



GEAVET TRAINING PROGRAMME FOR CSA

LIVESTOCK SMART SKILLS AND CLIMATE-SMART POST-HARVEST PROCESSING:

UGANDA

UNIT I.I USE OF METHANE GAS REDUCING FEEDS

ENGLISH VERSION

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Open Educational Resources



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PART I – LEARNING MATERIAL

1. Introduction

Livestock production plays a central role in Sub-Saharan Africa (SSA), providing food, income, cultural value, and livelihoods for millions of rural households. As the demand for animal-source foods increases due to population growth, urbanization, and rising incomes, the pressure on livestock systems to produce efficiently and sustainably has intensified. One of the most pressing environmental challenges associated with ruminant livestock is enteric methane (CH₄) emissions, which arise from microbial fermentation in the rumen. Methane is a potent greenhouse gas (GHG) with a global warming potential 28 times greater than carbon dioxide over a 100-year period, making livestock mitigation a strategic priority for global and regional climate frameworks.

In SSA, methane emissions are especially significant for two key reasons. First, the region is dominated by extensive and mixed crop livestock systems, where feed resources are often of low nutritive value, resulting in high methane intensity per unit of milk or meat produced. Second, the sector is undergoing rapid transformation, placing pressure on natural resources. Livestock are important assets not only economically but also socially, thus, strategies for climate mitigation must enhance rather than compromise productivity and livelihoods.

Smart feeding represents one of the most promising and immediately actionable approaches to reduce methane emissions while simultaneously improving animal productivity. Smart feeding encompasses a suite of interventions; including improved forage quality, ratio balancing, methane-reducing feed additives, better feed conservation practices, and dietary manipulation that alter rumen fermentation toward more energy efficient pathways.

This unit focuses specifically on methane reducing feeds, one of the core pillars of smart feeding. It compiles the latest scientific evidence, integrates SSA-specific case studies i.e. Uganda, Kenya, Tanzania, Ethiopia, Rwanda, South Africa etc. and aligns with European Union Frameworks including the *EU Green Deal*, *Farm to Fork strategy*, *European Climate Law*, and the *Global Methane pledge*.

The purpose of this learning material is to equip learners, trainers, and stakeholders with:

- A foundational understanding of methane emissions from livestock
- Practical feed-based mitigation strategies relevant to SSA systems
- Evidence from real cases involving Makerere University, ILRI, KALRO, TALIRI, and CIAT and application scenarios suitable for vocational training, field demonstrations, and extension work
- Alignment with green and digital competencies under the EU VET framework

2. Methane Production in Ruminants

Enteric Methane is a type of gas produced in the stomachs of cows, goats, sheep, and other animals when they digest food. When these animals eat grass or other feed, microbes in their stomachs break it down and during this process, they produce methane gas which the animals release mostly when they burp.

Enteric methane is produced during the microbial fermentation of feed in the rumen of cattle, sheep, goats, and other ruminants. Understanding this process is essential for designing effective feed-based mitigation strategies.

2.1. Rumen Fermentation Basics

The rumen is a complex fermentation chamber hosting bacteria, protozoa, fungi, and archaea. When fibrous plant material (cellulose and hemicellulose) enters the rumen, microbes break it down into volatile fatty acids acetate, propionate, butyrate, gases (CO₂ and H₂) and microbial protein - later digested in the small intestine. Volatile fatty acids provide 70-80% of the animal's energy, making rumen fermentation essential for productivity.

2.2. Methanogenesis Pathway

Methane is produced predominantly by a group of rumen microorganisms called methanogenic archaea. They use hydrogen (H₂) and carbon dioxide (CO₂) to produce methane through the following reaction: (CO₂ + 4H₂ → CH₄ + 2H₂O). Methane is then released mainly through eructation (belching). This process is biologically important because:

- It removes excess hydrogen, allowing fermentation to proceed smoothly
- But it leads to energy loss (2-12% of feed energy)
- And it generates a potent greenhouse gas

Thus, any strategy that reduces hydrogen availability, redirects hydrogen, or inhibits methanogens can lower methane emissions.

2.3. Factors Influencing Methane Production

Methane output varies depending on:

➤ Diet Composition

- High-fibre diet, low quality feeds → high methane
- High concentrate diets → lower methane

- Lipid rich feeds → reduce methane
- Tannin rich shrubs → inhibit methanogens

SSA livestock systems rely heavily on low quality crop residues and natural pastures, resulting in higher methane intensity.

➤ **Feed Digestibility**

Poor quality feeds degrade slowly, increasing hydrogen production and methane yield. Improving digestibility via legumes, forages, and supplements reduces methane per unit of product.

➤ **Animal Physiology and Breed**

Indigenous breeds (Ankole, Zebu, Boran, Small East African Goat) tend to have:

- Lower feed intake
- Higher fibre diets
- Lower productivity

This means their methane per litre of milk or KG of meat is higher, although total emissions per animal are often lower than high yielding exotic breeds.

➤ **Rumen Microbial Community**

Different methanogen species are dominant across production systems. Diet manipulation can shift the microbial community toward lower methane pathways.

2.4. Why Methane Intensity is High in SSA

Methane intensity refers to methane emissions per unit of animal product (milk or meat). SSA has some of the highest emission intensities globally due to:

- Poor quality forage
- Seasonal feed shortage
- Limited use of supplements
- Low productivity per animal
- Overgrazing and traditional grazing systems

This makes feed based methane mitigation both necessary and impactful in Eastern, Central, and Southern Africa.

3. Feed Quality Identification and Assessment

Feed quality is one of the strongest determinants of methane emissions in ruminants. High quality feeds improve digestibility, increase animal productivity, and reduce methane produced per unit of milk or meat. Understanding how to identify and assess feed quality is therefore a core skill for livestock keepers and extension staff.

3.1. Visual characteristics of Good Quality Feed

High quality forages are usually:

- Green in colour indicating adequate nutrients
- Leafy with a high leaf-to-stem ratio (leaves are more digestible)
- Soft and flexible but not overly fibrous
- Pleasant smelling which shows freshness and good preservation
- Legumes such as Lablab and *Desmodium* typically have higher protein content and better digestibility than grasses, making them valuable for methane reduction.

3.2. Characteristics of Low Quality Feeds

They include:

- Over mature grasses with thick, fibrous stems
- Sundried and weather-beaten pasture
- Crop residues such as maize stover, sorghum stover, and bean haulms
- Feeds that are brown, brittle, or muddy
- Feeds with low protein and high fibre

These feeds tend to slow digestion, longer rumen retention time and increased methane emissions.

3.2.1. Simple farmer-level assessment methods

- Color check i.e., Green = good, Brown/Yellow = poor.
- Leafiness i.e., more leaves = higher quality
- Softness test where soft and flexible stems = higher digestibility
- Smell test i.e., fresh smell = good, Musty smell = spoilage
- Particle size i.e., finer chopped feeds improve intake and reduce methane

3.2.2. Why is this assessment important?

To identify high quality feeds which: increases digestibility, speeds up rumen passage rate, reduces methane produced/unit of feed, improves

milk production and growth rate, and reduces methane intensity per kg of milk or meat.

4. Feed Based Methane Mitigation Strategies

Feed based strategies are the most immediately deployable, cost-effective, and scalable methane mitigation interventions in Sub-Saharan Africa. They work by improving feed quality, altering fermentation pathways, or directly inhibiting methanogens. This section outlines major strategies, both advanced and SSA-appropriate, supported by research from Makerere University, International Livestock Research Institute, Kenya Agricultural and Livestock Research Organization, International Center for Tropical Agriculture, and others.

4.1. Feed Additives Targeting Methanogenesis

This category includes compounds that directly inhibit methane producing microorganisms or redirect hydrogen away from methanogenesis.

4.1.1. 3-Nitrooxypropanol (3-NOP)

Mode of action: 3-NOP inhibits methyl coenzyme M reductase, an enzyme essential for methane synthesis in archaea. It is one of the most scientifically proven methane inhibitors globally.

Reduction potential:

- 20-40% reduction in dairy cattle
- 25-25% reduction in beef cattle
- Higher effectiveness in high quality diets (common in commercial systems)

Advantages:

- Does not impair animal health
- Improves feed use efficiency
- No residue in milk and meat (as per current regulations)

Limitations for SSA:

- Requires intensive feeding systems (TMR, dairy concentrates)
- Expensive and not widely available in African markets
- Not suitable for pastoral or extensive grazing systems

4.1.2. Red Seaweed (*Asparagopsis taxiformis*)

Mode of Action: Contains bromoform, which blocks methane production by inhibiting methanogenic enzymes.

Reduction Potential:

- Up to 80% methane reduction in controlled studies
- 20-60% in practical farm conditions

Advantages:

- Very powerful methane inhibitor
- Works at very low inclusion rates (0.2-0.5%)
- Potential for coastal cultivation in Africa

Concerns:

- Bromoform safety must be monitored
- Risk of residues
- Supply chain challenges
- Requires preserved form (dried, oil-extracted, or encapsulated)

4.2. Plant Secondary Compounds

Certain fodder shrubs and legumes naturally contain chemical compounds that help reduce methane production in the rumen. These compounds work gently within the animal's digestive system and are suitable for smallholder farmers because they come from plants already grown in many SSA countries.

4.2.1 Tannins

Tannins are found in fodder shrubs such as *Calliandra*, *Leucaena*, *Sesbania*, and some *Acacia* species. When included in the diet in moderate amounts, tannins slightly reduce the activity of methane producing microorganisms, improve how protein is used in the animal's body, increase milk yield by improving nutrient availability and help animals digest low quality roughages more effectively.

Research in Uganda, Kenya and Rwanda has shown that giving dairy cows small amounts of tannin rich shrubs (1-2 kg/day) leads to lower methane intensity and higher milk production (Barwani, 2023).

4.2.2 Saponins

Saponins are found in plants such as *Sesbania* and some legumes. They help reduce methane production by lowering the number of rumen protozoa, which are microorganisms that indirectly support methane forming bacteria.

Overall, plant secondary compounds offer a locally available, low cost, and practical methane mitigation option suitable for farmers across SSA.

4.3. Dietary Lipids

Dietary lipids are feeds that contain natural oils or fats. When added in small amounts to livestock diets, they help lower methane production because they slow down the microbes responsible for methane formation. Lipid rich feeds are already common in many SSA smallholder systems, making this one of the most practical mitigation strategies.

In Uganda and Tanzania, dairy farmers commonly use sunflower seed cake, cottonseed cake, and maize germ, which naturally contain oils. These feeds increase the energy content of the diet and improve productivity while reducing methane emissions per litre of milk or per kg of weight gain (Basarab et al., 2013).

Lipids work by slightly reducing fibre breakdown in the rumen and by limiting the activity of methanogenic microbes. The key is moderation: small amounts (5-6% of total diet dry matter) are beneficial, but excessive fat can reduce feed intake. Studies from TALIRI, ILRI and Makerere University show that including oil rich supplements in dairy cow diets can reduce methane by 5-15%, depending on the type and amount of supplement used. Farmers also report improved body condition and better milk yield due to higher dietary energy.

4.4. Nitrogen as a Hydrogen Sink

Nitrates provide another alternative “sink” for hydrogen in the rumen. Under normal conditions, hydrogen produced during fermentation is used by methane producing microbes. When nitrates are included in the diet, some of this hydrogen is redirected away from methane formation.

In SSA, nitrates are most commonly introduced through treated crop residues like Urea-molasses-multinutrient blocks or through commercial nitrate containing supplements used in semi intensive dairy systems. South Africa and parts of Kenya have adopted nitrate blocks in feedlots and dairy systems, with promising results.

When used correctly, and in small quantities, nitrate supplementation can reduce methane emissions by 10-20%. It also improves the use of low quality roughages like maize stover, making it suitable for dry season feeding.

However, nitrates must be used safely, because suddenly feeding large quantities can cause toxicity. Safe involves: introducing nitrates gradually, using controlled, prepared feed blocks, avoiding feeding to hungry animals on an empty stomach, and following recommended rates from extension agents or feed manufacturers.

4.5. Improved Forages and Feed Quality Enhancement

This is the most important strategy for SSA, impacting millions of smallholder farms.

4.5.1. Improved Forages

High quality forages reduce methane per unit of milk/meat by:

- Increasing digestibility
- Reducing retention time in the rumen
- Increasing feed intake and productivity

Key forages used in Uganda:

- *Brachiaria* hybrids (Mulato II *Brachiaria ruziziensis*, Cayman, Cobra)
- Improved Napier grass (Ouma 2, Kakamega 1, 2)
- Legume forages (*Desmodium*, *Clitoria*, *Lablab*)

Reduction Potential:

10-20% methane intensity improvement

4.5.2. Feed Conservation and Processing

- Chopping
- Silage making
- Hay making
- Molasses urea treatment
- Supplement blocks

These improve digestibility, directly reducing methane intensity

4.6. Concentrate Supplementation and Ration Balancing

Adding cereals, protein sources and minerals leads to:

- Faster rumen fermentation
- Higher propionate production
- Reduced methane

Reduction potential:

5-15% lower methane per kg of milk

Limitations:

- Cost

- Market volatility
- Not suitable for purely extensive systems

Table 1. Summary of Mitigation Options for SSA

| Strategy | Reduction Potential | Best for | Limitations |
|------------------|---------------------|----------------------------|---|
| 3-NOP | 20-40% | Intensive dairy/feedlots | Cost, availability |
| Seaweed | 20-80% | Coastal commercial dairies | Supply chain, safety |
| Tannins | 10-25% | Smallholders, agroforestry | Varied potency |
| Lipids | 10-25% | Dairy and feedlots | High inclusion can reduce fibre digestion |
| Nitrate | 10-20% | Semi-intensive | Toxicity risk |
| Improved forages | 10-30% | ALL SSA | Requires training |
| Ration Balancing | 5-15% | Dairy | Cost of concentrates |

5. References

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Sea Forest. (2024). *Methane reduction projects using Asparagopsis taxiformis in ruminants*. Sea Forest Pty Ltd. – Sea Forest website: <https://www.seaforest.com.au/Sea Forest>

PART 2 – CURRICULUM

Learning Objectives:

| KNOWLEDGE | SKILLS | ATTITUDES |
|---|---|--|
| <p><i>Students will know:</i></p> <ul style="list-style-type: none"> ● The biological processes of rumen fermentation and methane production ● The role and importance of hydrogen dynamics in methanogenesis ● The major categories of methane reducing feed interventions ● Feed quality identification and assessment ● The relationship between feed digestibility, animal performance and greenhouse gas emissions ● Relevance of methane reduction to EU and international climate frameworks | <p><i>Student will be able to:</i></p> <ul style="list-style-type: none"> ● Formulate simple rations that incorporate methane reducing feed options ● Identify and select appropriate forage species for methane mitigation in SSA systems ● Evaluate the nutritive value of common feeds using standard indicators ● Carryout basic feed conservation techniques ● Demonstrate safe and appropriate use for feed planning and emission estimation ● Collect basic field data | <p><i>Student will develop the following mindset:</i></p> <ul style="list-style-type: none"> ● A climate conscious mindset regarding livestock production ● Appreciation for sustainable, locally available feed resources ● Commitment to environmentally responsible livestock management ● Confidence in applying evidence based feeding strategies ● Willingness to innovate with new feeding technologies ● Ethical responsibility toward animal welfare and safe feeding practices |
| <p>TRANSVERSAL SKILLS INTEGRATED:</p> <ul style="list-style-type: none"> ● Critical thinking: Evaluating evidence for different feed interventions ● Problem solving: Selecting low cost methane mitigation solutions suitable for smallholders ● Communication skills: Explaining feeding recommendations to farmers and peers ● Collaboration and Teamwork: Conducting group field exercises on forage | | |

| |
|---|
| <p>quality and ration formulation</p> <ul style="list-style-type: none"> ● Decision making: Choosing appropriate interventions based on local resources |
| <p>DIGITAL SKILLS INTEGRATED:</p> <ul style="list-style-type: none"> ● Use of digital ration formulation tools e.g. FeedAssit, Rumen8, etc. ● Input and analyse feed data using simple spreadsheets or mobile forms ● Application of methane estimation tools like FAO GLEAM based calculators, IPCC Tier 2 models ● Access to online databases for forage quality and feed composition ● Use of mobile phones or tabs during field data collection |
| <p>GREEN SKILLS INTEGRATED:</p> <ul style="list-style-type: none"> ● Understanding of environmental impacts of livestock production ● Competence in climate smart livestock feeding practices ● Awareness of sustainable natural resource management ● Skills in selecting low emission, high efficiency forage species ● Ability to integrate agroforestry into farm systems ● Commitment to reducing waste and optimizing feed utilization |

Implementation plan of pedagogical activities - Scheme of work

| Duration: 3 hours | | | | |
|---|----------|--|--|---|
| Target: VET learners, Extension Workers, Livestock service providers and Farm | | | | |
| No. of Activity | Duration | Training Methods / Activity | What the trainers do | What the participants do |
| 1. | 30 min | <ul style="list-style-type: none"> ● Introduction to methane production and smart feeding | <ul style="list-style-type: none"> ● Present concepts using slides and short videos ● Facilitate discussions on SSA feeding system challenges esp. from Uganda | <ul style="list-style-type: none"> ● Listen actively, take notes ● Group discussions ● Identify methane sources in their local systems |

| | | | | |
|----|--------|---|--|--|
| 2. | 60 min | <ul style="list-style-type: none"> ● Feed Identification and Quality assessment (Practical field Demo) | <ul style="list-style-type: none"> ● Provide samples of Napier, legumes etc. ● Demonstrate visual and physical assessment of feed quality | <ul style="list-style-type: none"> ● Handle feed samples, classify feeds & estimate quality while recording observations ● Work in groups to evaluate local feeds |
| 3. | 30 min | <ul style="list-style-type: none"> ● Formulating Methane Reducing Diet | <ul style="list-style-type: none"> ● Teach ration formulation principles ● Demonstrate use of a digital ration planning tool. ● Provide worksheets with real feed data. | <ul style="list-style-type: none"> ● Work in teams to develop diets incorporating improved forages, tannins and lipids ● Enter feed values into digital tools ● Present their final diets |
| 4 | 1 hour | <ul style="list-style-type: none"> ● Integrated On-Farm Practical Session (Field Visit) | <ul style="list-style-type: none"> ● Carry out a visit to a farm implementing improved forages or <i>Calliandra</i> ● Demonstrate feeding techs. | <ul style="list-style-type: none"> ● Observe feeding practices ● Speak to farmers ● Record data trends like milk yield ● Evaluate forage plots |

Materials (What trainers need to have prepared):

- Samples of key Forages
- Weighing scales
- Measuring Cylinders
- Mobile phones or tabs
- Flipcharts
- Markers

- | |
|---|
| <ul style="list-style-type: none">• Worksheets• Demo Farms accessibility• Methane estimation calculators• Protective gears for field visits. |
| Other notes: <ul style="list-style-type: none">• Trainers to review safety protocols for handling Nitrate containing feeds |

PART 3 – ACTIVITY GUIDE

DESCRIPTION OF THE ACTIVITIES

1. Feed Quality Assessments and Classification

This activity introduces learners to the practical assessment of forage and feed quality using physical, sensory, and basic analytical indicators. Feed quality strongly influences methane production, productivity, and overall animal health. By engaging hands-on with real feed samples, learners gain the skills necessary to distinguish between low-quality roughages and high quality feeds suitable for methane reducing diets.

Learners work in small groups and receive a variety of feeds commonly used in SSA: Napier grass, *Brachiaria* hybrids, *Calliandra*, Maize stover, bean residues, and sunflower cake. Each group classifies feeds based on texture, colour, smell, leaf-to-stem ratio, fibre content indicators, and estimated crude protein. They then record observations on a worksheet and compare results across groups.

Trainers facilitate group discussions on why certain feeds e.g., *Calliandra* reduce methane intensity while others (e.g., maize stover) increase it. Learners link observations with theoretical knowledge on rumen fermentation and digestibility.

1. Aim of the activity:

- To enable learners to practically assess feed quality
- To link feed characteristics with methane production potential
- To prepare learners for ration formulation exercises

2. Duration: 1 hour

3. Material required:

- Fresh and dried feed samples
- Basins
- Gloves
- Knives or scissors

- Worksheets
- Markers
- A flipchart
- Optionally portable NIR tools or mobile feed apps.

https://www.youtube.com/results?search_query=Introduction+to+methane+production+and+smart+feeding

4. Step-by-step instruction of the task/practical exercise/case study:

- Trainer distributes feed samples and worksheet
- Learners assess each feed's physical characteristics
- Learners classify feeds into high, medium, and low quality
- Trainer guides discussion linking feed quality to methane emissions
- Groups present findings
- Trainer provides clarification and concludes the sessions

References/Sources/Further materials:

International Livestock Research Institute. (2022). *Feed assessment tools for East Africa*. ILRI Publications.

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2. Formulating Methane Reducing Diets Using Digital Tools

This activity equips learners with the capacity to design balanced rations that incorporate methane reducing feed options using both manual calculations and digital ration formulation tools. The session introduces participants to improved forages, tannin rich shrubs, lipid sources, ration balancing principles, and methane estimation calculators.

Working in small groups, learners use provided feed composition tables and digital tools (e.g., FeedAssist, Rumen8, or locally available apps). They develop diets for dairy cows, goats, or beef animals based on locally available feeds. Each group formulates two diets:

- Standard Farmer diet (baseline)
- Methane reducing diet including improved forage, tannin shrub, or lipid source.

Trainers guide learners through entering feed values, adjusting ratios, interpreting predicted methane emissions, and checking for nutritional adequacy (DM intake, crude protein, energy). Groups compare methane outputs from baseline versus improved diets, and present their results.

1. Aim of the activity: The activity aims to develop learners' practical skills in formulating balanced animal rations while introducing them to digital tools that support efficient feed planning. It also demonstrates how different diet compositions influence methane emission levels, enabling learners to make informed decisions that enhance both productivity and environmental sustainability.

2. Duration: 30 minutes

3. Material required:

- Mobile phones or laptops
- Feed composition tables
- Calculators
- Digital apps
- White board markers

4. Step-by-step instruction of the task/practical exercise/case study:

- Trainer demonstrates how to use ration tools
- Learners form groups and select an animal species
- Groups enter feed data into the tool
- Groups formulate baseline and methane reducing diets
- Groups compare predicted methane emissions
- Groups present findings: trainer gives feedback

References/Sources/Further materials:

Hawkins, J., et al. (2021). Methane prediction models for ruminants. *Journal of Dairy Science*.

Food and Agriculture Organization of the United Nations. (2024). *GLEAM: Livestock methane tools*. FAO Publications

3. On-Farm Demonstration-Evaluating Methane Reducing Feeds

This field based activity deepens learner understanding through direct observation and interaction with farmers implementing methane reducing feeding strategies. Learners visit a local dairy farm using improved forage varieties (e.g., *Brachiaria*, Improved Napier) and tannin rich shrubs (*Calliandra*, *Leucaena*). The objective is to help learners evaluate practical feeding practices, animal responses, forage management, and real world challenges in smallholder systems.

Participants observe cow feeding routines, forage chopping, silage pits, fodder shrub plots, and milk recording practices. Trainers explain how improved forages enhance

digestibility, why tannins reduce methanogenesis, and how lipid supplements (such as sunflower cake) influence fermentation pathways.

Learners interview farmers using a short questionnaire on costs, labour, feeding frequency, and observed changes in milk yield or animal health. They collect basic data such as milk yield, body condition scores, and feed quantities, linking field observations with theoretical concepts.

1. Aim of the activity: The activity aims to provide experiential learning through farm-level exposure, reinforce learners' understanding of methane-reducing strategies, and develop strong data collection and observation skills. This integrated approach enables participants to connect theory with practice while strengthening their capacity to apply climate-smart livestock management techniques.

2. Duration: 1 hour

3. Material required:

- Farm tools
- Notebooks
- Recording sheets
- Protective gear (boots, gloves)
- Phones/tablets for data entry
- Measuring buckets

4. Step-by-step instruction of the task/practical exercise/case study:

- Trainer briefs learners on safety and objectives
- Farm tour covering forage plots, feed storage, and feeding practices
- Learners observe animal responses and feeding behaviour
- Learners interview the farmer using guiding questions
- Groups collect simple data on yield and feeding
- Trainer facilitates group reflection and links observations to methane concepts

References/Sources/Further materials:

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