energies

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Figure S1. Visual aspect of non-wood pellets from pressing residual biomass from distillation of cellulosic bioethanol with addition by spraying and stirring of liquid-state food waste, immediately after freezing.

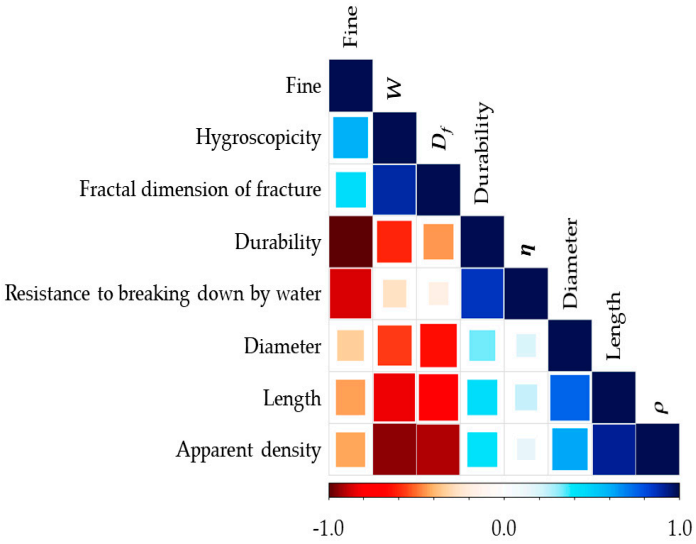

Figure S2. Correlogram for the linear relationships between variables of physical-mechanical quality of non-wood pellets from pressing residual biomass from distillation of cellulosic bioethanol with addition by stirring and spraying of liquid-state food waste, underwent to freezing-defrosting.

Table S1. Technical specifications of integrated set of pelleting.

Characteristic	Unit
Load capacity of feeder silo	250 kg
Engine potency	20 HP
Production capacity	250 kg h^{-1}
Nominal diameter of tungsten channel-forming die	200 mm
Nominal diameter of tungsten pressing rollers	2 × 100 mm
Maximum nominal temperature of die	150 °C
Diameter of pellet	6–8 mm
Apparent density of pellet	1000 – 1400 kg m^{-3}
Weight	850 kg
Dimensions of pelletizer machine	4200 mm × 2450 mm × 1750 mm

Table S2. Norms for the physical-chemical characterization of the starting material and supplement.

Norm/ Method	Property	Analysis	Instrument
		Proximate	
ASTM E871-82	Water		Horizontal airflow drying-oven (Marconi MAO35/5)
ASTM E871-82	Volatile material and fixed-carbon		Digital muffle furnace (SPlabor 1200DM/B)
ASTM D1102-84	Ash		Digital muffle furnace
		Elemental	
EN 15104	C, H, O, and N		Elemental analyzer (Flash Smart CHNS/O)
EN 15289	S		Elemental analyzer

American Society for Testing and Materials (ASTM);
European Norm (EN).

Table S3. Proximal and elemental properties of residual biomass from distillation of cellulosic bioethanol, and food waste from restaurants.

Ingredient	Proximate analysis, %				Ultimate analysis, %				
	Water	Volatile matter	Fixed-carbon	Ash	C	H	O	N	S
Residual biomass	12.2010	69.8500	24.3005	5.8495	53.0500	6.0505	39.7000	-	1.3000
Food waste	70.7505	74.8575	10.0775	15.0650	46.8005	6.7570	37.9505	3.0565	0.2585

Table S4. Range analysis for the effect of time of boiling, method of addition and storage condition on the variables of physical-mechanical quality and fractal dimension of mechanical fractures of non-wood pellets from residual biomass from distillation of cellulose bioethanol.

Variables	Level	Factor		
		A	B	C
Diameter, mm	L_1	5.9345	5.7900	5.9065
	L_2	6.0140	6.0290	5.8755
	L_3	5.7800		5.9465
	Range	0.2340	0.2385	0.0710
Length, mm	L_1	27.5560	24.5460	29.0805
	L_2	34.1370	33.6170	29.0110
	L_3	25.5510		29.1530
	Range	8.5860	9.0710	0.1420
Apparent density, kg m^{-3}	L_1	924.7975	799.5980	963.3260
	L_2	1026.1575	1117.6955	958.6305
	L_3	924.9850		953.9835
	Range	101.3600	318.0975	9.3430
Durability, %	L_1	96.1750	95.5130	99.6165
	L_2	97.9055	98.2390	96.2250
	L_3	96.5470		94.7860
	Range	1.7305	2.7260	4.8305
Fines, %	L_1	3.8250	4.4870	0.3835
	L_2	2.0945	1.7610	3.7750
	L_3	3.4530		5.2140
	Range	1.9910	2.0185	4.2140
Resistance to breaking down by water, min	L_1	54.6305	54.7220	58.7915
	L_2	56.1030	55.0980	53.1945
	L_3	53.9970		52.7445
	Range	2.1055	0.3760	6.0470
Hygroscopicity, %	L_1	9.7415	11.2295	8.8420
	L_2	8.4235	7.3790	8.9285
	L_3	9.5480		10.1420
	Range	1.3180	3.8505	1.2995
Fractal dimension of fractures by thermal shock	L_1	1.8540	1.9595	1.8530
	L_2	1.8530	1.7705	1.8530
	L_3	1.8580		1.8585
	Range	0.0050	0.2090	0.0055

Table S5. Analysis of lack-of-fit for the first-order surface response models for the interactive effect of time of boiling and method of addition on variables of physical-mechanical quality of non-wood pellets from pressing residual biomass from distillation of cellulosic bioethanol with liquid-state food waste.

Parameter	Estimate	Standard error	t value	p > |t|	R_{adj}^2
	Diameter, mm				0.6120
β_0, Intercept	5.6285	0.0600	93.4480	<0.0100 **	
β_1, Time of boiling, min	-0.0155	0.0040	-3.5435	0.0500 *	
β_2, Method of addition	0.2385	0.0355	6.7165	<0.0100 **	
	Length, mm				0.6000
β_0, Intercept	16.4770	1.7310	9.5180	<0.0100 **	
β_1, Time of boiling, min	-0.2005	0.1250	-1.6030	0.1150	
β_2, Method of addition	9.0710	1.0210	8.8840	<0.0100 **	
	Apparent density, kg m^{-3}				0.8450
β_0, Intercept	481.4065	31.6010	15.2340	<0.0100 **	
β_1, Time of boiling, min	-0.0185	2.2825	0.0080	0.9935	
β_2, Method of addition	318.0975	18.6370	17.0675	<0.0100 **	
	Durability, %				0.7480
β_0, Intercept	98.8970	0.7685	128.6680	<0.0100 **	
β_2, Method of addition	2.0180	0.3840	5.2520	<0.0100 **	
β_3, Storage condition	-2.7010	0.2350	-11.4785	<0.0100 **	
	Fines, %				0.7485
β_0, Intercept	1.1025	0.7685	1.4345	0.1575	
β_2, Method of addition	-2.0185	0.3840	-5.2520	<0.0100 **	
β_3, Storage condition	2.7015	0.2350	11.4785	<0.0100 **	
	Resistance to breaking down by water, min				0.7125
β_0, Intercept	60.3935	0.8575	70.4165	0.0500 *	
β_2, Time of boiling	0.3760	0.4290	0.8765	0.3850	
β_3, Storage condition	-3.0235	0.2625	-11.5140	<0.0100 **	
	Hygroscopicity, %				0.7725
β_0, Intercept	15.1770	0.4845	31.3235	<0.0100 **	
β_1, Time of boiling, min	-0.0190	0.0350	-0.5530	0.5825	
β_2, Method of addition	-3.8510	0.2855	-13.4760	<0.0100 **	
	Fractal dimension of fractures by thermal shock				0.9905
β_0, Intercept	2.1190	0.0050	421.6150	<0.0100 **	
β_2, Method of addition	-0.1840	0.0025	-73.3790	<0.0100 **	

β_3, Storage condition	0.0125	0.0015	8.1685	<0.0100 **

Significant code: ** $p < 0.01$; * $p < 0.05$.

Table S6. Potential applications for non-wood pellets from processing residual biomass from distillation of cellulosic bioethanol with addition by stirring and spraying of liquid-state food waste boiled for five minutes.

Variable	**Unit**	**Stirring**			**Spraying**			**Standard ***					
Potential application		Normal Unqualified	Frozen Unqualified	Defrosted Unqualified	Normal Residential	Frozen Residential	Defrosted Residential	ENPlus Residential			IWPB Industrial		
Class					A_1	A_1	A_1	A_1	A_2	B	I_1	I_2	I_3
Diameter, mm	mm	5.9565	5.9335	6.0500	6.0345	6.0335	6.0765	6–8	6–8	6–8	6–8	6–10	6–12
Length	mm	28.6010	28.5835	28.6835	39.7195	39.4500	39.8335	3.15–40	3.15–40	3.15–40	≤ 40	≤ 40	≤ 40
Apparent density	kg m^{-3}	810.2500	800.2335	795.3165	1250.8500	1250.3000	1250.0665	≥ 600	≥ 600	≥ 600	≥ 600	≥ 600	≥ 600
Durability	%	99.5665	95.8335	93.8835	99.7665	99.2330	99.1500	≥ 97.5	≥ 97.5	≤ 96.5	≥ 97.5	≥ 97	≤ 96.5
Fines	%	0.4335	4.1665	6.1165	0.2335	0.7670	0.8500	< 1	< 1	< 1	≤ 4	≤ 5	≤ 6

* Whitaker and Shield [1].

Table S7. Relative physical-mechanical quality of non-wood pellets from processing residual biomass from distillation of cellulosic bioethanol with addition by spraying of food waste boiled for five minutes.

Feedstock/ type of pellet	Pelleting operational condition				Variable				Reference
	Temperature, °C	Pressure, MPa	Water, %	Size, mm	Diameter, mm	Length, mm	Density, kg m^{-3}	Durability, %	
Residual biomass, normal	125	200	11.5	0.25	6.0345	39.7195	1250.8500	99.7335	
Residual biomass, Frozen					6.0335	39.4500	1250.3000	98.2665	
Residual biomass, Defrosted					6.0765	39.8335	1250.0665	97.6500	
Olive leaves	> 60	14–175	9	< 2.5	6	12.3	< 1000	88.6	Garcia-Maraver et al. [101]
Olive prunings	> 60		9	2.5–4	6	24	> 1000	-	
Olive wood	40–60		9	2.5–5	6	28.7	> 1000	91.7	
Moso bamboo plus rice straw	-	175	10–16	0.45–2	6	13.2–13.8	990–1350	94.1–99	Liu et al. [88]
Chinese fir	> 70	> 55	10–15	< 0.45	7	-	1110	-	Jiang et al. [90]
Camphor	> 70	> 55	10–15	< 0.45	7	-	1105	-	
Rice straw	> 70	> 55	10–15	< 0.45	7	-	1180	-	
Softwood Douglas fir	> 200	125	10	0.35–045	6	21	1110	-	Lam et al. [16]
Vigorous sugar maple	75–125	49–81.5	8.1–17.2	0.25–1	6	-	1026	-	Nguyen et al. [103]
Non-vigorous sugar maple	75–125	49–81.5	8.1–17.2	0.25–1	6	-	1038	-	
Mixed garden wastes	80–90	-	5–35	6.25–25.4	12–15	31.1–45.1	-	64.6–98.3	Pradhan et al. [105]
Treated wheat straw	95	-	-	1–1.6	6	-	969–1036	-	Gao et al. [100]

Corn stover plus starch flour	50–65	-	15–19	2–8	6	-	-	88–98.8	Djatkov et al. [102]
Corn cob plus starch flour	50–65	-	15–19	2–8	6	-	-	77.9–88.2	
Canola meal	-	-	-	0.35	6	-	-	> 99	Azargohar et al. [106]
Torrefied canola meal	-	-	-	0.35	6	-	-	> 99	
Microalgae	50–100	79.7–111.6	10.2	-	6	-	1192–1229	82–96.5	Hosseiniz and et al. [104]
Sawdust	50–100	79.7–111.6	9.9	0.6	6	-	817–1038	29–85.8	
Sawdust plus microalgae	50–100	79.7–111.6	-	-	6	-	1155–1207	72.4–97.7	