Factors affecting the quality of fuel pellets produced from waste biomass

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Abstract. The production of wood pellets has more than doubled between 2010 and 2015 to over 30 million metric tons. It is expected to grow to even more than 50 million metric tons by 2025. Thus, increasing demand for wood pellets for its energy utilization has prompted researchers to search for non-woody feedstocks. In this context, a potentially huge underutilized biomass such as garden waste can be explored as an alternative feedstock. The key factors affecting the quality of fuel pellets were evaluated during the garden waste pelletization process. Experiments were performed using a flat die pellet mill to investigate the effect of feedstock moisture content, die size, and milling size on pellet quality. Quality parameters such as pellet moisture, pellet length, bulk density, and durability were measured as per ASABE standards. Feed moisture content had a significant effect on durability and bulk density, with high quality pellets produced at the low feed moisture content (< 20%). The quality parameters of produced pellets were evaluated as per standards. It is concluded from the investigation that pellets produced at 5-10% feed moisture content using 15 mm die and fine shredded biomass satisfies the ISO standard and other norms.

1. Introduction

The global trade of wood pellets has shown a significant growth from 0.5 to 6.6 million tonnes (8.5 to 120 Peta Joule) between 2000 and 2010 [1]. Furthermore, the global wood pellet production was 19.1 million tons in 2012 and is projected to increase to 45.2 million tons in 2020 [2]. Therefore, the growing demand for wood pellets has stirred the demand for alternate non-woody biomass. On the other hand, garden waste (dry leaf litters) is an abundant and underutilized bio-resource which can be used as an alternative feedstock for the pellet manufacturers. Presently, there is no proven mechanism to dispose of garden waste in India, which raises many environmental problems. In addition, garden waste has lignin (a natural binder) which forms solid bridge during pelletization [3]. Thus, the binder cost may be avoided. In this context, garden waste can be a suitable feedstock for fuel pellets production.

Fuel pellets are used in many places, from household cookstoves to thermal power plants. Various standards have been prescribed both at national and global markets to maintain the quality of pellets. The quality of fuel pellets greatly depends on pelletization parameters. The moisture content is one of the pelletization parameters which regulates the friction between die and biomass [4]. Moreover, experimental investigations using a single pellet press are common in literature [5]. So, a pilot-scale investigation could evaluate the effects of controlling factors in a more realistic way. Only a few systematic pilot studies on biomass pelletization have been reported in the literature [3,5,6], and
therefore, this area requires further attention. The objective was to investigate the controlling factors for the garden waste pelletization process to produce standard quality fuel pellets.

2. Materials and methods

2.1. Feedstock and process
Dry garden biomass waste was collected from the institute campus at Mumbai, India. The detailed characterization of feedstock can be found in the literature [3]. Two shredders (a coarse and a fine) were used to grind the material. The screen sizes used in the present study were 6.35 and 25.4 mm (or, 1/4 and 1 inch). The ground material was then pass through a rotary drier to adjust the moisture content if necessary. A screw conveyor was used for automatic feeding during the pelletization process. Two flat dies (12 and 15 mm) were used for experiments. The rated power of the flat die pelletizer was 10 hp and the output capacity was of the order of 60-90 kg h⁻¹. Figure 1 shows the layout of the pilot-scale pellet plant used in this study.

![Diagram of the process flow diagram of a pilot-scale pellet plant](image)

**Figure 1.** The process flow diagram of a pilot-scale pellet plant.

2.2. Experiments and quality analysis of pellets
A full factorial experiment design with three independent variables was used in this study. The factors were feedstock moisture content (5-10%, 10-20%, 20-30%, 30-40%), mill screen size (6.35 and 25.4 mm), and die size (12 and 15 mm). A total 16 independent runs were carried out and each run was replicated thrice. Four response variables (pellet moisture content, pellet length, pellet bulk density, pellet durability) were measured according to the standards [7]. Pellet moisture content was measured using oven drying method (set at 105 ± 2 °C for 24 h). Pellet length was measured using a vernier calliper and average value of 10 random samples was reported. The bulk density was determined using a laboratory balance and a graduated cylinder (5 l) as per standard procedure [8]. The bulk density
value was the ratio of weight of pellets to the cylinder volume. Pellet durability was determined using a standard tumbler, similar to the procedure described in our earlier work [3].

3. Results and discussions

3.1. Effect of pelletization parameters on pellet quality

It can be seen from figure 2A that the pellet moisture content increased linearly with an increase in feedstock moisture content irrespective of particle size and die dimensions. Vaporization of water was observed during the pelletization process. The general trend showed a decrease in length of pellets produced beyond 20% feedstock moisture content (Figure 2B). This was probably due to the excess moisture inhibits particle agglomeration and reduces the length of pellets. The average bulk density of pellets reduced from 725 to 358 kg m$^{-3}$ with an increase in feedstock moisture content (Figure 2C). It can also be noticed that pellets produced with the smaller die (12 mm) had higher bulk density values. Durability of pellets reduced significantly at higher (>20%) feedstock moisture content (Figure 2D). Moreover, highly durable pellets were produced using the smaller die and finely shredded biomass. More details on these findings are available in our earlier published work [3].

Figure 2. Effect of pelletization parameters on pellet quality. [Where, S: Milling size; D: Die size]
3.2. Comparison with the standards

Note, it is required to keep affecting parameters in a certain range where high quality pellets can be produced at a high pellet mill capacity. Therefore, it is important to compare quality parameters of produced pellets with various standards. The moisture content of pellet should not be more than 10% as per the ISO (ISO 17225) and European standard (CEN/TS 14588). Run 1-4 fulfilled the standards set for the moisture content of pellets (Table 1), wherein the feed moisture content range was 5-10%. The pellet length influences the flow of fuel inside the reactor. Relatively longer pellets were produced at the low feedstock moisture content (< 20%). Moreover, the pellet length satisfies the standard requirement in all cases. As per ISO standard, the bulk density value should not be less than 600 kg m$^{-3}$. Pellets produced at a low feedstock moisture content fulfilled the standards corresponding to the bulk density. The norm recommends that the durability of pellets must not be less than 97.5%. In this study, Run 2 and Run 5 fulfilled the standards since low feed moisture content and smaller die showed higher pellet durability.

| Table 1. Evaluating the quality of fuel pellets as per standards. |
|---------------------------------------------------------------|
| Run | Moisture content | Pellet length | Bulk density | Durability |
| ISO 17225 | ≤ 10 % | 3.15 ≤ L≤ 40 mm | ≥ 600 kg m$^{-3}$ | ≥ 97.5 |
| CEN/TS 14588 | ≤ 10 % | < 4D | - | ≥ 97.5 |
| 1 | ✓ | ± | ✓ | × |
| 2 | ✓ | ✓ | ✓ | ✓ |
| 3 | ✓ | ± | ✓ | × |
| 4 | ✓ | ± | ✓ | × |
| 5 | × | ± | ✓ | ✓ |
| 6 | × | ± | × | × |
| 7 | × | ± | ✓ | × |
| 8 | × | ± | × | × |
| 9 | × | ✓ | × | × |
| 10 | × | ✓ | × | × |
| 11 | × | ✓ | × | × |
| 12 | × | ✓ | × | × |
| 13 | × | ✓ | × | × |
| 14 | × | ✓ | × | × |
| 15 | × | ✓ | × | × |
| 16 | × | ✓ | × | × |

✓: Both the guidelines fulfilled; ×: None of the guidelines fulfilled; ±: Either of guidelines fulfilled

4. Conclusions

The standard quality garden waste pellets were successfully produced during the pilot scale experiment. Feedstock moisture content showed a significant effect on bulk density and durability, and high quality pellets were produced at a relatively low moisture content (< 20%). The pellets produced during the Run 2 satisfied the ISO and European standard. Biomass moisture content of 5-10% and biomass size of 6.35 mm (mill screen) were found to be the optimum feedstock conditions for garden waste pelletization. Overall, this pilot-scale study concludes that the controlling factors play an important role to produce high quality fuel pellets from waste biomass. Furthermore, these results would be beneficial to pellet manufacturers exploring non-woody biomass feedstock.
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