Field lab: BioRich

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Summary

In 2018 and 2019 a pilot and an extended trial was instigated at a farm in Lincolnshire at the request of a member of Innovative Farmers. Its aim was to evaluate the effect of biochar fed to beef cattle on ammonia emission, manure ammonium and nitrate content, pH, worm burden and on the resultant manures' effect on grass growth. The biochar was produced from feedstock generated by the farmers' tree surgery business which included oak, beech and ash. In the pilot trial the cattle were fed 20g of biochar, per head, per day for one week which resulted in no discernible change in manure parameters. Hence, during the extended trial 300g of biochar, per head, per day for 28 days was provided. Although most parameters remained unaffected, it did appear that the nitrate content of manure from biochar fed cattle decreased compared to the control group. This may be as a result of improved ability to digest crude proteins in the presence of biochar in the gut although this remains unproven. There is still much to investigate and recommendations for future research are suggested.

1 Field lab aims

The aim of this field lab was to assess the effect of supplementing beef cattle diets with biochar, with specific regard to;

1.1 Ammonia emission from excreted manure

1.2 Ammonium and nitrate content of excreted manure

1.3 pH and dry matter content of excreted manure

1.4 The effect on faecal egg count (FEC)

1.5 The effect of biochar excreted in manure on grass growth in a pot trial

2 Background

A member of Innovative Farmers wanted to conduct research to understand the effect of adding his homemade biochar into the diet of his beef cattle herd. The motivation for this came from other studies which had established that, for some biochar feed supplements and stock animals, the biochar had resulted in improved growth performance and reduced ammonia and methane emission (Chu et al. 2013, (Leng, Preston and Inthapanya 2012). Hence, the trial would explore whether the health of the animal, emissions and quality of their manure would improve in order to reduce reliance on chemical intervention as well as providing more benefits to using their manure as a soil improver. The farmer co-designed a trial with Donna Udall of the Centre for Agroecology, Water and Resilience (CAWR) at Coventry University. The study included an initial simple pilot study involving nine Shorthorn cross Limousins. Each cow was given 20g of biochar every day for a week and the manure samples were collected and analysed. Although the farmer felt that there was a change in the manure from biochar fed cattle, no chemical change was detectable. Hence, he decided to apply to the Innovative Farmer Research Fund to expand the trial using more biochar and to analyse more parameters. The funds were awarded and preparation for the trial commenced in February 2019. This time, five cattle were fed 300g of biochar every day for 28 days, and a control group of five cattle had their normal diet. Their manure was collected and analysed for pH, moisture content, ammonium and nitrate. In addition, a pot trial (where rye grass was grown in 1 litre pots amended with control and biochar manure) was conducted to ascertain the effect of biochar and manure on rye grass growth as an indication of its effects on soil fertility.

3 Methodology and data collection

The farmer produced his own biochar from native wood (including oak, beech, ash etc) sourced from his tree surgery business. This material was pyrolysed in his Exeter Retort (Figure 1), ground to less than 2mm and bagged into 20g bags for the pilot trial in 2018.

Figure 1. The farmer's Exeter retort

For the Extended Trial, the biochar was ground into particles of less than 4mm in size, returned to the farmer and fed to the cattle via a 300g scoop.

The Pilot Trial

From the 14th May 2018, the farmer fed nine heifers one bag of biochar every morning for seven days. Three sets of manure samples were collected on the 14th day (prior to feeding) and every morning thereafter for eight days, placed in a plastic bag, tied and labelled. It was not noted which individual cows the samples were collected from. All samples were collected by day 10. The samples were stored in a fridge (4°C) until analysis. Four types of analysis were undertaken; dry matter, ammonia volatilisation and ammonium and nitrate (mineral nitrogen) content to establish if the addition of biochar to the diet had any effect on these parameters. Analytical details are provided in the appendix.

The Extended Trial

The findings of the pilot trial informed the nature of the extended trial and it was decided to use two groups of cows, one fed biochar in addition to their normal diet and another as a control with a normal diet and no biochar. Given the lack of detectable change in the manure samples of the pilot trial and after research into other similar trials, the farmer decided to use 300g per cow per day for 28 days. The biochar was added to the troughs on top of their usual barley feed (Figure 2).

Figure 2. Top dressing barley with biochar

From the 16th February until the 23rd March 2019 two sets of mob samples (i.e. from the dung of several cows) were taken from each group, one week prior to biochar start and one week after resulting in the collection of 96 samples. This time six types of analysis were undertaken; pH, moisture content, ammonia volatilisation, ammonium and nitrate content of the manure and a pot trial to establish the effects on rye grass growth. In addition, the farmer use a FECPAK (supplied by Techion https://www.techion.com/FECPAKG2) to assesses the worm burden in cattle by analysing manure.

For the pot trial, 21 treatments were established (four replicates) taking the manure from both groups of cattle and adding it to one litre pots of sieved sandy loam soil at high (60g) and low (30g) dosages which approximated to 250kg N per hectare and 125kg N per hectare rates. The pots were each sown with 0.5g of Italian ryegrass 'Fabio' (*Lolium multiflorum*) on the 20th May 2019. These were placed on benches outside and watered as necessary. The grass was cut three times and the dry weights determined on 4th July, 16th August and finally on 18th September 2019.

4 Results and discussion

Pilot Results

There were no differences in moisture content, nitrate, ammonium (data not shown). It is likely that this is due to the fact that the dosage rate (20g) was too low and that the experiment did not continue for long enough. Similarly, samples of manure from cows fed biochar and left to incubate for 1 week (Figure 3), did not show any change in ammonia volatilisation before or during the week they were fed biochar.

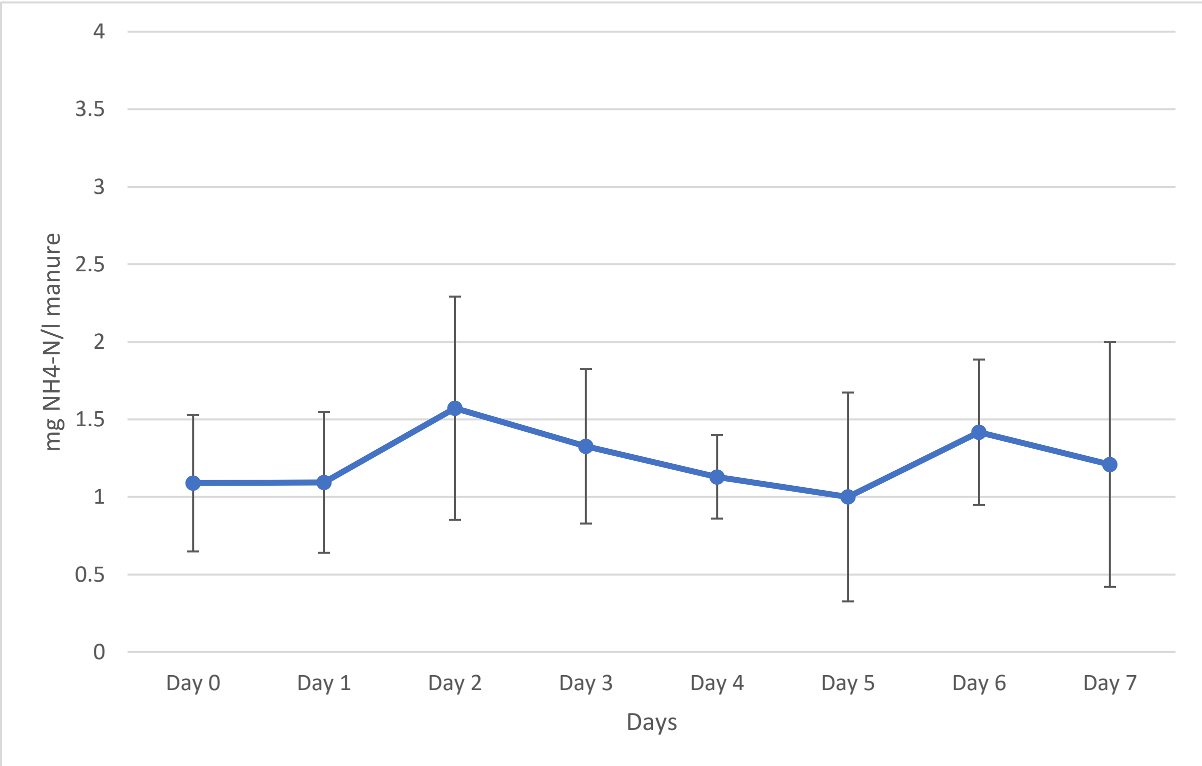

Figure 3. Ammonia Volatilisation from manure (standard deviations shown by error bars)

Extended Trial Results

Anecdotal Evidence

The farmer felt that his cattle responded well to the addition of biochar to their diet, in comparison to the control group. He reported that the biochar group seemed more 'settled' and that their feed intake was higher (although this was not recorded) but also there was less odour emanating from the manure of the biochar fed cows than there was from control.

Dry Matter

There appeared to be no difference in dry matter of manure from cows fed biochar and those not (Figure 4). Although there was a considerable increase in biochar dosage from the pilot trial 300g of biochar still constituted only a small part of their diet and therefore a change may not have been detectable.

Figure 4. Dry Matter Content of Manure after Biochar Addition

pH

No change in pH was detected (results not shown).

Ammonia Volatilisation

As with the pilot trial, there was no discernible difference between ammonia volatilisation from the manure of cows treated with biochar and those not (Figure 5). It is likely that our method was not sensitive enough to allow us to capture this data, because manure samples were later analysed in the laboratory rather than on site and after immediate expulsion from the cow.

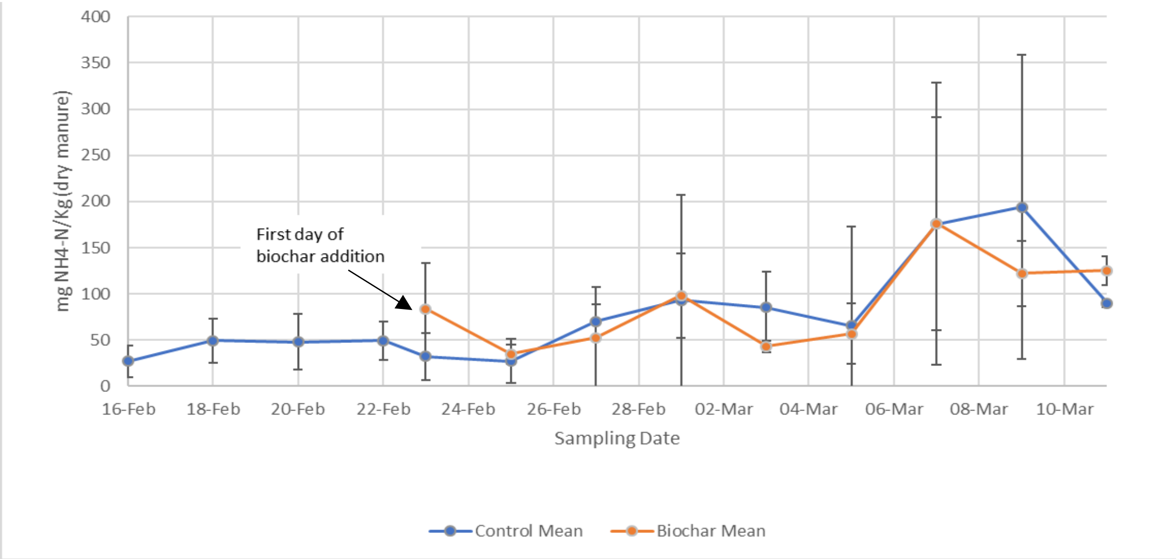

Figure 5. Ammonia Volatilisation from Manure after Biochar Addition (standard deviation given by error bars)

Ammonium Content

There was no difference in ammonium levels in the manure between control and biochar fed cows (Figure 6).

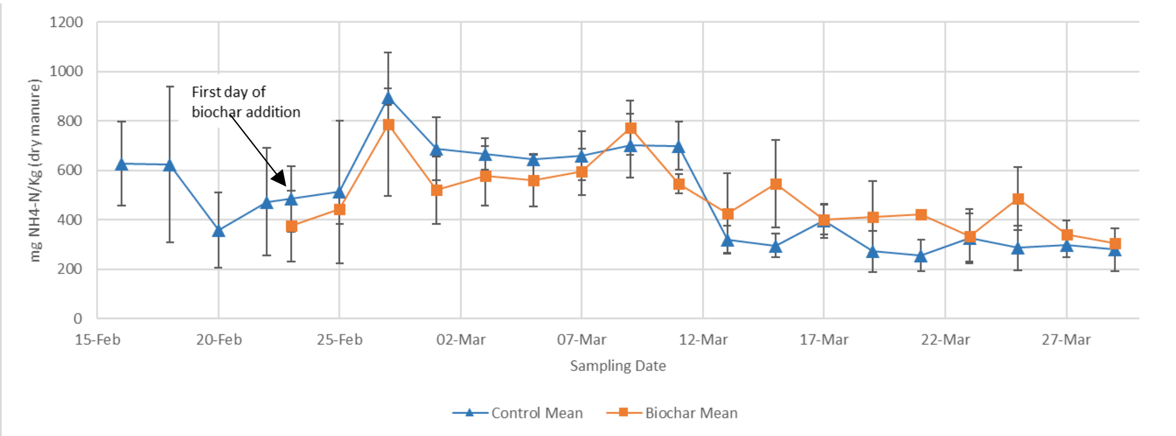

Figure 6. Ammonia Content of Manure after Biochar Addition (standard deviation given by error bars)

Nitrate Content

Nitrate levels did, however, appear to respond to biochar addition with levels tending to be lower in biochar fed cows (Figure 7).

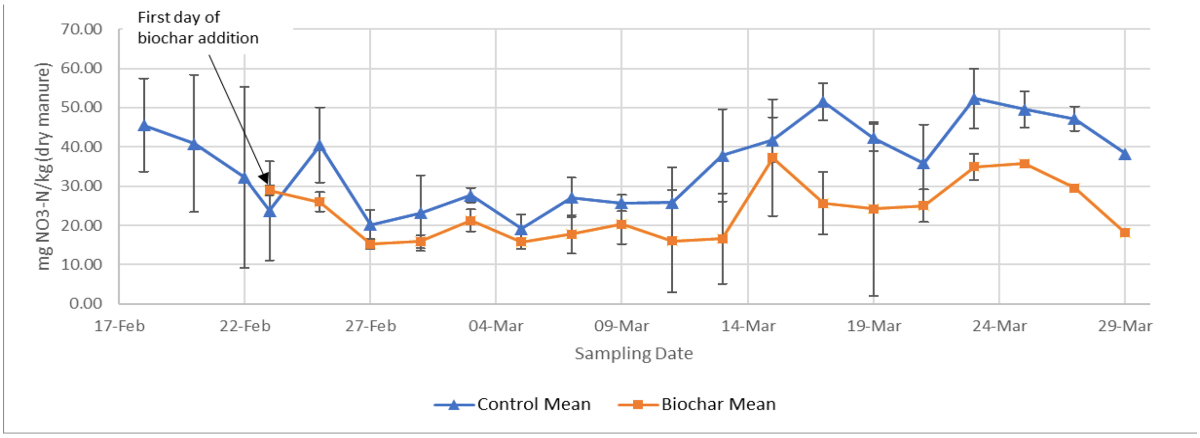

Figure 7. Ammonia Content of Manure after Biochar Addition (standard deviation given by error bars)

This was also reflected in nitrate expressed as a percentage of total mineral nitrate excreted (Figure 8).

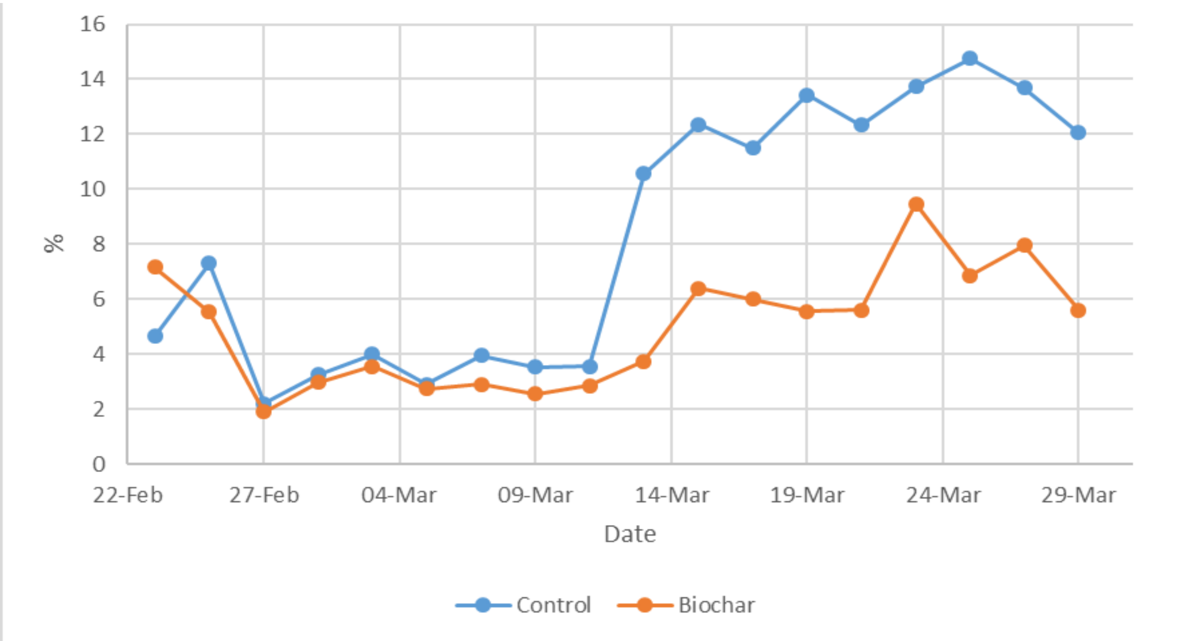

Figure 8. Nitrate as a percentage of Total Mineral Nitrogen in Manure with and without Biochar Addition

Effect on Grass Growth

There were no differences in grass growth between any of the treatments, despite the addition of nitrogen and other nutrients to all the treatments apart from the control. (Figure 9).

Figure 9. Mean Grass Dry Weight (g per pot). The total harvest from three cutting dates is shown.

Discussion

Although the pilot study did not result in a detectable change in the parameters discussed above, the farmer felt that there had been no detriment to his cattle and was convinced that, with a higher dosage, changes would be evident. Other similar studies have used higher dosage rates (up to 400g per head with cattle) (Toth and Dou 2016), hence the farmer decided to re-run the trial with 300g per head. In this extended trial, the farmer felt that the well-being of his cattle improved and notably the farmer felt that the biochar fed cattle had a higher dietary intake. This is borne out in other studies where higher dry matter intake (DMI) has been evidenced. For instance, in their study with six multiparous, late-lactation Holstein cows those fed on poor-quality corn silage and activated carbon increased not only their DMI but also apparent total-tract nutrient digestibility of fibres, hemicelluloses and crude proteins (Erickson, Whitehouse and Dunn 2011).

In our study there was no difference between the biochar fed cows and the control group with regard to pH of excreted manure. However, in their work Chu et al. (2013) studied the response of fattening pigs to bamboo charcoal included in their diet. They found that the two groups with different rates of biochar inclusion both had slightly higher pH (more alkaline) manure than the control group. They also found that biochar fed pigs showed improved growth performance, feed efficiency and faecal beneficial microflora composition (Chu et al. 2013).

Although it was not possible to discern a response in ammonia emission from our study, this was likely due to an insufficiently sensitive method. However, anecdotally, the farmer felt that less odour emanated from the manure of biochar fed cattle when compared to the control group. There is some evidence to support this claim from other studies. For instance, Chu *et al*. (2013) also found that ammonia and methane emission decreased by 55% and 62% respectively when biochar was fed to fattening pigs. In their *in vitro* study using rumen fluid from buffalo, Leng et al (2012a) found that methane production was reduced by 12% by adding 1% of biochar (Leng, Inthapanya and Preston 2012). In their *in vivo* study with 12 local cattle Leng *et al* (2012b) found that the addition of biochar to their diet not only increased live weight gain by 25% it also reduced methane emission by 22% (Leng et al. 2012).

While this study was not able to show a decrease in total nitrogen content of excreted manure from biochar fed cattle, other studies have found this to be the case. For instance, in their study assessing the effect of biochar on feed intake, digestibility, nitrogen retention and growth performance of goats fed *Bauhinia acuminata* as basal diet, Silivong and Preston (2016) found that faecal nitrogen decreased by 200mg per day (or 6.6%). With an improved DMI of 5% resulting from biochar supplementation of the diet, the overall nitrogen retention as a percentage of intake therefore also increased by 7.5% (Silivong and Preston 2016). Our study did find that the nitrate content of excreted manure from biochar fed cattle did appear to decrease (both absolutely and as a proportion of total mineral nitrogen). If verified in future studies, this could have important implications for the management of slurries and nitrate, especially in Nitrate Vulnerable Zones (NVZs) and with particular regard to the dairy industry.

This study was not able to find a discernible effect on grass grown with biochar enriched manure. However, neither did the manure mix have a detrimental effect. This then still leaves open the possibility of gaining further benefit from biochar as a feed supplement through a carbon credit scheme as that carbon in stored in grassland. In their 'back of an envelope' calculation Kammann et al. (2017) argue that assuming an average carbon content of fed biochar of 80% (which is a requirement of EBC feed certificate (EBC 2012) and produced within certain parameters at least 56% of the dry weight of the fed and manure-applied biochar will persist as stable carbon in soil for at least 100 years (Kammann et al. 2017; Lehmann et al. 2015). Hence, on a global scale, if all livestock feed comprised 1% biochar about 1.2% of global CO_2 emissions would be compensated.

Although it was not possible to establish an effect on cattle worm burden in this study – due to a lack of worms – it remains an interesting area of investigation as a reduction in anthelmintic use will be of importance to all farmers. The one study that has investigated the effect of biochar on faecal egg counts in goats found no effect of biochar supplementation but considered that this may have been due to the fact that the goats were wormed at the start of the experiment (Van, Mui and Ledin 2006). This demonstrates the dearth of sound studies into this area and it certainly provides an exciting avenue for future investigations.

5 Conclusions/Recommendations

Overall, this study has demonstrated that adding biochar to the diet of cattle is an easy and manageable intervention that may have positive connotations for animal health and carbon storage, as well as potential nitrates management. For this reason then it is felt that further studies are required. This simple trial was not able to demonstrate the effect of biochar on cattle health or improvements in grass growth but, anecdotally there have been some interesting conclusions borne out by other studies. It may be that the reduced nitrate in the manure resulted from improved nitrogen assimilation in the gut and that overall animal health did improve along with live weight gain. Future studies may include;

- Stock Health Trial - A similar trial to the above but with more farmers and different stock animals, monitoring weight and other easily obtainable stock parameters.
- Soil Health Trial - Again similar to the above but with manures analysed for a greater range of parameters conducive to soil health and an additional pot trial with either grass, wheat or vegetables.

The level of interest in the BioRich trial has been considerable, both from other farmers and wider industry including small and commercial biochar producers and potential biochar users (i.e. the dairy industry). CAWR staff continue to seek funding for future collaborations with Innovative Farmers.

6 Further reading

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Appendix

1. Dry matter. This was established for all samples by drying in an oven at (80°C) for 24 hours until weight stabilised.

2. Ammonia volatilisation analysis. 40 g of all samples (four replicates) were placed in 250ml bottles with an acid trap placed in the screw top and sealed. The acid trap comprised polyurethane foam pre-soaked in a solution of 10% phosphoric acid and 5% glycerol. (Ndegwa et al. 2009) The acid traps captured any ammonia volatilised from the sample for a period of 24 hours and then one week. The foam acid traps were removed and placed in 100ml of two molar potassium chloride (KCl) solution and shaken for one hour. The extract was then filtered through Whatman No.1 filter paper and analysed using a flow injection analyser (FOSS Fiastar).

3. Ammonium content analysis. 20g of all samples (four replicates) were placed in 250ml bottles along with 100ml of 2M KCl. This was then shaken for one hour and the extract filtered through Whatman No.1. This was then analysed for ammonium in the flow injection analyser.

4. Nitrate content analysis. As for ammonium but analysed for nitrate in the flow injection analyser.