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Bulk Materials Research Group

Energy Utilization of Secondary Raw Materials and Alternative Energy Sources

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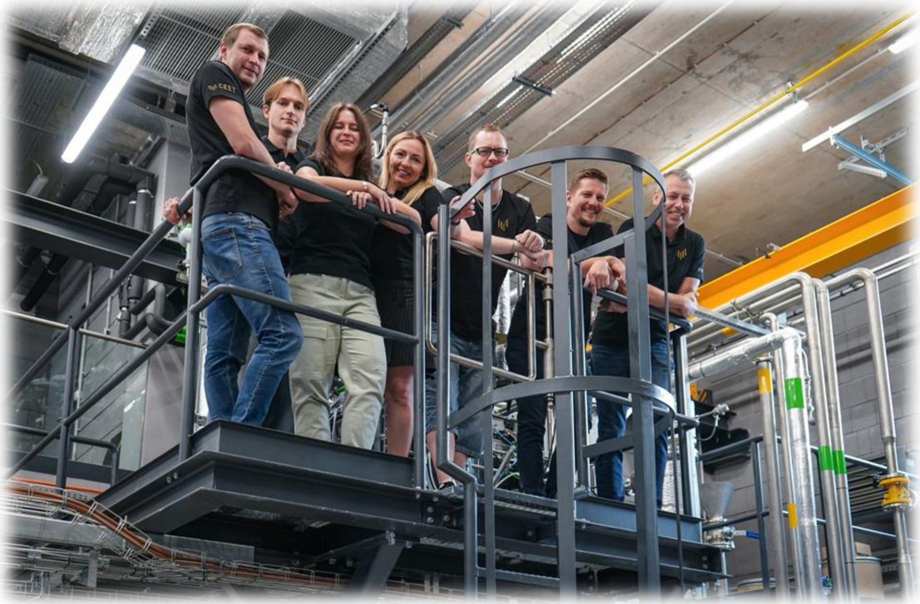

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Bulk Materials Research Group - Research and Measurement

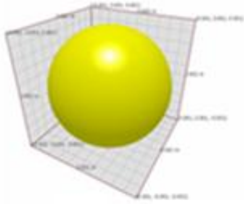
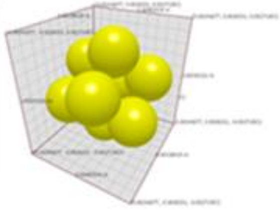
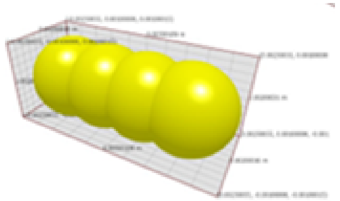
- Solving basic and applied research tasks in the areas of their processing, storage and transport.
- Study of mechanical-physical and geometric properties of bulk materials, necessary for assessing the initial state and subsequently design, engineering and mathematical models for their processing.
- The research group also conducts research in the field of material pelletization, especiallv biomass.



Keywords: bulk solid, powder, processing, DEM simulation, transport

Measurements:

- density,
- compressibility,
- permeability,
- moisture,
- particle distribution,
- shape,
- circularity,
- internal friction,
- external friction,
- roll friction,
- flowability,
- aeration,…

https://ceet.vsb.cz/en/research/research-groups/bulk-materials/index.html

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Biomass processing technology with the addition of binders for energy use

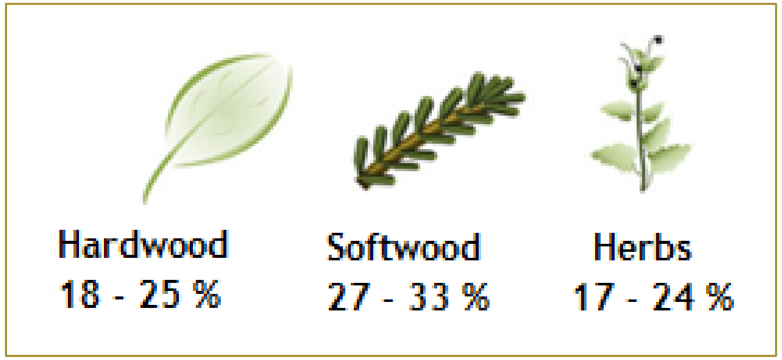
Ing. Veronika Sýkorová

Input material and binders

Input material: waste and surplus meadow hay (a).

Organic binders: lignosulfonate (b), flour (c), starch (d), carboxymethylcellulose (e).

Inorganic binders: magnesium carbonate (e), calcium carbonate (f).



Percentage of lignin in biomass

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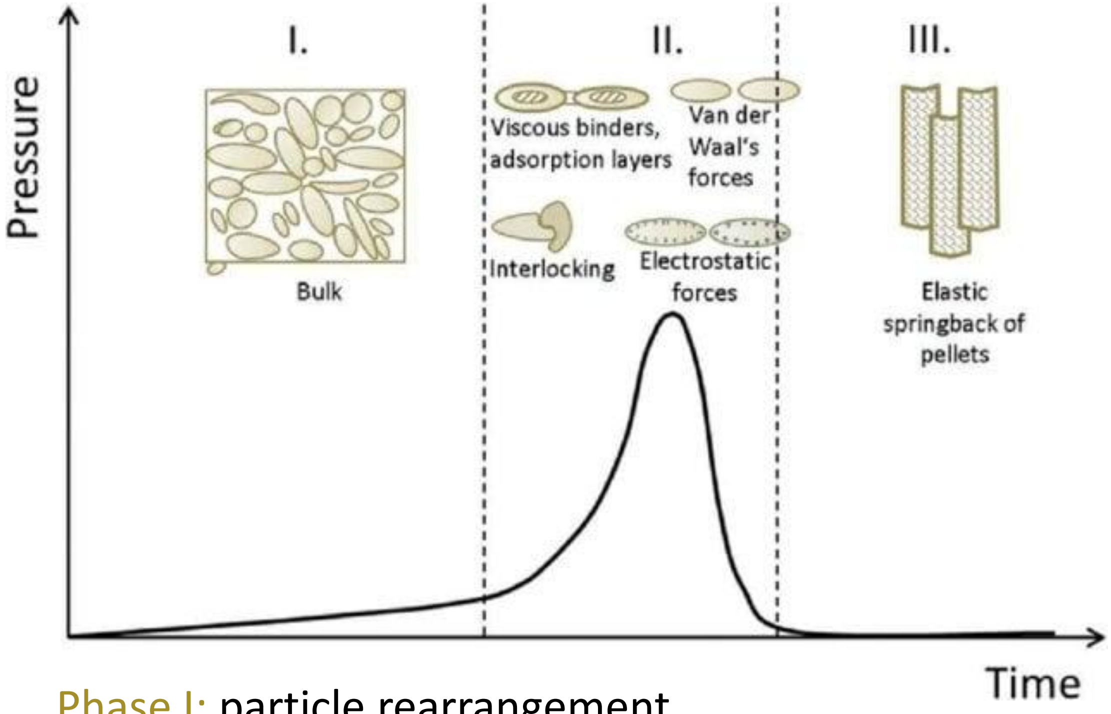
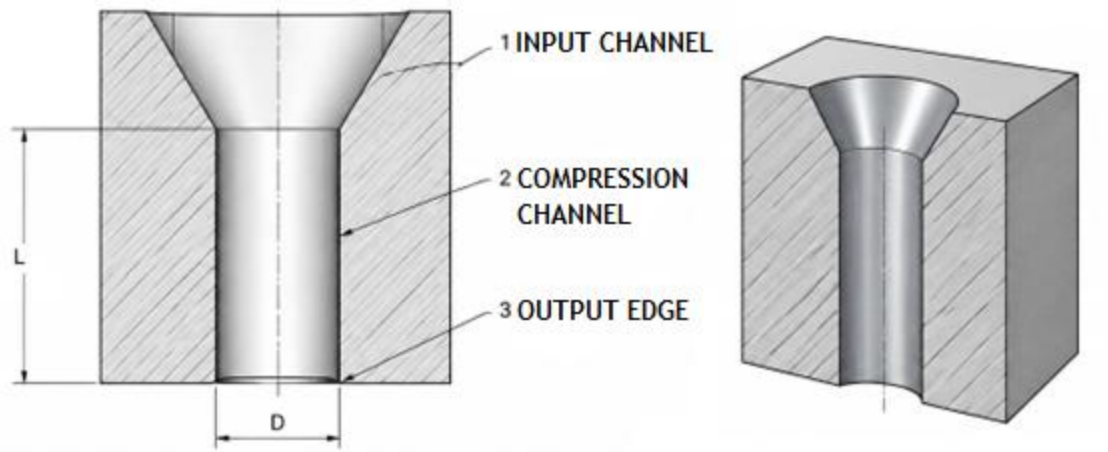
Pelletization

Pelletization is the process of compressing material particles into small, uniform, and energy-dense pellets.





Compression ratio (CR)

ratio between the effective length of the canal and its diameter

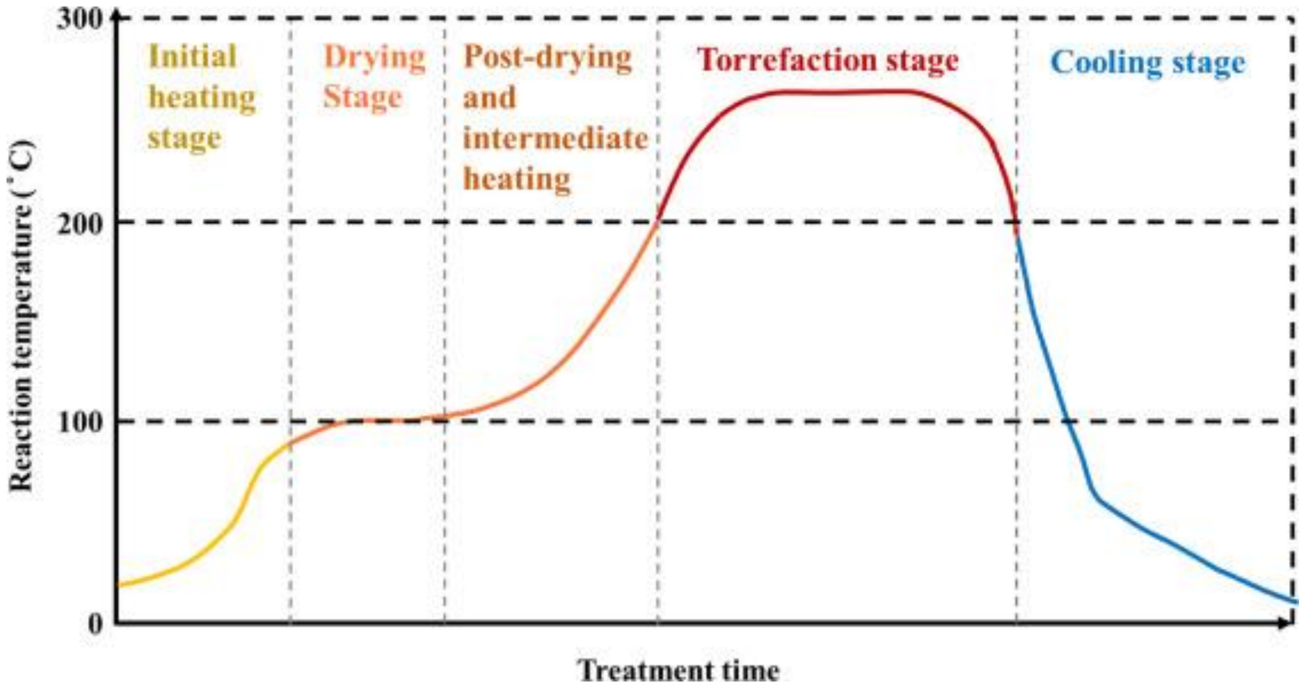
Phase I: particle rearrangement
Phase II: elastic-plastic deformation
Phase III: mechanical blocking of particles (solidification)

$$\boxed{CR = \frac{L}{D}}$$

L – effective working length of the channel (mm)
D – diameter of the die channel (mm)

Torrefaction

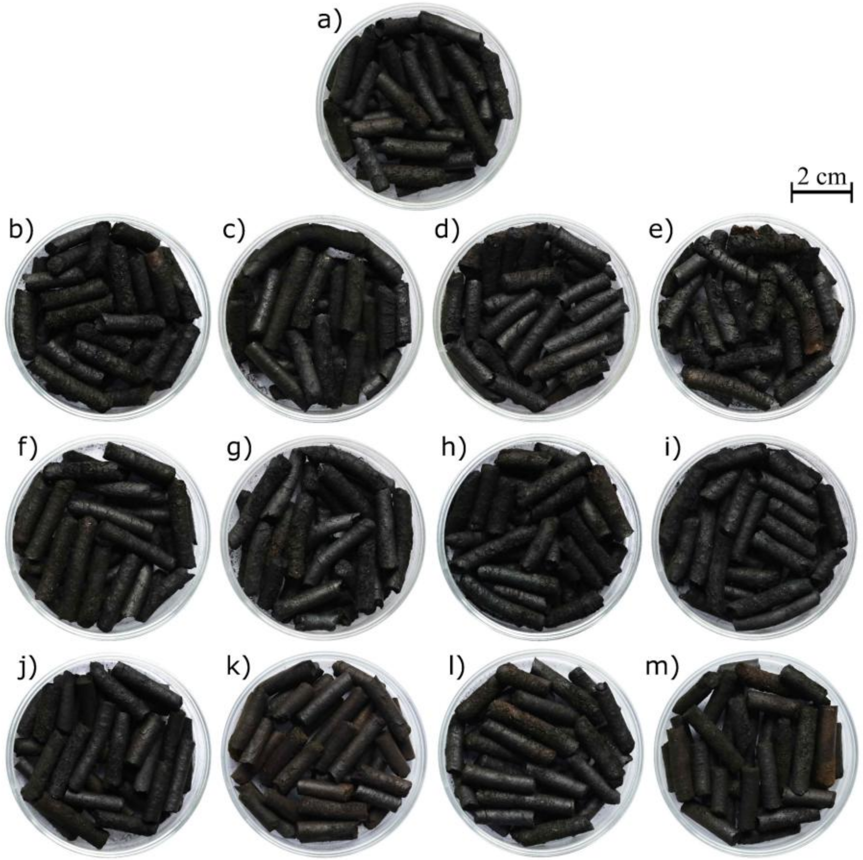
Torrefaction is a thermochemical process that takes place at temperatures from 200 to 300°C at atmospheric pressure in the absence of air.



- initial heating phase – biomass is heated to the desired temperature
- drying phase – temperature is maintained at a constant value until the rate of water evaporation decreases
- additional drying and intermediate heating – biomass is heated to a temperature of 200 °C; water that is physically bound is removed
- phase of torrefaction – occurs after the temperature exceeds 200 °C
- cooling phase – cooling of the product after torrefaction to ambient temperature

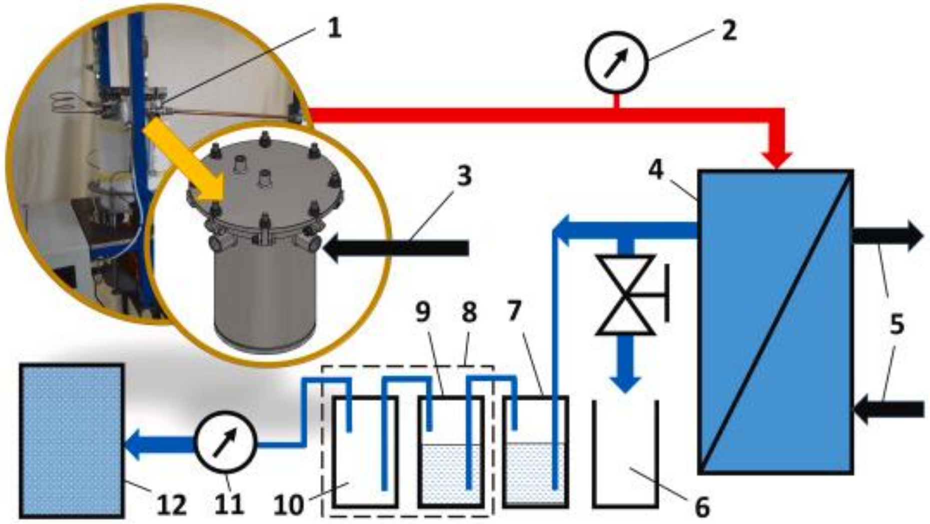
Conditions of torrefaction

Torrefaction took place in a small laboratory batch reactor (⌀13x20 cm) at a temperature of 250 °C in a nitrogen atmosphere, with a residence time of 2 hours.



Pellets after torrefaction

100 % hay (a),
2 % lignosulfonate (b),
15 % lignosulfonate (c),
2 % flour (d),
15 % flour (e),
2 % starch (f),
15 % starch (g),
2 % carboxymethylcelluse (h),
15 % carboxymethylcellulose (i),
2 % magnesium carbonate (j),
15 % magnesium carbonate (k),
2 % calcium carbonate (l),
15 % calcium carbonate (m)



Laboratory scale stand

1 – batch reactor,
2 – pressure gauge,
3 – electricity power,
4 – gas and oil water cooler,
5–inlet and outlet of cool water,
6–container for torrefaction oil,
7–water scrubber for gas purification,
8–cooling system,
9–impinger in the cooling system with isopropyl alcohol,
10–empty impinger in the cooling system for cleaning gas,
11–gas flow meter,
12–gas analyser.

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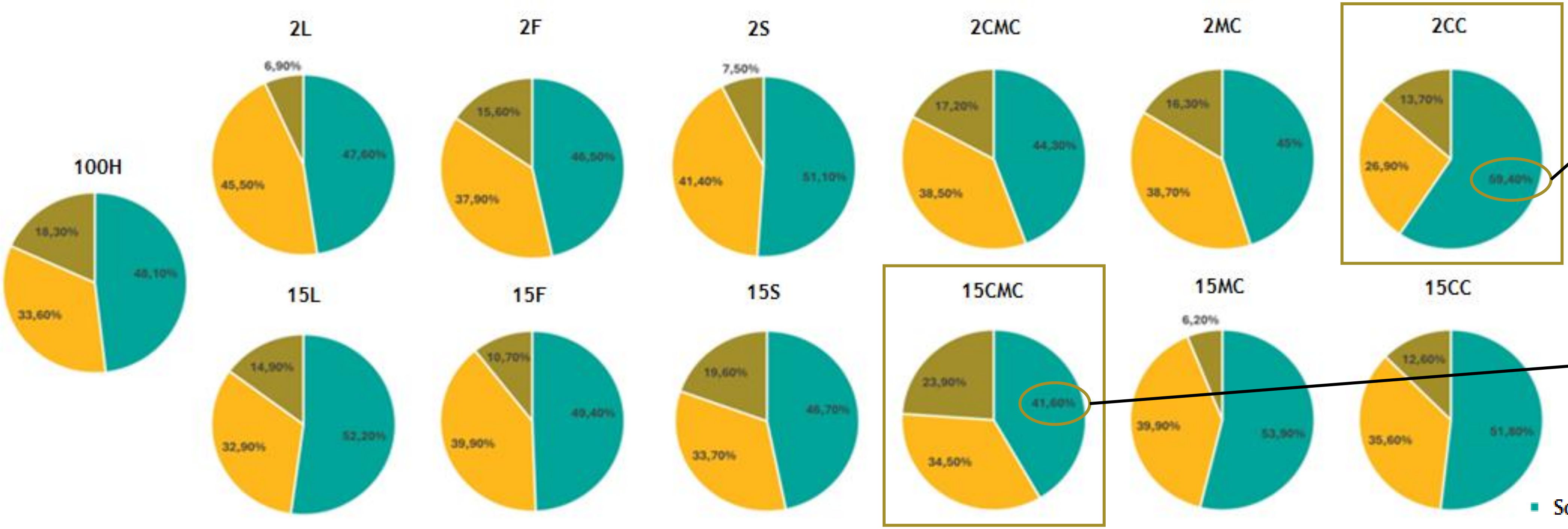
Results of torrefaction

AWL (Anhydrous Weight Loss) indicates the intensity of torrefaction. A higher AWL corresponds to a lower proportion of solid product after torrefaction.

AWL:
↑ 15CMC (58 %)
↓ 2CC (40 %)



↑ Solid residue:
2CC (59,40 %)

↓ Solid residue:
15CMC (41,60 %)

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Mechanical resistance (*PDI*) and hardness of pellets

↑ PDI of pellets before torrefaction: 15L (98.9 %)
↓ PDI of pellets before torrefaction: 2CMC (88.3 %)

↑ PDI of pellets after torrefaction: 15L (85.2 %)
↓ PDI of pellets after torrefaction: 2CMC (58 %)

↑ hardness of pellets before torrefaction: 15CC (62 kg)
↓ hardness of pellets before torrefaction: 2CMC (30 kg)

↑ hardness of pellets after torrefaction: 2MC and 2CC (23 kg)
↓ hardness of pellets after torrefaction: 2CMC (7 kg)

↓ PDI and hardness of pellets before and after torrefaction: 2CMC

After torrefaction, the pellets become more brittle and their mechanical resistance and hardness decrease.

Resistance of water absorption

↑ WI of pellets before torrefaction: 100H (22 %)
↓ WI of pellets before torrefaction: 15L (7 %)

↑ WI of pellets after torrefaction: 15CMC (4 %)
↓ WI of pellets after torrefaction: 15MC (0.6 %)

The pellets after torrefaction are hydrophobic.

The wettability index (*WI*) determines the resistance of pellets to water absorption.
The higher the WI, the worse the resistance to water absorption.

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Elemental analysis

Sample	C (%)	H (%)	N (%)	S (%)
100H	43,59	6,23	1,04	0,09
2L	43,43	6,18	0,99	0,15
15L	42,75	6,03	0,88	**0,76**
2F	43,65	6,22	1,06	0,10
15F	43,26	6,27	1,15	0,10
2S	43,48	6,20	1,06	0,11
15S	43,32	6,27	0,92	0,10
2CMC	43,29	6,17	0,97	0,08
15CMC	42,60	6,12	0,85	**0,05**
2MC	42,98	6,16	1,02	0,09
15MC	**40,29**	5,81	0,92	**0,06**
2CC	43,28	6,11	1,02	0,11
15CC	**40,20**	5,56	0,86	**0,07**
100H T	60,02	5,15	1,63	0,16
2L T	60,92	5,09	1,60	0,23
15L T	57,18	4,81	1,34	**0,62**
2F T	62,52	4,93	1,77	0,18
15F T	57,59	5,41	1,74	0,14
2S T	57,97	5,34	1,65	0,15
15S T	62,42	5,00	1,62	0,15
2CMC T	59,49	5,15	1,64	0,12
15CMC T	61,66	4,70	1,43	0,12
2MC T	61,05	4,75	1,75	0,19
15MC T	**51,61**	4,78	1,34	0,11
2CC T	56,16	5,15	1,48	0,12
15CC T	**50,84**	4,04	1,32	**0,04**

CSN EN ISO 17225-6
Max. nitrogen content: 2 %
Max. sulphur content: 0.3 %

Max. nitrogen content after torrefaction 1.77% (2F T).
Torrefaction took place in a nitrogen atmosphere.

The limit for sulfur content was exceeded in samples 15L and 15L T.
The higher sulfur values in lignosulfonate at a higher ratio were due to the content of sulfonate groups.

During torrefaction, carbonization occurred, with the carbon content in some samples increasing to almost 63 %.

Energy parameters

Sample	Moisture (%)	Volatile combustible (%)	Non-volatile combustible (%)	Ash (%)
100H	6,42	71,80	16,90	4,88
2L	6,00	71,76	17,43	4,82
15L	5,84	69,53	17,83	6,80
2F	5,92	71,73	17,72	4,63
15F	6,25	72,07	17,24	4,45
2S	5,91	72,18	16,77	5,14
15S	6,31	72,48	16,90	4,31
2CMC	5,85	71,73	17,19	5,23
15CMC	6,63	70,77	17,25	5,35
2MC	6,21	71,36	16,76	5,66
15MC	5,14	69,91	**15,33**	9,63
2CC	5,58	71,55	16,89	5,98
15CC	4,77	69,51	**14,13**	**11,59**
100H T	2,97	50,06	38,18	8,79
2L T	3,14	45,51	41,00	**10,35**
15L T	4,19	44,59	37,95	**13,26**
2F T	3,40	42,21	44,31	**10,09**
15F T	2,55	52,73	36,29	8,44
2S T	2,74	52,31	36,11	8,85
15S T	3,08	41,68	45,82	9,43
2CMC T	3,50	47,36	39,40	9,75
15CMC T	4,66	40,96	42,89	**11,50**
2MC T	3,80	38,51	44,54	**13,16**
15MC T	4,91	46,76	**30,70**	**17,62**
2CC T	2,44	53,08	34,32	**10,16**
15CC T	2,88	45,50	**31,05**	**20,58**

CSN EN ISO 17225-6
Max. moisture content: 15 %
Max. ash content: 10 %

The limit for ash content was exceeded before torrefaction for sample 15CC.
The limit for ash content was exceeded after torrefaction for samples 2L T, 15L T, 2F T, 15CMC T, 2MC T, 15MC T, 2CC T and 15CC T.

For pellets before torrefaction, volatile combustible was the most prominent component.
After torrefaction, there was an increase in non-volatile combustible.

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Calorific value and annual pellet consumption

Sample	Qv (MJ/kg)
100H	15,671
2L	15,728
15L	15,532
2F	15,759
15F	15,618
2S	15,683
15S	15,533
2CMC	15,671
15CMC	15,241
2MC	15,338
15MC	13,493
2CC	15,467
15CC	13,982
100H T	23,507
2L T	22,180
15L T	22,154
2F T	24,125
15F T	22,750
2S T	22,432
15S T	24,299
2CMC T	22,994
15CMC T	21,341
2MC T	23,257
15MC T	18,864
2CC T	22,262
15CC T	18,943

CSN EN ISO 17225-6
Min. calorific value: 14.5 MJ/kg

The limit was not met by pellets before torrefaction 15MC and 15CC.

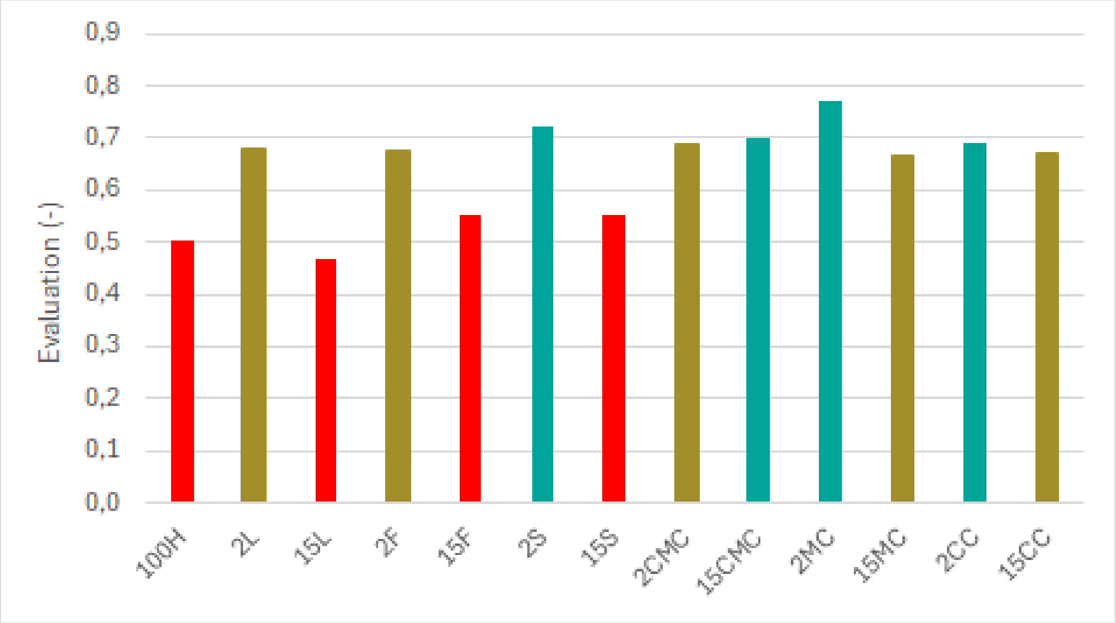
After torrefaction, there was a significant increase in the calorific value of all samples. The lowest calorific values were found in samples 15MC T and 15CC T.

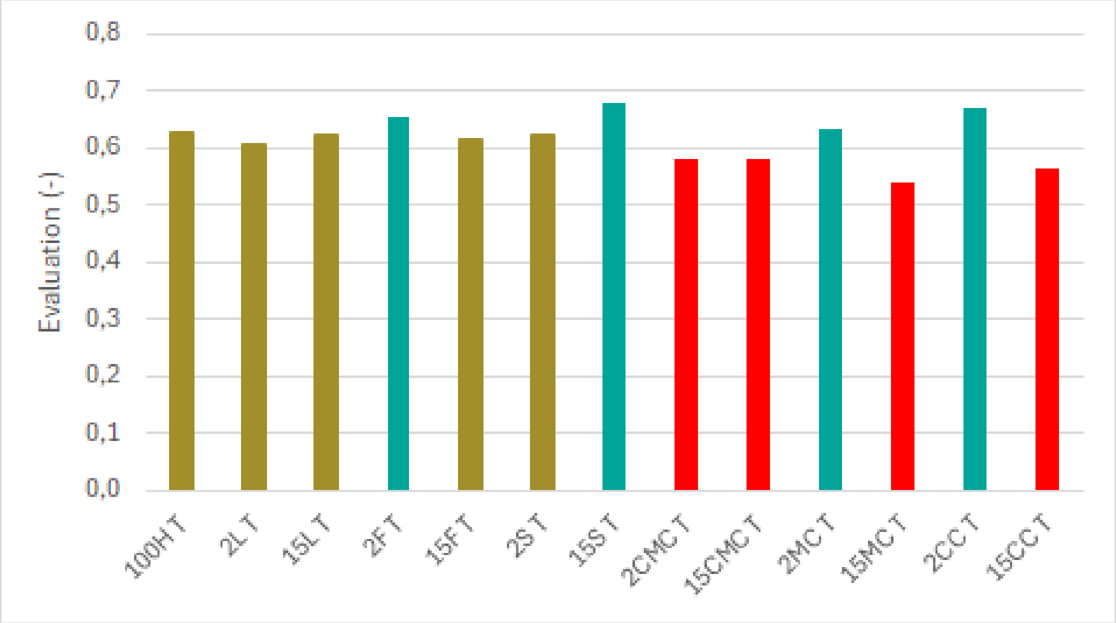
Carbonates at a ratio of 15 % reduce the calorific value of the input material.

↑ consumption of pellets before torrefaction: 15MC, 15CC
↓ consumption of pellets before torrefaction: 2F, 2L

↑ consumption of pellets after torrefaction: 15MC, 15CC
↓ consumption of pellets after torrefaction: 15S, 2F

Evaluation of pellet quality before and after torrefaction from the perspective of monitored parameters





From the results it can be observed that in most cases the pellet samples that contained a lower binder content achieved better results, with the 2MC and 2CC samples achieving the best results both before and after torrefaction on average. The 2S sample also achieved very good results, followed by the 2F sample.

By optimally selecting the content and type of binder in the mixture for pellet production, it is possible to achieve high-quality pellet properties before and after torrefaction while maintaining the economy of the production process.

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Thank you for your attention.

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