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Feasibility of production and combustion of pellets from straw and energy crops

Key external stakeholders:

Energy Crop and Tillage Farmers
Biofuel Pellet Manufacturers
Solid Biofuel Suppliers
Consumers
Policy Makers
Scientific Community

Practical implications for stakeholders:

The significance of this research for stakeholders is as follows

- *Farmers* may be able to take advantage of a new market for their energy crops and tillage residues
- *Industry* can use the data from this project to build a pellet production industry based on non-woody feedstock
- *Policy Makers* can now take into account that a pellet production industry based on non-woody feedstock can be economically viable in Ireland and make a contribution towards national Bioenergy and greenhouse gas targets
- *Consumers* benefit from the availability of information on the quality of non-wood pellets and their performance during combustion
- *Scientific Community* Little systematic information has been available up until now on the production, quality and combustion of pellets from non-woody material. The data which has come from this project has increased the technical information available to the scientific community in this area

Main results:

- Pellets can be produced from a range of materials including willow. miscanthus, rape straw, barley straw and wheat straw. The best quality pellets were those manufactured from willow followed by those manufactured from miscanthus.
- Pellet production rate was highest for willow followed by miscanthus. Rape straw, wheat straw and barley straw proved comparatively difficult to pellet.
- Pellets manufactured from feedstock mixtures exhibited chemical characteristics intermediate between their parent materials
- Particulate emissions, gaseous emissions and boiler wall deposits were lowest for willow pellets followed by Miscanthus pellets. Emissions and boiler wall deposits were higher during the combustion of pellets manufactured from cereal and rape straws.
- Feedstock costs represented 66% of pellet production costs on average, other major costs were pelleting and cooling (11%), grinding (10%) and personnel (9%). Considering current energy prices, the production of non-woody biomass pellets competes favourably with oil and gas price and is considered economically viable.

Opportunity / Benefit:

This project has shown that pellets can be manufactured from energy crops and tillage crop residues. Thus, the project has increased the utility and attractiveness of energy crops and tillage crop residues.

Collaborating Institutions:

University College Dublin

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Collaborators: Dr JJ Leahy University of Limerick
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1. Project background:

Many factors are set to accelerate the use of biomass as fuel: increasing mineral fuel prices, the need to abate greenhouse gas emissions and reduce dependence on imported fuel, and pressures to achieve EU substitution targets. In Ireland, biomass pellets used in stoves or small boilers could achieve a substantial saving in the use of oil and gas for residential/commercial heating, which currently accounts for 14% of our total greenhouse gas emissions and 18% of total energy demand.

The use as fuel of pellets made from sawdust and shavings has been increasing rapidly throughout Europe. Sweden and Denmark have already virtually exhausted this source. In Ireland, the estimated supply of sawdust is about 200,000 wet tones. Recently-announced grant schemes for domestic and commercial biomass stoves and boilers are likely to stimulate a rapid increase in demand for pellets, which are already being imported from many countries. With several pellet plant projects at an advanced stage of planning, sawdust supplies are likely to become depleted in the near future.

Pelleting upgrades the fuel and facilitates its utilisation in several ways:

- It reduces dust emission in the handling of the fuel
- It improves the flow properties, which simplifies conveying and storage
- It increases the bulk density, which eases storage and transportation
- It leads to a more stable, uniform product with more efficient combustion control

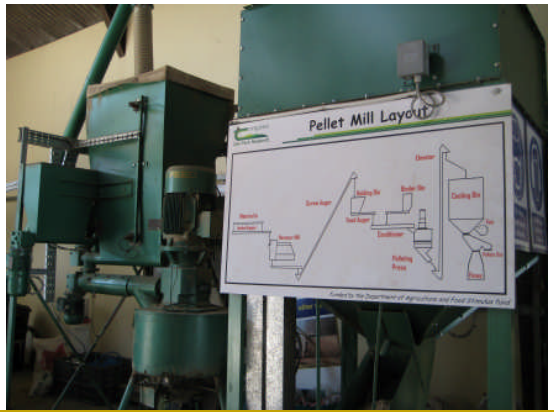
These advantages are likely to stimulate its use in small stoves and boilers, where its enhanced properties will outweigh its extra cost. However, several issues remain to be resolved before a market for non-wood pellets can develop. First, the technology to process the various potential feedstocks into durable, stable pellets needs to be established. Second, the fuel properties of the pellets and any effects on boiler/stove performance and flue emissions have to be measured. Finally, all the costs of raw material production, assembly and processing, and the effect of plant scale on these costs, are necessary information for any potential investor.

2. Questions addressed by the project:

- Can solid biofuel pellets be produced from non-woody feedstocks?
- What are the chemical and physical characteristics of non-wood pellets and how do they compare with wood pellets?
- What are the combustion characteristics of non-wood pellets?
- Is the production of non-wood pellets likely to be economically viable?

3. The experimental studies:

A pilot scale pellet plant was installed at Oak Park, Carlow and used to manufacture pellets from willow, Miscanthus, rape straw , barley straw and wheaten straw. The rate of pellet production for pellets of each feedstock was quantified and the physical and chemical properties of the pellets were measured in the laboratory.



Combustion tests of the pellets from the different feedstocks were conducted in a combustion test rig (below) which was built at Oak Park. Combustion efficiency and deposition on chamber walls were measured during the combustion tests, measurements were also made of particulate and gaseous emissions.
Geographical information systems were used to determine the optimum location for pellet plants based on non-woody biomass. The project also quantified the economic cost of non-woody pellets.

4. Main results:

- Pellets were produced from a range of materials including willow. miscanthus, rape straw, barley straw and wheat straw. Pellet production rate was highest for willow followed by miscanthus. Rape straw, wheat straw and barley straw proved comparatively difficult to pellet and, consequently, pellet production rates were low. The energy required for pellet production was inversely proportional to production rate. Pellets were manufactured from mixtures of both miscanthus, willow and rape straw.
- Laboratory analysis revealed that the best quality pellets were those manufactured from willow followed by those manufactured from miscanthus. Pellets manufactured from cereal and rape straws had relatively high concentrations of ash, sulphur, nitrogen and chloride which would be expected to lead to higher emissions in addition to boiler corrosion.
- Pellets manufactured from feedstock mixtures exhibited chemical characteristics intermediate between their parent materials demonstrating that this practice can be used to make the best of one characteristic of a parent material to alleviate the worst properties of another parent material.
- Combustion Trials: Particulate emissions, gaseous emissions and boiler wall deposits were lowest for willow pellets followed by Miscanthus pellets. Emissions and boiler wall deposits were higher during the combustion of pellets manufactured from cereal and rape straws. High concentrations of carbon monoxide and particulate matter were emitted during the combustion of rape straw pellets.
- Feedstock costs represented 66% of pellet production costs on average, other major costs were pelleting and cooling (11%), grinding (10%) and personnel (9%). Considering current energy prices, the production of non-woody biomass pellets competes favourably with oil and gas price and is considered economically viable.

5. Opportunity/Benefit:

The use of non-woody pellets offers a number of potential benefits which include import substitution and greenhouse gas mitigation in addition to offering an alternative enterprise for farmers. This project has shown that pellets can be manufactured from a range of feedstocks including willow, Miscanthus, rape and cereal straw. Among non-wood pellets, pellets manufactured from willow and Miscanthus were easiest to make, had the highest quality and had the lowest levels of particulate and gaseous emissions on combustion. Although pellets manufactured from rape and cereal straw had less favourable characteristics, it was found that these feedstocks could be successfully incorporated into pellets manufactured from a mixture of feedstocks in which the best characteristics of one parent material were used to alleviate the worst characteristics of another parent material. Thus, the project has increased the utility and attractiveness of energy crops and tillage crop residues. This benefit is available to all stakeholders.

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6. Technology transfer:

The results of the project were disseminated to the public and to the industry at the following events
Open Day, Oak Park, 26 June 2007
Bioenergy 2007, Oak Park, Carlow 30 August 2007
Green Energy Fair, Gowran, 27-29 October 2007
Bioenergy 2008 – Athenry
Open Day, Teagasc Knockbeg Farm, 25 June 2009
Pellet Open Day, Oak Park, 16 April, 2009

Main publications:

Carroll, J and Finnan, J (2012) Physical and chemical properties of alternative biomass pellets. *Biosystems Engineering (*in print)
Carroll JP and Finnan J (2012) Particulate and gaseous emissions from the combustion of alternative biomass pellets. *Biosystems Engineering (*submitted)
Nolan A, MC Donnell K, MC Siurtain M, Carroll JP, Finnan, J and Rice, B (2009) Conservation of Miscanthus in Bale form. *Biosystems Engineering* **104**, Issue 3, 345-352
Nolan A, Mc Donnell K, Devlin GJ, Carroll JP and Finnan J (2010) Potential availability of non woody biomass feedstock for pellet production within the Republic of Ireland. *International Journal of Agricultural and Biological Engineering* **3** (1)
Nolan A, Mc Donnell K, Devlin GJ, Carroll JP and Finnan J (2010) Economic Analysis of Manufacturing Costs of Pellet Production in the Republic of Ireland Using Non-Woody Biomass. *The Open Renewable Energy Journal* **3**, 1-11
Carroll JP, Nolan A and Finnan J (2008) Comparison of Miscanthus and Wood Pellets. Carroll, Nolan and Finnan. – Agricultural Research Forum Tullamore, March 2008.

7. Compiled by: Dr. John Finnan