Innovation brief

RESEARCH PROGRAM ON Livestock

Photo Vishwanathan/CCAFS

Adapting biofuel technology to convert crop residues into nutritious livestock feed

KEY MESSAGES

- Crop residues offer an abundant, accessible source of animal feed that could help boost livestock productivity in developing and transition countries without increasing environmental degradation – if their nutrients can efficiently and effectively be 'unlocked' from the lignocellulosic biomass in which they are bound.
- Second-generation biofuel technologies have already been developed to extract sugars from lignocellulosic biomass for ethanol production and the same can be used to convert straws and stovers into more digestible feed concentrates at scale.
- Scientists at the International Livestock Research Institute (ILRI) and Indian Institute of Chemical Technology (IICT) have found two of these technologies – steam treatment and Two Chemical Combination Treatment (2-CCT) – show significant promise for converting crop residues into nutritious feed concentrates at scale.
- The technologies could yield benefits for both rural populations and the environment because it would boost livestock productivity and offer new income streams, while taking pressure off land and water allocation and reducing environmentally damaging crop residue disposal practices such as rice straw burning.
- To establish the overall feasibility of the concept, the research team requires a larger pilot plant from which to trial different engineering options, chemical combinations, crop residue types and livestock species, as well as to develop mechanisms for minimising environmental impacts.

INTRODUCTION

As global demand increases for meat and milk, it is imperative to find ways to boost livestock productivity without contributing further to greenhouse gas emissions, pollution and land-use pressures. In developing and transition countries, productivity is currently hampered by limited access to affordable, quality livestock feed.

Crop residues are an abundant, accessible resource that could help to fill this gap, if their nutrients – most of which are bound up in a substance called lignin and are indigestible to ruminant animals – can be made more accessible. Scientists at ILRI and IICT have successfully adapted biofuel production technology to convert crop residues into nutritious livestock feed concentrates.

This advance in technology has significant potential to boost livestock productivity – whilst improving environmental sustainability – in developing and transition countries across the globe. Now, the research team is seeking support to build a pilot plant where they can focus on the best ways to optimise the technologies and assess the economic feasibility of scaling up their application.

Photo caption: A farmer in India prepares feed for her cattle. Crop residues in India are a popular feed source for livestock, which significantly reduces competition between human and animal food sources.

ILRI
INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

THE CHALLENGE: SOURCING QUALITY, AFFORDABLE LIVESTOCK FEED

Smallholder livestock production is the mainstay of large sectors of rural populations in the developing world but benefits from livestock production are constrained by the availability of affordable, quality feed. Limitations on feed include biophysical factors such as access to arable land and water, alongside social constraints like on-farm labour competition and shortages.

Feed costs relative to farm-gate produce prices are increasing, reducing farmers' income and increasing the costs of animal-sourced food for consumers. This has a direct impact on the poor, who already do not consume enough animal-source foods, which contain essential protein and micro-nutrients that are critical for small children and pregnant and nursing mothers.

The way forward needs to be two-pronged:

1. increase the availability of affordable off farm produced feed
2. use feed resources that do not compete with land and water allocation for direct food production.

THE POTENTIAL OF CROP RESIDUES

Farmers have used cereal crop residues – the leftover stems and stalks from crops like rice, wheat, corn and sorghum – as an animal feed source since ancient times, particularly in developing and transition countries. They don't require specific land and water allocation because the crops are grown primarily for their edible grains or pods, and they are extremely abundant. About 3.8 million metric tons are produced each year, but farmers often dispose of them by burning that causes air pollution and increases greenhouse gas emissions.

Despite these residues being packed full of carbohydrates, in the form of cellulose and hemicellulose, around 70% of them are undigestible because they are bound together with a substance called lignin which, in this form, animals' gut flora can't break down. Until now, scientists have been unable to develop scalable economically viable methods of releasing these carbohydrates.

This is where the repurposed biofuel technology comes in. Scientists in the biofuel industry have found ways to efficiently extract sugars from lignocellulosic biomass, such as crop residues, to create bioethanol on a large scale without taking up land and resources that could otherwise be used to grow food. This quest for 'second-generation' biofuel (biofuel not made from edible biomass) has attracted billions of US dollars of private and public sector investment.

While interest in upscaling biofuel production has waned in recent years due to the drastic drop in the price of oil, several of the pre-treatment processes developed to break the lignocellulosic bond show promise for animal feed improvement. These are based on mediating temperature, pressure and acidity levels, either as single or combined interventions, and they have the potential to be game changers for feed resourcing.

Steam Pre-treatment tank. Photo ILRI

Steam Explosion tank. Photo ILRI

Loading sorghum crops in Burhaiah Thanda village, Andhra Pradesh, India. After threshing the residue is sold to the Rusni Distillery for ethanol production. Photo ILRI/Stevie Mann

A woman harvests sorghum in India's Andhra Pradesh; this sweet sorghum variety will be used as food at home while its residues will be used for livestock feed and also to produce ethanol. Photo ILRI/Stevie Mann

THREE PROMISING TECHNOLOGIES

ILRI and its partners have explored the impact of three second-generation biofuel technologies on the fodder quality of a wide range of cereal straw and stovers:

1) Steam treatment (by Nagarjuna Fertilizers), whereby intermittent live steam is injected to heat stovers to 160°C for ten minutes, and then the stovers are exploded into a receiver tank
2) Ammonia Fiber Expansion (AFEX, by Michigan Biotechnology Institute), in which ammonia vapor is added to the biomass under moderate pressure and temperature
3) Two Chemical Combination Treatment (2-CCT, by IICT), whereby stovers are treated with two chemicals and the treated biomass is washed, squeezed and dried.

PROOF OF PRODUCTIVITY

In the IICT labs, the scientists tested out the three processes using various types of straw and stovers, and their work revealed that digestibility of the treated residues increased by 8.9% using steam explosion; 19.3% using AFEX; and 38.2% using 2-CCT.

This *in vitro* study was followed by an *in vivo* experiment with sheep fed on 'complete feeds' made from 71% treated rice stovers and 29% other nutrient concentrates (as well as a control version using untreated crop residue) over a period of 70 days. As some concerns were raised about health impacts from a by-product of the AFEX treatment process, the *in vivo* trial was limited to the other two technologies.

The trial results showed that the 2-CCT treatment had the greatest effect on livestock productivity, promoting an accumulated live weight gain of 6.12 kg, which was 3.7 times that of the control group. A remarkable difference in productivity over a relatively short period of time.

The results for steam treatment were also promising. While the method was less effective in increasing *in vitro* digestibility than 2-CCT, it was found to have a dramatic, positive effect on voluntary feed intake, resulting in an intake of 4% of live weight in male sheep. This very high intake prompted weight gain of 3.92 kg, which is 2.4 times that of the control group.

The research team concluded that both 2-CCT and steam treatment were worthy candidates for further exploration. The 2-CCT was particularly advantageous for its high productivity and the relatively low cost of the infrastructure required, and steam treatment had the benefit of needing no chemical inputs and being relatively quick and simple to carry out.

WINS FOR SMALLHOLDERS AND THE ENVIRONMENT

Scaling up this technology could offer multidimensional win-win situations for rural people and the environments in which they live.

Since the technology would be implemented within a small and medium business and franchise environment, smallholder farmers and disadvantaged rural people would benefit directly from greater livestock productivity and sales of feed concentrate.

With more intensive use being made of crop residues, less water and arable land would be needed for feed production, and there would also be reduced pollution from straw burning, resulting in a lower environmental footprint for livestock production overall.

> " The experiments really showed the potential for these two objectives – providing a very nutritious feed source for animals, while creating a value-added product out of crop residues and mitigating the need for burning – to be met together. "
>
> **Ravindranath Kajjam, IICT Scientist**

Farmers harvest sorghum crop. After threshing, the residue is sold to the Rusni Distillery for ethanol production. Photo ILRI

NEXT STEPS

While the results of the *in vivo* experiments were extremely promising, they were limited by the quantity of treated biomass that could be produced in a timely manner within the IICT lab's small-scale facilities, and as such the trial was carried out only with small ruminants (sheep) and with the residue of only one crop (rice).

To generate sufficient data to establish the economic feasibility of decentralised commercial plants – and explore the relative benefits of different engineering options, chemical combinations, crop residues and livestock species – the researchers need support to construct a larger pilot plant with a capacity of one ton per day.

This phase would also be a good time to reconfirm that there are no food safety issues of the treated biomass for the milk and meat that is produced. During the pilot phase, the following studies could be carried out with a view to developing mechanisms for minimising environmental impacts:

a. optimisation and recycling of water to save consumption, reduce wastage, and create a zero-discharge plant

b. utilisation of lignin that is removed from the crop residue to generate steam in the boiler

c. using solid wastes from the process for making compost.

> "The demand for meat and milk is going up. So we need to increase productivity and efficiency, while reducing greenhouse gas emissions. This is an opportunity across Africa, Asia and South America – anywhere where there are a lot of crop residues that are currently burned and there's a deficit in animal feed. It's got global potential."

Chris Jones, ILRI's Program Leader for Feed and Forage Development

CONCLUSION

Scaling 2-CCT, steam explosion or a combination of the two will not only improve livestock production and productivity but also reduce the need for arable land and water allocation for feed production. It will help transition from practices with considerable negative environmental impacts, such as straw burning, towards win-win opportunities.

Successful scaling of the technology will represent a major step toward mitigating feed shortages in the implementing country, while offering multiple business, employment and income opportunities.

IMPLICATIONS AND RECOMMENDATIONS

- Several second-generation biofuel technologies show considerable potential for creating high-quality, planet-friendly feed concentrates from abundantly available resources: cereal crop residues.
- More research is required to optimise these methods for animal feed purposes, and assess the economic feasibility of scaling up production.
- The steam treatment method needs to be further investigated in terms of its mismatch between low digestibility and high dry-matter intake.
- The 2-CCT method needs to be reworked with different soft chemicals to reduce processing costs without compromising its effectiveness.
- The possibility of hybridising the two technologies needs to be explored.
- Further research is required into how to neutralise the effluent, especially in the case of 2-CCT.
- The food safety of milk produced from animals fed the concentrates needs to be studied (this has already been done for meat).
- To answer the above research questions, the research team requires a pilot plant with a capacity to produce one ton of treated crop residues per day.

Sheep feed on crop residues in Doyogena, Ethiopia. Photo ILRI\Zerihun Sewunet

> "Using these different methods to break the lignocellulosic bond for animal nutrition purposes is very expensive. That's why people didn't venture into experimenting with this [for crop residues] before. But in the case of bioethanol production, billions and billions of dollars have already been invested. So we wanted to piggyback on whatever investment is already there."

Padmakumar Varijakshapanicker, Acting Head of ILRI's Feed Technology Research Platform in Hyderabad, India

Acknowledgements

ILRI and IICT's research on spin-offs for crop residue feed enhancement from second-generation biofuel technology is made possible through the support of the CGIAR Research Programs on Livestock, and Livestock and Fish before it (which are supported by contributors to the CGIAR Trust Fund https://www.cgiar.org/funders/), and the Indian Council of Agricultural Research.

Special mention must be made of the following contributing team members, whose work has significantly contributed to the body of knowledge available on the topic:

- **Michael Blümmel**: a distinguished former scientist in ILRI's feed and forage development program, who passed away in 2020. He led the development of this area of research over many years, and none of the advances cited here would have been possible without his drive and exceptional commitment to employing highest-quality science to find real-world solutions for the world's neglected small-scale livestock keepers.
- **Chris Jones and Padmakumar Varijakshapanicker**, ILRI
- **Ravindranath K and Gangavaram V M Sharma**, IICT Scientist (ex)

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CONTACT

Chris Jones
Program Leader for Feed and Forage Development, ILRI
C.S.Jones@cgiar.org

Padmakumar Varijakshapanicker
Acting Head of ILRI's Feed Technology Research Platform in Hyderabad, India, ILRI
V.Padmakumar@cgiar.org