Utilisation of clear-fell forestry residues as a biomass energy source: Brash bale production, storage and comminution costs and analysis of brash bale contents

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Introduction Clearfell forestry residues (brash) consisting of branches, crowns, reject logs, off-cuts, small diameter stems and trees are estimated in Britain at 0.82 million oven dried tonnes (odt) per year (McKay, 2005). Brash has a large biomass energy potential but in the raw state the high-volume: low-density ratio renders it financially unviable. Machines that gather, compress, bind and produce brash bales may offer a means of recovery at acceptable cost. Utilisation of the energy content requires comminution of brash bales to woodchips of specific size of known moisture content (MC). The aim of this study was to determine: outputs from commercial scale brash bale production and conversion to wood fuel; and inherent properties of brash compared to parent logwood.

Material and methods Mature stands of Lodgepole Pine (*Pinus contorta*), and Sitka Spruce *(Picea sitenchis)* in a 10.2 ha forestry site at AFBI, Hillsborough, Northern Ireland were clear-felled during winter 2007. In a randomised block experiment with 4 replicates brash was formed into windrows within the Pine and Spruce areas. A John Deere 1490 D brash baler collected and processed brash into bound brash bales 0.6m diameter x 3.0m long, dropped in-situ then transported to roadside by a Valmet 860 forestry forwarder and row stacked up to 4m high. Randomly selected brash bales from each species were labelled, weighed fresh and stacked apart for long term mass and MC monitoring, carried out each year in 2007, 2008 and 2009. On three separate occasions during this period a Starchl 450HP mobile woodchipper with a 25mm chip size screen, separately chipped brash bales and logwood directly from stacks into tractor drawn 18m^3 capacity silage trailers. The brash bale and logwood production and chipping operations were recorded manually using calibrated stop watches and laptop computers, trailers were weighed gross and tare on a certified weighbridge. Standard laboratory methods were used to determine MC, particle size distribution, phosphorus (P) and potassium (K) and gross energy (Ge) content. Production costs were calculated from standard industry cost tables (Keatley, 2008). Baling and analysis data were analysed as two way ANOVA factorial design; chipping data as one way ANOVA.

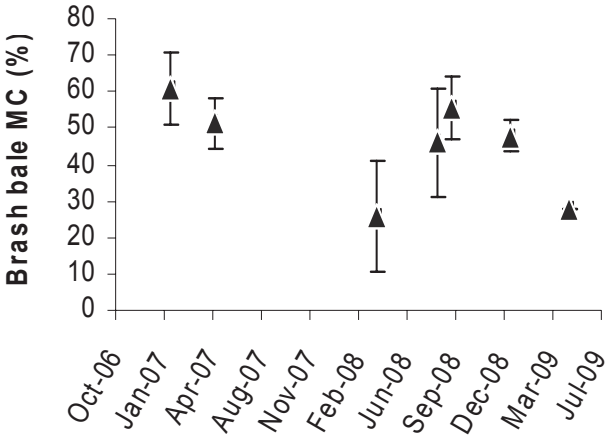

Figure 1 Changes in brash bale moisture content from February 2007 to May 2009 (mean of species). Vertical bars +/- sem.

Results and discussion The production rate of the brash bales (mean fresh weight 414 kg), was 28.2 and 28.8 bales/hr for the Pine and Spruce respectively (ns), but the tonnage per area was significantly greater ($P<0.05$) for the Pine (191 t/ha) *vs* the Spruce (92.4 t/ha). Brash bale recovery to roadside averaged 24 bales/hr (sd 3.2) with no significant differences ($P>0.05$) between the Pine and the Spruce areas. Fresh brash bale mean MC at harvest was 60.7%, falling to 50.1% after 28days. Although the MC fluctuated widely during 2008/9 (Fig 1) indicating drying and re-moistening it was below 30% on two of the sampling dates. The brash bales passed through the chipper at an average of 69.2 sec/bale (sd 25.0) giving an output of 6.4 odt/hr. Logwood chipping gave a significantly higher ($P<0.05$) rate at 8.05 odt/h.
Pine and Spruce brash bales, when compared to logwood, had significantly ($P<0.005$) higher levels of P (848mg/kg *vs* 157 mg/kg DM), K (3928mg/kg *vs* 1076 mg/kg DM), Ge (20.24 MJ/kg *vs* 19.95 MJ/kg DM). The chipped brash had a significantly ($P<0.05$) higher proportion by weight of fine particles <3.15mm, 9.7% *vs* 4.7% than the logwood. The mean cost for brash bale production was £7.98/odt. Comminution of brash bales and logwood to fuel ready chip had mean costs of £15.06 and £13.12/odt respectively.

Conclusions Brash baling was found to be an effective system for gathering and storing brash prior to chipping for utilisation as fuel. The bales were capable of drying naturally down to below 30% moisture under suitable weather conditions. However the rate of chipping was slower for brash bales than for logwood. Chipping costs were higher for brash than logwood. Brash had significantly higher nutrient (P and K) and gross energy levels and a higher proportion (by weight) of fine particles (<3.15mm) than logwood.

Acknowledgement This work was funded by the Department of Agriculture and Rural Development

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