Influence of feed moisture and hammer mill operating factors on bagasse particle size distributions

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Abstract: Physical properties of ground bagasse could be important for processes such as densification. Bagasse chops into 20–25 cm slice at three moisture content 8, 12 and 16% (wb) were ground using a hammer mill (0.5 hp) with three screen sizes of 1, 2.5 and 4 mm at two hammer mill speeds 1400 and 2000 rpm. Physical properties of grinds such as geometric mean diameter of grind particles, particle size distribution were determined. The highest specific energy consumption was 750 kj kg^{-1} for the sample that has the highest moisture content, using smallest screen size and at 2000 rpm hammer mill speed. And least specific energy consumption was 11 kj kg^{-1} for the sample that has the least moisture content, using the largest screen size (4 mm) and at 1400 rpm speed. Four distributions were examined. For 1, 2.5 and 4 mm screen sizes normal, Generalized Extreme Value and log-normal distribution have the best performance, respectively.

Keywords: bagasse, hammer mill, specific energy, particle size distribution.

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1 Introductioneee

Asia is the primary producing region of sugar cane (45%), while South America is the second largest producing region (35%) (FAO, 2012). 4.3 MT bagasse of sugar cane is annually produced in Iran (Agricultural ministry of Iran, 2010). Khuzestan province has the first rate of producing sugar cane among the others in Iran. (Najafi et al., 2009).

Utilization of crop residues as an energy source can solve environmental problems by reducing the emission of greenhouse gases to the environment. Processes such as gasification, pyrolysis, and hydrolysis/fermentation convert biomass to energy. None of these processes can use of energy in the preparation process of biomass. The first step in preparing biomass as a feedstock is size reduction. Size reduction is important because it is the main consumer operation needs a specific average size of particles and particle size distribution (Jafari, 2008). Size reduction of bagasse is also necessary for pelleting process. Non-densified bagasse is very bulky and inhomogeneous making it difficult to introduce in modern conversion technologies. For pellet production, the material should be first chopped by grinding (Samson et al., 2005). Particle size reduction increases the total surface area, pore size of the material and the number of contact points for inter-particle bonding in the compaction process (Drzymala, 1993). Energy required for grinding depends on its initial particle size, moisture content, material properties, mass feed rate, and machine variables (Bitra et al., 2009). Performance of a grinding device is often measured in terms of energy requirement, geometric mean diameter, and resulting particle size distribution (Adapa et al., 2011). Fang et al. (1997) found that screen opening size was the most significant factor affecting mill performance. Samson et al. (2005) reported

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a specific energy consumption of 161.64 kJ kg^{-1}, when a hammer mill with a screen size of 5.6 mm was used to grind switch grass.

An investigation of grinding switchgrass at 10%–12% wet basis (wb) moisture content in a hammer mill was reported by Jannasch et al. (2001). They found a specific energy of 55.9kW ht^{-1} for both 5.6 and 2.8 mm screen sizes. Geometric mean diameter and particle size distribution of biomass grinds are important factors that affect the binding characteristics for densification and are useful information in the design of pneumatic conveyors and cyclones. Mani et al. (2004) studied the effect of particle size on time required for rearrangement of particles during compaction for four biomass species in a single pelleting unit. Their results showed that particles rearrangement was shorter when the particle sizes of the grinds were smaller. Another study carried out by Adapa et al. (2010) observed that particle size distribution was suitable for densification which had normal distribution, skewed to right and had negative value in kurtosis. Jafari (2008) modeled Size distributions of swichgrass grinds with Weibull probability density function. Yang et al. (1996) fitted log-normal distribution equation to alfalfa particle size distributions achieved from a hammer mill. They found that median size and standard deviation were 238 mm and 166, respectively. The objective of this research was to investigate the relationships between screen size of hammer mill and moisture content of biomass in two hammer mill speed on resulting distributions properties with considering energy consumption for selecting the best condition for bagasse grinding.

2 Materials and methods

2.1 Biomass material preparation

Bagasse of sugarcane that was planted in Amirkabir agricultural and industrial company, located in Khuzestan, Iran, was transferred to College of Abouraihan, University of Tehran. The initial moisture contents of bagasse pill was 38% (wb), hence for reducing moisture content bagasse pill was spread in thin layer at room condition to achieve the equilibrium moisture content. The equilibrium moisture content was 8% (w.b). The bagasse pill was cut into pieces of 20–25 cm lengths prior to size reduction with a hammer mill.

2.2 Conditioning of biomass

In addition of moisture content 8%, bagasse chops were conditioned in two moisture contents of 12% and 16% wet basis. By spraying water uniformly on the chopped, bagasse were conditioned to the required moisture content. The conditioned materials were placed in a plastic bag and were stored for 48 hours at 5ºC to obtain biomasses with moisture content of 12% and 16% (wb). The moisture conditioning error was within a range of ±5.3%.

2.3 Moisture content measurement

The moisture content of air dried chopped bagasse was measured by the method given in ASAE Standard S358.2 for forage (ASAE, 2006). A sample of 25 g was oven dried for 24 h at 105ºC.

2.4 Hammer mill grinder and measurements of commination energy consumption

Chopped biomasses were subsequently grounded by hammer mill grinder (Retch KG 3057, Haan, Germany) after conditioning. The grinder has three blades, attached to a shaft powered by a 0.5 hp electric motor. The shaft rotated at 50 Hz. For grinding the biomasses, three screen sizes of 1, 2.5, and 4 mm were used. Weighed chopped biomasses were manually fed into the grinder in certain time, this arrangement provided relatively constant feeding rate in milling process. Sample feed rates ranged from 0.4 to 0.5 kg min^{-1}. Each treatment was repeated three times. The power drawn by the hammer mill motor was measured using a power analyzer (lutro, DW 6090). The power analyzer measured the voltage (V), current (A), active power (W), reactive power (W), power factor (PF), active electric energy (Wh), frequency (Hz) and time. All recorded data were logged into a laptop. During milling process, the specific energy consumption (E) was measured using Equation 1.

$$E = \frac{\int_0^T (P_t - P_0)\, dt}{m_{DM}} = \frac{\int_0^T \Delta P_t\, dt}{m_{DM}} \quad (1)$$

where E is the total specific net energy for size reduction (kj kg^{-1}), P_t is the power in Watt consumed by hammer mill while grinding biomasses at time t, P_0 is the average power consumption in Watt under idle conditions (without feeding biomasses) of the milling machines, ΔP_t is the net power consumption in Watt in hammer mill as grinding biomass at time t, and m is the mass of biomass in kg to be grounded. Power drawn by the hammer mill motor was recorded every 1 s. Each test was performed in replicates of three (figure 1).

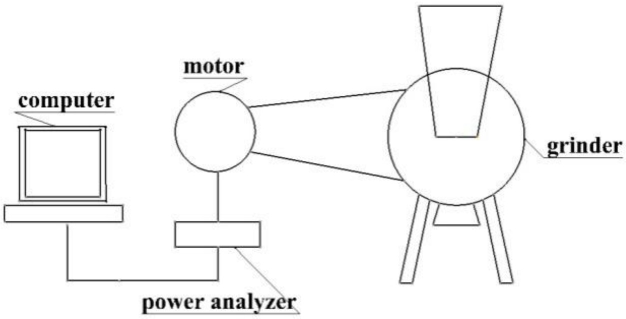


Figure 1 Hammer mill and data logging system

2.5 Modeling for dimensional properties

Size distributions of samples in all scenarios were modeled with four probability density functions. These functions were: (1) Normal, (2) Log normal, (3) Weibull, and (4) Generalized Extreme Value. The probability density functions (*f(x)*) for four distributions are showed in Table 1.

Table 1 The Normal, Log normal, Weibull and G.E.V probability Density function

Distribution	Probability distribution function
Normal	$f(x)=\left(\frac{1}{\beta\sqrt{2\pi}}\right)exp\left(-\frac{1}{2}\left(\frac{x-\alpha}{\beta}\right)^2\right)$
Log normal	$f(x)=\left(\frac{1}{(x-\alpha)\gamma\sqrt{2\pi}}\right)exp\left(-\frac{1}{2}\left(\frac{\ln(x-\alpha)-\beta}{\gamma}\right)^2\right)$
Weibull	$f(x)=\frac{\gamma}{\beta}\left(\frac{x-\alpha}{\beta}\right)^{\alpha-1}exp\left(-\left(\frac{x-\alpha}{\beta}\right)^{\gamma}\right)$
G.E.V	$f(x)=\frac{1}{\beta}\left[1+\gamma\left(\frac{x-\alpha}{\beta}\right)\right]^{(-1/\gamma)-1}exp\left\{-\left[1+\gamma\left(\frac{x-\alpha}{\beta}\right)\right]^{-1/\gamma}\right\}$

According to the equations expressed in Table 1, for the Normal, Log normal, Weibull and Generalized Extreme Value distributions, α is location or shift parameter, β is scale parameter and is γ shape parameter. The normal distribution with $\alpha = 0$ and $\beta = 1$ is called the standard normal distribution or the unit normal distribution. Whenever α is equal to zero Log normal distribution is called two parameters distribution, otherwise it is called three parameters distribution. Whenever α is equal to zero and β equals one the Log normal distribution is called standard Log normal distribution. In this study, Log normal distribution with three parameters was used. If α is equal to zero, the Weibull distribution is called two parameters distribution; otherwise it is called three parameters distribution. In this paper, for modeling the data, three parameters Weibull distribution was used. The four probability density functions were fitted to the empirical probability density, to estimate the parameter values. The adjustable parameters for each probability density function were estimated using the EasyFit 5.5 Professional software.

3 Results and discussion

3.1 Energy requirement for grinding

Table 2 shows the average specific energy consumption for grinding biomasses using the hammer mill with three different screen sizes of 1, 2.5, 4 mm and three moisture contents of 8%, 14% and 16% (%, wb). The highest amount of specific energy was consumed in the sample with the highest moisture content 16%, using the smallest hammer mill with screen size of 1mm, at 2000 rpm hammer mill speed (750 kj kg^{-1}). Additionally, the lowest specific energy was consumed in the sample with the lowest moisture content of 8%, using the largest hammer mill with screen size of 4 mm, at 1400 rpm hammer mill speed (11 kj kg^{-1}). Similar results are reported for alfalfa grind by Samson et al. (2005) They reported that energy consumption for grinding switch grass at moisture content of 13% (w. b.) using a hammer mill screen sizes of 5.6 mm were 161.64 kJ kg^{-1}. Screen size had a negative correlation with specific energy consumption of the samples tested. As the size of screen on the grinder's screen increased from 1 to 4 mm specific energy consumption decreased significantly due to the fact that the biomasses should be fine enough to pass the hammer mill screen size and this causes more energy consumption to size reduction of biomasses. For example, in grinding the samples by increasing screen size from 1 to 4 mm at 8% (wb) moisture content at 1400 rpm hammer mill speed specific energy consumption decreased from 155 to 11 kJ kg^{-1}. Energy consumption decreased by 91% when the screen size was increased from 1 to 4 mm.

Table 2 energy consumption and geometric mean of particles

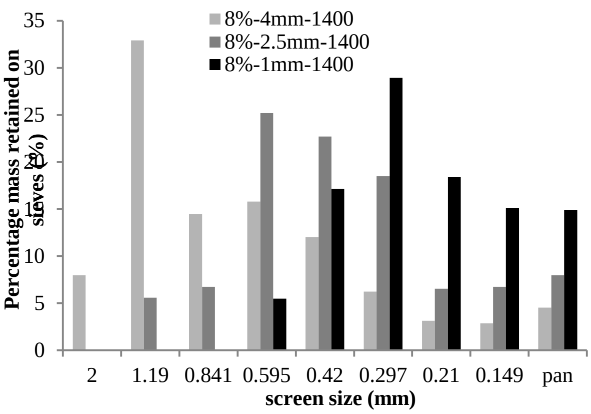
moisture content	aperture size	speed	geometric mean of ground material	geometric standard deviation	energy consumption
8	1	1400	0.28	0.24	155
8	2.5	1400	0.47	0.28	40
8	4	1400	0.76	0.31	11
8	1	2000	0.27	0.23	190
8	2.5	2000	0.38	0.27	44
8	4	2000	0.56	0.36	20
12	1	1400	0.31	0.26	330
12	2.5	1400	0.48	0.28	100
12	4	1400	0.81	0.34	19
12	1	2000	0.3	0.26	380
12	2.5	2000	0.4	0.28	105
12	4	2000	0.57	0.34	32
16	1	1400	0.33	0.25	530
16	2.5	1400	0.52	0.32	230
16	4	1400	0.86	0.32	49
16	1	2000	0.35	0.26	750
16	2.5	2000	0.45	0.31	370
16	4	2000	0.58	0.35	72

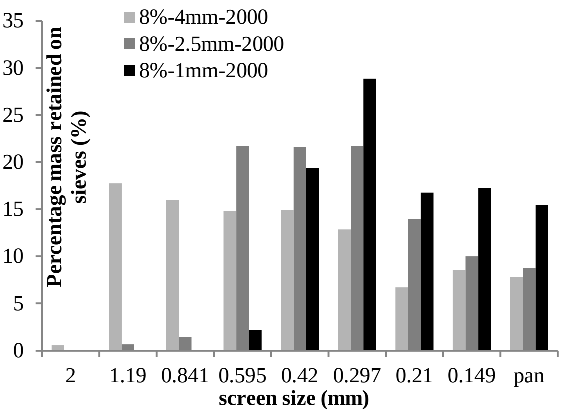
It has also been observed that the specific energy required to grind samples depended on the moisture content of biomasses (Table 2). Moisture content had a positive correlation with specific energy consumption of the biomass tested. Higher moisture content resulted in higher specific energy consumption. This can be explained by the fact that an increase in moisture content of samples would increase the shear strength of the materials (Annoussamy et al., 2000). Igathinathane et al. (2007) showed that a mat of moist switchgrass at 51% moisture content offered more resistance to shear than a mat of dry material at 20% moisture content. Also, it has been found that by increasing the size of screen on the grinder's screen from 1 to 4 mm, the effects of moisture content on specific energy consumption decreased. For example, in the screen size of 4 mm the energy consumption decreased by 22% when moisture content decreased from 16% to 8% (%, w.b) while this amount was 29% for 1 mm screen size at 1400 rpm hammer mill speed.

3.2 Particle size of hammer mill size reduction

3.2.1 Size distribution

Figure 2 shows the particle size distribution of bagasse grounded by three hammer mill screen sizes and three moisture contents at two hammer mill speeds. The graphs show the skewness of the distribution, which was similarly reported for alfalfa grind (Ghorbani et al., 2010), and peanut hull (Fasina, 2008). The skewness to right for samples with 8% (%, wb.) was higher than that of other conditioned samples (lower skewness). The grinds passing through the screen size of 4 mm had a wider size distribution with a higher geometric mean diameter in comparison with the grinds passing through screen sizes of 2.5 and 1 mm. Mani et al. (2003) found that the wider particle size distributions were suitable for the compaction process (i.e. pelleting). Throughout the compaction, smaller (fine) particles reposition and fill in the empty spaces of larger (coarse) particles which results in producing denser and durable pellets (Tabil, 1996; Mani et al., 2003).





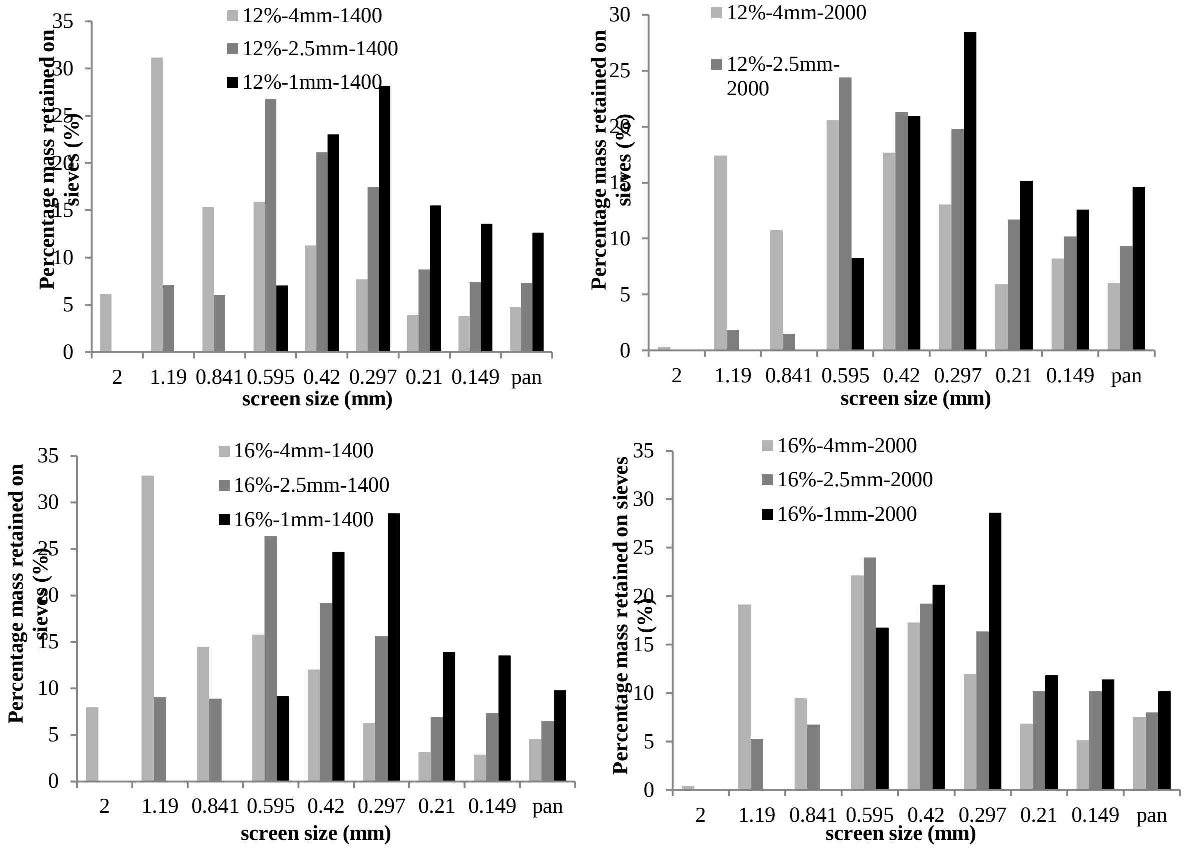


Figure 2 Histogram of particle size distribution of samples in all scenarios

3.2.2 Effect of moisture content and hammer mill speed Geometric mean of particle sizes

The geometric mean of grind bagasse particles in all scenarios are shown in Table 2. Average geometric mean particle size of samples in three moisture contents, increased slightly by increasing moisture content from 8 to 16 (%, w.b) (Figure 3). It has been observed that particle sizes in 2000 rpm hammer mill speed were finer than 1400 rpm hammers mill speed. Von Bargen et al. (1981) reported that hammer mill yielded fine and coarse particles at high and low speeds, respectively, for wheat straw, corn residues, and grain sorghum. By increasing the hammer mill speed, value of Geometric mean particle size decreased. Similar results were reported for hammer mill grinds of alfalfa (Yang et al., 1996), wheat straw (Mani et al., 2004; Himmel et al., 1986), corn stover, switchgrass and barley straw (Mani et al., 2004). From Figure 3, it can be figured out that in larger screen sizes, the difference of Geometric mean particle size between the two speeds becomes higher. Geometric standard deviation, did not maintain a specific trend with an increase in moisture from 8% to 16% (w.b) which was due to the uncertain fracture properties of fibrous materials.

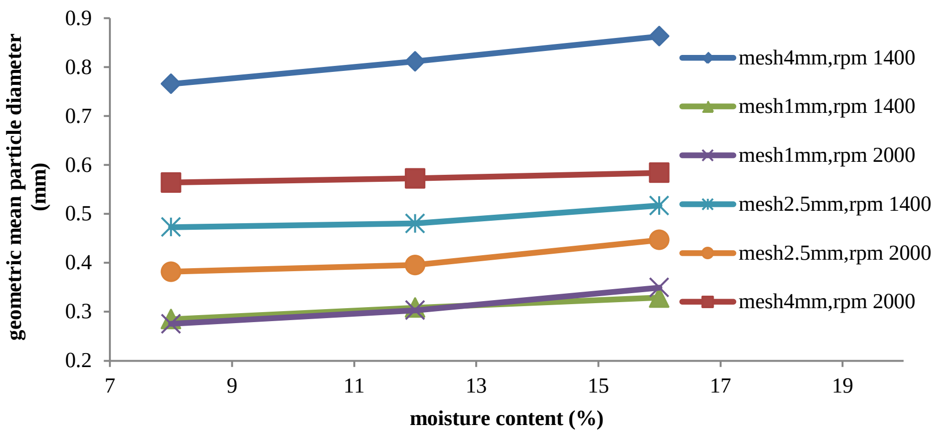


Figure 3 Effect of moisture content on geometric mean particle diameter

3.3 Analysis of size distribution

3.3.1 Selecting grinding condition suitable for densification

Table 3 Measure of particle size distribution of ground samples obtained from all scenarios

Moisture (%)	speed (RPM)	screen size (mm)	shapiro-wilk test	skewness	kurtosis	reject
8	1400	1	W= 0.883 ; P= 0.17	0.315	-0.863	No
8	1400	2.5	W= 0.845 ; P= 0.065	0.706	0.572	No
8	1400	4	W= 0.9 ; P= 0.251	0.624	-0.724	No
8	2000	1	W= 0.875 ; P= 0.138	0.241	-1.369	No
8	2000	2.5	W= 0.86 ; P= 0.095	0.033	-1.816	No
8	2000	4	W= 0.925 ; P= 0.437	-0.742	-0.127	No
12	1400	1	W= 0.873 ; P= 0.133	0.382	-0.961	No
12	1400	2.5	W= 0.942 ; P= 0.608	0.783	-0.267	No
12	1400	4	W= 0.816 ; P= 0.031	1.643	2.901	Yes
12	2000	1	W= 0.9 ; P= 0.249	0.339	-0.729	No
12	2000	2.5	W= 0.901 ; P= 0.259	0.209	-1.49	No
12	2000	4	W= 0.962 ; P= 0.817	-0.087	-0.939	No
16	1400	1	W= 0.871 ; P= 0.126	0.549	-0.688	No
16	1400	2.5	W= 0.972 ; P= 0.913	0.826	0.504	No
16	1400	4	W= 0.823; P= 0.038	1.704	3.34	Yes
16	2000	1	W= 0.911 ; P= 0.323	0.384	-0.648	No
16	2000	2.5	W= 0.964 ; P= 0.838	0.436	-0.333	No
16	2000	4	W= 0.961 ; P= 0.81	0.235	-0.95	No

Table 3 shows the measure of particle size distribution of samples from hammer mill using three different screen sizes of 4, 2.5 and 1 mm, three moisture contents at two hammer mill speeds 1400 and 2000 rpm. Using the Shapiro-Wilk test, it has been found that the all samples are normally (distributed $P < 0.05$), except for samples that conditioned 12% and 16% moisture content and obtained from 4 mm screen size at 1400 rpm hammer mill speed. As before mentioned that densification process size distribution of samples must be wide (Tabil, 1996). Hence, the grinds should be normally distributed (Shapiro-Wilk test: $P > 0.05$), should have skewed towards right (lower skewness values), and lower peak than expected for the normal and wider distribution of data (negative Kurtosis values). Upon application of this concept on Table 3 and considering the specific energy consumption from Table 1, the best mode can be selected. Therefore, for grinding samples that have 8 % moisture content which was ground by 2000 rpm speed, using 1 mm screen size sample is better for densification because of lower values of skewness and kurtosis, but it has higher energy consumption. For ground sample using 2.5 mm screen size which was ground 2000 rpm speed, that sample was better because of the same value in specific energy consumption approximately. For grinding samples that wetted 12% (w.b), using 1 mm screen size that sample is better in order to densification which was ground with 1400 rpm hammer mill speed because of has lower energy consumption and approximately same value in skewness and kurtosis (kurtosis slightly higher). Grinding samples that pass out form 2.5 mm screen size have the same value of energy consumption approximately, but grinding with 2000 rpm hammer mill speed resulted in lower skewness and kurtosis than 1400 rpm. Moreover, for using 4 mm screen size, grinding samples which were ground by 2000 rpm have normal distribution and they are suitable for densification while the sample which was ground with 1400 rpm was not normal distributed. And for samples that conditioned 16% moisture (w.b), using 1 mm screen size which was ground with 1400 rpm hammer mill speed that sample is better because of lower energy consumption and approximately the same value in skewness and kurtosis. By considering 2.5 mm screen size, both of skewness and kurtosis were higher in 2000 rpm than 1400 rpm but the specific energy consumption for 1400 speed was significantly lower than 2000 rpm speed and for that grinds which was throw out from 4 mm screen size resulted in produce better compacts due to lower skewness and kurtosis while consumed slightly more energy.

3.4 Modeling results

The ground samples obtained from three screen size, three moisture content, and two hammer mill speed were modeled using the Normal, log-normal, Weibull and Generalized Extreme Value probability density functions distribution. The results for modeling of all scenarios distributions of are shown in Tables 4 and 5.

In order to compare the models resulted from distributions fitting with experimental data, Kolmogorov - Smirnov method was used. The calculated values of constant factors of grounded samples probability density functions, and rating of the functions regarding to the Kolmogorov - Smirnov index are shown in Table 4 and 5, respectively.

For grinds obtained from 1 mm screen size, normal distribution had the best prediction and Log-normal had the worst prediction. For grinding materials using 2.5 mm screen size, Generalized Extreme Value had the best prediction and Weibull had the worst prediction. And for grinds from 4 mm screen size, Weibull and Log-normal distribution had the best prediction and normal had the worst prediction. Therefore, modeling distribution of ground bagasse was dependent on screen size of hammer mill, and independent from moisture content. It seems that in the smaller than 1 mm screen sizes normal has good performances and Log-normal has a bad performance, for median screen sizes Generalized Extreme Value has good performances and Weibull has a bad performance, and for larger than 4 mm screen size Weibull and Log-normal have good performances and normal has a bad performance. It seems more studies on distribution types of ground biomasses are needed, and if necessary, standards ANSI/ASAE Standards (2006) should be reviewed because they are highly sensitive to the type of distribution (Miao et al., 2011).

Table 4 Calculated parameter values of the different probability density functions for all grinding scenarios at 1400 rpm

scenarios	Distribution	Location parameter	Scale parameter	Shape parameter	Kolmogorov - Smirnov	Rank
8%-1mm-1400	Norma	11.111	10.246	-	0.19979	1
	Log-normal	0	0.49972	2.7068	0.42198	4
	Weibull	0	18.755	0.33333	0.33333	2
	G.E.V	6.5904	9.4287	-0.10849	0.22856	3
8%-2.5mm-1400	Normal	11.111	8.73	-	0.30674	2
	Log-normal	0	0.5881	2.3453	0.34256	3
	Weibull	0	14.17	1.7598	0.36153	4
	G.E.V	6.6223	6.2063	0.12973	0.22001	1
8%-4mm-1400	Normal	11.111	8.7059	-	0.22575	4
	Log-normal	2.3	5.139	-1.4092	0.20336	3
	Weibull	2.3	9.4798	0.73018	0.16561	1
	G.E.V	6.5818	6.776	0.08495	0.19701	2
12%-1mm-1400	Normal	11.111	10.299	-	0.19201	1
	Log-normal	0	0.44574	2.7193	0.40164	4
	Weibull	0	18.834	2.596	0.3694	3
	G.E.V	6.1945	9.1033	-0.03887	0.19311	2
12%-2.5mm-1400	Normal	11.111	8.5526	-	0.28536	2
	Log-normal	0	0.54283	2.3899	0.32461	3
	Weibull	0	14.49	1.8649	0.42552	4
	G.E.V	6.8807	6.0268	0.14167	0.2045	1
12%-4mm-1400	Normal	11.111	8.8353	-	0.20584	4
	Log-normal	3.8	5.2391	-0.89663	0.1457	1
	Weibull	3.8	5.4248	0.6336	0.1509	3
	G.E.V	4.3317	4.3317	0.35766	0.15057	2
16%-1mm-1400	Normal	11.111	10.54	-	0.18743	1
	Log-normal	0	2.7181	0.43054	0.3998	4
	Weibull	0	18.91	2.4309	0.34565	3
	G.E.V	5.8918	8.6916	0.02304	0.1953	2
16%-2.5mm-1400	Normal	11.111	7.9476	-	0.26655	2
	Log-normal	0	2.3964	0.49228	0.31548	3
	Weibull	0	14.221	2.0036	0.3311	4
	G.E.V	7.0205	5.7993	0.11558	0.22363	1
16%-4mm-1400	Normal	11.111	7.98	-	0.19907	4
	Log-normal	2.88	2.1934	7.9373	0.13105	1
	Weibull	2.88	6.1237	0.65728	0.17248	3
	G.E.V	5.9887	4.884	0.32703	0.14639	2

Table 5 Calculated parameter values of the different probability density functions for all grinding scenarios at 2000 rpm

scenarios	Distribution	Location parameter	Scale parameter	Shape parameter	Kolmogorov - Smirnov	Rank
8%-1mm	Normal	11.111	10.743	-	0.24102	1
	Log-normal	0	2.5875	0.82932	0.42941	4
	Weibull	0	18.531	2.0884	0.33333	3
	G.E.V	6.3507	9.6621	-0.09262	0.24401	2
8%-2.5mm	Normal	11.111	9.1991	-	0.20623	2
	Log-normal	0	2.0407	1.2431	0.24455	3
	Weibull	0	13.236	1.237	0.27105	4
	G.E.V	7.7635	9.6354	-0.29109	0.18912	1
8%-4mm	Normal	11.111	5.563	-	0.19254	3
	Log-normal	-149.05	5.0757	0.03306	0.20505	4
	Weibull	-2.05E+08	2.05E+08	5.04E+07	0.19115	2
	G.E.V	10.218	6.5067	-0.68517	0.16258	1
12%-1mm	Normal	11.111	10.044	-	0.19902	1
	Log-normal	0	2.7386	0.38895	0.39204	4
	Weibull	0	18.778	2.7699	0.33972	2
	G.E.V	6.4855	9.1334	-0.07651	0.35765	3
12%-2.5mm	Normal	11.111	9.1046	-	0.1801	2
	Log-normal	0	2.1542	1.0172	0.27153	3
	Weibull	0	13.615	1.404	0.27663	4
	G.E.V	7.1507	8.814	-0.14622	0.1662	1
12%-4mm	Normal	11.111	6.6522	-	0.16225	2
	Log-normal	-117.6	4.8567	0.04923	0.17256	3
	Weibull	-6.1359	19.339	3.0925	0.17499	4
	G.E.V	8.707	7.1459	-0.30847	0.13893	1
16%-1mm	Normal	11.111	10.07	-	0.1984	1
	Log-normal	0	2.7423	0.36989	0.43397	4
	Weibull	0	18.803	2.7437	0.42113	3
	G.E.V	6.3535	8.8777	-0.04342	0.20113	2
16%-2.5mm	Normal	11.111	7.4831	-	0.21512	2
	Log-normal	0	2.4027	0.49714	0.23085	3
	Weibull	0	14.201	2.1745	0.40898	4
	G.E.V	7.6126	6.7475	-0.06276	0.15919	1
16%-4mm	Normal	11.111	7.154	-	0.14736	2
	Log-normal	-27.631	3.6417	0.17519	0.15793	4
	Weibull	-2.2077	15.03	2.0717	0.15362	3
	G.E.V	7.9769	6.9523	-0.1443	0.13162	1

4 Conclusions

The following conclusions are drawn from this study on the chopped bagasse:

(1) Higher moisture content, smaller screen size, higher speed resulted in higher specific energy consumption during hammer mill grinding of biomass.

(2) For grinds obtained from 1 mm screen size normal distribution had best prediction. For grinding materials using 2.5 mm screen size Generalized Extreme Value had best prediction. And for grinds from 4 mm screen size Weibull and Log-normal distribution had best prediction.

(3) With increasing moisture content value of geometric mean particle diameter of bagasse grinds were increased.

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