Spin-off technologies from 2nd generation biofuel: potential game changers for upgrading cereal straws and stovers for livestock feed in India

Michael Blümmel[a,*], Sudharakan, D. S.[b] , Sharma, G. V. M.[c], Ravindranath, K[c] and Padmakumar, V.[a]

[a]International Livestock Research Institute (ILRI), c/o ICRISAT, Patancheru 502324, India and PO Box 5689, Addis Ababa Ethiopia

[b]Nagarjuna Fertilizers and Chemicals Limited, R&D Centre, Warangal, Medak – 502 279, India

[c]CSIR-Indian Institute for Chemical Technology, Hyderabad 500607, India

[*]Corresponding author: m.blummel@cgiar.org

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Introduction

Lignocellulosic biomass is the most abundant renewable biomass on earth with an annual production of about 10–50 billion metric tons. Cellulose is the major constituent in lignocellulosic biomass ranging from about 300–550 g/kg followed by hemicelluloses which constitutes about 150–350 g/kg, and lignin which constitutes about 60–300 g/kg. Cellulose is a linear polymer of cellobiose which itself is made up of a glucose to glucose dimer in the β 1–4 glucan configuration. This β 1–4 glucan configuration conveys molecular stability to cellulose when compared to starch, a glucose to glucose dimer in the α 1–4 glucan configuration. Thus, lignocellulosic biomass is not that different from the primary products of cereals— the starch in grains—even though their respective accessibility to mammalian digestive enzymes is very different. Considering the huge quantities of lignocellulosic biomass available and the high nutritive quality of their hexose and pentose sugars, it comes as no surprise that attempts to upgrade lignocellulosic biomass for livestock fodder reach back to the beginning of the 20th century. The work on 2nd generation biofuels (biofuels derived from lignocellulosic biomass) was motivated by reasons very similar to those of the early animal nutritionists—the abundance of lignocellulosic biomass and its content of basic sugars.

The work on 2nd generation biofuels (biofuels based on lignocellulosic biomass rather than on grains as in 1st generation biofuel) has attracted multibillion dollars of US investment during the last two decades. It may be feasible to utilize spin-offs from 2nd generation biofuel technologies to upgrade lignocellulosic biomass for animal feeding by increasing the accessibility of sugars in plant cell walls. Key processes in 2nd generation biofuel that matter for livestock feed resources are: 1) post harvest collection and mechanical pre-treatment of lignocellulosic biomass; 2) physical-chemical-biological pre-treatment to disrupt lignin-hemicelluloses-cellulose matrices, partially hydrolyze weaker linkages of pentoses in hemicelluloses structure and make hexoses in cellulose more susceptible to enzymatic hydrolysis; and 3) design and application of targeted and tailored enzyme cocktails.

For animal nutritionists, pre-treatment technologies up to the generation of glucose (or equivalents) are interesting from where rumen microbes and mammalian enzymes can take over. This paper will describe the impact of three 2nd generation biofuel technologies on fodder quality of a wide range of Indian cereal straws and stovers: 1) Steam treatment; 2) Ammonia fiber expansion (AFEX); and 3) IICT 2-chemical combination treatment (2CCT). The paper will also present a cost-benefit analysis of treatments.

Key findings

Comparison of effectiveness of steam, AFEX and 2CCT treatment on in vitro measurements

Increases in in vitro gas production and true in vitro organic matter digestibility (IVOMD) measured after 48 hours of incubation were greatest upon 2CCT, followed by AFEX and finally steam treatment (Table 1).

Table 1: Summary of effects of steam, ammonia fiber expansion and 2CC treatment on in vitro gas production (GP) and true in vitro digestibility[-1] after 48 hours of incubation. U = untreated; T = Treated

Spin-off technology	n	In vitro GP after 48 hours (ml/200 mg)		True IVOMD after 48 hours (%)	
		U	T	U	T
Steam treatment	4	48.6	53.6	62.9	71.8
AFEX treatment	10	42.9	51.5	65.1	84.4
2CC treatment	11	39.7	66.7	55.9	94.1

[-1] The average difference between true and apparent IVOMD is about 12.9 percentage units (van Soest 1994). Increments in digestibility are similar independent of expression as apparent or true digestibility.

Two chemical combination treatments on average increased true IVOMD by 38.2 percentage units from 55.9 in untreated straws and stovers to 94.1% after treatment. This is a significant increase and converts the straws and stovers into concentrate feeds.

Livestock productivity in sheep fed total mixed ration (TMR) consisting of 70% untreated and steam explosion and 2CCT treated rice straw

The 2CCT treatment had the greatest effect on livestock productivity promoting an accumulated live weight gain (LWG) of 6.12 kg after 10 weeks which is 3.7 times that of the TMR containing untreated rice straw. These findings give collateral to the statement that crop residues can be turned into concentrates by 2CCT treatment.

Interestingly, while steam explosion treatment was less effective in increasing in vitro digestibility than 2CCT, its positive effect on voluntary feed intake was found to be dramatic resulting in an intake of 4% of live weight in male sheep. This very high intake promoted accumulating LWG of 3.92 kg. Digestibility, which is 2.4 times that of sheep fed TMR with untreated rice straw. It is important to point out that steam explosion treatment does not use any chemicals, does not take much treatment time and is generally simple. Carcass study has also been completed and showed no negative effects of treatment on either sheep or mutton.

Cost-benefit estimates of 2nd generation biofuel technologies for upgrading ligno cellulosic biomass as feed

The kind of straws and stovers investigated for this work are widely traded for urban and peri-urban dairy production in India. An interesting feature of this fodder market is that price premiums exist for quality differences between straws and stovers from the same crop traded at the same time and place. Based on price premiums for digestibility at straw and stover fodder markets we estimate a treatment cost-benefit ratio of at least 1: 2.

Conclusion

Applying spin-off technologies from 2nd generation biofuel to upgrading the feeding values of straws crop residues can be a game changer. It will not be a farmer technology but should be embedded into small and medium business enterprises.