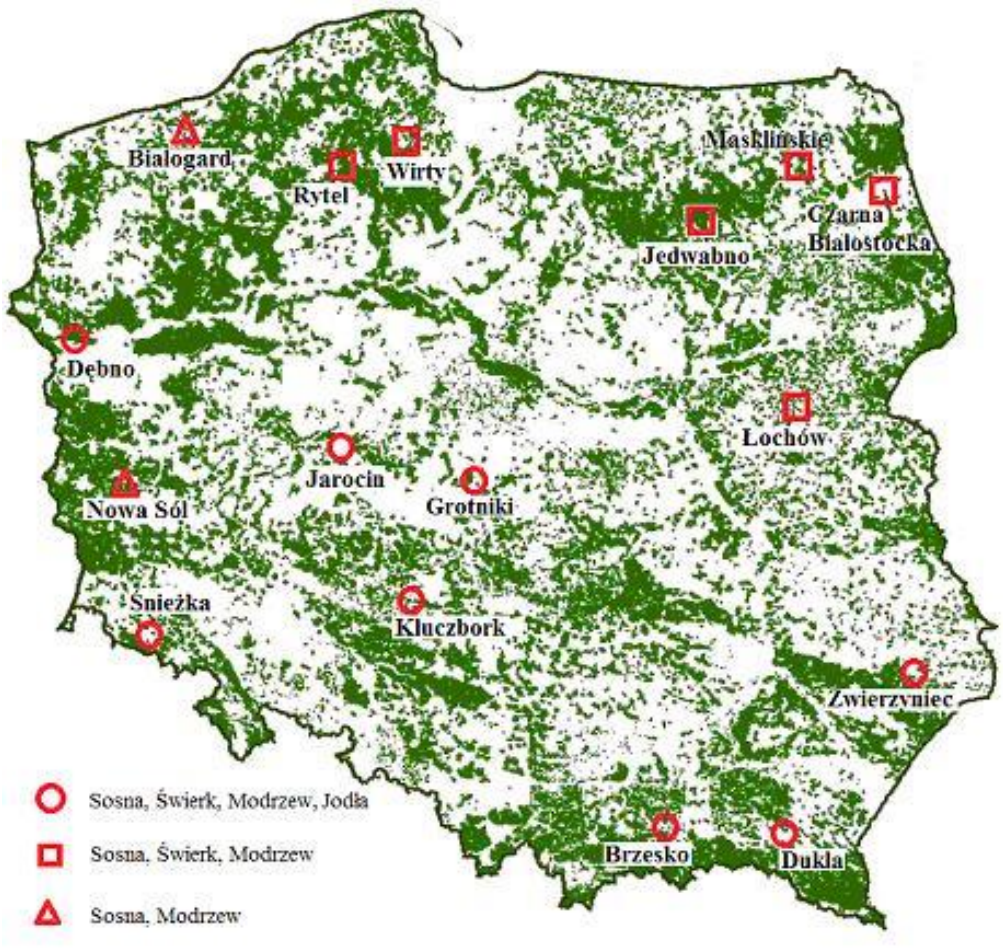
Introduction - seed extraction plants

Currently, Poland has 16 seed extraction plants, which include both upgraded, old established before the Second World War, and new based on modern technologies. The latter are usually electrically driven, so that the storage are full of hollow cones. According to data from the years 2009-2014 in Poland annually seed extraction amount to an average 360 Mg of cones of different species.



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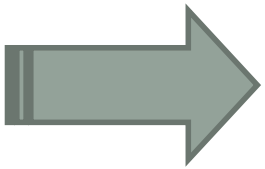
Purpose and scope of the study

Purpose:

The study attempts to identify oven dry and net calorific value of cones of four species:

- Scots pine (*Pinus sylvestris* L.),
- Norway spruce (*Picea abies* L.),
- European larch (*Larix decidua* Mill.),
- European silver fir (Abies alba Mill.),

and determine the parameters affecting the profitability of transport..

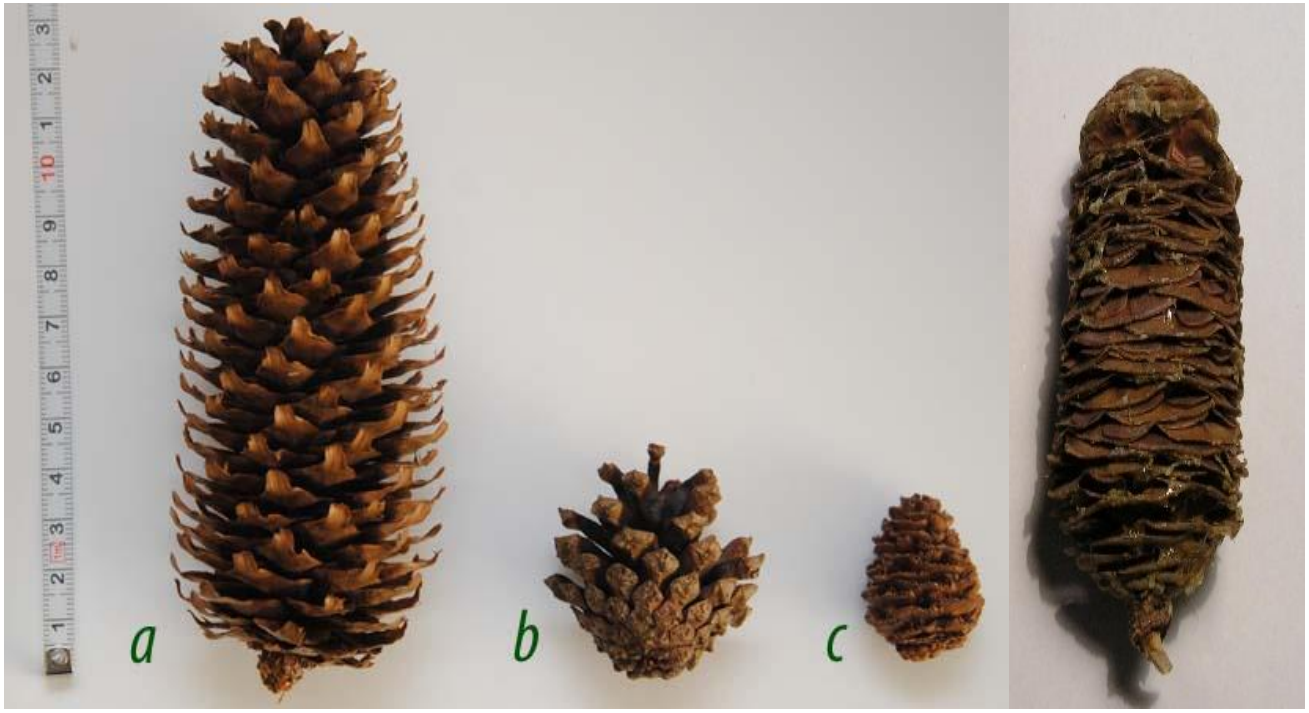


Scope:

- Determination of
- the heat of combustion,
- Calculation of calorific value,
- Determination of specific and bulk density,
- Determination of conversion factor,
- Analysis of the results.

Material and methods

Empty cones



Norway spruce | Scots pine | European larch | European silver fir

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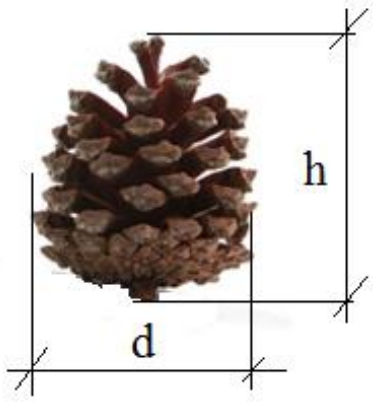
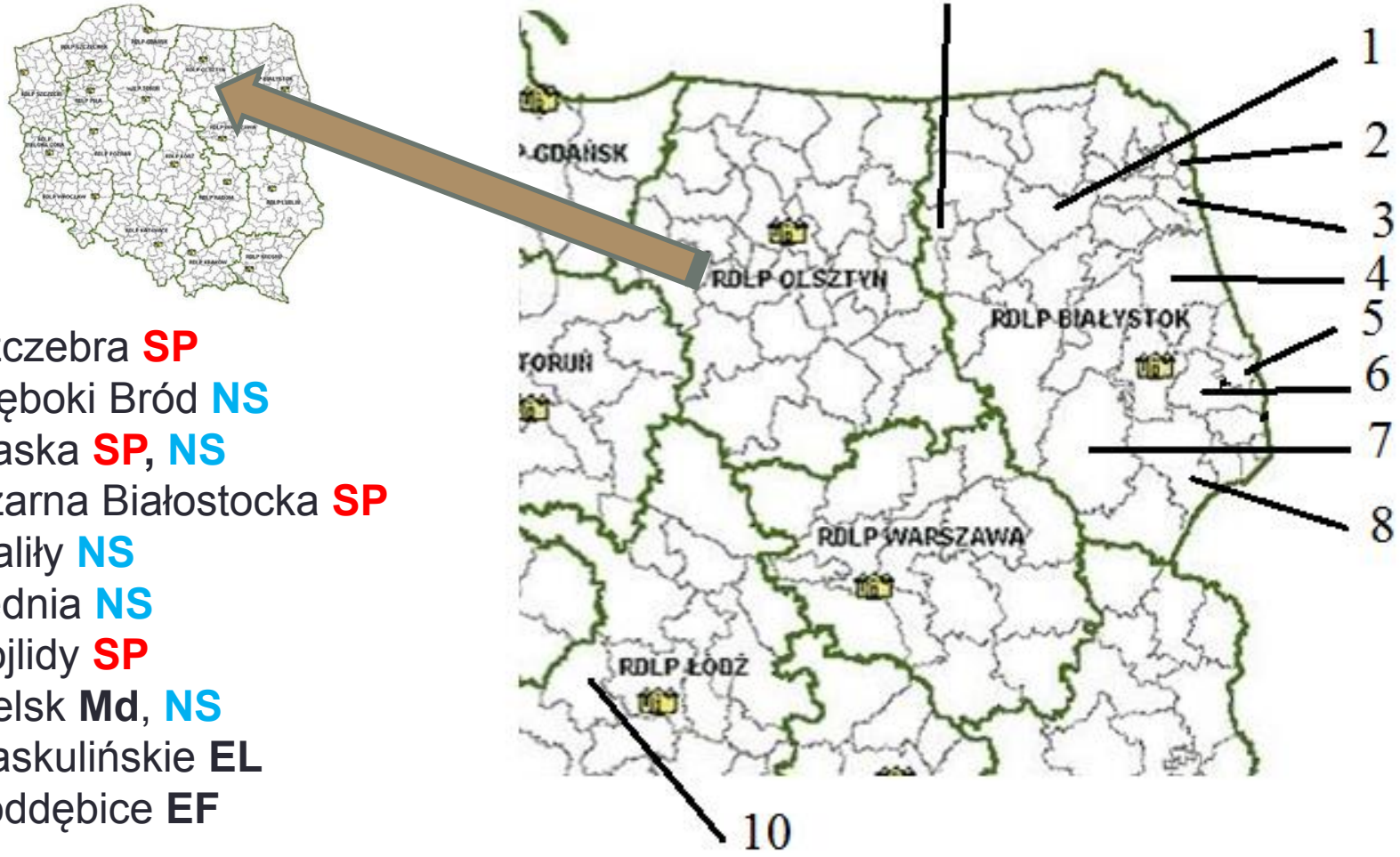
Material and methods - basic parameters of the studied cones

- 100 cones were measured
- The length and diameter (thickness) was measured by electronic caliper (± 0.1 mm) in two perpendicular directions at the same height, and the average value was determined.
- Mass (± 0.01 g) determined by integrated scale and moisture analyzer RADWAG WPS210S.



h – cone lenght
d – cone thickness

Material and methods - places of origin of cones



1. Szczebra **SP**
2. Głęboki Bród **NS**
3. Płaska **SP**, **NS**
4. Czarna Białostocka **SP**
5. Waliły **NS**
6. Żednia **NS**
7. Dojlidy **SP**
8. Bielsk **Md**, **NS**
9. Maskulińskie **EL**
10. Poddębice **EF**

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Material and methods - combustion heat, calorific value, density of cones

- The heat of combustion and calorific value were determined based on the standard ISO 1928: 2002
- To determine the calorific value hydrogen content of 6.3% was assumed
- Specific density (± 0.01 $g \cdot cm^{-3}$) was determined using a helium pycnometer Stereopycnometr Quantachrome Instruments and computer program Pycnometersoftware (a version of 2.7)
- The bulk density (± 0.1 $kg \cdot m^{-3}$) wet (BDar) and dry (BDD) was determined on the basis of procedures and relationships in line with PN-EN 15103: 2010

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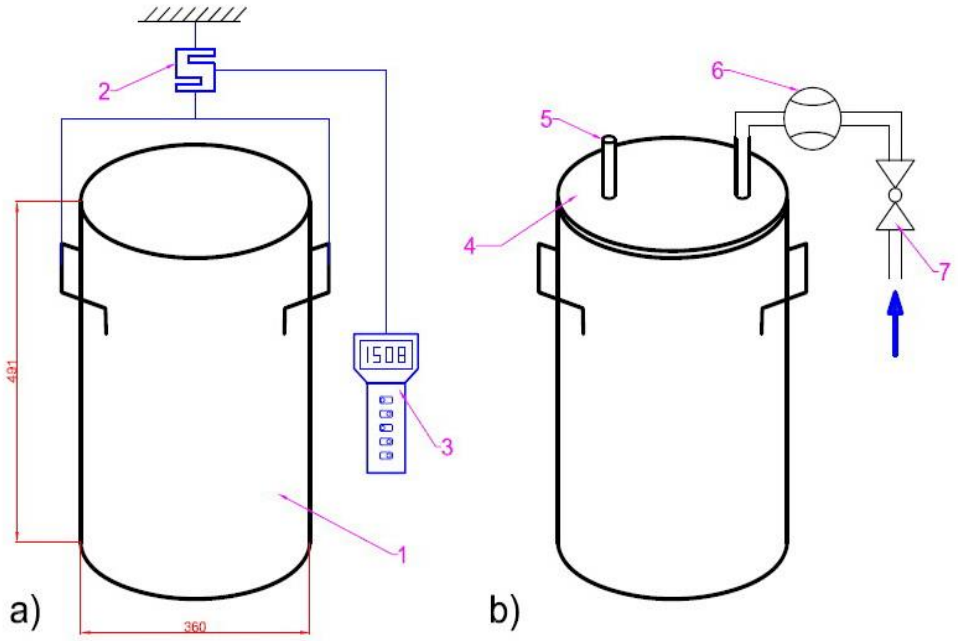
Material and methods - conversion factor



Scheme of the measuring system:
a - bulk density, b – conversion factor:
1 - vessel, 2 - strain gauge, 3 - recorder,
4 - cover, 5 - vent, 6 - flow meter, 7 - valve

On the basis of the volume of liquid contained in a vessel and the volume of the measurement vessel, conversion factor for empty cones K_z was calculated

$$K_z = \frac{V_0 - V_w}{V_o}$$

V_o – the volume of the vessel, m^3,
V_w – the volume of fluid poured into the vessel, m^3.

Results - basic parameters of the studied cones

Cone type	Forest district	Average (±SD) [mm]		Coefficient of variation	
		length	thickness	length	thickness
Norway spruce	Żednia	-	-	-	-
	Głęboki Bród	118,59 (±13,63)	54,53 (±5,07)	11,50	9,31
	Bielsk1	145,85 (±19,49)	62,41 (±6,55)	13,36	10,49
	Płaska1	111,10 (±13,25)	54,36 (±4,41)	11,93	8,11
	Waliły	119,42 (±13,06)	52,96 (±5,07)	10,93	9,57
Scots pine	Szczebra	39,01 (±4,53)	33,38 (±5,08)	11,61	15,22
	Czarna Białostocka	41,43 (±5,22)	36,30 (±5,86)	12,61	16,13
	Dojlidy	37,62 (±5,37)	31,68 (±5,38)	14,28	16,97
	Płaska	41,77 (±4,16)	35,64 (±4,39)	9,95	12,33
European larch	Bielsk	25,83 (±4,63)	20,89 (±3,37)	17,95	16,15
	Maskulińskie	37,56 (±3,90)	22,47 (±2,04)	10,38	9,06

No differences: Spruce Głęboki Bród – Waliły, Pine Płaska – Czarna Białostocka

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Results - heat of combustion, calorific value of cones [MJ·kg^{-1}]

Type	Average (±SD)	Minimum	Maximum	Coefficient of variation	Average (±SD)	Minimum	Maximum	Coefficient of variation
	heat of combustion				calorific value of cones			
Norway spruce (*Picea abies* L.)	20,08 (±0,87)	18,49	21,05	4,35	18,78 (±0,87)	17,19	19,75	4,66
Scots pine (*Pinus sylvestris* L.)	19,04 (±0,70)	17,74	19,86	3,67	17,74 (±0,70)	16,44	18,56	3,94
European larch (*Larix decidua* Mill.)	20,37 (±0,48)	19,38	20,96	2,37	19,07 (±0,48)	18,08	19,66	2,54
European silver fir (*Abies alba* Mill.)	20,79 (±0,61)	19,81	21,85	2,94	19,49 (±0,61)	18,51	20,55	3,14

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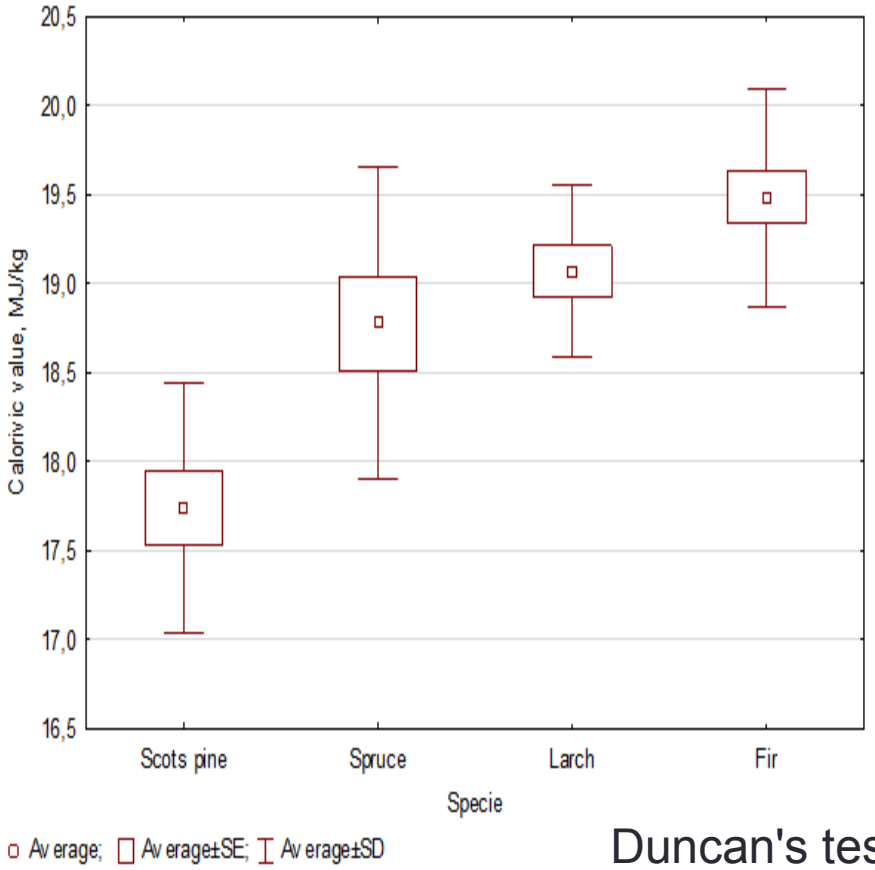
Results - calorific value of cones [MJ·kg^{-1}]



Cone type	SP	NS	EL	EF
SP		+	+	+
NS	+		-	+
EL	+	-		-
EF	+	+	-	

Duncan's test showed significant differences in calorific value between Scots pine and other species, and between the Norway spruce and European silver fir, $p < 0.05$

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Results – specific density [kg·m^{-3}]

Cone type	Average (±SD)	Minimum	Maximum	Coefficient of variation
Norway spruce *(Picea abies* L.)	1229,83 (±8,88)	1217,50	1246,70	0,72
Scots pine *(Pinus sylvestris* L.)	1306,48 (±13,61)	1290,30	1329,10	1,04
European larch *(Larix decidua* Mill.)	1144,11 (±30,70)	1097,00	1172,90	2,68

Results – bulk density (BD_{ar}) [$kg \cdot m^{-3}$]

Cone type	Origin	Average (±SD)	Minimum	Maximum	Coefficient of variation
Norway spruce (*Picea abies* L.)	Żednia	111,40 (±1,93)	109,28	114,98	1,73
	Głęboki Bród	122,02 (±3,96)	116,62	125,18	3,24
	Bielsk	113,72 (±2,32)	111,31	117,02	2,04
	Płaska	109,99 (±1,98)	108,87	112,95	1,80
	Waliły	118,27 (±3,28)	113,00	125,00	2,78
Scots pine (*Pinus sylvestris* L.)	Dojlidy	214,88 (±7,74)	204,69	224,26	3,60
	Szczebra	195,96 (±4,95)	190,01	203,47	2,53
	Czarna Białostocka	189,76 (±1,10)	188,38	191,23	0,58
	Płaska	213,80 (±5,53)	206,00	227,00	2,59
European larch (*Larix decidua* Mill.)	Maskulińskie	223,87 (±2,97)	219,00	230,00	1,33
	Bielsk	195,77 (±7,43)	186,54	204,69	3,79

Moisture of cones 8-11%

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Results - conversion factor

Cone type	Origin	Average (±SD)	Coefficient of variation
Norway spruce (*Picea abies* L.)	Żednia	0,20 (±0,01)	6,99
	Głęboki Bród	0,19 (± 0,01)	2,60
	Bielsk	0,18 (±0,00)	0
	Płaska	0,18 (±0,01)	2,74
	Waliły	0,23 (±0,02)	10,83
Scots pine (*Pinus sylvestris* L.)	Dojlidy	0,27 (±0,01)	3,12
	Szczebra	0,24 (±0,01)	2,24
	Czarna Białostocka	0,24 (±0,00)	1,85
	Płaska	0,26 (±0,01)	5,12
European larch (*Larix decidua* Mill.)	Maskulińskie	0,55 (±0,01)	0,94
	Bielsk	0,32 (±0,01)	2,55

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Conclusions

- The heat of combustion determined in accordance with the standard ISO 1928: 2002 amounted to Scots pine - 19.04 $MJ \cdot kg^{-1}$, Norway spruce - 20.08 $MJ \cdot kg^{-1}$, European larch - 20.37 $MJ \cdot kg^{-1}$ and Silver fir - 20.79 $MJ \cdot kg^{-1}$.
- The calculated calorific value of cones of these species was respectively 17.74 $MJ \cdot kg^{-1}$, 18.78 $MJ \cdot kg^{-1}$, 19.07 $MJ \cdot kg^{-1}$ and 19.49 $MJ \cdot kg^{-1}$
- Specific density of the cone was determined, which is in the range from 1097 to 1329 $kg \cdot m^{-3}$. It is lower than the density of wood substance reported in the literature.
- The bulk density of the tested cone is from 9 to 18% of a specific density. The highest is for the European larch cones, and the lowest for Norway spruce cones.
- Conversion factors for cones of Scots pine and Norway spruce are respectively 0.25 and 0.20, and for European larch cones 0.44.

Thank you for your attention