Quality and Productivity in Comminution of Small Diameter Tree Bundles

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- Introduction to small-diameter tree bundles -

What we know:

- Bundling whole-trees from early thinnings has become an important assortment within Nordic bioenergy supply chains.

- Bundling technology has allowed the process of bundling small diameter trees from thinnings to be a viable option within the procurement process (Ala-Vari and Ovaskainen 2013, Bergström et al. 2015, Nuutinen and Björheden 2016).

- Operational competitiveness dependent on a variety of variables… stand characteristics and market prices.

- Reduction of supply chain costs via terrain and road transportation (Bergström and Di Fulvio 2014, Kärhä et al. 2009).

Photo: Fixteri (www.fixteri.fi)

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- Objective of the comminution and productivity study -

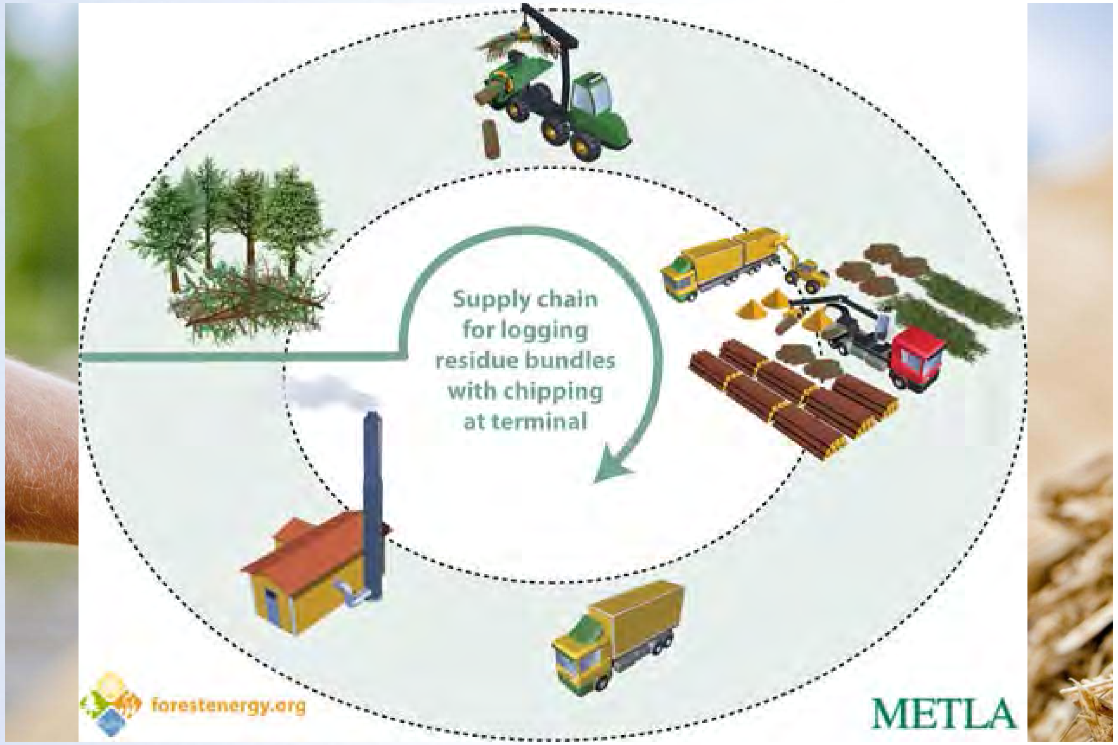

Photo: Fixteri (www.fixteri.fi), Forest Energy Portal (forestenergy.org).

<u>What we know:</u>

- Quality of wood chips is dependent on technology and raw material utilized (Eriksson et al. 2013).
- Comminution of our forest raw material is primarily through chipping (cutting) and grinding (blunt impact) processes (Eriksson et al. 2013).

<u>What we didn’t know:</u>

- What are the measurable qualities of fuel wood chips produced from small-diameter whole tree bundles.
- Qualities and productivities produced by machine type and processing function.

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- Methodology: Study design -

- The study was conducted in the municipality of Padasjoki (Central Finland) during March, 2014.
- Bundles were produced from small-diameter whole-trees utilizing a Fixteri FX15a small tree bundler in May, 2013.
  - Approximate dimensions of bundles: 2.6 m x 60 – 70 cm (0.6 m^3 s.).
  - Size of whole trees in bundles: 15 – 35 dm^3 (5 – 13 cm (dbh)) with average stem sizes of 25 dm^3 (9 cm (dbh)).
  - Composition: ¼ Scots pine (*Pinus sylvestris* L.), ¼ Norwary spruce (*Picea abies* (L.) Karst.), ¼ Downy birch (*Betula pubescens*), and ¼ Black alder (*Alnus Glutinosa*).
  - Storage: Roadside storage (2 months), terminal storage (6 months); Approximately 1,000 m^3 s. of cross layered bundles 5 m in height were placed at the terminal study site.
  - Comminution: Six machine runs comminuting 327.4 m^3 loose (128.4 tonnes).

Table 1. Technical information of the studied machines.

Machine model	Engine power [kW]	Diameter of chipping drum [mm]	Number of chipping blades	Dimension of infeed aperture [mm]	Di-mension of sieves [mm]	Load space vol. [m^3][1]
A	Volvo, 562	1300	2	1090x 700	100, comb	54
B	Volvo, 525	860	10	1000x 600	80x80	50
C	Mercedes Benz, 468	1040	24	1200x 820	80x80	94
D	Cummins, 400	1440	4		80x120	55
E	Cummins, 496	900	2	1000x 720	120, comb	94
F*	Own, ≤ 330	-	-	-	-	97

*Machine type F may be equipped with various engine options up to 330 kW, chipper knife set up when producing wood fuel, diameter capacity of 610 mm, and 610x1524 mm mill opening.

[1]Measured volume loaded onto either trailer or trucks.

Photo: Fulvio Di Fulvio

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- Methodology: Time study, sampling and analysis of fuel chips -

Time Study:

- Continuous time study occurred, each machine comminuting one load.
- Effective working time (E_0h) varied 15 – 30 min.

Sampling and analysis of fuel chips:

- SFS- EN ISO 17225-1: Fuel quality classes and specification for solid biofuels.
- SFS- EN ISO 15149-1: Particle size analysis specification.
- SFS- EN ISO 15103: Bulk density.
- SFS-EN ISO 14774-2: Moisture content.
- Mass of wood fuel chips measured at the plant for each load.
- Three 50 dm^3 chip samples were collected from different points immediately after loading.
- Sub samples were placed into plastic bags (combined in lab).
- Sample particle size determined with digressive diameter classes of sieves
    - 100 mm, 62 mm, 45 mm, 31.5 mm, 16 mm, 8 mm, 3.15 mm.
- Samples air dried to moisture content <20%, then sieved for 15 min.
- Particles of each sieve size weighed (accuracy .1 g).

Table 2. Particle size classes for wood chips and hog fuel in SFS-EN ISO 17225-1

Class	Main fraction, minimum 60 w-% (mm)	Coarse fraction, w-% (mm)	Maximum length for oversized particles (mm)
P16S	3.15=<P=< 16	=<6% > 31.5 mm	=<45 mm
P16	3.15=<P=< 16	=<6% > 31.5 mm	=<150 mm
P31S	3.15=<P=< 31.5	=<6% > 45 mm	=<150 mm
P31	3.15=<P=< 31.5	=<6% > 45 mm	=<200 mm
P45S	3.15=<P=< 45	=<10% > 63 mm	=<200 mm
P45	3.15=<P=< 45	=<10% > 63 mm	=<350 mm
P63	3.15=<P=< 63	=<10% > 100 mm	=<350 mm
P100	3.15=<P=< 100	=<10% > 150 mm	=<350 mm
P200	3.15=<P=< 200	=<10% > 200 mm	=<400 mm
P300	3.15=<P=< 300	must be reported	
Proportion of fines (<3.15 mm)			
F05	=< 5%		
F10	=< 10%	Requirement for P31S and P45S	
F15	=< 15%	Requirement for P16S	
F20	=< 20%		
F25	=< 25%		
F30	=< 30%		
F30+	=>30%	Max value must be reported	

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- Results of the comminution and productivity study -

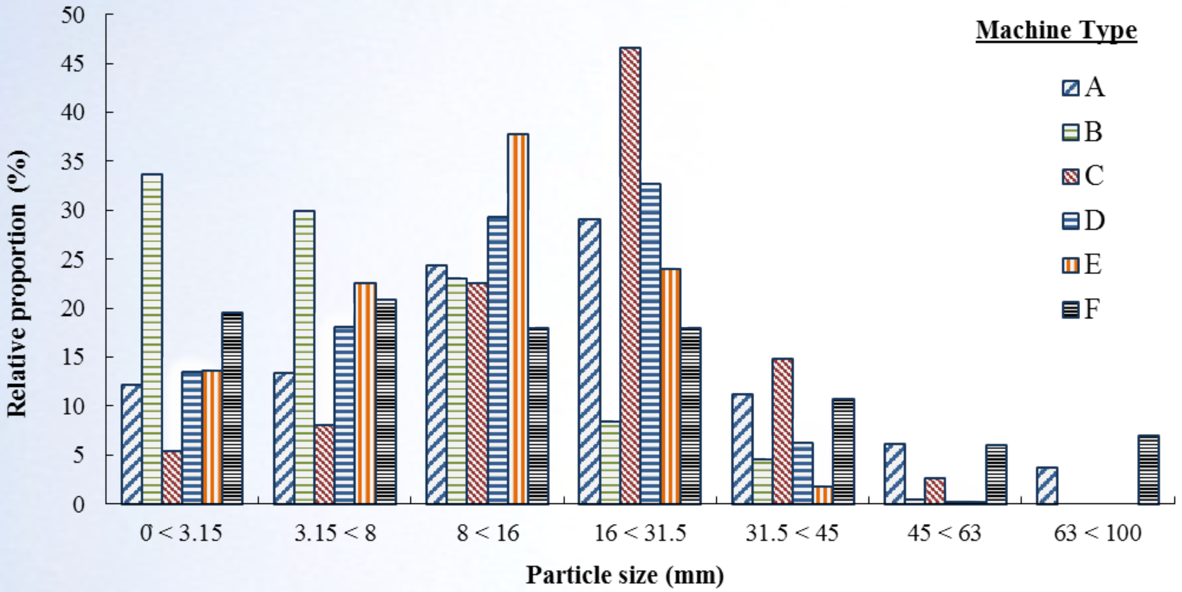

Figure 1. Particle size distribution of comminuted wood fuel chips.

Table 3. Particle size classes for chips comminuted for studied machines by SFS-EN ISO 17225-1, mean particle size, moisture content, moist and dry bulk density.

Machine type	Main fraction class [w-%]	Fine fraction class [w-%]	Mean particle size50% [mm]	Moisture content [w-%]	Moist bulk density after chipping [kg/m^3]	Dry bulk density [kg/m^3]
A	P31S (66.8)	F15 (12.2)	16.08	51.9	371	178
B	P31S (61.3)	F30+(33.7)	5.79	59.9	417	167
C	P31S (77.2)	F10 (5.4)	20.64	54.7	353	160
D	P31S (80.1)	F15 (13.5)	13.02	51.9	369	177
E	P16 (60.4)	F15 (13.6)	10.93	55.0	351	158
F	P456 (67.5)	F20 (19.5)	12.30	58.0	259	109

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- Results of the comminution and productivity study -

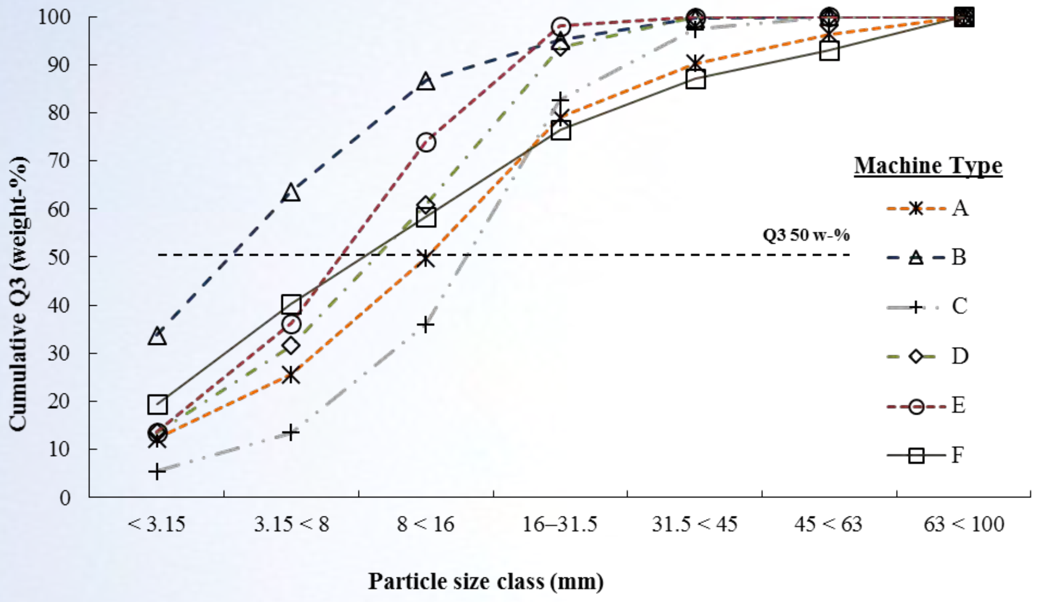

Figure 2. Cumulative particle size distribution of fuel wood chips.

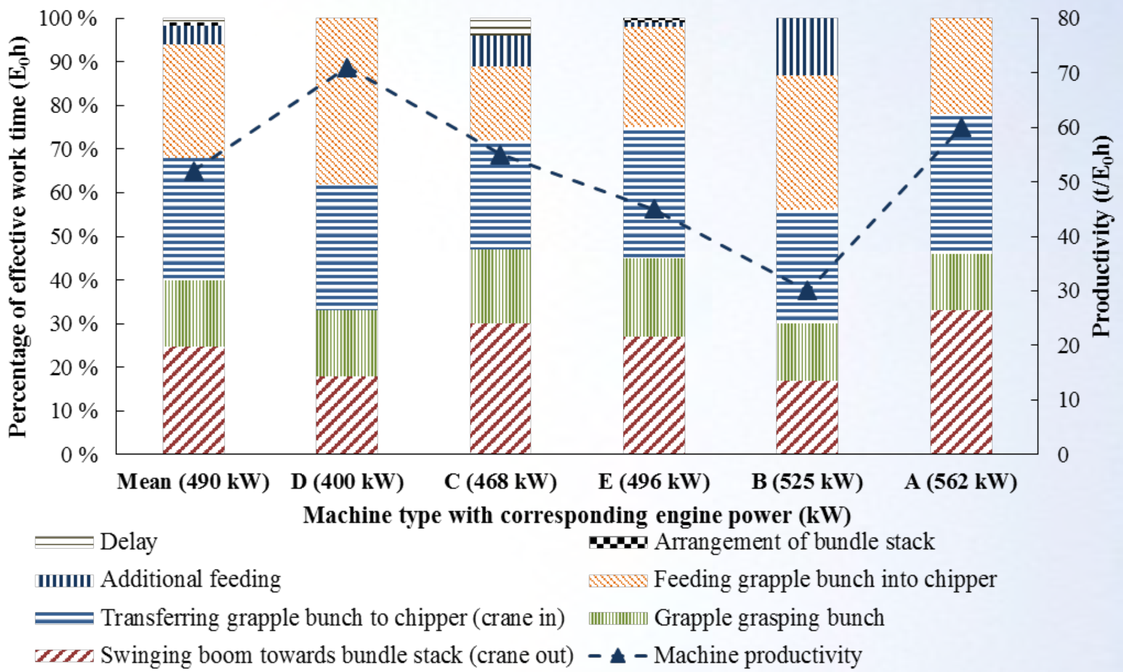

Figure 3. Effective hour chipping productivity (t/E_0h) of forest chips by dry mass basis and distribution of working time among tested machines.

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- Discussion and conclusion: Quality -

Moisture content:

- High moisture content (52 – 60%) and plant requirements.
    - Bundle storage size and configuration.
- No trend identified between sieve size and moisture content, as previously (Jylhä 2013).
- Machine type B: Moisture content 60% and 33.7% F particles <3.15 mm diameter.

Particle size:

- Mean particle size variation 5.79 – 20.64 mm.
- Dry bulk density 109 – 178 kg/m^3.
- 8.4 – 46.6% of the dry mass of whole-tree bundles was within 16 < 31.5 mm.
- Machine type B.
- Machine type F.

Photo: Fulvio Di Fulvio

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- Discussion and conclusion: Productivity -

Time study:

- Swinging boom towards bundle stack (25%).
- Transferring grapple bunch to chipper (28.4%).
- Feeding the grapple bunch into the chipper (26.2%).

Productivity:

- Dry mass basis productivity varied 29.8-71.3 t/E_0h with a mean of 52.2 t/E_0h.
  - Whole-tree bundle productivity at 32 t/E_0h (Kons et al. 2015).
  - Terminal vs. roadside comminution.
  - Dry mass productivities of logging residues (29 t/E_0h), whole-trees (25 t/E_0h) and stumps (17 t/E_0h); mean weight of grapple bunch 119 – 237 kg (Nuutinen et al. 2014).
  - Average weight of grapple bunch of chippers was 466 kg.

Photo: Fulvio Di Fulvio

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- Contact information and references -

Thank you for your attention!

Further information on the study: Quality and productivity in comminution of small-diameter tree bundles.

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