Effects of Forces, Particle Sizes and Moisture Contents on mechanical behaviour of densified briquettes from Ground Sunflower Stalks and Hazelnut Husks

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Table S1. Determined tangent curve model coefficients and statistical analysis of ground sunflower stalks briquettes of 11.23 % (w.b.).

Particle Size *PS* (mm)	Force *F* (kN)	*A* (kN)	*B* (mm^{-1})	*n* (-)	F-Ratio (-)	F-Critical (-)	*p*-Value (-)	R^2 (-)
***0 (0-10)**	100	3,174 ±0,045	0,015 ±0,001	2	0,029 ±0,015	3,856 ±0,003	0,866 ±0,035	0,999 ±0,000
	200	2,156 ±0,054	0,015 ±0,000		0,024 ±0,003	3,858 ±0,002	0,878 ±0,008	0,999 ±0,000
	300	2,387 ±0,049	0,016 ±0,001		0,016 ±0,005	3,859 ±0,001	0,901 ±0,016	0,999 ±0,000
	400	2,692 ±0,651	0,016 ±0,001		0,005 ±0,001	3,858 ±0,000	0,945 ±0,006	0,999 ±0,000
3 (0-3)	100	3,147 ±0,415	0,016 ±0,001	2	0,013 ±0,001	3,855 ±0,005	0,911 ±0,005	0,999 ±0,000
	200	3,154 ±0,882	0,017 ±0,001		0,032 ±0,032	3,855 ±0,005	0,869 ±0,074	0,999 ±0,000
	300	2,697 ±0,409	0,016 ±0,001		0,027 ±0,031	3,853 ±0,003	0,883 ±0,079	0,999 ±0,000
	400	2,978 ±0,397	0,016 ±0,001		0,002 ±0,002	3,854 ±0,004	0,973 ±0,035	0,999 ±0,000
6 (3-6)	100	3,575 0,736	0,016 0,001	2	0,039 ±0,002	3,854 ±0,006	0,844 ±0,004	0,999 ±0,000
	200	2,903 ±0,565	0,016 ±0,001		0,070 ±0,051	3,855 ±0,004	0,799 ±0,077	0,999 ±0,000
	300	2,519 ±0,458	0,016 ±0,001		0,048 ±0,042	3,856 ±0,003	0,836 ±0,079	0,999 ±0,000
	400	2,551 ±0,461	0,016 ±0,001		0,017 ±0,015	3,855 ±0,005	0,902 ±0,045	0,999 ±0,000
10 (6-10)	100	3,040 ±0,189	0,014 ±0,003	2	0,058 ±0,037	3,856 ±0,006	0,817 ±0,063	0,999 ±0,000
	200	2,211 ±0,062	0,014 ±0,002		0,064 ±0,044	3,856 ±0,005	0,807 ±0,069	0,999 ±0,000
	300	2,200 ±0,171	0,015 ±0,002		0,042 ±0,037	3,856 ±0,004	0,846 ±0,074	0,999 ±0,000
	400	2,371 ±0,007	0,015 ±0,002		0,017 ±0,019	3,856 ±0,004	0,907 ±0,062	0,999 ±0,000

*0 (0-10) mm – Control, *A* is the force coefficient of mechanical behaviour (kN), *B* is the deformation coefficient of mechanical behaviour (mm^{-1}), *n* is the fitting curve function exponent (-), *F*-Ratio is the value of the F test (-), *F*-Critical is the critical value that compares a pair of model (-), *p*-Value is the significance level used for testing a statistical hypothesis (-), R^2 is the coefficient of determination (-), *F*-Ratio < *F*-Rritical or *p*-Value > 0.05 indicates significant (based on MathCAD 14 software).

Table S2. Determined tangent curve model coefficients and statistical analysis of densified briquettes of ground sunflower stalks for particle size 0-10 mm

Moisture Content ***MC*** **(% w.b)**	**Force** ***F*** **(kN)**	***A*** **(kN)**	***B*** **(mm^{-1})**	***n*** **(-)**	**F-Ratio (-)**	**F-Critical (-)**	***p*-Value (-)**	**R^2 (-)**
14.44	100	1,705 ±0,151	0,015 ±0,000	2	0,039 ±0,001	3,858 ±0,001	0,844 ±0,004	0,999 ±0,001
	200	1,451 ±0,026	0,015 ±0,000		0,030 ±0,001	3,858 ±0,001	0,863 ±0,005	0,999 ±0,000
	300	1,680 ±0,229	0,016 ±0,001		0,009 ±0,001	3,858 ±0,001	0,924 ±0,008	0,999 ±0,000
	400	1,550 ±0,112	0,015 ±0,000		0,001 ±0,001	3,857 ±0,000	0,985 ±0,018	0,999 ±0,000
16.89	100	1,397 ±0,042	0,014 ±0,000	2	0,051 ±0,004	3,856 ±0,001	0,822 ±0,006	0,999 ±0,001
	200	1,385 ±0,050	0,016 ±0,001		0,030 ±0,005	3,857 ±0,001	0,864 ±0,011	0,999 ±0,000
	300	1,256 ±0,018	0,015 ±0,000		0,009 ±0,003	3,857 ±0,001	0,925 ±0,010	0,999 ±0,000
	400	1,320 ±0,075	0,015 ±0,000		0,004 ±0,001	3,857 ±0,000	0,955 ±0,007	0,999 ±0,000

For particle sizes 0-10 mm (Control)

Table S3. Determined tangent curve model coefficients and statistical analysis of ground hazelnut husks briquettes of 12.64 (% w.b.)

Particle Size *PS* (mm)	Force *F* (kN)	*A* (kN)	*B* (mm^{-1})	*n* (-)	F-Ratio (-)	F-Critical (-)	*p*-Value (-)	R^2 (-)
***0 (0-10)**	100	7.835 ±0.219	0.016 ±0.000	2	0.002 ±0.002	3.858 ±0.000	0.993 ±0.009	0.999 ±0.000
	200	8.150 ±1.184	0.017 ±0.001		0.000 ±0.000	3.861 ±0.000	0.549 ±0.635	0.999 ±0.000
	300	8.558 ±0.091	0.018 ±0.000		0.002 ±0.001	3.859 ±0.001	0.989 ±0.001	0.999 ±0.000
	400	8.200 ±0.969	0.018 ±0.001		0.005 ±0.003	3.859 ±0.001	0.982 ±0.005	0.999 ±0.000
3 (0-3)	100	2.4765 ±0.042	0.015 ±0.000	2	0.001 ±0.001	3.858 ±0.001	0.989 ±0.011	0.999 ±0.000
	200	9.788 ±0.569	0.018 ±0.001		0.002 ±0.001	3.858 ±0.001	0.973 ±0.012	0.999 ±0.000
	300	9.848 ±0.724	0.0175 ±0.001		0.001 ±0.000	3.8595 ±0.004	0.9875 ±0.001	0.999 ±0.000
	400	9.240 ±1.866	0.017 ±0.001		0.001 ±0.000	3.858 ±0.001	0.985 ±0.006	0.999 ±0.000
6 (3-6)	100	6.363 ±0.293	0.017 ±0.001	2	0.002 ±0.001	3.859 ±0.000	0.971 ±0.004	0.999 ±0.000
	200	5.329 ±0.937	0.016 ±0.001		0.001 ±0.001	3.858 ±0.001	0.992 ±0.008	0.999 ±0.000
	300	5.391 ±0.819	0.016 ±0.001		0.001 ±0.000	3.858 ±0.002	0.983 ±0.002	0.999 ±0.000
	400	5.839 ±0.131	0.017 ±0.011		0.001 ±0.000	3.858 ±0.000	0.979 ±0.008	0.999 ±0.000
10 (6-10)	100	2.477 ±0.042	0.015 ±0.000	2	0.001 ±0.001	3.858 ±0.001	0.989 ±0.011	0.999 ±0.000
	200	2.927 ±0.021	0.016 ±0.001		0.002 ±0.001	3.857 ±0.002	0.968 ±0.019	0.999 ±0.000
	300	2.763 ±0.281	0.015 ±0.001		0.002 ±0.001	3.858 ±0.002	0.965 ±0.014	0.999 ±0.000
	400	3.248 ±0.206	0.015 ±0.000		0.004 ±0.002	3.859 ±0.001	0.955 ±0.018	0.999 ±0.000

*0 (0-10) mm – Control

Table S4. Determined tangent curve model coefficients and statistical analysis of densified briquettes of ground hazelnut husks for particle size of 0(0-10) mm (control)

Moisture Content *MC* (% w.b)	Force *F* (kN)	*A* (kN)	*B* (mm^{-1})	*n* (-)	F-Ratio (-)	F-Critical (-)	*p*-Value (-)	R^2 (-)
14.83	100	6.547 ±0.561	0.018 ±0.001	2	0.001 ±0.000	3.859 ±0.000	0.972 ±0.001	0.999 ±0.000
	200	5.753 ±1.240	0.017 ±0.001		0.001 ±0.000	3.859 ±0.001	0.984 ±0.004	0.999 ±0.000
	300	6.280 0.553	0.018 ±0.000		0.003 ±0.001	3.860 ±0.001	0.960 ±0.010	0.999 ±0.000
	400	5.873 ±0.204	0.018 ±0.000		0.003 ±0.002	3.859 ±0.001	0.961 ±0.014	0.999 ±0.000
17.34	100	4.273 ±0.031	0.016 ±0.000	2	0.002 ±0.000	3.859 ±0.001	0.962 ±0.006	0.999 ±0.000
	200	4.778 ±0.857	0.018 ±0.001		0.002 ±0.003	3.860 ±0.001	0.971 ±0.030	0.999 ±0.000
	300	3.757 ±0.182	0.017 ±0.000		0.003 ±0.003	3.858 ±0.000	0.946 ±0.000	0.999 ±0.000
	400	3.585 ±0.648	0.019 ±0.002		0.010 ±0.006	3.859 ±0.002	0.925 ±0.025	0.999 ±0.000

Table S5. Ground sunflower stalks briquette volume, bulk density and volume energy at moisture content of 11.23% (w.b.)

Force, *F* (kN)	Particle Size *PS* (mm)	Briquette Volume *VL* ($x10^{-5}$ m^3)	Briquette Bulk Density *DS* (kg m^{-3})	Briquette Volume Energy *VE* ($x10^6$ J m^{-3})
100	*0	7.27 ± 0.10	669.05 ± 9.39	12.71±0.67
	3	7.71 ± 0.02	696.51 ± 11.12	11.42±0.55
	6	7.54 ± 0.85	653.29 ± 19.33	12.89±0.21
	10	7.26 ± 0.62	662.68 ± 62.07	14.23±1.83
200	*0	6.22 ± 0.19	781.59 ± 25.29	21.15±0.03
	3	6.14 ± 0.52	877.97 ± 88.56	21.60±3.39
	6	6.06 ± 0.13	812.87 ± 99.26	23.62±1.94
	10	6.10 ± 0.83	788.01 ± 33.99	23.97±0.41
300	*0	5.70 ± 0.16	853.22 ± 25.05	28.36±0.21
	3	5.63 ± 0.12	964.41 ± 23.15	29.85±1.93
	6	5.53 ± 0.61	891.99 ± 29.32	30.24±0.36
	10	5.58 ± 0.91	863.20 ± 13.33	31.93±0.31
400	*0	5.22 ± 0.03	931.75 ± 6.49	37.24±1.18
	3	5.64 ± 0.13	963.58 ± 22.65	34.92±0.16
	6	5.31 ± 0.54	927.68 ± 41.42	37.35±0.13
	10	5.28 ± 0.95	914.15 ± 0.19	39.68±0.46

*0 (0-10) mm – Control

Table S6. Ground sunflower stalks briquette volume, bulk density and volume energy at particle size of 0(0-10) mm (control)

Force *F* (kN)	Moisture Content *MC* (mm)	Briquette Volume *VL* (x10^{-5} m^3)	Briquette Bulk Density *DS* (kg m^{-3})	Briquette Volume Energy *VE* (x10^6 J m^{-3})
100	11.23	7.27 ± 0.10	669.05 ± 9.39	12.71 ± 0.67
	14.44	7.06 ± 0.08	707.75 ± 7.72	11.14 ± 0.07
	16.89	7.73 ± 0.02	669.64 ± 2.55	10.14 ± 0.10
200	11.23	6.22 ± 0.19	781.59 ± 25.29	21.15 ± 0.03
	14.44	6.13 ± 0.09	820.91 ± 12.98	18.03 ± 0.58
	16.89	6.49 ± 0.11	796.87 ± 14.32	16.45 ± 0.53
300	11.23	5.70 ± 0.16	853.22 ± 25.05	28.36 ± 0.21
	14.44	5.51 ± 0.09	906.03 ± 21.11	25.04 ± 0.44
	16.89	6.16 ± 0.12	841.65 ± 16.62	21.55 ± 0.57
400	11.23	5.22 ± 0.03	931.75 ± 6.49	37.24 ± 1.18
	14.44	5.45 ± 0.01	916.74 ± 1.81	29.52 ± 0.34
	16.89	5.96 ± 0.02	866.63 ± 1.07	25.63 ± 0.67

Table S7. Ground hazelnut husks briquette volume, bulk density and volume energy at moisture content of 12.64% (w.b.)

Force *F* (kN)	Particle Size *PS* (mm)	Briquette Volume *VL* (x10^{-5} m^3)	Briquette Bulk Density *DS* (kg m^{-3})	Briquette Volume Energy *VE* (x10^6 J m^{-3})
100	*0	11.24 ± 0.20	806.05 ± 12.61	9.74 ± 0.17
	3	12.39 ± 0.20	796.10 ± 18.02	8.48 ± 0.19
	6	10.03 ± 0.07	777.18 ± 2.98	10.28 ± 0.14
	10	7.55 ± 0.33	765.60 ± 33.83	10.66 ± 0.39
200	0	9.35 ± 0.29	969.63 ± 26.11	18.07 ± 0.23
	3	10.41 ± 0.23	955.36 ± 20.13	16.82 ± 0.41
	6	8.60 ± 0.15	909.14 ± 16.20	18.68 ± 0.57
	10	6.48 ± 0.05	890.58 ± 6.00	19.71 ± 0.27
300	0	8.95 ± 0.10	1017.68 ± 10.48	24.80 ± 0.20
	3	9.79 ± 0.02	1019.31 ± 1.71	23.57 ± 0.12
	6	7.85 ± 0.05	994.28 ± 6.34	26.05 ± 0.21
	10	5.86 ± 0.00	981.03 ± 5.86	28.09 ± 0.26
400	0	8.62 ± 0.03	1056.69 ± 2.69	30.20 ± 0.48
	3	9.45 ± 0.09	1054.57 ± 7.94	29.75 ± 0.36
	6	7.52 ± 0.01	1038.37 ± 0.49	32.40 ± 0.74
	10	5.70 ± 0.09	1011.18 ± 14.62	35.12 ± 1.88

*0 (0-10) mm – Control

Table S8. Ground hazelnut husks briquette volume, bulk density and volume energy at particle size of 0(0-10) mm (control)

Force, *F* (kN)	Moisture Content *MC* (mm)	Briquette Volume *VL* (x10^{-5} m^3)	Briquette Bulk Density *DS* (kg m^{-3})	Briquette Volume Energy *VE* (x10^6 J m^{-3})
100	12.64	11.24 ± 0.20	806.05 ± 12.61	9.74 ± 0.17
	14.83	11.00 ± 0.39	827.99 ± 25.91	9.03 ± 0.17
	17.34	10.96 ± 0.22	866.75 ± 24.94	8.45 ± 0.06
200	12.64	9.35 ± 0.29	969.63 ± 26.11	18.07 ± 0.23
	14.83	9.38 ± 0.37	974.99 ± 33.12	16.87 ± 0.77
	17.34	9.82 ± 0.42	963.48 ± 50.90	13.68 ± 1.16
300	12.64	8.95 ± 0.10	1017.68 ± 10.48	24.80 ± 0.20
	14.83	9.11 ± 0.14	1006.97 ± 5.07	21.80 ± 0.23
	17.34	9.55 ± 0.41	996.15 ± 50.68	18.18 ± 0.60
400	12.64	8.62 ± 0.03	1056.69 ± 2.69	30.20 ± 0.48
	14.83	8.97 ± 0.00	1021.25 ± 10.54	26.11 ± 0.12
	17.34	9.95 ± 0.79	955.10 ± 72.29	18.85 ± 0.25

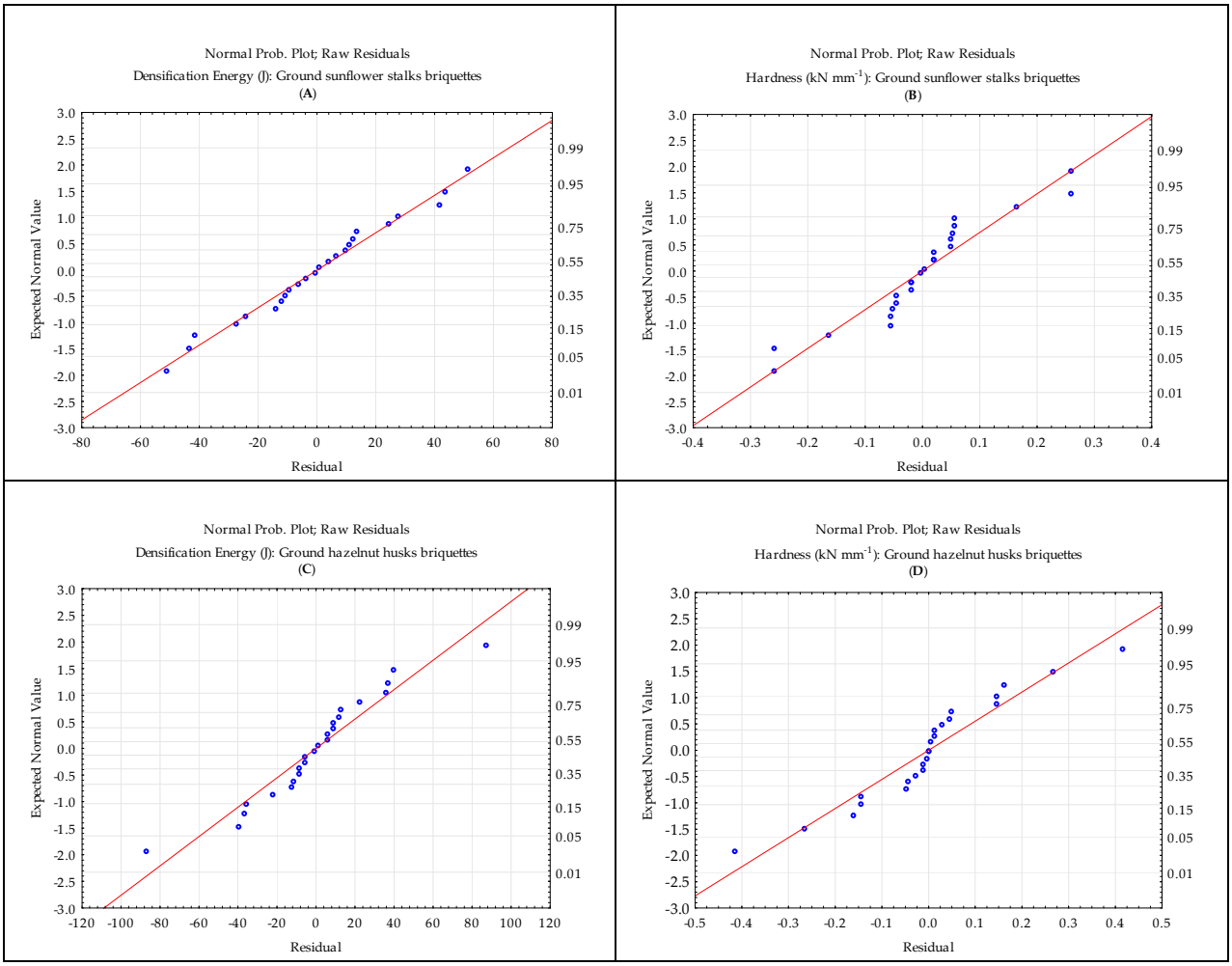

Figure S1. Normal probability plots of densification energy (**A**) and hardness (**B**) of ground sunflower stalks, and densification energy (**C**) and hardness (**D**) of ground hazelnut husks briquettes under the effects of force and moisture content similar to other determined parameters.

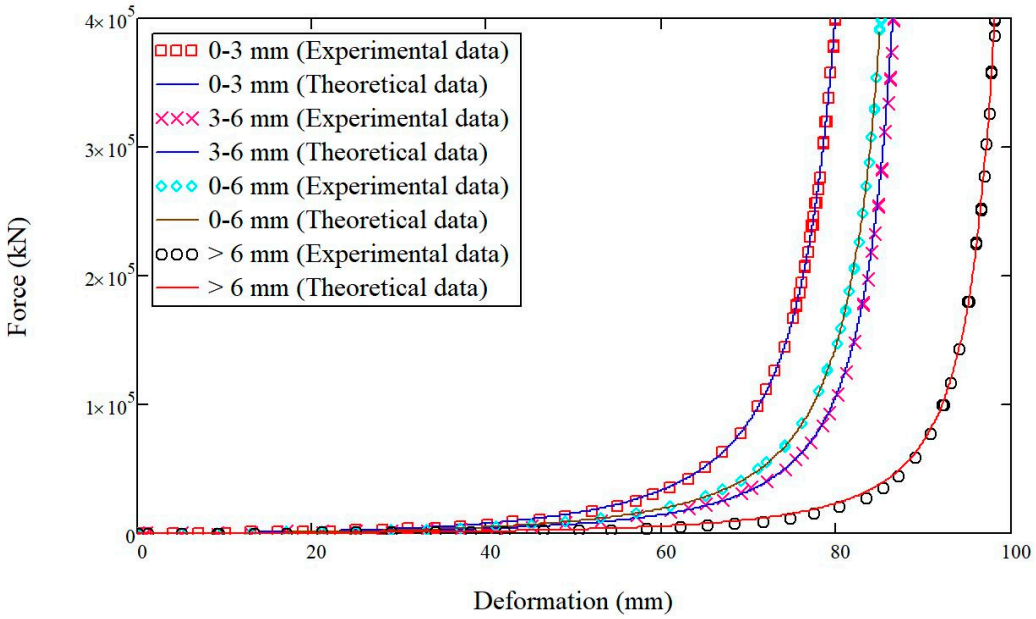

Figure S2. Force-deformation curves of ground hazelnut husks particle sizes at moisture content of 12.64 % (w.b.)

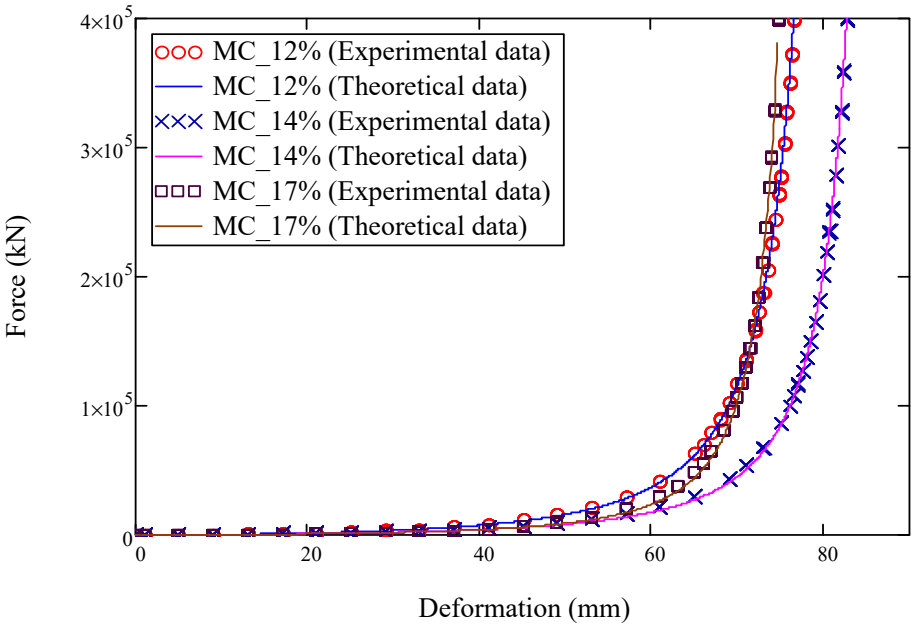

Figure S3. Force-deformation curves of ground hazelnut husks at different moisture content for particle size of 0 (0-10) mm