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Manipulating the ensilage of maize whole-crop, cob and stover

Key external stakeholders:

Livestock farmers, contract tillage farmers, commercial companies, ruminant nutritionists, anaerobic digestion biogas producers, Dept. Agriculture, Food and the Marine

Practical implications for stakeholders:

Maize silage can be an expensive feed to produce, and variation in yield, quality and some conservation traits remains a limitation to the attractiveness of this crop.

- The optimal harvest date for whole-crop maize varies with the hybrid sown, the weather pattern of that year and the particular balance required between crop yield and quality.
- Circumstances exist where some farmers can reduce fertiliser nitrogen (N) input without lowering the yield or quality of maize silage.
- Maize cobs and stover can be successfully ensiled separately.
- An indigenous ‘wild type’ lactic acid bacteria can be present on a crop and prevail over added lactic acid bacteria added to maize at ensiling.
- Upgrading stover digestibility, to increase whole-crop nutritive value, remains an unfulfilled goal.

Main results:

- The higher whole-crop yields achieved with high biomass later-maturing hybrids of forage maize result from higher yields of stover compared to more conventional early-maturing hybrids.
- The digestibility of whole-crop maize can increase and then decline during September-October, and this profile differs among hybrids. There is therefore a unique optimal time at which to harvest each hybrid.
- Similar yields, nutritive value, ensiling characteristics and aerobic stability occurred when maize was grown with either a high permitted input of organic N or of organic N plus inorganic N fertiliser.
- Inoculation with added lactic acid bacteria did not improve silage aerobic stability because of the activity of an indigenous ‘wild type’ lactic acid bacteria.
- Two types of white-rot fungi reduced rather than improved the digestibility of conserved stover.

Opportunity / Benefit:

- Greater precision can now be exercised during the production and harvest of forage maize, or of cob and stover, to produce ensiled feed of a particular quality.
- Costs can be reduced in some circumstances by using less N fertiliser, without any negative implications for maize yield or quality traits.
- Limitations were identified to improving the aerobic stability of maize silage and to upgrading stover nutritive value. These limitations remain to be solved. However, an indigenous lactic acid bacteria with potential to improve aerobic stability was discovered.

Collaborating Institutions:

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1. Project background:

Forage maize has the potential to produce a very high yield of biomass, of high digestible energy content and ensilability, in a single harvest. These yield and quality traits can be altered by the hybrid and N fertiliser input used. Whereas well developed crops should not produce effluent during ensilage, whole-crop maize silages do tend to be aerobically unstable during feedout, and the resultant aerobic deterioration can diminish the quantity and quality of feed used.

The cob (high digestibility and starch content) and stover (high fibre and buffering capacity; relatively low digestibility) components of whole-crop maize provide contrasting energy and ensilability characteristics, and both of these components undergo considerable changes during the maturing phase of the crop in September-October. Although forage maize is normally ensiled as a whole-crop and fed to ruminants, the potential exists to ensile cob and stover separately. These components can be recombined in optimal combinations prior to feeding, or they can be fed separately to different categories of livestock. In addition, the separate ensilage of these two quite different substrates provides the opportunity to differentially manipulate their fermentation during ensilage. This has potential to improve the efficiency of conservation or improve the nutritive value of the conserved products. It also provides the opportunity to exploit non-agricultural uses of maize cob, stover or whole-crop.

2. Questions addressed by the project:

- How do high biomass hybrids of forage maize compare to more conventional early-maturing hybrids (those currently used to provide feed for ruminants in Ireland) in terms of the relative contributions of cob and stover to the whole-crop during the maturing phase of the crop in September-October? What are the subsequent effects of hybrid and harvest date on the conservation characteristics of whole-crop silage, and how differentially do the cob and stover affect these conservation characteristics?
- How does a high biomass hybrid of forage maize compare to more conventional hybrids, when grown with high permitted rates of organic or total N input, in terms of the relative contributions of cob and stover to the whole-crop during the maturing phase of the crop in September-October? What are the subsequent effects of N application rate, hybrid and harvest date on the conservation characteristics of whole-crop silage, and how differentially do the cob and stover affect these conservation characteristics?
- What are the effects of three lactic acid bacteria, thought to differ in their effects on silage aerobic stability, on the temporal profile of fermentation and subsequent aerobic stability of silages made from the chemically contrasting cob and stover components of forage maize?
- Can either of two white-rot fungi (Pleurotus ostreatus or Trametes versicolor), known to be capable of upgrading low digestibility lignocellulosic substrate, improve the digestibility of maize stover? Is the response affected by the part of the stover digested or by its physiological state at harvest?

3. The experimental studies:

- Using a split-plot design with three replicate blocks, six hybrids of forage maize (four conventional [FAO 190-230] and two high biomass [FAO 260-280]) were harvested on three dates between mid-September and late October. In each case, (a) the yield and chemical composition of the whole-crop, and of the cob and stover components, was assessed, and (b) samples of each of these entities were ensiled in laboratory silos, and silage chemical composition, yeast numbers and aerobic stability were quantified.
- Using a split-plot design with three replicate blocks, three hybrids of forage maize (two conventional and one high biomass), grown under two nitrogen input regimes (33 vs. 168kg available N/ha), were harvested on three dates between mid-September and late October. In each case, (a) the yield and chemical composition of the whole-crop, and of the cob and stover components, was assessed, and (b) samples of each of these entities were ensiled in laboratory silos, and silage chemical composition, lactic acid bacteria and yeast numbers, and aerobic stability were quantified.
- Maize cobs and stover were ensiled in laboratory silos following treatment with no additive, Lactobacillus plantarum MTD-1, Lactobacillus plantarum 30114 or Lactobacillus buchneri 11A44. Triplicate silos were opened after 3, 10, 35 or 130 days ensilage, and silage chemical and microbiological (using both

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traditional and molecular biology techniques) composition, and aerobic stability characteristics, were determined.

- Three components of maize stover (leaf, upper stem and lower stem) were harvested on each of three dates (early September, early October and early November) and digested with each of two white-rot fungi (Pleurotus ostreatus and Trametes versicolor) for one of four digestion durations (1-4 months). A split-plot design was used, with three replicate blocks.

4. Main results:

- High biomass hybrids had a lower content of cobs, and these in turn were less mature, compared to conventional hybrids. The higher whole-crop dry matter (DM) yield for the high biomass hybrids reflected their higher yield of stover DM. Across all hybrids, whole-crop DM digestibility increased until 7 October (due to the increasing starch content of the cobs and the increasing cob proportion in the whole-crop) and declined thereafter (due to the increasing fibre content in the stover, and probably a simultaneous decline in fibre digestibility). Whole-crop silages had more restricted and heterolactic fermentations at later harvest dates, and this was more pronounced with conventional hybrids. Overall, the fermentation characteristics of the whole-crop reflected the different contributions of the cob and stover components.
- Increasing the rate of applying N fertiliser had no effect on the DM yield, nutritive value, ensiling characteristics or silage aerobic stability associated with the whole-crop under the prevailing conditions (soil had relatively high organic N content; accumulated ambient heat units during crop growth were low). Although the water-soluble carbohydrate (g/litre aqueous content) and buffering capacity results indicated that whole-crop maize was readily ensilable, the ensilability characteristics of the stover were more challenging than for the cobs.
- The nutritive value, aerobic stability and DM recovery of cob and stover silages were not improved by inoculation with Lactobacillus plantarum MTD-1, Lactobacillus plantarum 30114 or Lactobacillus buchneri 11A44. This was due to the highly heterolactic secondary fermentation that dominated the later stages of the 130 day ensilage process. The latter was most likely promoted by an indigenous epiphytic Lactobacillus buchneri.
- Both white-rot fungi reduced rather than increased herbage DM and neutral detergent fibre digestibility after a four month digestion. This may reflect the rapid utilisation of readily digestible cell wall carbohydrate by the fungi substantially reducing the opportunity for lignin degradation to improve digestibility. While Pleurotus ostreatus showed the ability to degrade acid detergent lignin after more than 1 month of digestion had elapsed (this effect was most evident with leaf and upper stem), leading to a partial recovery in DM digestibility, the Trametes versicolor showed no such effect.

5. Opportunity/Benefit:

- Greater precision can now be exercised during the production and harvest of forage maize, or of cob and stover, to produce ensiled feed of a particular quality.
- Costs can be reduced in some circumstances by using less N fertiliser, without any negative implications for maize yield or quality traits.
- Limitations were identified to improving the aerobic stability of maize silage or to upgrade stover nutritive value. These limitations remain to be solved. However, an indigenous lactic acid bacteria with potential to improve aerobic stability was discovered.

6. Dissemination:

Main publications:

Lynch, J.P., O'Kiely, P. and Doyle, E.M. (2012). 'Yield, nutritive value and ensilage characteristics of whole-crop maize, and of the separated cob and stover components – nitrogen, harvest date and cultivar effects.' *Journal of Agricultural Science (Cambridge)*, [doi:10.1017/S0021859612000342].

Lynch, J.P., O'Kiely, P. and Doyle, E.M. (2012). 'Yield, quality and ensilage characteristics of whole-crop maize and of the cob and stover components: harvest date and hybrid effects.' *Grass and Forage Science*, [doi: 10.1111/j.1365-2494.2012.00868.x].

Lynch, J.P., O'Kiely, P., Murphy, R. and Doyle, E.M. (2012). 'Changes in chemical composition of three maize stover components harvested at sequential maturities and digested by white rot fungi. *Journal of the Science of Food and Agriculture* (under review).

Lynch, J.P., O'Kiely, P., Waters, S.M. and Doyle, E.M. (2012). 'Conservation characteristics of corn ears and stover ensiled with the addition of Lactobacillus plantarum MTD-1, L. plantarum 30114, or Lactobacillus buchneri 11A44.' *Journal of Dairy Science*, 95: 2070-2080.

Lynch, J.P., O'Kiely, P. and Doyle, E.M. (2010). 'Conservation characteristics of maize cultivars ensiled as

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whole-crop, cob or stover at sequential stages of maturity.' In: (eds. H. Schnyder, J. Isselstein, F. Taube, K. Auerswald, J. Schellberg, M. Wachendorf, M. Hermann, M. Gierus, N. Wrage and A. Hopkins) *Proceedings of 23rd General Meeting of the European Grassland Federation*, Kiel, Germany (29 August – 2 September, 2010). *Grassland Science in Europe*, 15: 356-358.

Lynch, J.P., O'Kiely, P. and Doyle, E.M. (2010). 'Yield and chemical composition of contrasting maize cultivars at sequential stages of maturity.' *Proceedings of a joint meeting of the Agricultural Research Forum and the British Society of Animal Science* (Cambridge University Press), Belfast, 12-14 April, p322.

Lynch, J.P., O'Kiely, P. and Doyle, E.M. (2010). 'Yield and agronomy of contrasting cultivars of maize harvested at sequential stages of maturity in 2008 and 2009.' *Proceedings of the Irish Plant Scientists Association meeting*, University College Dublin, 2-4 June, 2010. Paper S3-1.

Lynch, J.P., O'Kiely, P. and Doyle, E.M. (2011). 'Conservation characteristics of ensiled maize whole-crop, cob and stover – harvest date, cultivar and N application rate effects.' *Proceedings of the British Grassland Society* 10th Research Meeting, 20-21 Sept. 2011, Belfast. Published by British Grassland Society. p55-56.

Lynch, J.P., O'Kiely, P. and Doyle, E.M. (2011). 'Dry matter recovery and aerobic stability of maize whole-crop, cob and stover silages – harvest date and cultivar effects.' *Eucarpia – 29th Fodder Crops and Amenity Section meeting*, Dublin, 4-8 September 2011. *Book of Abstracts* – p66.

Lynch, J.P., O'Kiely, P. and Doyle, E.M. (2011). 'Yield and chemical composition of whole-crop maize and its components – harvest date, cultivar and N application rate effects.' *Proceedings of the Agricultural Research Forum*, Tullamore, 14 & 15 March, p95.

Lynch, J.P., O'Kiely, P., Murphy, R. and Doyle, E.M. (2012). 'Changes in chemical composition of three maize stover components harvested at sequential maturities and digested by white rot fungi.' *Proceedings of the Agricultural Research Forum*, Tullamore, 12 & 13 March, p114.

Lynch, J.P., O'Kiely, P., Murphy, R. and Doyle, E.M. (2012). 'White-rot fungal digestion of maize stover components harvested at sequential maturities.' In (Editors K. Kuoppala, M. Rinne and A. Vanhatalo) *Proceedings of the XVI International Silage Conference*. Hameenlinna, Finland, 2-4 July 2012, p220-221.

Lynch, J.P., O'Kiely, P., Waters, S.M. and Doyle, E.M. (2012). 'Conservation characteristics of maize stover ensiled with the addition of *Lactobacillus plantarum* MTD-1, *L. plantarum* 30114 or *L. buchneri* 11A44.' In (Editors K. Kuoppala, M. Rinne and A. Vanhatalo) *Proceedings of the XVI International Silage Conference*. Hameenlinna, Finland, 2-4 July 2012, p372-373.

Lynch, J.P., O'Kiely, P., Waters, S.M. and Doyle, E.M. (2012). 'Conservation characteristics of maize cob ensiled with the addition of *Lactobacillus plantarum* MTD-1, *L. plantarum* 30114 or *L. buchneri* 11A44.' In: (eds. P. Golinski, M. Wanda & P. Stypinski) *Proceedings of 24th General Meeting of the European Grassland Federation*, Lublin, Poland (4-7 June, 2012). *Grassland Science in Europe*, 17:373-375.

Popular publications:

Lynch, J., O'Kiely, P. and Doyle, E. (2012). 'Improving forage maize production in Ireland.' *T.Research*, Spring 2012, Vol. 7 (No. 1): p17.

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