CHAPTER ONE. INTRODUCTION

Applied animal nutrition: is a branch of nutritional science that deals with scientific principles and practices of animal feeding based on:

- Chemical composition of feed stuffs
- Nutritional requirement of livestock for maintenance and production
- Technical knowledge of ration formulation (cost effective livestock feeding)
- Feed manufacturing technology and quality control measures

Components of animal feeds

- Feed is any material which after ingestion by animals is capable of been digested, absorbed and utilized for physiological processes.

- Feed can be described as an edible material that nourishes required nutrients to the body.

- Not all components of ingested materials are digested.

- For example, in grasses and hay part of the feed are digestible and some parts they contain are indigestible components.

- The components of feed which are capable of been utilized by animals are described as nutrients.

Traditional vs Scientific Animal Feeding

Traditional animal feeding

- Traditional animal feeding is feeding animals with out planning for any particular purposes like milk production, meat production, traction power or wool production
- It is not based on nutrient requirement
- Arbitrary feeding of animals for maintenance and all purposes together

Scientific animal feeding

- Scientific Animal feeding are animal feeding based on well designed feeding experiments conducted to obtain nutrient requirement of livestock species for particular production function(meat, milk ,skin ,hair and wool production)

- Nutrient requirement of animals depends on:
  i. Species of an animal
  ii. Class or age of maturity
  iii. Production level
  iv. Climate
  v. Exercise or activity of animals

1.1. Importance of scientific feeding

- To deliver an adequate supply of the nutrients required to meet the animal needs
- To achieve a balance of ingredients that will optimise rumen function and nutrient utilisation
- To ensure the ration can provide the required nutrition within the animal intake capacity
- To make the most of the lowest cost (often home grown) feeds for the greatest economy
- To provide rations which can be fed effectively with the equipment and facilities available.

Feeding experiments

- The art of scientific animal feeding was originally developed from feeding experiments and experiences

- Feeding experiment is the most useful method of obtaining results which have direct application to feeding practices

- A feeding experiments are records of the results produced in terms of growth (weight gain per day), milk yield (liters/ml per day), egg production or other products from a given feed

Requirement of scientific feeding experiments

- It could be conducted in various experimental arrangements based on statistical design(CRD, RCBD, Factorial design and Latin square)
- At least four animals are required in a treatment
- Amount of feed offered and refused are recorded on daily basis. This will show the average amount of feed (on DM basis) consumed over the study period
- Performance of animals (Average daily gain, ADG; or milk per day or other) are evaluated

Cont’d..,

- Animal of the same breed, sex and age are required
- Animals should be free of any diseases/parasites
- Animals should have similar physiological status (Lactation, pregnancy, growth etc) status (Lactation, pregnancy, growth etc)
- There should be adaptation period of at least 15 days to the environment and the experimental diets

Types of scientific feeding experiments

1. Comparative feeding trials

Experiments with two parallel diets

2. Feeding trial with lab animals

The use of rats , mouse and hamstring for testing new diets new diets

3.Purified diet methods

The use of amino acids and pure minerals for testing specific nutrient requirements

4. Germ free technology

Controlled experiment to avoid any microbial contamination (eg. Studies on Rumen microbial functions)

Cont’d..,

5. Group feeding and individual feeding experiments

Ex. Poultry feeding experiments, fish feeding experiments(group feeding)

Sheep and cattle feeding experiments(individual feeding)

6. Controlled and adlibtum feeding

Limited amount of feed (controlled) and excess amount in adlib feeding

7.Paired feeding trial

Comparison of basal and experimental diets

8. Slaughter experiments

Analysis of carcass composition for nutrient retention

Definition of some terms in applied animal nutrition

- **Food (feed):** is a material which can be ingested by animals and capable of being digested, absorbed and utilized.

- However, not all components of food are digested and absorbed by the animal. However, not all components of food are digested and absorbed by the animal

- **Nutrients:** components of food which are capable of being utilized by animals are known as nutrients.

- Nutrients can be organic or inorganic origin.

Cont’d..,

- **Roughages:** are feeds that are high in fiber content and low in energy content.

- They contain more than 18 % crude fiber (CF) on dry matter basis.

- **Concentrates:** are feeds with less than 18% CF on dry matter basis (e.g. cereal grains, energy on dry matter basis (e.g. cereal grains, energy supplement; oilseed cake, protein supplement).

- Concentrate can be from mixtures of various feedstuffs or single feedstuff.

Cont’d..,

- **Ration:** Any feed or feed mixture and water an animal is given for 24 hours.
- It does not indicate whether it is adequate or not.

- **Balanced ration:** A ration formulated to provide all nutrients required by an animal both in quantity or quality.

- **Supplement:** Any feed or mixture of feeds added to the total ration of an animal to increase the nutrient value of the diet

Cont’d..,

- **Ad libitum :** a diet offered free-choice, allowing animals to eat as much as they desire, (typically for 10% leftover from daily allotment).

- **Restricted (controlled) feeding:** is the opposite of ad libitum feeding

- **By-product:** feed ingredient produced as a result of industrial manufacturing (could be from plant or animal; e.g. bran, meat meal, respectively)

Cont’d..,

- **Cake:** residue which remains after pressing seeds, meat or fish to remove oil, fat or other liquid

- **Bran:** coarse outer grain coatings separated during processing (e.g. wheat bran, maize bran)

- **Chaff:** husks or other seed coverings and other plant parts separated from seed during harvest or processing processing

- **Feed additives:** an ingredient or combination of ingredients added, usually in small quantities, to the basic feed mix for the purpose of fortifying the basic mix with certain essential nutrients, medicines or hormones, etc.

CHAPTER TWO. EVALUATION OF FEED STUFFS

- Evaluation of livestock feed is important to quantify the potential of feeds in supplying nutrients to the animals and the extent of utilization.

- The nutritive value of a given feed can be evaluated in various ways:

  - ***Chemical***
  - ***Biological***
  - ***Micro biological***

Importance of feedstuff evaluation

- **Feed evaluation is bases for improved feeds and feeding systems**
- **Feed evaluation is used to;**
  - **To determine the nutritive/quality of feedstuffs**
    - **Chemical composition, digestibility, Energy and Protein values, anti-nutritional substances**
  - **Identify if there is deficiency of nutrient/s in the diet**
    - **Correct supplementation**
  - **Assess the potential and select new forage varieties as animal feeds**
  - **To compare feedstuffs**
  - **Identify best mixes from different ingredients**
    - **Ration formulation**
  - **To monitor performance of animals**

Importance of feedstuff evaluations…

- **What are evaluated;**
  - **Supply of nutrients**
  - **Supply of energy**
  - **Supply of protein and its quality**
  - **Voluntary intake**
  - **Animal performance**

Methods of feed evaluation

- ***Basically three methods;***
  - ***Chemical***
  - ***Biological***
  - ***Micro biological***
- **Also physical analysis gives a slight clue on feed quality Experience depended**
  - **Visual**
  - **Leaf to stem ratio**
  - **Stage of maturity**
  - **Contamination**
  - **Smell**
  - **etc**

Methods of feed evaluation…

- **Chemical**
  - **Proximate**
  - **Detergent/Van Soest**
  - **Other nutritional analysis**
    - **Mineral analysis- atomic absorption**
    - **Bomb calorimetry**
    - **Amino acid analysis**
- **Biological**
  - **Digestion trial**
  - **Metabolism trial**
  - **Growth or lactation performance trial**
- **Microbiological**
  - **In *vitro* -- in tube**
  - **In *situ* -- in site (organ)**

Chemical Analysis

- **Key points:**
  - **What is chemical analysis**
  - **Importance of knowing the chemical composition of feeds**
  - **Common methods of chemical analysis used in feed analyses**

Chemical Analysis…

- **Reveals the chemical composition of feeds**
  - **Give a picture of what the feed is made of**
- **Knowlwge of feed chemical composition is imprtant;**
  - **For balancing ration**
  - **For selection of feeds from various options**
  - **Replacing of feeds by others with similar potential**
  - **It is the base for other feed analysis and**

Chemical Analysis…

- **What factors affect animals productive performance?**

- **The two feed related factors affecting animal performance are:**
  - **DM intake**
  - **Nutritive value of the consumed feed**
    - **Digestibility and availability of the nutrients**

- **Therefore, it is important to measure the feed related characteristics that determine its intake and digestibility, such as;**
  - **Fiber, lignin, protein, soluble carbohydrates, tannins, etc**

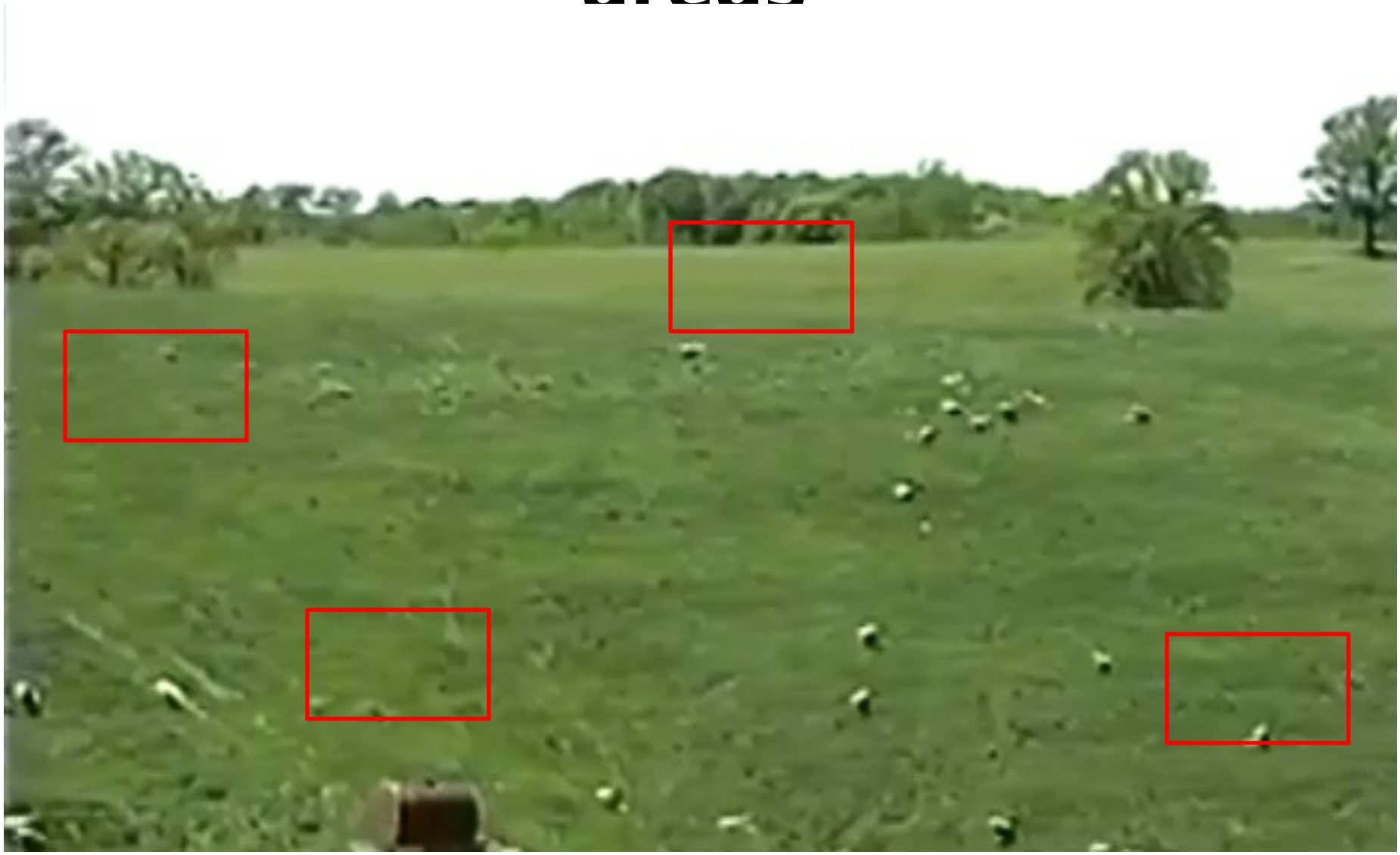
Chemical Analysis…

- **Chemical Evaluation methods:**
  - **Proximate analysis (Weende system)**
  - **The Van Soest method (the detergent system)**

Sampling, sample collection and processing for chemical analysis

- ***Why sampling?***
  - ***To save time, energy/labor and capital***
- ***How to sample?***
  - ***Different methods can be employed***
  - **Sample/s is/should be representative/s the batch under consideration**
- ***From where to sample?***
  - **Fields**
  - **Storages**
  - **Liquids**

Random Sampling of grazing areas



Sampling, sample collection and processing for chemical analysis…





Natural pasture hay stacked in loose form on a raised structure (Adugna, 2008)







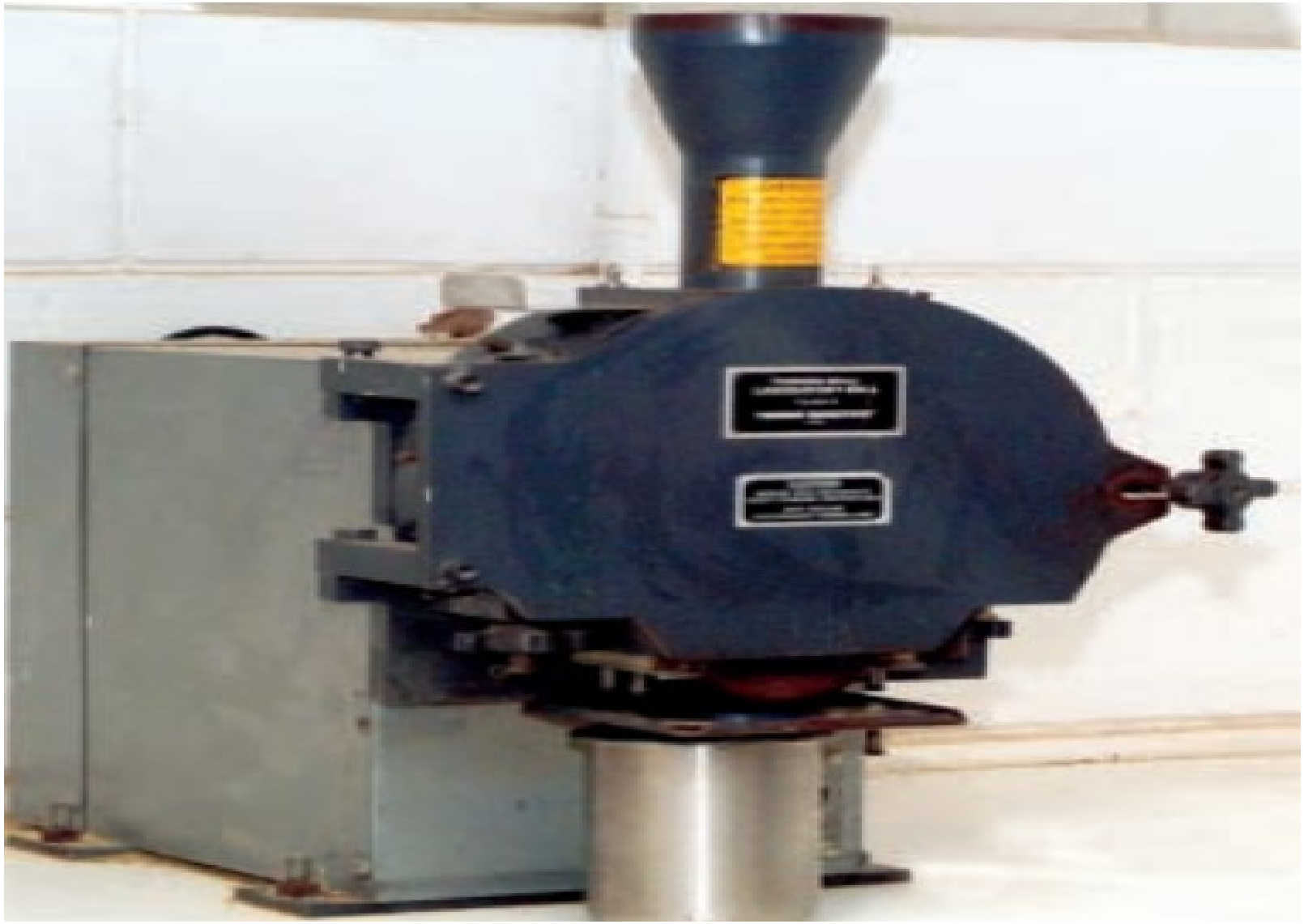


Sampling, sample collection and processing for chemical analysis…

Sample processing/ and storage:

- **Sample processing/preparation**
  - Drying and grinding
  - Sample preparation is conducted according to sample type and analyses requested/required
- **Storage**
  - Use good storage materials
  - Store in a secure and dry place

Laboratory mill



Proximate analysis (Weende method)

- **The oldest, devised in 1865 by Henberg and Stohman of the Weende experimental station in Germany**
- **Simple, repeatable and relatively inexpensive**
- **Feed samples are analysed into six fraction:**
  - **Water/DM**
  - **Crude protein (CP)**
  - **Ether extract (EE)**
  - **Crude fibre (CF)**
  - **Nitrogen free extract (NFE)**
  - **Ash (mineral matter)**

Moisture/DM determination

- **Feed moisture or DM content is the most easily and commonly determined**
- **Principle:drying a known quantities of feed sample to constant weight at 100^{o}C**
- **Its determination is important for?**

- **DM determination can involves two steps;**
  - **Drying in a forced air oven at 55- 60^{o}C overnight to determine the partial DM value.**
  - **Samples are then milled and can be used for the second step in total DM determination**

Equipments: Sensitive balance











Equipments: oven





Equipments: Crucibles







Equipments: Spatula

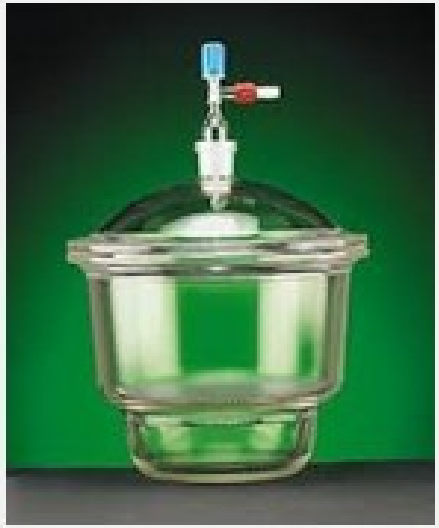


Equipments: Desiccators

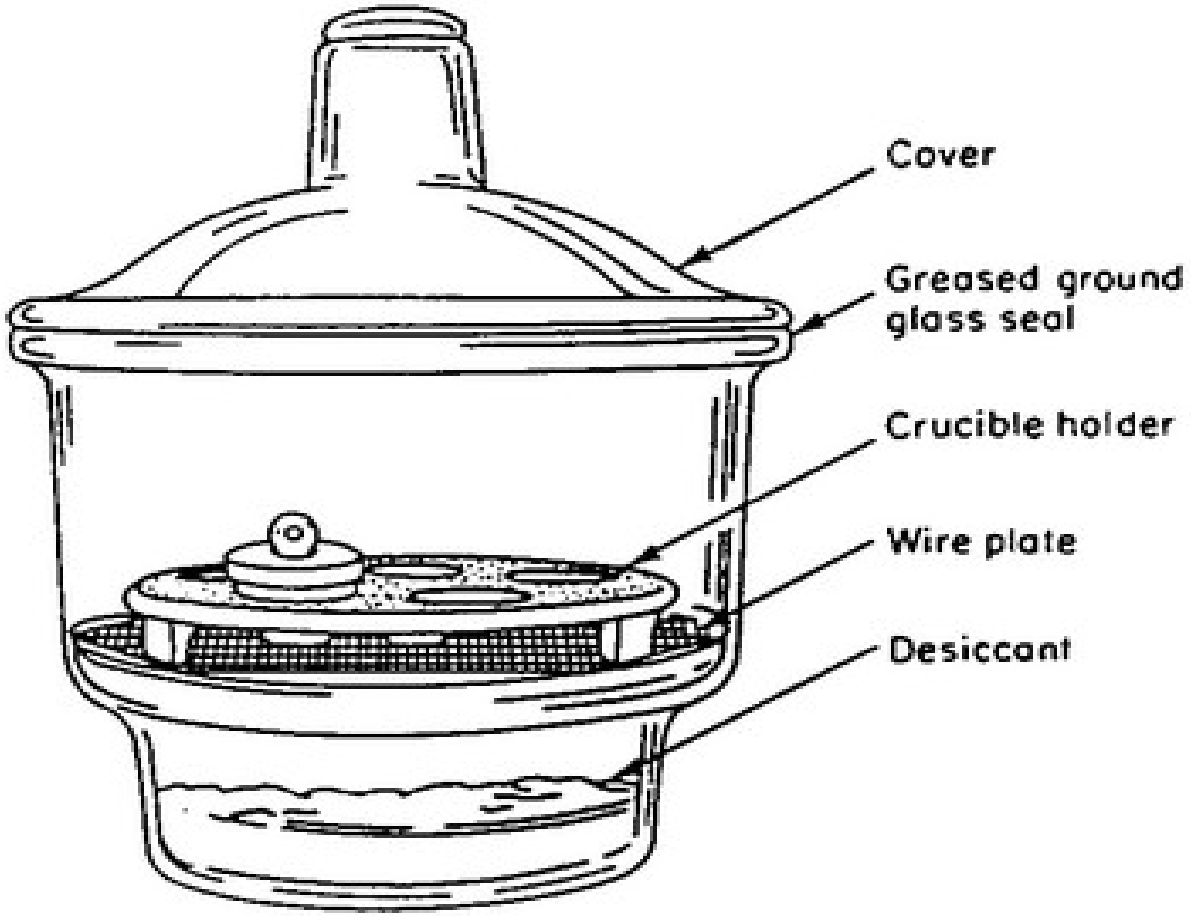









Equipments: Desiccators…



DM/Moisture determination…

- **Procedure (AOAC, 1995):**
  - Dry empty and clean crucibles over night at 105^{0}C in an oven
  - Cool the crucibles in a desiccators to a room temperature
  - Label/code and weight the empty crucible and record the weight (W1)
  - Add about 2 grams ground sample to the already weighed crucible (i.e. crucible + sample weight) and record the weight (W2)
  - Dry the crucible+ sample in an oven for overnight at 105^{0}C
  - Remove the dried crucible+ sample from the oven and allow to cool to room temperature in a desiccators
  - Then weigh the oven dried crucible+ sample

DM/Moisture determination…

- **Calculations:**

$$\%\text{Moisture} = \frac{\text{Initial sample weight- final sample weight}}{\text{Initial sample weight}} * 100$$

$$= \frac{(W2 - W1) - (W3 - W1)}{(W2 - W1)} * 100$$

$$\%\text{DM} = \frac{\text{Dry sample weight}}{\text{Initial sample weight}} * 100$$

$$= \frac{W3 - W1}{W2 - W1} * 100$$

OR

- **%DM = 100-%Moisture**

DM/Moisture determination…

- ***Example 1*** **: Let assume you want to determine the moisture/DM content of Rhodes grass hay. You took samples from the Rhodes grass hay heaps following the sampling and sample processing procedures and perform the DM analysis according the procedures. You recoded the following data; weight of empty crucible (W1) =17.3450 gram, crucible+ sample weight (W2) =19.3358 gram, and weight of oven dried crucible+ sample (W3) = 19.1378 gram. Then calculate the moisture and/or DM content of the Rhodes grass hay?**
- **Answer are: %Moisture=9.95 and %DM = 90.05**

DM/Moisture determination…

- **Possible errors with DM determination**
  - **Loss of volatiles (VFA and lactic acid) in**

    silage and any fermented products
  - **Most likely will underestimate DM**
- **Improved methods/solutions**
  - **Freeze drying**
  - **Drying in vacuum ovens**
  - **Drying at lower temperature**

Ash determination

- **Represents the total mineral content**
  - **A residue remaining after burning of all the organic nutrients**
- **Principle: when a feed sample is burned at 600 ^{o}C for 2 hrs or between 500-550^{o}C for 12-16 hrs, water and the organic matter will be removed**
- **Equipments required:**
  - **Sensitive balance**
  - **Spatula**
  - **Crucibles**
  - **Oven**
  - **Desiccators**
  - **Muffle furnace**
  - **Tongs**

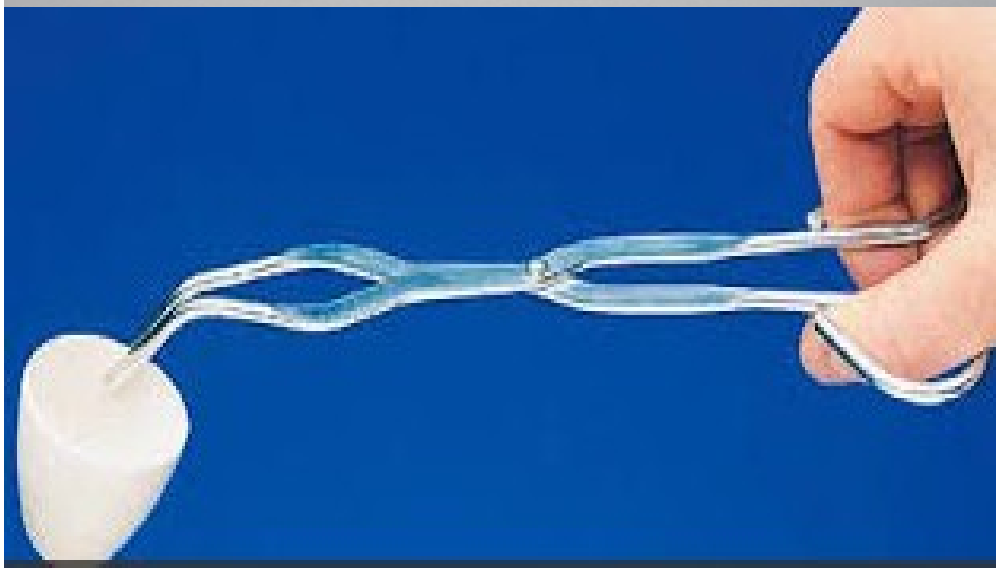
Equipments: Muffle furnace (different types)



Equipments: Tongs









Ash determination…

Procedure:

- Dry empty and clean crucible in an oven at 105 ^{0}C overnight
- Cool the crucibles in a desiccators
- Label and weight the empty crucible (W1)
- Add about 2 g sample to the weighted crucible and take the weight (W2)
- Ignite the sample + crucible in a muffle furnace at 550 ^{0}C over night
- Take the ignited sample + crucible from the furnace using a tong and cool in to room temperature in the desiccators and then take the weight (W3)

Ash determination…

- **Calculations**

$$\%Ash = \frac{\text{Ash weight}}{\text{Sample weight}} * 100 = \frac{W3-W1}{W2-W1} * 100$$

- **OR**
  - Ash can also determined along with DM determination. In this case, the sample + crucible after drying (W3) can be directly placed in a muffle furnace and ignited and then taking the weight (W4)

  - Therefore;

$$\%Ash = \frac{\text{Ash weight}}{\text{Sample weight}} * 100 = \frac{W4-W1}{W2-W1} * 100$$

Ash determination…

- ***Example*** : **Assume you want to determine the ash content of "Attela" and you performed the analysis in three replications following the above procedures. You recoded the following data. Then calculate the % ash of the "Attela"?**

Rep.	Crucible code	Crucible wt (g)	Crucible + sample wt (g)	Ignited crucible + sample wt (g)
1	H	14.0163	16.0187	14.1325
2	L	17.3408	19.3426	17.4564
3	M	11.8944	13.8953	12.0104

Answer = 5.8%

Ash determination…

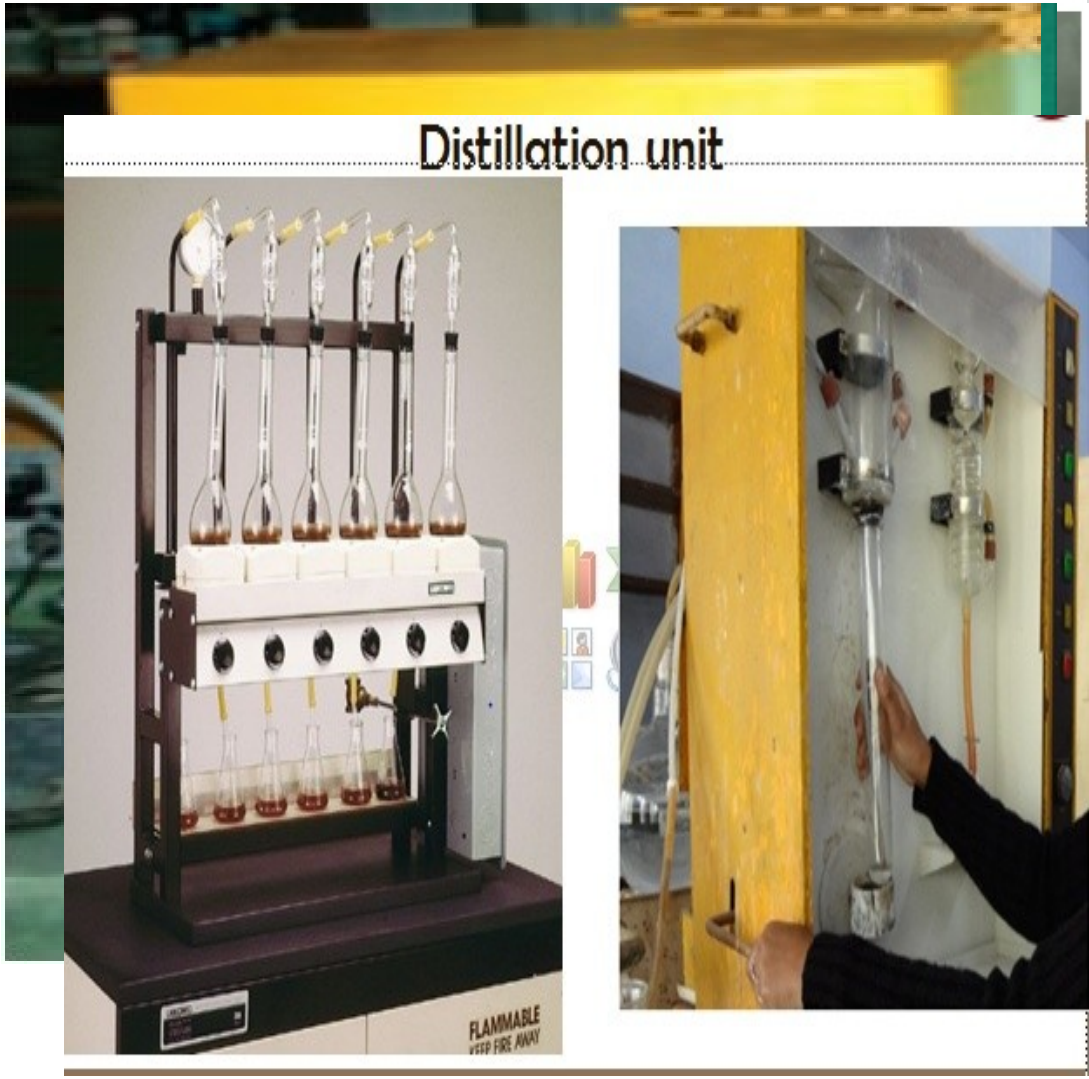
- **Limitations in Ash determination:**
  - **Does not give individual minerals**
  - **Possible errors**
    - **High temperatures can volatilize some elements (Cl, Zn, Se, & I)**
      - **Underestimate mineral content**

Crude protein (CP) determination

- **CP determination is also one of the most commonly performed analysis in Animal Nutrition Laboratory**
- **CP provides information on protein content of feedstuffs for ration balancing optimum animal performance**
- **Kjeldahl method is used to analyze CP, by determining %N of the sample**
- **Principle:**
  - **Feed sample is digested in Con' H_2SO_4 (96-98%) in the presence of $K_2SO_4/CuSO_4/TiO_4$ as catalyst feed N converted to ammonium sulfate made alkaine with NaOH (40%) converts ammonium sulfate ammonia—traped in boric acid solution titrated in standard acid solution (HCl/H_2SO_4). The ml of acid consumed to titrate= the ml N in the sample**

CP determination…

- **Equipments :**
  - **Sensitive balance**
  - **Automatic burette**
  - **Digestion tube (250 ml)**
  - **Digestion block**
  - **Distillation unit**
  - **Erlenmeyer**



CP determination…

- **Reagents and their preparation:**
  - **H_2SO_4 (96-98%)**
  - **NaOH (40%) to prepare add 400gNaOH/1litre**
  - **Standard acid solution/HCl or H_2SO_4/**
  - **Indicators**
    - **Boric acid (H_3BO_3)**
    - **Methyl red**
    - **To prepare the indicator solution;**
      - **Boil 4 liter of distilled H_2O**
      - **Add 160g H_3BO_3 and cool to next day**
      - **Add 2.8 ml methyl red**
      - **Add 4 ml bromocresol green**

CP determination…

- **Kjeldahl CP determination has 3 phases:**
  - **Digestion**
  - **Distillation**
  - **Titration**
- **Digestion;**
  - **Digest the sample with con' H_2SO_4**
  - **Oxidize OM to CO_2 + H_2O + ammonium sulfate [$(NH_4)_2SO_4$]**
  - **Digest @ 420 ^{0}C until the liquid become transparent**
  - **Cool and add distilled H_2O**
- **Distillation phase;**
  - **NaOH (40%) converts ammonium sulfate to $NH4^+OH^-$**
  - **When heated $NH4^+OH^-$ is distilled to a Erlenmeyer/conical flask containing boric acid/ indicator solution**

CP determination…

- **Titration;**
  - **Titrate the content collected in the conical flask with standard acid**
  - **Record the amount acid consumed**

CP determination…

- **Procedure:**
  - **1) Weigh about 1 g sample and record (W1) and transfer to digestion tube (250 ml)**
  - **In each batch use one blank**
  - **2) Add catalyst (2 kjeldahl tablets)**
  - **3) Add 20 ml con' H_2SO_4, and if foaming is a problem add a few drops of anti-foaming agent**
  - **4)Place the tubes in a digestion unit (20 tubes including the blank)**
  - **5)Digest the sample @420 ^{0}C for at least 1 h**
  - **6) Turn the digestion unit off, remove the tubes, allow them to cool for 10-20 minutes**
  - **7) Add about 80 ml distilled H_2O to each tube**
  - **8) Place conical flask containing 25-30 ml of boric acid solution under the outlet of the condenser of the distillation unit**

CP determination…

- 9) Add 50 ml of NaOH (40%) and distilled
- 10) Titrate the contents collected in the conical flask with standard acid solution
- 11) Record the ml of standard acid consumed to titrate for each tube including the blank
  - ml of acid consumed by the sample containing tubes (Va)
  - ml of acid consumed by the blank tube (Vb)

- %N=[1.4007*(Va-Vb)*N]/W*%DM
  - Va=ml of acid used for sample titration
  - Vb= ml of acid used for blank titration
  - N= Normality of the standard acid
  - W= sample weight

CP determination…

- **%CP= %N*F** conversion factor

  F= **6.25 for all forage feeds and mixed feeds**
  5.70 for wheat grain
  6.38 for milk

- **Why CP?**
- The protein determined in the Weende/proximate analysis is referred to as crude protein as opposed to true protein.

- This is due to the fact that CP may contain nitrogen from other compounds commonly called non-protein nitrogen containing compounds (e.g. urea, amino acids, nucleic acids). They are usually present in small quantities in natural feeds and thus do not involve an appreciable error.

CP determination…

- ***Example*: following the CP determination procedure you record the following data for forage sample;**
  - **Sample weight used = 1.0012 g**
  - **N=0.1**
  - **ml of acid consumed by the blank =0.20 ml**
  - **ml of acid consumed by the sample = 10.3 ml**
  - **Then calculate %N of the forage sample?**
  - **Answer (%CP = 8.83)**
- **From the *above example* , if the DM content of the forage sample is 87.5%, the CP%DM is 10.1**

Crude fat/ Ether Extract (EE) determination

- **Fat is extracted from the sample by dissolving in petroleum ether**
- **The ether is evaporated in Soxhlet apparatus**
- **The remaining residue is crude fat**
- **Principle:**
  - **The sample is dissolved in petroleum ether, which extracts the fat; solvent is distilled and the residue is dried and weighed.**
  - **There are different Soxhlet apparatus/methods of fat extraction the procedure may vary according to the instruction for this specific Soxhlet apparatus/method**

Why crude fat

- The EE fraction includes all the feed components soluble in ether (or other organic solvents).

- The fraction is called ether extract because it includes not only true fats but also other fat soluble materials such as carotene, sterols, waxes, essential oils, chlorophyll, etc. However the true fats usually make the largest proportion in most feeds.

EE determination…

- **Equipments**
  - **Sensitive balance**
  - **Heating apparatus with temperature control.**
  - **Extraction thimbles, free from fat and ether washed/ or filter paper.**
  - **Reflux unit**
  - **Soxhlet-type extractor**
  - **Desiccator**
  - **Buchner funnel connected to suction**
  - **Oven**
- **Reagent**
  - **Petrol ether (40–60 °C boiling point)**

EE determination…



EE determination…

- **Procedure (Using filter paper):**
  1. **Weigh the filter paper and record (W1)**
  2. **Add about 1 g sample in the filter paper and recod the weight (W2)**
  3. **Tie with fat free thread**
  4. **Extract the sample with ether in Soxhlet extractor for about 8 hrs**
  5. **Remove the filter papers with extracted samples, evaporate the ether, dry over night @ 105 ^{0}C and record the weigh (W_3)**

  %EE =[Weight of EE/Sample weight]*100

EE determination…

- **Example**: **Assume, you are asked to determine the EE content of forage X and you a prepared sample for it. Following the EE determination procedures you recoded the following data:**
  - **Filter paper weight =0.9398g**
  - **Filter paper + sample weight =1.9394 g**
  - **Extracted oven dried filter paper + sample weight =1.8640 g**
  - **Then %EE=7.54**

- **If the DM content of forage X in Example 11 is 87.8%, then EE%DM is 8.59**

Crude Fiber (CF) determination

- **The carbohydrate portion of the feed is found in two fractions;**
  - **CF**
  - **NFE**
- **CF fraction of the feed is a less digestible portion of carbohydrate**
- **It is determined by using an ether extracted (fat free) sample;**
  - **boiling in dilute acid**
  - **boiling in dilute base**
  - **filtering**
  - **drying and burning in furnace**
- **The difference in weight after and before**

CF determination…

Procedure

1. Weigh out a small quantity of ether extracted sample (W_1)
2. Reflex/ boiling the sample with dilute H_2SO_4 (1.25% H_2SO_4) for 30 min and filter it.
3. Reflex/ boiling the sample again with dilute NaOH (1.25% NaOH) for another 30 min and then filter the residue.
4. Dry the residue and weigh (W_2)
5. Ash the residue to oxidize off the CF and weigh the ash (W_3)
6. Calculate the CF

$$\% CF = \frac{W2 - W3}{Initial\ Wt\ (W1)} X\ 100$$

CF determination…



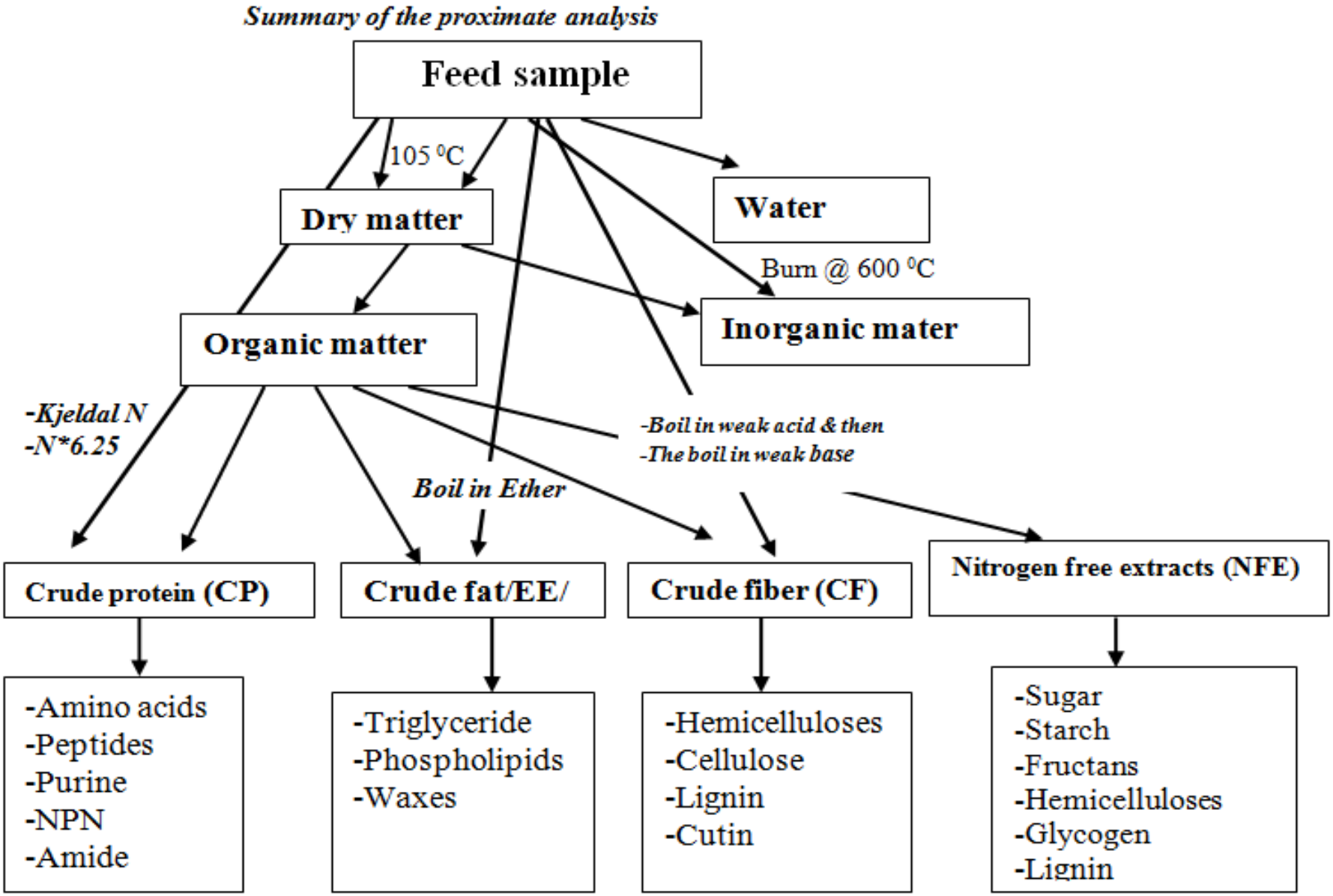


Nitrogen Free extract (NFE)

- **NFE contains primarily the readily available /highly digestible carbohydrates such as;**
  - **Sugars and starches**
  - **But it may also contain some hemicelluloses and lignin, particularly in forages**

% NFE = 100 – (% water + % CP + % CF +% EE + % Ash)

Chemical analysis/composition



Limitations of Proximate analysis

- **Not accurate**
  - **The crudes**
    - **Crude fat: Ether removes waxes and some other compounds not considered digestible**
    - **CP: assumes that all N is contained in protein with an N content of 16%, which is incorrect**
    - **CF: does not provide an accurate representation of the least digestible fibrous part of the feed in many cases**
  - **Errors in NFE fraction are caused by double determination of some constituents in different fractions**

    Example:
    - **Lignin found in CF, NFE**
    - **Hemicellulose found in CF, NFE**
    - **Organic acid found in EE, NFE**
    - **Pigments found in EE, NFE**

Limitations of the Weende method…

1. The ash fraction may contain materials of organic origin such as sulphur and phosphorus from proteins.

- Also loss of some volatile materials in form of sodium, chloride, potassium, phosphorus and sulphur will occur during the ignition process. Due to this weakness in the procedure, the ash fraction obtained may not be true representative of the inorganic substances in feeds.

2. The crude fiber fraction was intended to include all less digestible components of the feed but only portion is recovered under this fraction. This undermines the quantity of less digestible components in the feeds.

Limitations of the Weende method...

- Crude fiber is not a chemically uniform substance and it mainly consists of cellulose, hemicelluloses and lignin. In the Weende method the residue which remains after boiling in acid and alkaline (cellulose, hemicelluloses and lignin) is considered as unavailable to all animals.

- But cellulose and hemicelluloses (structural carbohydrates) are similar in their nutritive value and much important for ruminant animals than for monogastric animals.

- The lignin is unavailable to all animals. The ruminant animals can partially utilize the cellulose and hemicelluloses because of the microorganisms in

Limitations of the Weende method...

3. The NFE fraction was meant to include the highly digestible carbohydrates. However, it was criticized because portion of hemicelluloses and lignin are known to be present and over estimates the value of highly digestible carbohydrates.

- The Weende method is still in use and the criticism is mainly when employed to determine chemical composition of fibrous feeds (forages and roughages). With fibrous feeds, problems of considerable magnitude have frequently been experienced.
- As a result many researchers have tested various procedures with the aim of providing a more definite separation of feed carbohydrates than the Weende method of feed analysis. A procedure which gained wider acceptance by nutritionist is the one developed by Peter J. Van Soest and co-workers in the USA in 1967.

The Detergent Extraction methods(The Van Soest method)

- The Van Soest method involves separation of feed dry matter into two fractions: one with high digestibility and the other with low digestibility.

- The fraction with high digestibility is composed of those constituents found in the cell (cell contents) while the less digestible portion is found in the cell wall of plants (cell wall constituents or cell wall components).

- The two factions are separated by boiling the feed sample in a neutral detergent solution for a period of one hour and the filtering (the neutral detergent solution is prepared from sodium lauryl sulphate and ethylenediamine-tetraacetic acid, EDTA).

- The more soluble and accordingly more digestible nutrients come out in the filtrate. The portion which is less soluble and thus less digestible remains as a residue.

The Detergent Extraction...

- The fraction which is soluble in the neutral detergent solution (neutral detergent solubles, NDS) are composed mainly of sugars, starches, lipids and proteins and known to be highly digestible.

- The residue is composed of mainly cellulose, hemicelluloses, lignin and silica and some protein bound in fiber is also called neutral detergent insolubles. The neutral detergent insolubles are referred to as neutral detergent fiber (NDF).

- The NDF values are higher than the CF values obtained in the Weende method. This is so because in the Weende method the hemicelluloses and lignin partially come under NFE and thus undermine the CF value.

The Detergent Extraction...

- In the Van Soest method all the hemicelluloses and lignin come in the NDF fraction and thus higher values than the conventional CF values.

- The NDF values are known to correspond more closely to the total fiber fraction of forage materials. However, the NDF fraction is not a uniform entity chemically and its digestibility is under the influence of lignin present.

- Based on this fact Van Soest proposed that the amount of lignin present determined to be able to predict the digestibility of NDF.

The Detergent Extraction…

- **The acid detergent fiber (ADF):** The ADF is obtained by refluxing feed samples with acid detergent solution (prepared from sulphuric acid and cetyltrimethyl-ammonium bromide) for about an hour and filtering.

- The residue remaining after filtering is the acid detergent fiber (ADF) and is composed of cellulose, lignin and some amounts of silica.

- The difference between NDF and ADF is that the former consists of most of feed hemicelluloses and a limited amount of protein not present in ADF.

- The amount of hemicelluloses in the feed sample can be estimated from the difference between the NDF and ADF.

- The ADF is known to have good statistical correlation with the digestibility of forages.

The Detergent Extraction...

- **The acid detergent lignin (ADL):** The ADF is a preparatory step for determination of acid detergent lignin. The ADF is treated with sulphuric acid (72%) to dissolve the cellulose.

- It is filtered and the residue remains after washing and drying is weighed and then ashed. The loss in weight estimates the lignin while the weight of ash represents the amount of silica. The acid detergent lignin is also known as acid insoluble lignin.

- The amount of lignin in feed sample can also be determined by an alternative method which involves oxidation of the lignin of ADF with excess of acetic acid-buffered permanganate solution. The lignin determined in this procedure is known as permanganate lignin.

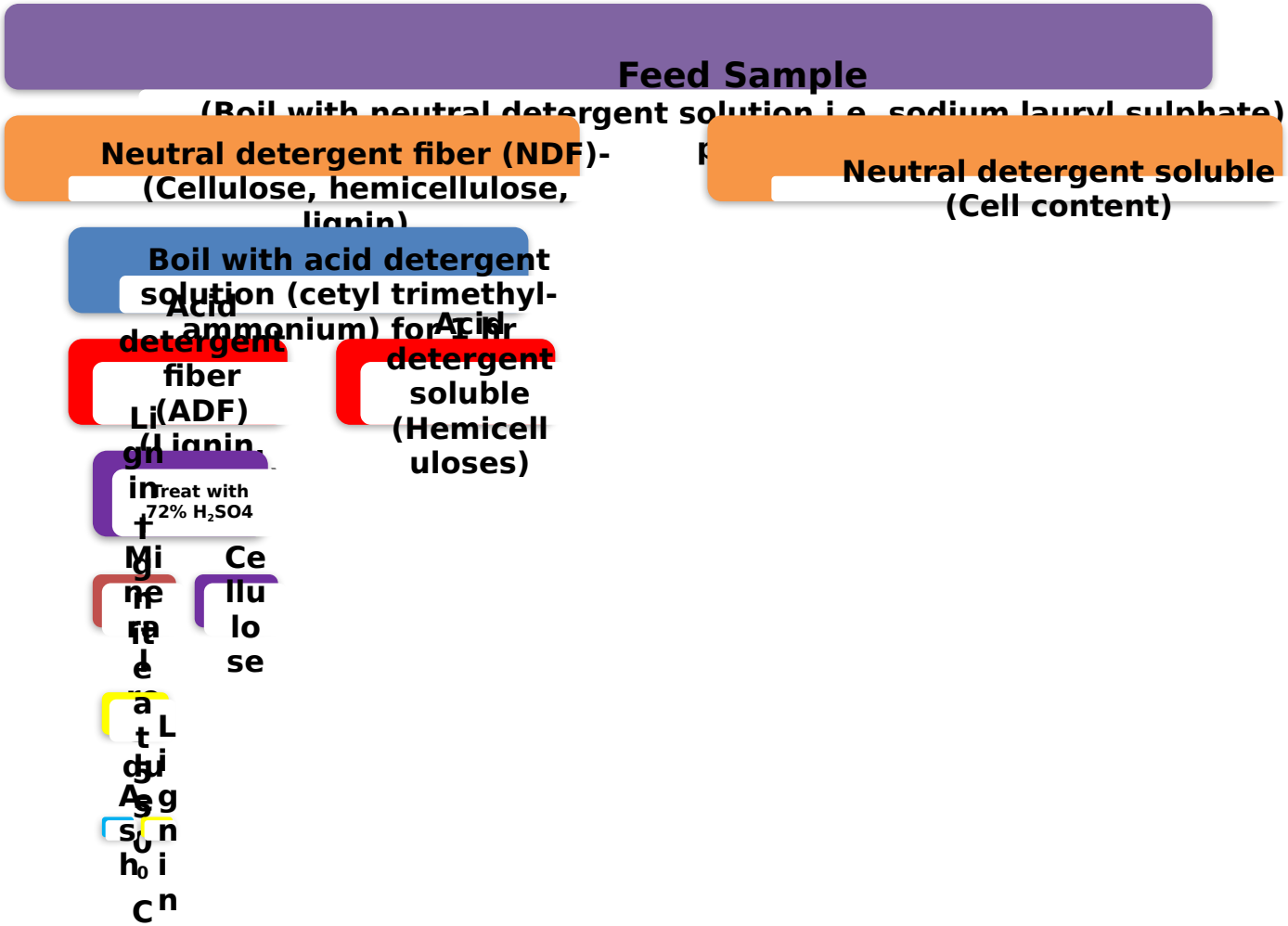
The Detergent Extraction...

Classification of forage fractions using the detergent methods of Van Soest (McDonald *et al*., 2010)

Fraction	Components
Cell contents (soluble in neutral detergent)	Lipids
	Sugars, organic acids and water-soluble matter
	Pectin, starch
	Non-protein nitrogen
	Soluble protein
Cell wall constituents (fibre insoluble in neutral detergent)	
Soluble in acid detergent	Hemicelluloses
	Fibre-bound protein
Acid-detergent fibre	Cellulose
	Lignin
	Lignified nitrogen
	Silica

The Detergent Extraction…

Summery of the Detergent method



2.2. Digestion and metabolic experiments

- **Chemical analysis of feeds can provide information on the potential value of feeds for supplying nutrients.**

- **Thus chemical analysis is regarded as a first step in assessing the potential value of the feeds in supplying nutrients to animals.**

- **Determination of digestibility of feeds can be regarded as the second step in feed evaluation.**

- **The digestibility of feed is defined as the proportion which is not excreted in the feces and which is, assumed to be absorbed by the animal.**

Digestibility…

- **Digestibility refers to a proportion of feed DM/nutrient capable of digested by along the GIT**
- **In this consideration, the digested portion is assumed to be absorbed by the animal**
- **But, all the digested component of the feed may not totally absorbed and utilized by the animal**
- **However, not all fecal components are actually undigested feed residues.**
- **Part of fecal material may arise from cellular material abraded from the lining of the gut and also enzymes and other substances secreted into the digestive tract and not reabsorbed.**

Digestibility…

- **The presence of substances not from feed origin leads to an underestimation of the proportion of the feed absorbed by the animal.**

- **This is why digestibility values are referred to as ‘’apparent’’ digestibility as opposed to true digestibility of feeds.**

- **The true digestibility of feeds is not carried out in practice because it is not simple.**

- **Also the amount of substances in feces arising from metabolic origin is insignificant and apparent digestibility values are considered sufficient for practical purposes.**

Digestibility…

- **Digestibility is measured by;**
  - ❖ ***In vivo* method – within an animal**
  - ❖***In vitro* method –(without animal) in the laboratory**
  - ❖***In Sacco* (Nylon bag digestibility) method**

Digestibility…

Why Measuring Digestibility?

Digestibility…

- **Digestibility measurement has numerous advantages.**
  - **As an indicator of forage quality in determining the nutritive value of a feed**
  - **As a predictor of animal performance**
  - **Digestibility data can offer an insight into the proper feeding and management of animals.**

In vivo measurements

- Whole tract measurements



– Feces = 20-50% loss of DE
– Gasses + Urine = 15-25% ME
– Heat = 5-15% loss of NE

Digestibility, *In Vivo*

- **Digestibility refers to the proportion of consumed feed DM/nutrient which is not recovered in the faeces**
- **Thus, assumed to be absorbed from the GIT**
- **It uses feeding trials to determine what is consumed, digested and excreted**
- **Calculated as:** $\frac{\text{DM intake- DM in faeces}}{\text{DM intake}}$

$$\frac{\text{Nutrients in feed} - \text{Nutrients in feaces}}{\text{Nutrients in feed}} \times 100$$

- **It is commonly expressed in terms of DM and as coefficient or percentage**

Digestibility, *In Vivo…*

- **Digestibility of feedstuff is determined by feeding trial with animals**
- **To undertake digestibility trial the following things should be fulfilled;**
  - **The experimental feed**
  - **The experimental house specially designed house for keeping the experimental animals**
  - **The experimental animals**
  - **Fecal collection equipments**
- **Apparatus used in digestibility trials**
  - ✓**Pens**
  - ✓**Bags**
  - ✓**Meshes**

Digestibility, *In Vivo…*

- **In determining the digestibility of feeds the following procedures are used;**
  - **The feed in question is analyzed for its chemical composition**
  - **At least 3 (preferably 4) apparently healthy animals of the same species, age and sex should be used;**
    - ✓ **Avoid animal to animal variation**
    - ✓ **Replication increases accuracy**
  - **Male animals are preferable as it is easy to collect feces and urine separately**
  - **During the trial period animals should be confined either in a specially constructed metabolism stall/ metabolism cages/**

Digestibility, *In Vivo…*



Metabolic cage

Digestibility, *In Vivo…*



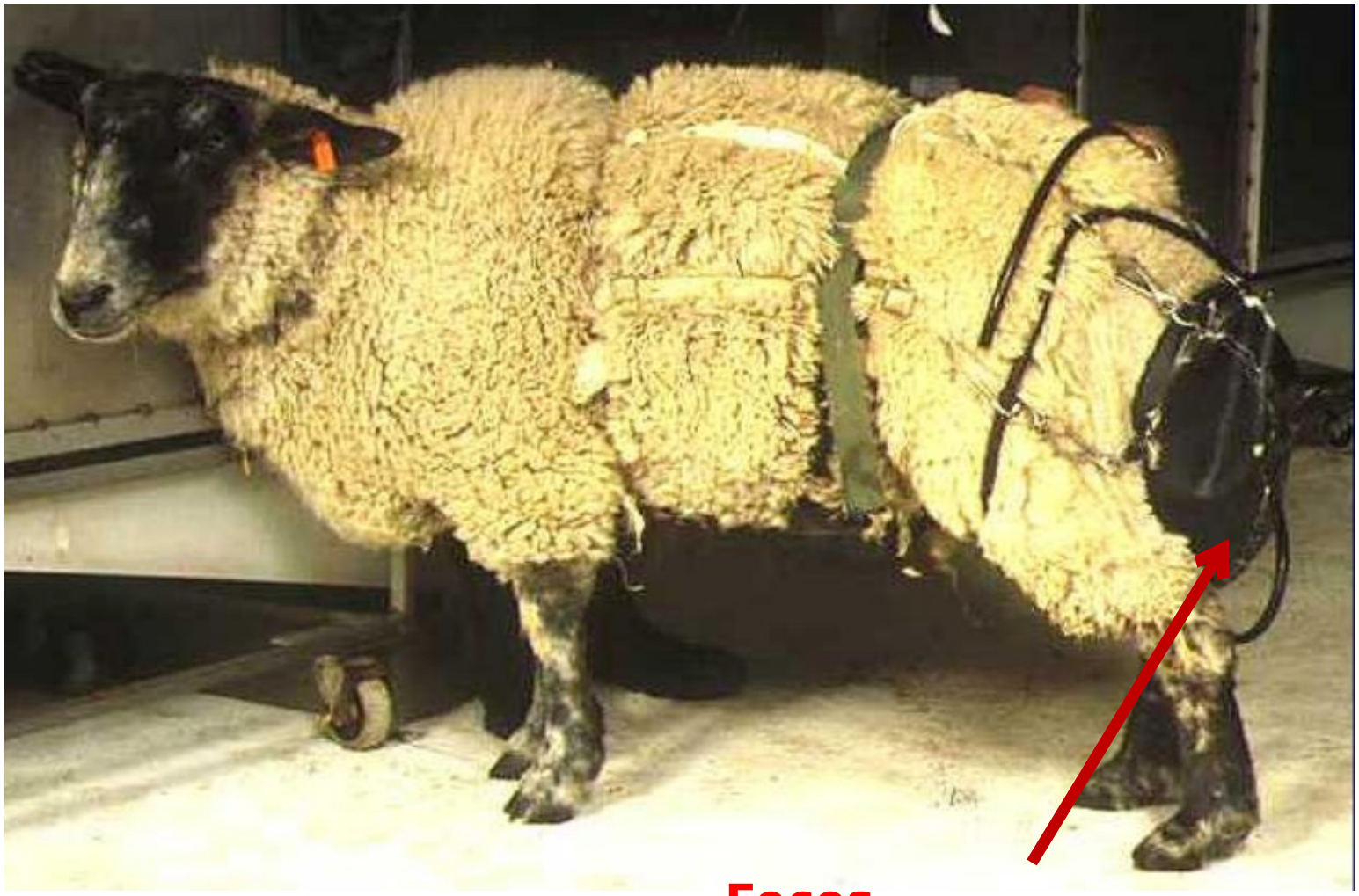
Digestibility, *In Vivo…*



Digestibility, *In Vivo…*



Digestibility, *In Vivo…*



Feces collecting bag

Digestibility, *In Vivo…*

- **2 stages in digestibility trial;**
  - **Adaptation period (1st)**
    - **At least 7 days**
  - **Collection period (2nd)**
    - **14 days**
- **During the collection period daily record of;**
  - **Food offered**
  - **Residue left and**
  - **Feces voided should be taken**

Digestibility, *In Vivo…*

- **The experimental feed should be;**
  - **Mixed carefully**
  - **Fed to the animal for at least 1 week before the actual collection of the feces**
  - **Provided at the same time each day**
  - **Also provided in the same amount**

  A representative sample of the food offered, residue left and feces voided are taken for analysis

Digestibility, *In Vivo…*

- **A varieties of methods of digestibility determination of feeds can be used;**

- **After undertaking chemical analysis, we undertake digestibility trial to see how much of the ingredients are degraded in the digestive system.**
- **There are different methods of estimating digestibility. This include**

A. Conventional method(Direct method)

B. Difference method

C. Indicator method

In Vivo (Direct method)

- **This is a direct measurement that involves keeping an animal in a metabolic cage and measuring the feed intake and the fecal output.**
- **The feed and feces are analyzed for nutrients of interest to determine nutrient digestibility.**
- **The difference between the amount of nutrients consumed and excreted in the feces is the amount digested and absorbed.**
- **Therefore, this requires quantification of feed consumed and total feces excreted.**

In Vivo (Direct method)…

- **Dry-matter digestibility (DMD) is determined by recording the amount of DM of the feed offered and complete collection of the faeces excreted over a period of time**

$$DMD = \frac{\text{DM intake} - \text{Faecal DM excreted}}{\text{DM intake}}$$

- **Digestibility can be expressed either as coefficient or percentage**

- **Example 1: A sheep consumed 4 kg fresh Rhodes grass having 3 kg DM & excreted 1.5 kg of feces having 1 kg DM:**

In Vivo (Direct method)…

- **Example 2** **A steer was fed 3.7 Kg hay/day (alone) for 3 weeks. At the end the average daily weight of the feces excreted was 5.662kg. Samples of the hay and feces had the DM of 84.97% and 22.36%, respectively. The % DMD of the hay?**
  - **Answer = 59.7 %**

- **The digestibility of other/individual nutrients can be determined in the same way using the digestibility formula**

In Vivo (Direct method)…

- **One may undertake nutrient digestibility to quantify what % of protein, OM, ether extract, or other nutrients digested in the conventional method. In this case, we use the following formula:**

$$\% \text{ Digestibility} = \frac{\text{Nutrient intake} - \text{Nutrient in feces}}{\text{Nutrient intake}} \times 100$$

In Vivo (Direct method)…

Example 2

- **A pig is housed in a metabolism cage where feed intake and fecal output is measured. It consumes 20 kg of the test diet, and excreted 10 kg of feces. The percentage of CP in the feed is 15 and of the feces is 7. What is the protein digestibility of the diet?**
- **Protein intake = 20 kg x 0.15 = 3 kg**
- **Fecal protein = 10 kg x 0.07 = 0.7 kg**

% Digestibility = $\frac{\text{Nutrient intake – Nutrient in feces}}{\text{Nutrient intake}} \times 100$

% Digestibility = $\frac{3 - 0.7}{3} \times 100$

= 76.6%

In Vivo (Difference method)

- **Used to determine the digestibility of feeds that can't be fed alone**

- **This method is used when studying the digestibility of combination of feeds.**

- **Basal diet: When studying digestibility by difference, basal diet is the diet we want to combine with our test feed.**

- **The objective is to determine the digestibility of the test feed not the basal diet.**

In Vivo (Difference method)

DMD of test feed = DM intake of test feed –[Faecal DM of test feed – Faecal DM of basal feed]

DM intake from test feed

- **To determine the digestibility of the test feed, first we determine the digestibility of the basal diet, then combine the basal diet and test feed and run digestibility trial and get digestibility of the test feed by difference.**

- **The ration digestibility is the sum of digestive amounts of its components.**

In Vivo (Difference method)

- **Example: If the sheep ate 0.50 kg test feed having DM content of 900 g/kg together with basal diet and the faecal out put increased from 1.5 to 1.85 kg per day the DMD of the taste feed would be calculated as:**

$$\frac{[0.45 - (1.85 - 1.5)]\text{kg}}{0.45} = 0.222 \text{ or } 22.2\ \%$$

In Vivo (Difference method)

- **Nutrient digestibility of test feed = $\frac{A - (B - C)}{A}$**

Where:

A = Nutrient in test feed

B = Nutrient in the feces of mixed diets

C = Nutrient in the feces from basal feed

In Vivo (Indirect/indicator method)

- **It may not be practical to undertake measurements of feed intake or fecal output to estimate digestibility under certain circumstances.**

- **However, digestibility could be estimated by using indigestible materials as indicators. The concentration of the indicator material should be determined in feed and fecal samples to calculate the digestibility value.**

- **Used when it is difficult to measure directly either feed intake or fecal output or both due to lack of suitable equipment or due inherent nature of the trial**
  - **Feeding of animals in group**
  - **Grazing animals**

In vivo (Indirect/Indicator method)

- **Under such circumstances digestibility can be determined by using markers**

- **The indicator could be natural constituent of the feed (e.g. Lignin, n-alkanes of long chain length) while indicators mostly added to foods are chromic oxide (Cr_2O_3) and titanium dioxide for ruminants and mono-gastric animals, respectively.**

- **Indicators like lignin which are natural constituents of feeds are also known as internal indicators while those added to feeds are external indicators.**

In Vivo (Indirect/indicator method)

- **Digestibility = $\frac{\text{g indicator/kg feces - g indicator/kg food}}{\text{g indicator/kg feces}}$**

- **Example : If the concentration of indicator in the feed was 10 g/kg and the increased to 20 g/kg in the feces, then the digestibility, is 0.50 or 50%**

In Vivo (Indirect/indicator method)…

- **Two types of indicators used may be used;**
  - **Natural indicator /marker (lignin ADF, N-alkane, etc.)**
  - **Artificial /chemical marker (Cr_2O_3) added into the diet**
- **An ideal indicator/marker should be;**
  - **Inert and no effect on the animal**
  - **Mixed uniformly with the feeds**
  - **Totally or highly recoverable in the feces**
  - **Unabsorbed/ metabolized in the GIT**
  - **Physically similar to associated with the feed**
  - **Non- poisonous to the consuming animal**

Limitations of ***In vivo*** digestibility

- **It relies on the use of animals**
- **Cost of setting up animal trials is prohibitive**
- **It is labor-intensive & time-consuming**
- **Requires large quantities of the forage to be analyzed**

In-vitro methods

- **This is a laboratory method used mainly to determine digestibility of feeds for ruminants.**

- **Since digestibility trials are laborious, there have been different attempts were made to determine the digestibility of feeds by reproducing in the laboratory the reactions which take place in the alimentary tract of the animal.**

- **This is called in vitro method of determining digestibility. In such cases we use only one or two animals as opposed to the other methods which require more animals.**

In vitro methods

- ***In vitro*** **techniques have been developed to provide;**
  - **Cheaper**
  - **Faster and**
  - **Easier techniques to predict availability of certain nutrients to animals**
- **They predict *in vivo digestibility* by *simulating in vivo fermentation* of feedstuffs;**
- **Factors that should be considered when trying simulating the rumen environment include;**
  - **pH**
  - **Buffering capacity**
  - **Temperature**
  - **Anaerobic environment**
  - **Nitrogen sources**

In-vitro methods

- **It involves two stage where feed sample is first incubated with buffered rumen liquor and then with pepsin.**

- **The most widely used procedure is the one developed by Tilley and Terry (1963) which is known as ‘’two-stage in vitro’’ method.**

- **Incubation of feed samples with rumen liquor under anaerobic condition reflects the rumen environment.**

- **In this first step the finely ground feed samples are placed in the test tubes and incubated for 48 hours with rumen liquor and buffer solution under anaerobic environment.**

In-vitro methods

- In the second stage the bacteria are killed by addition of hydrochloric acid (pH 2) and incubated with pepsin for further 48 hours. Finally the insoluble residue is filtered off and dried in an oven and weighed.

- The dried residue is ignited to arrive at the organic matter (OM) in the residue. The digestible organic matter is obtained by the difference between OM in the feed sample and the residue.

In sacco degradability method

- **This technique was developed at Rowett Research Institute in the United Kingdom.**
- **Also known as;**
  - ***In situ* rumen degradability**
  - **Terylene (Dacron) technique**
  - **Nylon-bag technique**
- **The method involves use of indigestible materials such as nylon or silk for making bags of standard size (6.5 *14 cm) and pore (40-60 micro meter).**
- **The method provides a means of ranking feeds according to rate and extent of degradability of dry matter and other nutrients.**

In sacco degradability method

- **Feed sample is putted in to a nylon bags and place in the rumen of fistulated animal**
- **Determines the disappearance of incubated feeds**
- **Measures degradability (≠ digestibility)**
  - **Digested feeds > pore size not considered degraded**
- **Estimates the *extent* and *rate* of degradation**

In sacco rumen degradability…

Principle:

- **The incubation of feeds in nylon bags inside the rumen is used to measure the degradation of feedstuffs;**
  - **The amount/weight loss during incubation=the amount degraded**
  - **Digestibility can be measured by analyzing the residues for NDF**
- **Degradability of;**
  - **DM**
  - **Nitrogen**
  - **Energy, etc., can thus be measured against time**

In sacco rumen degradability…

- **General procedures:**
  - **Known amount (2.5-5 gm) of ground feed samples are placed in small bags made up of nylon**
  - **The bags are tightly closed by plastic tube and placed in the ventral part of the rumen of a fistulated animal**
  - **Incubating in the rumen (from 3-120 hrs) depending on the type of feed. The rate of digestion of dry matter or chemical constituent can be determined by removing the bags at varying intervals**
  - **Removing the bags from the rumen**
  - **Immediately after removing rinsing and washing the bags by cold running tap water by gently rubbing/ machine washing**

In sacco rumen degradability…

ILCA manual

- Weigh clean and dry nylon bag (Bw)--oven dry at 60–65°C for 30 minutes
- Weigh about 2 g of a 2mm ground sample and add to the empty bag (Swa)
- Tie the bags tightly using nylon string resistant to microbes
- Anchor the bags with about 50 cm of nylon chord (about 25 cm for sheep/goats) to the cannula top
- Place the bags deep into the rumen of a fistulated animal
- Incubate for 0, 6, 12, 24, 48, 72, 96 and 120 hours for forages and up to 48–72 hours for concentrates
- Place the 120 hr samples in the rumen on the morning of day 1 of incubation in each fistulated animal On the next morning (day 2), insert the 96-hour samples at the same hour as the day 1 samples…
  - 40 to 60 bags for cattle
  - 8-10 bags for seep and goat

In sacco rumen degradability…

Methods of bag addition and removal

- Sequential addition
- Sequential removal

- Immediately wash the bags (including the zero hour samples) with cold water for about 30 minutes in a
  washing machine
- Or under running tap water while rubbing gently between thumb and fingers until the water
  runs clear
- After washing, drying at 60-65 Co for 48 hrs and then cool the bags in the desiccators and weigh the residue and the bag **(Swb)**

In sacco rumen degradability…

$$\text{DM disappearance} = \frac{(Swa-Bw)xDMa - (SWa-Bw)xDMb}{(Swa-Bw)xDMa} \times 100$$

Where:

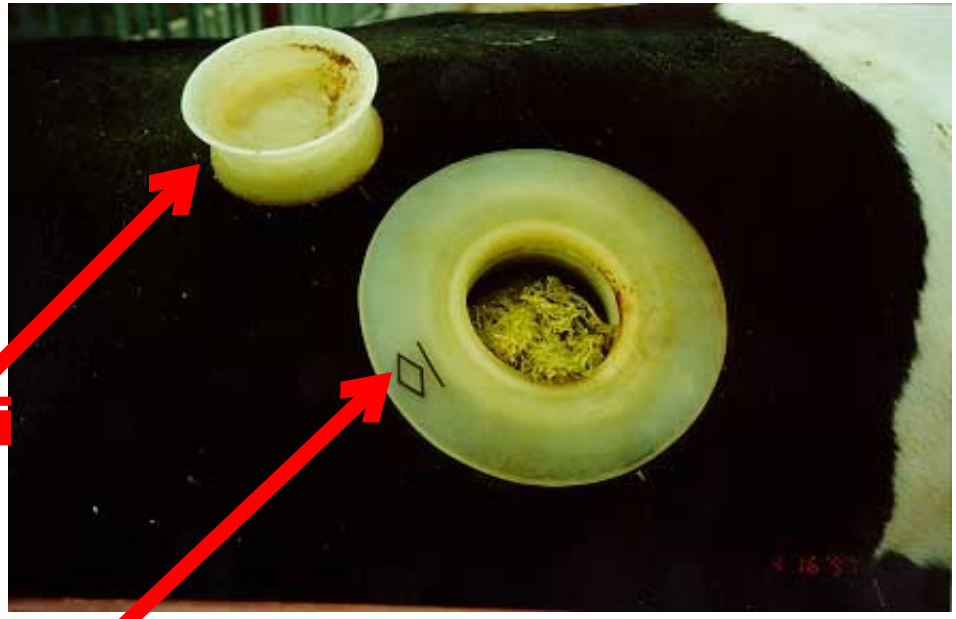
Swa= weight of original + sample nylon bag

Swb = weight of sample + nylon bag after incubation

Bw = weight of empty nylon bag

DMa = DM of feed sample





Coveri
ng

Rumen
canola









When the animal is resting



Plastic gloves can be used during taking samples from rumen

Taking of rumen fluid



In sacco rumen degradability…

- **The rate and extent of feed degradation is time dependent**
- **Feed in a rumen = immediately soluble + insoluble but degradable + undegradable fractions**
  - **The insoluble but degradable fraction is time dependent**
- **Let;**
  - **The immediately soluble fraction = a**
  - **The insoluble, but degradable fraction =b**
  - **The undegradable fraction = u**
    - **a+b+u=100%**
    - **a+b= the amount that can be degraded in the rumen**

In sacco rumen degradability…

- **The general equation used to calculate rate degradation is:**

$$P = a + b(1 - e^{-ct})$$

Where:

P = is DM degradation at time t a=intercept

b = potentially degradable fraction

c = rate of degradation of b

t = time of incubation

Factors affecting digestibility

Two major groups affecting feed digestibility;

1. Feed factors

- **Chemical composition**
- **Stage of growth and genotype**
- **Plant fraction**
- **Feed preparation and treatment (physical, chemical and biological)**
- **Enzyme supplementation of feeds**
- **The presence of anti-nutritional factors**

2. Animal factors

- **Species**
- **Age**
- **Level of feeding**
- **Physiological status of the animal**

QUIZ

1. **A pig was given 2.0 kg/day DM of a food containing 150 g/kg DM crude protein and excreted 0.4 kg/day DM of feces containing 175 g/kg DM protein. Calculate both the DM and the crude protein digestibility and the digestible crude protein (DCP) content of the food?**

2. **As a check on the measurement of digestibility in Question 1, the food contained 10.0 g/kg DM of chromic oxide as an indicator and the feces contained 50.0 g/kg DM chromic oxide. Calculate the digestibility coefficient of given feed.**

- **Did the measured DM digestibility agree with that estimated using the indicator?**

Feed Intake

- **Voluntary feed intake (VFI)= amount of feed consumed voluntarily in a given period of time, commonly per 24 hrs by an animal**
  - **Free access to that feed/ *ad libtim* feeding**
- **Animals eat to get the nutrients they require for different purposes;**
  - **Maintenance**
  - **Growth (including fat deposition in mature animals)**
  - **Milk production**
  - **Work**
  - **etc**
- **Animals usually continue to eat until they get the amount of nutrients that satisfy their needs**

Importance of VFI

- **Determines level of production;**
  - **Animal productive efficiency is largely dependent on daily rate of feed intake**
- **Diet formulation**
- **Prediction of animal performance**
- **Design and control of production systems**
- **Assessment of animal–resource interactions in grazing ecosystems**

(Illius *et al*., 2000)

Factors Affecting Feed Intake in Ruminants

- **Can be grouped in to three (McDonald *et al.*, 2002);**
  - **Feed characteristics**
  - **Animal related factors**
  - **Environmental conditions**

Factors Affecting Feed Intake in Ruminants: Feed related factors

- **Feed physical characteristics**
  - Moisture
  - Particle size
  - Density
- **Feed chemical characteristics**
  - Energy concentration
    - ME or NE
  - Fiber content
    - NDF
    - Lignin
  - Nutrient content/balance/for microbes
    - Proteins, amino acids (N)
    - Minerals (like S, P, Na and Co)
  - Added Ionophores

Factors Affecting Feed Intake in Ruminants: Feed related factors…

- **Associative effects of feeds/nutrients on feed intake;**
  - **Occur mostly during supplementation**
- **Three purposes of ruminant diet supplementation (Hinton, 2007);**
  - **To maximize rate of growth or production,**
  - **To correct deficient dietary component/s**
  - **To pay off insufficient or poor-quality pasture**
- **In general, supplementation seems to improve the overall DMI, but may have positive or negative effects on intake of the basal forage**

Factors Affecting Feed Intake in Ruminants: Feed related factors…

- **Associative effects occur when digestion or intake of one feed is dependent of the other**
- **Associative effects that may exist between forages on digestion and intake;**
  - **Increased intake (grass + legume)**
  - **increased digestion when poor forage is supplemented with high nitrogen content**
  - **modification of rumen digestive processes (PSM-- tannins, saponins)**
- **Anti-Nutritional Factors** can also affect VFI

Factors Affecting Feed Intake in Ruminants: Animal related factors

- ***Physiological status of the animal*;**
  - **Age**
  - **Pregnancy**
  - **Lactation**
  - **Work and activity**
  - **Genotype and size**
  - **Body composition**

Factors Affecting Feed Intake in Ruminants: Environment related factors

- ***Environmental temperature***
  - **Heat stress –reduce feed intake**
  - **Cold usually increases intake by stimulating appetite**
    - **But to cold persisted for longer time— detrimental**
- ***Housing***
  - **Provision of shade in hot climates increases intake**
    - **Reducing the impact of heat stress**
- ***Disease***
- ***Availability of water***

Energy value of feeds

- It is the inherent power of feeds to supply energy essential to the reproduction, maintenance, growth and milk production of animals.

- The ability of a feed to supply energy is therefore of great importance in determining its nutritive value in the evaluation of feeds.

CHAPTER 4

Feed Stuffs and their classification

Classification and Properties of Feedstuffs…

- **Simple categories used:**
  - **Fresh forage**
  - **Conserved forage**
  - **Concentrates**
  - **By-products**

Fresh forages

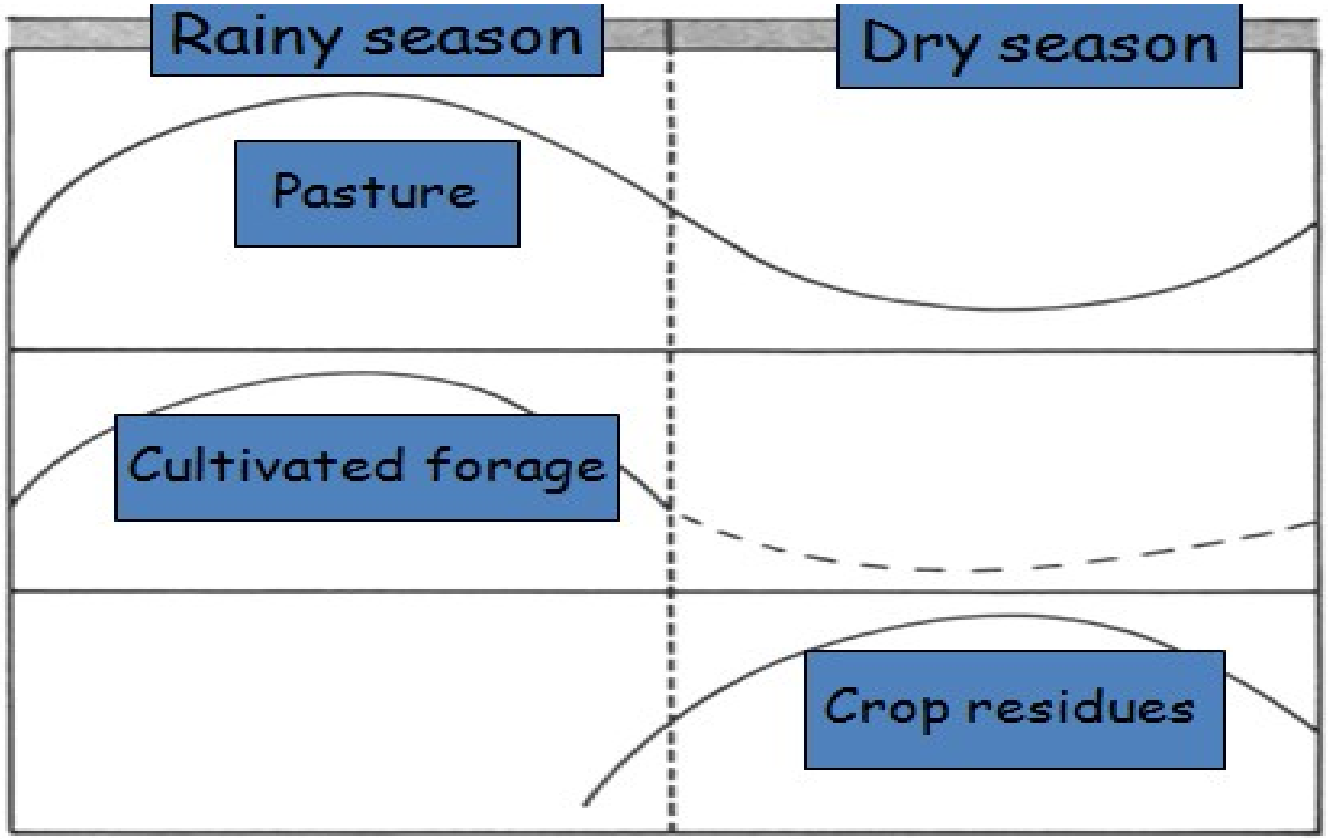
- **Grass**
- **Legume**
- **Roots**
- **Whole crop**
- **Tree forges (tropics)**

Common features;

- **Fed fresh (but often conserved too)**
- **High water content**
- **Variable in composition**
- **Fibrious feeds**
- **Best utilized by ruminant**

Conserved forages

- **Why conservation?**



www.fao.org/docrep/005/af298e/af298E12.htm

Conserved forages…

- **Conserved forages;**
  - **Hay**
  - **Silage**

Conserved forages—Hay

- **Hay?**
- **Hay making?**
- **Types of hay:**
  - **Grass hay**
  - **Legume hay**
  - **Mixture of grass and legume**
- **Forms of hay**
  - **Standing hay**
  - **Cut hay**

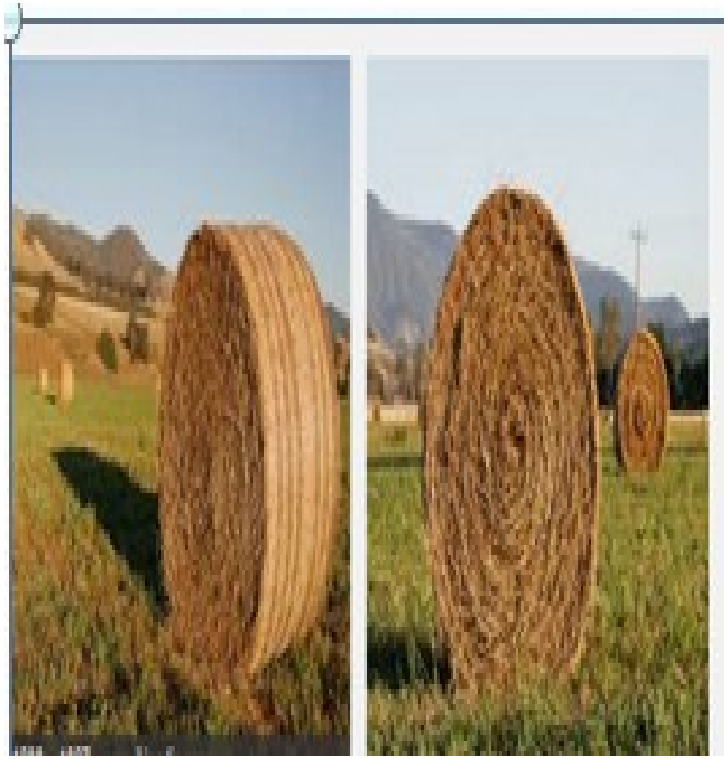
Conserved forages…



Natural pasture hay stacked in loose form on a raised structure (Adugna, 2008)







Conserved forages—Hay …

- **Factors affect hay quality:**
  - Stage of maturity when cut
  - Chemical changes occurring during drying
    - Action of the plant enzymes
    - Action of microbes
    - Oxidation
  - Weather conditions during harvest
  - Leaching due to rainfall
  - Excessive sunlight

- **Factors affect hay quality…**
  - Season of the year
  - % of leafiness
  - Methods of handling
  - Moisture content of the material
  - Storage conditions
  - Plant species
  - Heat damage
  - Pests

Conserved forages—Hay …

- **Sensory or visual evaluation;**
  - **Stage of maturity**
  - **Leafiness**
  - **Color**
  - **Oder condition**
  - **Presence of foreign materials**
- **Laboratory /chemical analysis;**
  - **DM, CP, ADF, NDF etc.**
- **Animal evaluations;**
  - **Fistulated animal**
  - ***In vivo* digestibility**

Conserved forages—Silage

- **Silage?**
- **Silo?**
- **Ensilage?**
- **How silage is preserved/principle?**
- **Silage making is achieved via inhibiting of the activities of plant and microbial enzymes**

Types of silo









Types of silo..







Conserved forages—Silage…

- **Types of silages:**
  - **High moisture/direct cut silage > 72 -74% moisture**
    - **Prone to seepage**
  - **Wilted silage-50-65% moisture**
  - **Haylage- 40-50% moisture**
    - **Poor compaction—problem in eliminating air**

Conserved forages—Silage…

- **Factors affecting silage quality:**
  - **Plant enzymes**
  - **Microbes;**
    - **Desirable-- LAB**
    - **Undesirable-- clostridia and enterobacteria**
  - **DM content of silage (30-35% DM is recommended)**
  - **Seepage loss**
  - **Fodder crop species+ stage of maturity**
  - **Packing and sealing**

Conserved forages—Silage…

- **Methods of silage Making:**

A. Preparation of forage;

- **Generally harvested at flowering stage**
- **35-40% DM**
- **Chop to proper size**

B. Addition of preservatives;

- **Molasses, urea, salt, acids limestone etc.**

C. Filling the silo;

- **Uniform distribution of the material**
- **Complete within least time**

D. Covering and sealing the silo



Fine-chopped maize is easily compacted.



Concentrates

- **Feed ingredients that are low in fiber content, high in energy or protein or both.**
- **Categorization;**
  - **Energy concentrates**
  - **Protein concentrates**
  - **Overlap energy/protein, protein/energy**
  - **Mineral and vitamin concentrates (compound mixtures)**

Classification and Properties of Feedstuffs:

Concentrates—Energy sources

- **Cereal grains**
  - **Barley, maize, millet, oats, rice, sorhgum(milo), wheat**
  - **Common features:**
    - **Dry, >850 g DM/kg**
    - **High in starch and low in fibre**
    - **High ME content, eg for ruminants > 11 MJ ME/kg DM**
    - **Feeds for monogastrics and ruminants**
    - **Relatively low CP content, <130 g CP/kg DM**
    - **Cereals deficient in lysine and methionine**
    - **Cereals generally deficient in calcium, 1-2 g/kg DM**

Classification and Properties of Feedstuffs:
Concentrates—Protein sources

- **Subgroups;**
  - **Legume grains and seeds**
    - **Examples (Field beans, Lupins,Peas)**
  - **Oil seeds**
    - **Examples (cottonseed, linseed, groundnuts (peanuts), soya bean, sunflower, rapeseed**
  - **Oil cakes and meals**
  - **Examples (cottonseed cake, linseed cake, soyabean meal, rapeseed meal)**
  - **Animal origin**
    - **Examples (Fish meal, blood meal, meat and bone meal, skimmed milk powder)**

Common features:

- **Dry, >85% DM**
- **Many contains toxic compounds**
- **High in CP, 25-40% DM**
- **High in ME content, > 12 MJ ME/kg DM**

Common features:

- **Dry, >90% DM**
- **High in oil, 20-50% DM**
- **High in CP, 20-30% DM**
- **High in ME content**

Common features:

- **Dry, >90% DM**
- **High in CP, 20-45% DM**
- **Deficient in cystine & methionine (& lysine)**
- **Relatively high, but variable, in ME content**
- **Hgh phosphorus, 6-12 g/kg DM**
- **Low in calcium, 2-3 g/kg DM**

Classification and Properties of Feedstuffs:

Concentrates—Protein sources…

- **Common charctersitics of animal origin protein sources;**
  - **Dry, >850 g DM/kg**
  - **High in protein, eg 650 g CP/kg DM**
  - **High in rumen UDP(except skimmed milk)**
  - **Rich in vitamin B-complex**
  - **Rich in minerals**
  - **Expensive**

Classification and Properties of Feedstuffs: *Concentrates—By-products*

- **Categorization—difficult**
  - **Overlap with concentrates (eg oil cakes)**
  - **Overlap with forages (eg straw)**
  - **Wide range of nutritive value**
- **A suggested method—based on source, rather than quality;**
  - **Cereal –grain processing by-products**
  - **Malting, brewing and distilling by-products**
  - **Cereal crop-residues**
  - **Sugar industry by-products**
  - **Fruit and vegetable processing by-products**
  - **Tropical agro-industrial by-products**

Classification and Properties of Feedstuffs: *Concentrates—By-products…*

Cereal-grain processing by-products

- **Include;**
  - **Maize germ meal—from wet milling of maize**
  - **Maize gluten feed—from wet milling of maize to extract starch**
  - **Maize gluten meal—from wet milling of maize**
  - **Oat feed—from oatmeal production for humans**
  - **Rice bran**
  - **Wheat bran (mainly husk)—from milling wheat**
  - **Wheat feed—from milling wheat (mix of bran and starchy fraction)**

Classification and Properties of Feedstuffs: *Concentrates—By-products…*

- **Malting, brewing and distilling by-products;**
  - **Example**
    - **Brewers grains**
      - **200 g DM/kg,**
      - **Fed fresh or ensiled, if farm near brewery**
      - **Good for dairy farm because it is very high in protein, high in UDP particularly in high yielding dairy cow**
- **Cereal crop-residues;**
  - **Example**
    - **Cereal straws**
      - **World interest because of large production**
      - **Low quality forages, but can be improved by treatment**
    - **Maize cobs**

Classification and Properties of Feedstuffs: *Concentrates—By-products…*

- **Legume-grain processing by-products**
  - **Examples (Bean husks,Lentil husks, Pea husks)**
- **Legume crop-residues**
  - **Example (Bean straw, pea straw, rape straw, soya bean straw,soya bean pods)**
- **Sugar industry by-products**
  - **Examples (molasses beet, molasses cane, sugar beet pulp, sugar beet tops, sugar cane bagasse,sugar cane tops)**

Classification and Properties of Feedstuffs: *Concentrates—By-products…*

- **Fruit and vegetable processing by-products**
  - **Example (Citrus pulp)**
- **Also waste products from;**
  - **Cassava peel**
  - **Banana waste**
  - **Tea wastes**
  - **Coffee pulp**
  - **Feather meal**
  - **Yeast**
  - **Poultry manure**
  - **Poultry litter**
  - **Rumen contents (from abattoirs)**