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GEAVET TRAINING PROGRAMME FOR CSA

CLIMATE SMART AGRICULTURE:

NIGERIA

UNIT 2.2 SILAGE PRODUCTION

ENGLISH VERSION
GEAVET Project n° 101129027

Open Educational Resources

PART I – LEARNING MATERIAL

1. Introduction

Silage preparation for ruminants is not well-adopted in Nigeria compared to other temperate countries, where it is a major feed component for dairy cows. During the period of luxuriant growth of forages (wet/rainy season), traditional smallholder cattle, sheep and goat farmers in Nigeria rely solely on the available grasses for animals to graze. The excess forage is often not preserved to make provision for the dry season, when feeding of ruminants becomes more difficult, due to a decline in quantity and quality of Natural pastures. However, the event of climate change and its visible consequences on the feed shortage, farmer-herder conflicts and decreased ruminant productivity, silage production is gaining attention as a strategic technology to ensure year-round feed availability, sustainable production and profitability. Contrary to the wider interest in silage production among commercial farmers to bridge the gaps of feed shortage, its adoption among smallholder/traditional farmers has not been encouraging, probably due to a lack of required skills and knowledge on the preparation and evaluation of the silage quality. Therefore, this training guide aims to provide smallholder farmers with the skills and knowledge on silage production as a climate-resilient feed for ruminants to mitigate feed challenges during the dry season, improve productivity, support food and nutrition security and reduce greenhouse gas emissions.

1.1. Potential of Silage as a Climate-Smart Feed for Ruminants

Silage is any material (feed resources) produced under anaerobic conditions (absence of air/oxygen). It is basically a preservation technology for any moist forages/crops, and by-products. This is based on lactic acid fermentation, whereby lactic acid bacteria (LAB) convert water-soluble carbohydrates into lactic acid and other fermentation acids (propionic, acetic, butyric acids, etc). Silage offers great opportunities in mitigating climate change effects on livestock, characterised by temperature extremes, variable rainfall patterns, and prolonged dry seasons, which reduce the quantity and quality of forages and animal performance (Jimoh et al., 2021). Silage production for ruminants guarantees feed all-year-round (Sahoo, 2018), enhances resource use efficiency for increased feed intake, growth rate and milk yield (Olorunnisomo, 2015) and lower greenhouse gas emissions, especially enteric methane (Gastelen et al., 2019). Therefore, the adoption of silage technology by smallholder farmers in Nigeria should be tailored towards a more sustainable and productive future.

1.2. Inventory of Common Feed Resources for Silage Production in Nigeria

Nigeria has a vast amount of feed resources (both conventional and non-conventional) that are/can be utilised for the preparation of silage. A feed resource for ensiling should have adequate dry matter and water-soluble carbohydrate content, and a low buffering capacity. Water-soluble carbohydrates promote the population of lactic acid bacteria needed to increase the fermentation rate and lactic acid production. It is possible to ensile almost any plant material and agro-industrial by-products; the most important crops for ensiling worldwide are whole maize plants, legumes and numerous grasses. Some common feed resources that could be ensiled are listed in Table 5. Any of these feed resources can be ensiled solely or in combination with other feed resources. For example, legumes can be ensiled with grasses or agro-industrial by-products. The purpose of the addition of legumes to other nitrogen-deficient feed resources to produce silage is to improve the protein content of the ensiled mixtures. The combination of grasses and legumes in ruminant feed is effective for a highly nutritious diet. Any of these feed resources can be combined in different proportions to produce different silage types. Examples of potential silage types include: Moringa mixed with wheat offal and guinea grass in varying ratios (Asaolu et al., 2015), cassava leaf and peel silages (Anaeto et al., 2013) and Albizia lebbeck-Cassava peel-silage (Ajayi and Omotoso, 2018) and silage from maize stover, maize husk and *Andropogon gayanus* (Ogunbosoye and Odedire, 2022).

Table 5. Inventory of potential feed resources for silage production

Category	Examples	Key Benefits	Major Limitation
Grass species	● Guinea grass. Elephant/Napier grass. ● Sorghum (forage and grain), ● Maize (forage and grain).	● Energy source. ● Has moderate water soluble carbohydrates. ● Relished by ruminants. ● Low buffering capacity.	● Low in protein content.

Category	Examples	Key Benefits	Major Limitation
Herbaceous/ tree legumes	● *Gliricidia,* ● *Leucaena,* ● *Moringa,* ● *Albizia (*pods and leaves), ● *Lablab,* ● *Centrosema,* ● *Mucuna*	● Rich in protein. ● Acceptable to ruminants. ● Rich in minerals. ● Readily available. ● Secondary metabolites (e.g. Tannin & Saponin)	● High buffering capacity. ● Low in carbohydrates. ●
Crop Residues	● Cassava peel. ● Maize stover. ● Corn cob. ● Groundnut haulm. ● Cowpea husk. Cowpea vines. Sorghum stover.	● Rich in fibre and energy. ● High in dry matter.	● Low in nutritional content. ● Poorly digestible. ● Bulky to transport. ●
Agro-industrial-by products	● Wheat offal, Corn bran, Cassava pulp, Brewers dried grain, Rice bran, molasses, fruit wastes, plantain peels.	● High in energy content. ● Increase the nutrient content and fermentation rate of ensiled materials. ● Can be used as additives for ensiling. ● Used as adsorbents.	● Lower in protein content

A GRASS SPECIES

Image 26. Elephant grass

(Source: Plantvillage)

Image 27. Guinea grass

(Source: Apni Kheli)

Image 28. Northern Gamba grass
(Source: TRM (2025)

Image 29. Maize plant
(Source: Pixabay)

Image 30. Sorghum plant
(Source: TamilNadu Agricultural University)

B HERBACEOUS/ TREE LEGUMES

Image 31. *Gliricidia*

Image 32. Moringa plant

(Source: IITA, 2024)

Image 33. *Leucaena leucocephala*

Image 34. *Lablab purpureus*

(source: Weeds of Australia)

Image 35. *Centrosema molle* (Source: Sheldon Navie)

C CROP RESIDUES

Image 36. Cassava peels
(Source: Acowas, 2025)

Image 37. Corncobs
(Source: Sisman *et al.*, 2022)

Image 38. Cowpea haulm
(*Source: Feedipedia, 2025)*

Images 39a & b. Groundnut haulm

(Source: Weseh *et al.,* 2017)

D AGRO-INDUSTRIAL BY-PRODUCTS

Images 40a & b. Wheat offal

(Source: Afrimash)

Image 41. Brewers Dried Grains (BDG)

Images 42. Watermelon waste[a]

Image 43. Fruits & vegetable wastes[b]

[a](Source: FinancialNigeria, 2017)

[b](Source: Yemisi Odusanya, The Guardian, Nigeria, 2017; Business Post, Nigeria, 2018)

Image 44. Plantain peels

(Source: NatureNews)

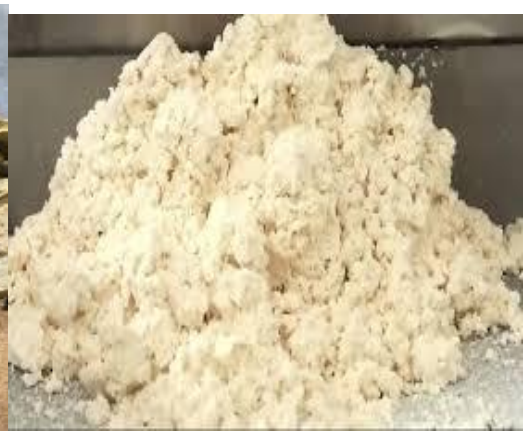

Image 45. Cassava pulp

(Source KBAF, 2018)

2. Mixed Grass-Legume Silages and Climate Smart Livestock Production

Herbaceous legumes, when ensiled with forage grasses, whole grains, or agro-industrial by-products, play a significant role in mitigating environmental pollution, especially enteric methane emissions in ruminants. The antinutritional factors in legumes (tannin, saponin) alter the rumen fermentation processes and growth of microbial population. Methane production tends to increase when ruminants are fed mature grass, while it declines when forage legumes are fed (Cao *et al.,* 2011). Therefore, transitioning from grass to forage legume species tends to decrease enteric emissions due to a lower amount of structural carbohydrates and a faster rate of passage. This shifts the fermentation pattern towards higher propionate production. Increased rumen nitrogen

use efficiency reduces the volume of carbon excreted as carbon dioxide and methane, as well as N losses via urine. Hence, the adoption of mixed grass-legume silages in ruminant feeding will promote an eco-friendly environment, which is the core of climate-smart livestock production.Watch the videos on Napier grass silage making (https://www.youtube.com/watch?v=dVukxXh7x2Q), the step-by-step preparation of maize silage in a dug-out pit (https://www.youtube.com/watch?v=1KMDzTfqmIE) as well as how silage made at home using a concrete pit lined with a plastic sheet or nylon (https://www.youtube.com/watch?v=168c14_EPmA)

3. Evaluation of Silage Quality

The quality of silage is determined by several factors, including the type, age at harvest, inherent nutrient content (e.g., water-soluble carbohydrates, protein, dry matter content), buffering capacity of the materials (grasses, legumes, or agro-industrial by-products), and levels of contamination with soil and silage additives used. The ensiling management factors include: chop length of forage, wilting time, compaction, filling and sealing, silo types and fermentation types. Post-ensiling factors are the length of fermentation and the feed-out phase. Good quality silage should have a pleasant odour, a characteristic colour (bright, light green, yellowish-green, or brownish-green), and texture (firm and not slimy) of the original ensiled material, a high nutritional value and be free of mould. Watch videos on visual assessment of silage quality (https://www.youtube.com/watch?v=Jx0T9ozNYz8) and what a feed test, such as the evaluation of silage means (https://www.youtube.com/watch?v=S2zlPm212ZE).

3.1. Do's and Don'ts of Silage Preparation

Silage should be prepared carefully to ensure a successful ensiling process to obtain quality silage. Harvest forage at the appropriate age when the nutrient (protein and carbohydrate) contents are at optimal levels. Ensure that plant compositions are adequate in water soluble carbohydrates, dry matter, but lower in buffering capacity. Avoid ensiling crops/forages with high moisture content, inadequate water soluble carbohydrates and high buffering capacity, which may result in clostridia fermentation and spoilage of silage. Moist plants/crops should be wilted to increase their DM content. Additives high in water-soluble carbohydrates should be added to increase the rate of fermentation. Filling of the silo should be timely. Ensure the ensiled materials are adequately sealed to prevent entry of air/oxygen and aerobic deterioration or spoilage, caused by yeasts and moulds growth. During feed-out and storage periods, the silo should be properly covered to prevent re-entry of air/oxygen.Watch videos on the step-by-step procedures of silage making (https://www.youtube.com/watch?v=vFCWE7TeCs4), how to ensile any grass to make it good silage or good feed (https://www.youtube.com/watch?v=p_RzsyV-aIM)

and how to make maize and surface silage (https://www.youtube.com/watch?v=kyMiebvXVuI).

3.2. Step-by-Step Guide to Grass-Legume Silage Preparation

- Harvest the forage at the right stage of growth (grasses- before or at the start of flowering, legumes at about 10% bloom, depending on species) when the protein, carbohydrate and dry matter are at optimal levels.
- Chop the forage to the desired length (2-5 cm) to ensure easy compaction, faster fermentation rate and increased intake.
- Wilt the forage to a moisture content (65-70%) or dry matter (30-35%) that will prevent loss of nutrients via effluents and clostridia fermentation.
- Mix the grass-legume according to the right proportion (70:30) and add water-soluble-rich additives (e.g. molasses, corn bran, inoculants, etc.) to speed up fermentation and improve the palatability.
- Fill the silo/container (plastic bags, drums, or pits lined with polyethene nylon) in layers and compact immediately to eliminate air/trapped oxygen.
- Seal the compacted materials completely with an airtight nylon sheet, and weigh it down with heavy objects to maintain constant pressure and prevent air re-entry.
- Leave the material to ferment (21-45 days or 60-120 days).
- Open the portion required to assess the quality (smell, colour, texture) and feed animals. Discard silage with mould and a pungent smell.
- Close and seal the ensiled material properly and immediately after feeding to reduce exposure to air and prevent spoilage.
- Silage Making Process (Step-by-Step Procedure) by Moses Smash. here
- How to ensile any grass to make it good silage or good feed by Hamiisi Semanda. here
- Napier Grass Silage Making by Fred Dairy Farm. here

3.3. Step-by-Step Guide to Maize Stover Silage Preparation

- Collect maize stover immediately after grain harvest or 2 days after, and ensure that it is free of soil.
- Wilt to a desired dry matter (30-35%) level.
- If too dry, sprinkle water on it to a desired moisture content (about 65-70%).
- Chop to an appropriate length to ease compaction.

- Add additives such as molasses, urea or legumes to increase the fermentable sugar for lactic acid production, protein content, and breakdown of fibre.
- Fill the silo in layers with ensiled stover, and compact each layer to expel air.
- Seal the ensiled stover with a plastic nylon sheet once the silo is full, and place sandbags or heavy wood on top to weigh it down and maintain the pressure.
- Allow to ferment for 21-120 days.
- Open the silage to feed after the expiration of the fermentation day.
- Cover the silage immediately after each day of feeding out to prevent re-entry of air and spoilage.

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PART 2 - CURRICULUM

Learning Objectives

KNOWLEDGE	SKILLS	ATTITUDES
Students should be able to: • Explain silage as a climate-smart feed. • Identify common feed resources for silage. • Describe a guide to silage-making. • Identify and assess the best forage/crops to make silage • Discuss the preparation of mixed silages of grass and legumes, and maize stover • Highlight the factors that determine the quality of silage. • Evaluate silage quality.	*Students should be able to:* • Prepare pit or plastic drum silage. • Analyse silage quality (pH, dry matter, smell, mould growth, etc.) • Implement simple silage management plans. • Apply criteria to identify and select good-quality silage for livestock feeding.	*Students should be able to:* • Appreciate the importance of silage production as climate-smart feed. • Demonstrate commitment to reducing waste and responsible environmental sensitivity. • Advocate for climate-smart feeding practices. • Demonstrate teamwork and collaboration during group monitoring and problem-solving tasks. • Support the adoption of silage making for innovative and climate-smart feed production.

TRANSVERSAL SKILLS INTEGRATED:

- **Problem-solving:** Identifying and addressing challenges that could affect the quality of silage before, during and after silage production.
- **Time management**: Ability to effectively manage the timeframe allocated to silage production processes with respect to harvesting of forage, wilting, chopping and filling, Compaction and sealing, monitoring of temperature and pH, as well as feed-out period to prevent re-entry of air and spoilage of silage.
- **Attention to details:** Ensuring accurate monitoring and record keeping of the

entire processes (e.g. dry matter content, chop length, compaction, air exclusion, etc.) to obtain a high-quality silage.
- **Adaptability** to changes in weather conditions, materials used to ensile, and other prevailing factors that could affect silage quality.
- **Communication:** Effective communication with group members, trainers and other groups in sharing experiences.
- **Critical thinking:** Assessment of silage quality to make informed decisions about the production processes and guide against further errors.
- **Safety awareness**: Making safety a priority during harvesting, compaction and handling of equipment.
- **Continuous learning**: Eagerness to improve skills and knowledge through any relevant opportunities.
- **Record keeping**: Effectively maintaining records of all the production (harvesting date, moisture content, silage acids, pH, etc.) and management processes.

DIGITAL SKILLS INTEGRATED:

- **Weather and moisture prediction**: To access real-time weather for planning the time of harvesting forage at the appropriate time and moisture content.
- **Data analysis**: On soil, weather, crop growth, nutrient content of crop before ensiling to optimise silage production processes.
- **Silage management software**: To monitor silage temperature, fermentation acids, pH, and mould growth to predict silage quality and stability.
- **Decision support systems**: Needed to predict silage quality for the purpose of making informed decisions about silage production and management practices.
- **Remote monitoring** of silage using mobile apps, sensors and software (Botlink Insites, FarmBrite, etc.) for tracking silage production and management and providing accurate real-time data.

GREEN SKILLS INTEGRATED:

- **Sustainable forage management:** Identifying and selecting suitable forage crops with high biomass yield for production to adapt to changing climatic conditions while ensuring a constant supply of a balanced feed all year round.
- **Sustainable resource (water) management:** Knowledge of water conservation techniques to ensure the cultivation of pastures all year round for silage production.
- **Livestock and feed management:** Knowledge of feeding systems that align with silage production without negatively impacting the environment, and understanding the link between silage quality and its effects on animal health and overall livestock performance.
- **Waste reduction and circularity:** Identifying waste generated from agro-

industries or farm-generated waste for reuse and incorporation into feed compositions for silage production.

Implementation plan of pedagogical activities (Scheme of work / Session plan)

Duration: 2 hours 20 mins				
Target: VET learners, Diploma certificate holders/trainees, smallholder farmers, and agricultural advisors (gender-balanced; mixed experience)				
No.	**Duration**	**Training Methods / Activity**	**What the trainers do**	**What the participants do**
1.	45 min	Problem-Based Learning (PBL): "Silage For All-Year-Round Feeding."	● Introduce silage-making as a forage conservation technique ● Guide learners to identify local forages/crops suitable for silage. ● Introduce the principles of silage production. ● List the factors to consider in forages/crops for silage-making. ● Prepare a Elephant grass-*Lablab purpureus* in plastic drums	● Work in groups to share experiences ● Ask questions ● Suggest feed resources that are suitable for silage production.

2.	45 min	Hands-on Demonstration Training	● Itemise the materials required to prepare maize stover silage, ● Explain the factors influencing silage quality. ● Demonstrate: the preparation of maize stover silage and *Albizia lebbeck*-Cassava peel silage. ● Open the ensiled materials after 30-45 days, and conduct physical/visual and sensory assessment of silage quality.	● Participate actively in the activities and questions ● Train others.
3.	50 min	Collaborative Reflection Forum	● Summarise course contents ● Upload short videos on WhatsApp group.	● Participate actively and comment on posts.
Materials (What trainers need to have prepared): ● Forage crop samples (Grasses, herbaceous and tree legumes, maize stover, additives, e.g. corn bran) and other available feedstuffs/ingredients ● Plastic drum, Nylon sheet, ● Videos of silage preparation				
Other notes:				

PART 3 – ACTIVITY GUIDE

DESCRIPTION OF ACTIVITIES

1.” Silage For All-Year-Round Feeding“ Problem-Based Learning Activity

The dynamics of climate change on livestock during the dry season have consistently resulted in inadequate and poor-quality grasses for grazing and forage scarcity, leading to weight loss, reduced reproductive performance, low milk yield, and poor health status of animals. This scenario calls for a viable option of feed supply for feeding all year round. Trainees were presented with a scenario in which smallholder sheep and goat farmers in a community struggle to feed their animals during the dry season, having wasted the opportunity to preserve the available and excess forage during the rainy season. The trainer asked the trainees how they could preserve the excess forage as silage to ameliorate the situation. After much deliberation and discussion within the groups, they were guided on silage-making technology. Trainees were made to understand the benefits and challenges, identify the suitable crops/forages, learn the basic principles of silage-making, assess silage quality and its management, and develop strategies/plans for an all-year-round supply of silage for feeding of small ruminants. The trainer then presented a plan for producing a variety of silage from the identified inventories of feed resources within their environment. They were guided specifically on steps to produce a quality silage from grass-legume mixtures (e.g. Elephant grass and *Lablab purpureus*), and maize stover silage. The trainees' performance was assessed. Adoption of silage technology for the preservation of feed resources by farmers presents a greater opportunity for resolving the consequences of climate change on ruminants caused by fluctuations in feed quality and quantity.

1. **Aim of the activity:** To produce high-quality silage for all-year-round feeding of small ruminants

2. **Duration:** 45 min

3. **Material required:**

- Pictures of identified forages/crops
- Silage production and quality management guides
- Video clips of silage-making
- Pictures of Plastic containers/drums
- Nylon sheeting
- Whiteboards

- Markers
- Flip charts

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

Preparation of Elephant Grass-*Lablab purpureus* silage in plastic drums:

- ➢ Harvest the grass (elephant grass) and legumes (Lablab purpureus) before the flowering or bloom stage of growth.
- ➢ Wilt for at least 24 hours under the shade to a moisture content of 60-65%.
- ➢ Chop the forage to a length of 1-3cm.
- ➢ Mix both forages according to a desired grass-legume ratio, and add additives (e.g. molasses) to the forage mixtures, and mix thoroughly.
- ➢ Fill the plastic drum with the forages in layers, and compact to eliminate air or oxygen.
- ➢ Cover and seal up the ensiled materials with a polythene nylon sheet.
- ➢ Place a heavy sandbag on the ensiled materials and allow them to ferment for 45 days.
- ➢ Open the ensiled material after 45 days, take the samples needed for analysis and portions to feed.
- ➢ Cover up the silage and reseal immediately after each time of feeding to prevent re-entry of air and spoilage.

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2. Hands-on Demonstration Training: Preparation of Maize Stover Silage and *Albizia lebbeck*-Cassava peel Silage

The trainer asks the trainee to list the materials commonly used to make silage and identify which of the listed feedstuffs are more suitable for silage production based on factors that could affect the quality of silage. Trainees were provided with the following materials to ensile: tree legumes (*Albizia lebbeck* leaves), molasses, cassava peels, maize

stover, etc. Trainees were divided into 2 groups: the *Albizia lebbeck*-Cassava peel silage group and the maize stover silage group. Each of the groups would use a plastic drum and a dug-out concrete pit to ensile. Before ensiling, trainees were briefed on the factors that could result in the production of poor-quality silage. After the brief talk, they were instructed to commence the silage-making activities, following the steps of silage making, where each group are to ensile the allotted materials (feedstuffs) for 45 days. After 45 days, the plastic drums and bunker pit were opened to assess the quality of silage. Silage quality indicators (both visual and sensory), provided by the trainer, would assist learners in assessing the silage quality.

1. Aim of the activity: To prepare maize stover silage and Legume-crop residue (*Albizia-lebbeck*-cassava peel) silage for feeding of small ruminants

2. Duration: 45 min

3. Material required:

- Pictures of cassava peels
- *Albizia lebbeck* leaves
- Silage quality assessment guides
- Video clips of silage-making,
- Pictures of Plastic containers/drums
- Nylon sheeting

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

- **Preparation of Maize Stover Silage**
    - Collect maize stover immediately after grain harvest or 2 days after, and ensure that it is free of soil.
    - Wilt to a desired dry matter (30-35%) level.
    - If too dry, sprinkle water on it to a desired moisture content (about 65-70%).
    - Chop to an appropriate length to ease compaction.
    - Add additives such as molasses, urea or legumes to increase the fermentable sugar for lactic acid production, protein content, and breakdown of fibre.
    - Fill the silo in layers with ensiled stover, and compact each layer to expel air.
    - Seal the ensiled stover with a plastic nylon sheet once the silo is full, and place sandbags or heavy wood on top to weigh it down and maintain the pressure.
    - Allow to ferment for 21-120 days.
    - Open the silage to feed after the expiration of the fermentation day.

- Cover the silage immediately after each day of feeding out to prevent re-entry of air and spoilage.

➢ **Preparation of *Albizia lebbeck*-Cassava peel silage**

- Harvest fresh foliage of *Albizia lebbeck* from the tree and *Panicum maximum* (Guinea grass) at the sixth week re-growth interval
- Chop the foliage into 3-5 cm lengths
- Allow the leaves of *Albizia lebbeck* and Guinea grass to wilt under the shade for 24 hours.\
- Collect fresh cassava peel.
- Weigh each of the materials: cassava peel, *Albizia lebbeck* and Guinea grass in the proportion of 60, 25 and 15%, respectively.
- Mix all the materials to form a homogenous mixture
- Fill the plastic drum (120 litres) lined with a nylon sheet with the materials in layers.
- Compact the materials manually to eliminate trapped air until the plastic drum is filled.
- Wrap the exposed inner nylon sheet over the ensiled material in the plastic drum tightly.
- Place heavy sandbags of 50-60kg on the ensiled materials.
- Allow ensiled materials to ferment for 28 days.
- Open the silage after 28 days for quality assessment.

References/Sources/Material needed:

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3. Collaborative Reflection Forum

The trainer requested that trainees reflect on what was taught, share their real-life experiences, challenges, and successes, and, in doing so, respect for individuals' opinions and ideas, as well as constructive feedback, were the ground rules of the forum. The trainers engaged the trainees through open-ended questions to harvest the lessons learnt from the training exercise to stimulate discussions within the various groups of trainees, while key takeaways and actionable points from the discussions were highlighted and summarised.

1. Aims of the activity: To facilitate a collaborative reflection forum for TVET trainees/farmers to share experiences, challenges, and best practices in livestock feed and feeding management.

2. Duration: 50 minutes

3. Step-by-step instructions of the task/practical exercise/case study:

- **Collaborative Reflection Forum on silage production**
    - Welcome all the participants and define the purpose of the forum
    - Get the trainee engaged in an activity to encourage participation
    - Trainees present case studies on lessons taught, with a focus on successes and failures.
    - Trainees discuss case studies in small groups with emphasis on major challenges, best practices, and areas for improvement.
    - Reflection and sharing of major takeaways
    - Develop actionable plans for trainees to apply to learnings in their own contexts.

References/Sources/Further materials:

Not required