The effect of storage on the quality properties of Oilseed Rape straw pellets

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1. Summary

With the growing demand for biomass for alternative energy supplies, it would be prudent to investigate alternative sources of energy. The layer study of which this is part will investigate the effect of pre and post pelletization storage on the quality and combustion properties of oilseed rape straw, which, unlike wood pellets, have had little or no detailed research upon the variation of the physical, chemical, biological and combustion properties over the period of storage. This paper focuses on the effect of storage time on oilseed rape straw pellets in terms of pellet quality. The quality of oilseed rape straw pellets was assessed in terms of durability, hardness and particle density. Results show the quality of the pellets is affected by storage time. The durability and particle density of pellets increased between 2 weeks and 3 months storage, before decreasing up to 12 months storage. The hardness of pellets continuously increases during the 12 months storage. It is clear storage time influenced the properties of OSR straw pellets, but it is suspected that there are other factors (e.g. binder, raw material, natural variations) that could be affecting these quality parameters.

2. Introduction

The two main sources of biomass for energy generation are purpose-grown energy crops and waste materials (Larkin *et al*., 2004). Energy crops, such as Miscanthus and Short Rotation Coppice, are cultivated mainly for energy purposes and are associated with the food vs fuels dilemma, which is concerned with whether land should be used for fuel rather than food production. The use of residues from agriculture, such as straw, for energy generation circumvents the food vs fuel dilemma and adds value to existing crops (The German Solar Energy Society, 2005).

An example of an agricultural residue that could be used as a fuel for energy generation is Oilseed Rape (OSR) straw (*Brassica napus*). In the UK, the total area of OSR harvested increased between 2000 and 2008 from 332,000 ha to 598,000 ha, respectively, representing 12.6% of the total crop area (DEFRA, 2009). Currently there is not a significant market for OSR straw in the UK, and a large proportion of it is chopped and incorporated into the soil through ploughing.

Research by Glen (1990) suggests ploughing straw back into the soil increases slug population, which could have important implications for slug damage to subsequent crops of oilseed rape, when the seedling is at the most vulnerable stage of growth. Slugs are considered to be minor pests of crops in the UK, although they are regarded as important pests in Belgium and France (Glen, 1990).

Development of a market for OSR straw would add value to the gross margin of the crop at farm level (Booth *et al*., 2005) as well as controlling pests caused by the straw incorporation.

The main problem with straw is its relatively low density when baled. The bulk density of loose and standard baled straw is approximately 40 kgm^{-3} and 100 kgm^{-3}, respectively, compared with the bulk density of unprocessed wood residue, which is approximately 250 kgm^{-3} (Demirbas, 2001; Tripathi *et al*., 1998). The relative low density of straw makes it more expensive to transport compared to wood and coal because a lower mass of straw can be transported per unit volume. Additionally a larger storage area/volume is required for baled straw compared to wood chip. Densification into pellets increases the bulk density of biomass (Obernberger and Thek, 2004; McMullen *et al.*, 2005) and as a result, the net calorific content per unit volume is increased (Bhattacharya *et al*., 1989) and the storage, transport and handling of the material is easier and cheaper (Balatinecz, 1983; Bhattacharya *et al*., 1989; Samson *et al*., 2000; Kaliyan and Morey, 2006). As a consequence of the densification, straw will fired in a more controlled manner (Staniforth, 1979).

A further concern is that storage of biomass can result in oxidative self-heating or spontaneous heating of the stored material (Meijer and Gast, 2004) and can result in changes in the chemical constituents (Assarsson, 1969), dry matter losses, and changes in the moisture content reducing the value and quality of the end product.

Previous research has investigated how storage affects the characteristics of pellets. These studies suggest the storage of wood pellets in piles increases the risk of temperature development and cake formations due to the agglomeration of fines. These are important problems affecting pellet durability, and consequently their quality. This development of temperature is caused by plant cell respiration and microbiological activity that releases heat, which accumulates due to limited air passages inside the pile and the low conductivity of wood materials (Kubler, 1987). Lehtikangas (2000) found the durability of pellets decreased with storage time, with pellets produced from fresh bark and logging residues tending to absorb atmospheric moisture.

Previous research has investigated how storage of raw material affects the characteristics of pellets made from forestry materials (Lehtikangas, 2000), but there is no awareness of research to date investigating the effect of storage on the physical, chemical and biological properties of OSR straw and pellets.

3. Description of the work

Pellet production and storage

OSR straw pellets were produced by Alchemy Technologies (3 Llys Le Breos, Mayals, Swansea, SA3 5DL).

Initial laboratory-scale tests were carried out to determine if the product could be pelletised and if any binder was required. OSR straw was milled using a Christy Norris 24 x 12 hammer mill (Christy and Norris Ltd., Chelmsford, UK) and pelletised using a California Pellet Mill 2000 (CPM) (California Pellet Mill Co, Crawfordsville, U.S.A.) and pellets were produced with a 16 mm die diameter.

Calcium Lignosulfate (Borregard-Lignotech, Sarpsborg, Norway) was added to milled straw prior to pelletisation at a concentration of 5% (w/w) as binder. Research by Klinner *et al*. (1977) showed the best compromise between high density, good durability, and low overall power consumption of straw wafers was obtained when a binding agent was added to chopped straw. The study also demonstrated without binder, wafers appear unsuitable for handling by most mechanical means. Also, work done by Esteban *et al.* (2009) has shown that using lignosulfonate as a binder with residual biomass from poplar plantations the productivity increased and the energy demand decreased.

OSR straw pellets were stored for 2 weeks, 1, 3, 6 and 12 months. The pellets were stored as 10kg ± 0.5kg aliquots in plastic airtight zip bags (305 x 405 mm) (Harrison Packaging, Chorley, Lancashire, UK). At each storage time period following pelletisation, samples of biomass pellets were taken from three separate bags and analysed in triplicate

Pellet properties

Table 1 shows the average moisture content (%), ash content (%), volatile content (%) and gross calorific value (MJ/kg).

OILSEED RAPE STRAW PELLETS PROPERTIES	
Moisture content (%)	11,41
Ash content (%)	8,72
Volatile content (%)	91,9
Gross Calorific Value (MJ/kg)	17,61

Table 1.: Properties of Oilseed Rape Straw Pellets.

Pellet durability

A pellet tester was used to assess pellet durability. The pellet tester consisted of a dust tight box made of rigid steel material with smooth and flat surfaces. The box dimensions were 300 x 300 x 125 mm, with a 230 x 50 mm long baffle affixed symmetrically to a diagonal of one of the 300 x 300 sides (Figure 1).

Figure 1.: Durability box

A 1.5 kg ± 0.5 kg sample of pellets was weighed and the fines separated by hand using a sieve with round screw holes of 3.15 mm diameter. A 0.5 kg ± 0.2 kg test portion of pellets was taken from the sample and placed in the pellet tester. The pellet test portion was tumbled in the pellet tester at a rotational speed of 50 rpm for 500 rotations. The test portion was removed from the pellet tester and manually sieved using a sieve with round screw holes of 3.15 mm diameter. The sample remaining in the sieve was weighed using a balance Precisa XT 3200D balance (Precisa Instruments Ltd, Dietikon, Switzerland) to the nearest 0.1g. This process was repeated for a further two test portions.

The mechanical durability of pellets was calculated using the equation:

$$D_u = \left(\frac{m_A}{m_E}\right) \times 100$$

Where, Du = Mechanical Durability (%)

M_e = Mass of pre-sieved pellets before tumbling treatment (g)

M_a = Mass of sieved pellets after the tumbling treatment (g)

Pellet particle density

The particle density of individual pellets was measured using a gas comparison pycnometer (AccuPyc 1305, Micromeritics Instrument Corp, Norcross, Ga.) in which helium under pressure (up to 19.500 psi) was allowed to flow from a previously known reference volume into a sample cell containing the pellet sample. Based on the pressure difference between the sample cell and the reference cell, the pycnometer calculated the volume of the material in the sample cell. The ratio of the mass of material in the sample cell to the volume measured by the pycnometer is the particle density (McMullen *et al.*, 2005; Colley *et al.*, 2006; Fasina, 2008). The particle density of 50 pellets (in duplicate) was measured for each storage period.

Particle hardness

A texture analyser (Instron 5543) was used to determine pellet hardness, following Richards (1990), Tabil (1996), Colley *et al*. (2006), Adapa *et al.* (2003) and ASAE standard S368.4 (2000). Fifty pellets were tested from each sample lot. A single pellet was placed on its natural position in the Instron 5543 and an increasing load was applied at a constant rate of 10 mm/s, until the test specimen failed by cracking or breaking. The maximum force needed to rupture the pellet sample was determined directly from the computer interfaced with the texture analyzer. This force was taken as a measure of pellet hardness.

4. Results

The durability (or abrasive resistance) test simulates the mechanical handling of pellets, and measures the amount of fines that are produced when pellets are tumbled in a durability box under specific conditions. A high amount of fines in the storage system of an end-user can cause failures in the fuel feeding system or dust emissions during storage.

Figure 2 shows how the length of time pellets were stored affected the durability for pellets produced with OSR straw. The results obtained to date show durability increased up to 3 months of storage and then start decreasing. The increase in the durability during the first three months could be related to the binder properties, but it needs to be verified with further work to prove the role that the binder is playing in the OSR straw pellets. Pellets stored for more than three months, had the risk of a decrease in the pellet durability. The durability of the OSR straw pellets was high (Adapa *et al*., 2003), ranging from 94 to 96%.

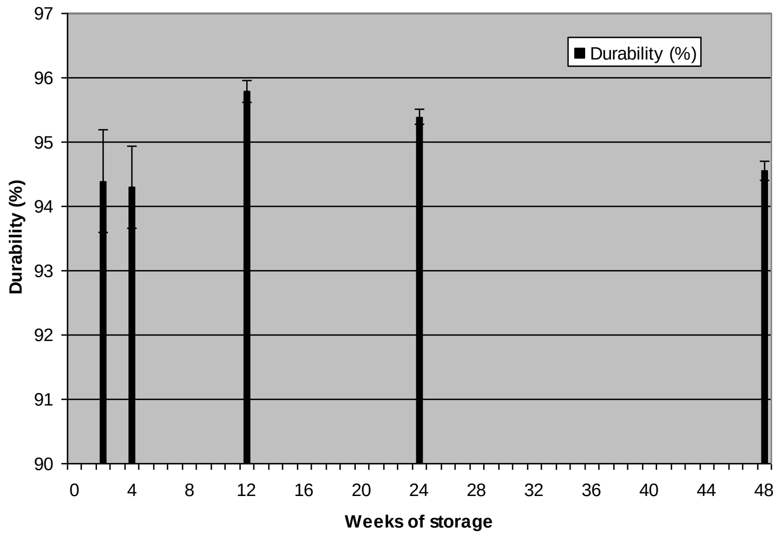

Figure 2.: Effect of storage (up to 12 months) on the durability of pellets.

Particle density has been identified (Fasina and Sokhansanj, 1995) as an important parameter in the design of systems for the ventilation and cooling of pellets during storage, a quality parameter of densified fuels (ASAE, 1991) and important for combustion characteristics (e.g. denser particle pellets have shown longer time to burn) (Obernberger and Thek,2004). The results showed a similar tendency to that for the pellet durability. However, the variations in particle density with storage time are small (Figure 3). These results can be affected for the binder, the storage of the pellets and natural variations of the pellets.

Previous research (Fasina, 2008) showed particle density decreased linearly with increasing moisture content from 5% to 21% (approximately), but the change in the particle density was minimal. This suggests it would be unlikely we would see changes in the particle density of the OSR straw pellets because the variation in the moisture content of the OSR straw pellets during storage varied by less than 1%. It may be thought that the natural variations in the particle density are caused by a non-uniform compression of grinds during pellet manufacturing and the particle size of the raw material (Mani *et al*., 2006) and variations of 50 kg/m^3 can be considered marginal (Shankar *et al.,* 2009).

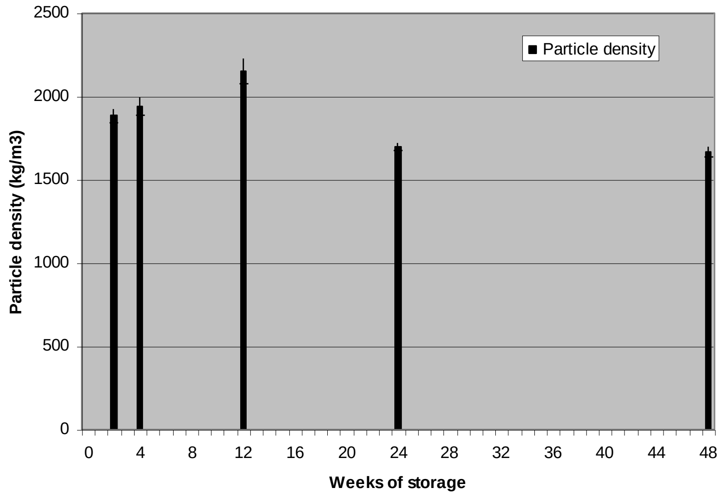

Figure 3.: Effect of storage (up to 12 months) on the particle density of the pellets.

Hardness (or compressive resistance or crushing resistance) is the maximum crushing load a pellet can withstand before cracking or breaking. It is used to simulate compressive stress due to the weight of the top pellets on the lower pellets during storage (Kaliyan and Morey, 2009). It is very important to combine this test with the durability test, as the hardness test does not indicate the dusting potential of the pellets during handling, storage and transportation.

The hardness results (Figure 4) followed a different trend to the results obtained for durability and particle density of OSR straw pellets during storage. The OSR straw pellet hardness clearly increased with the storage time. Variation in the pellet hardness may be due to the properties of the binder, the properties of the raw material (i.e. straw), the storage of the pellets or to natural variations. These natural variations may be due to: a)variation in the length of pellets (longer pellets usually having higher breakage points that shorter ones) b)presence of cracks in some pellets and c) non-uniform compression of grinds during pellet manufacturing resulting in uneven strength within the pellet.

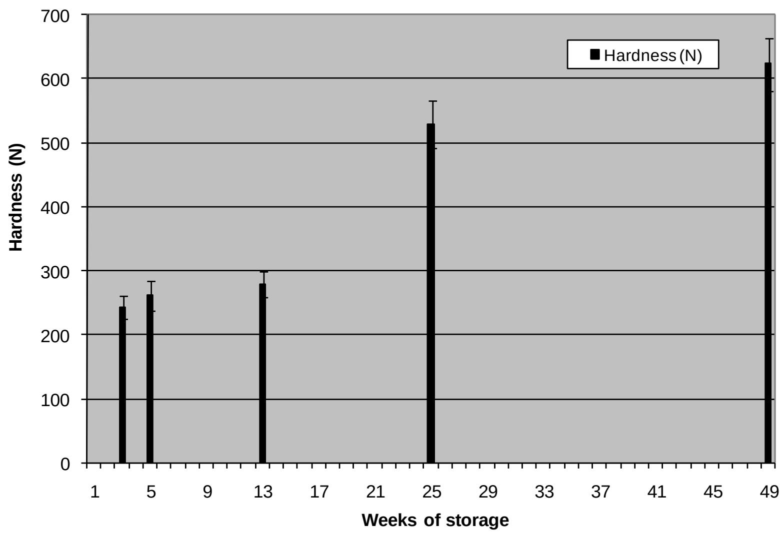

Figure 4.: Effect of storage (up to 12 months) on the hardness of pellets.

5. Conclusions

- Oilseed Rape Straw pellets could be a potential biomass fuel source.
- Storage of pellets could affect their quality properties.
- Durability and particle density of pellets increased up to 3 months storage and then decreased up to 12 months of storage.
- The hardness of the pellets has increased continuously from 2 weeks storage of pellets up to 12 months.
- The variation in the quality properties of pellets can be affected by the presence of binder, the storage time, and other natural variations of the raw materials and the pellets.

6. Acknowledgements

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