Theme 2: Forage conservation

FERMENTATION PROCESS IN SILAGE

Level 3 – Part I

Topic	Training & information Content
2.1	Fodder conservation and storage
2.2	Estimating ideal time of harvesting
2.3	Guideline for silage making
2.4	Fermentation process in silage
2.5	Treatment of straw with Urea
2.6	Making of urea/molasses/mineral lick
2.7	Management of silage pit (feed out)
2.8	Estimating fodder supplies for dry season feeding & planning of feeding management

1. You will learn about (learning objectives):

- ❑ The trainee understand the different processes which influence the silage making
  - What is silage
  - Fermentation – phases
  - Water soluble carbohydrates

IMPORTANT

This module has two parts; this is part I – download Part II to continue to END.

2. What is Silage

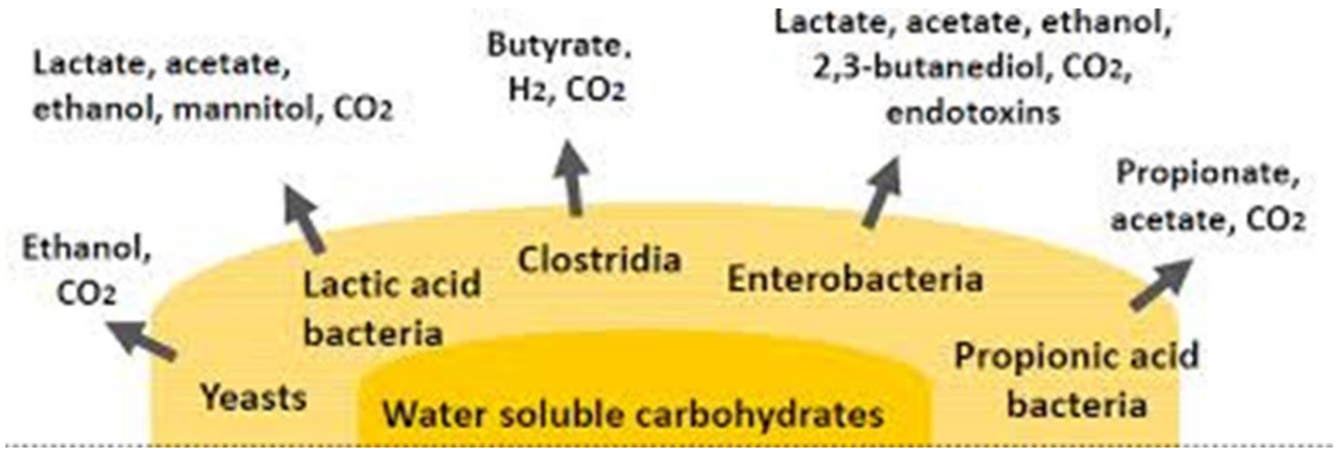
- Silage is an end product where chopped forage material of high moisture content (30-40% DM) is fermented to produce stable feed that resists further breakdown when stored under anaerobic conditions.

- The aim of silage making is to retain the nutrients present in fresh forage and prepare palatable feed (for dairy cows). This is possible through anaerobic fermentation.

3. Fermentation

Fermentation = Sugar → (volatile) organic acids + alcohol

1. Fermentation does not require oxygen.
2. It does not occur within the living cells. It requires only enzymes and substrate (forage material).
3. Different substrates oxidize to form alcohol or organic acids.
4. Incomplete oxidation of substrate occurs and, hence less energy is produced.
5. It occurs mainly with the help of yeast or bacterial cells.



Different micro organisms use forage material to form alcohol or organic acids

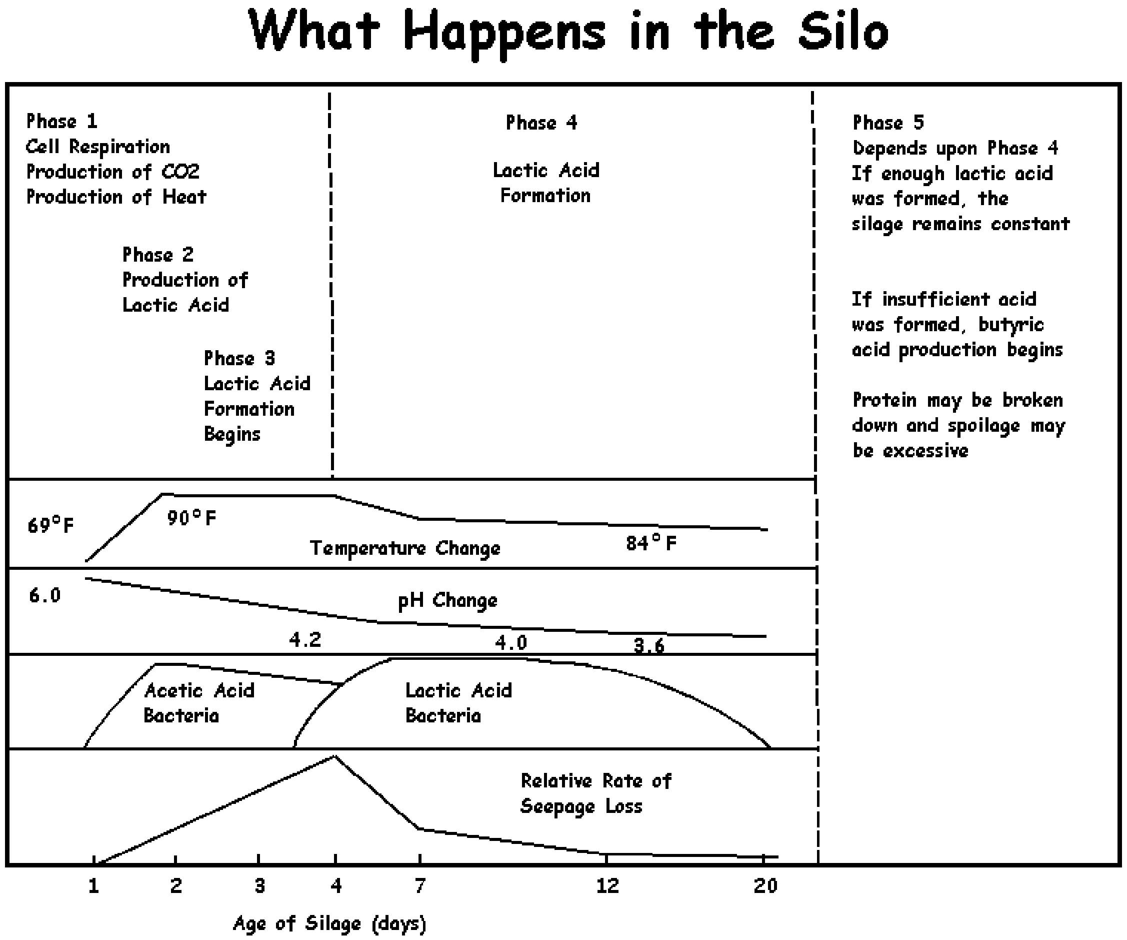
4. Why efficient fermentation is needed

- To preserve nutrients in order to optimize livestock (including dairy cows) intake and performance.
- To minimize forage dry matter lost during the fermentation process and spoilage at feed out.
    - fermentation losses can be 12 - 15% for good fermentation; but much higher for a poor one.
    - spoilage losses can sometimes be significant.

5. Fermentation is not always perfect

- Silage results from a biological processes; the silage making process doesn't always work perfectly.

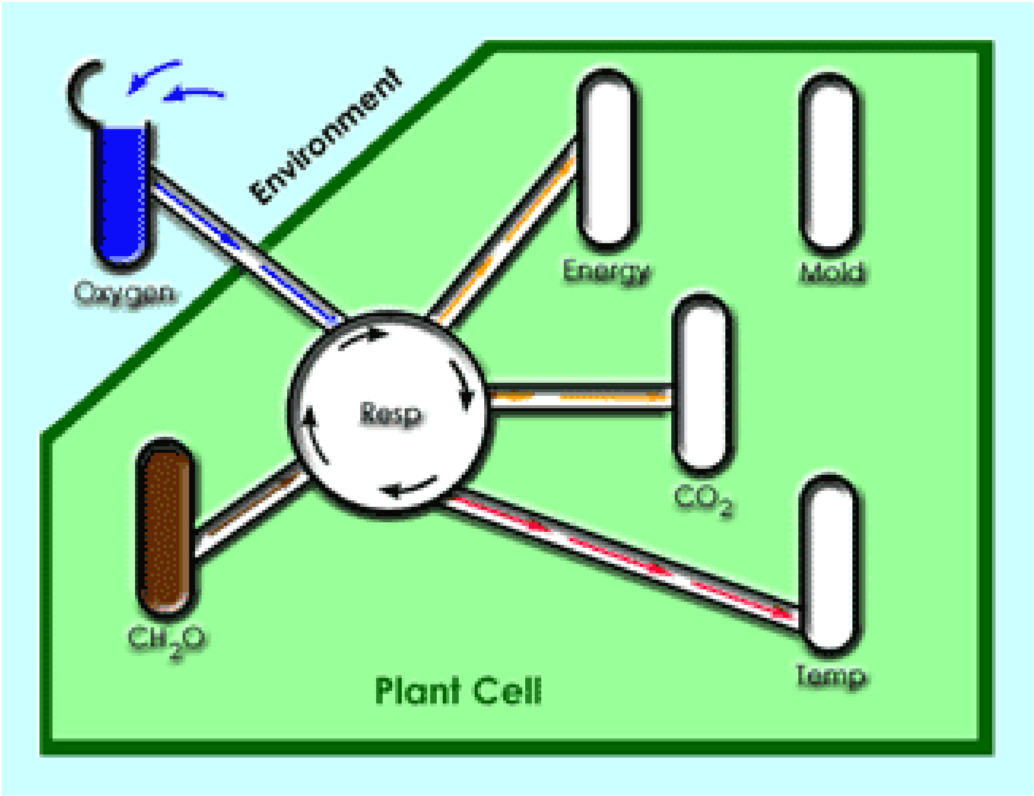
- During an anaerobic silage fermentation, micro-organisms feed on sugars and other water soluble carbohydrates in the forage material to produce organic acids, such as lactic acid and acetic acid. This lowers the pH and creates an environment where the resulting silage is preserved.



6. Respiration

- Respiration is the conversion of carbohydrates into energy.
- Until plant cells are dead or have no oxygen available, they respire (breathe) to generate the energy they need for normal activity.

1. Respiration may occur both in the presence and absence of oxygen.
2. It occurs only in living cells.
3. Sugar is oxidized and CO_2 and H_2O are formed as end products.
4. Complete oxidation of forage material (substrates) occurs, hence produces large amount of energy.
5. Respiration can occur in any living cell.



6.1 Respiration Cont'd…

- Respiration is necessary to deplete the forage mass of oxygen shortly after it has been put in a sealed structure.
- However, respiration burns up carbohydrates (forage quality) and produces heat, so its duration should be minimized.
- Prolonged respiration in the forage mass can reduce forage carbohydrates levels which can affect the fermentation process negatively.

6.2 Respiration Cont'd...

- In addition, prolonged respiration allows rapid growth of mould in the forage as well as forage heating.

- Minimizing the amount of oxygen in the forage mass when it is in a sealed structure is the best way to shorten the respiration period and avoid unnecessary mould growth, quality loss or a potential silo fire.

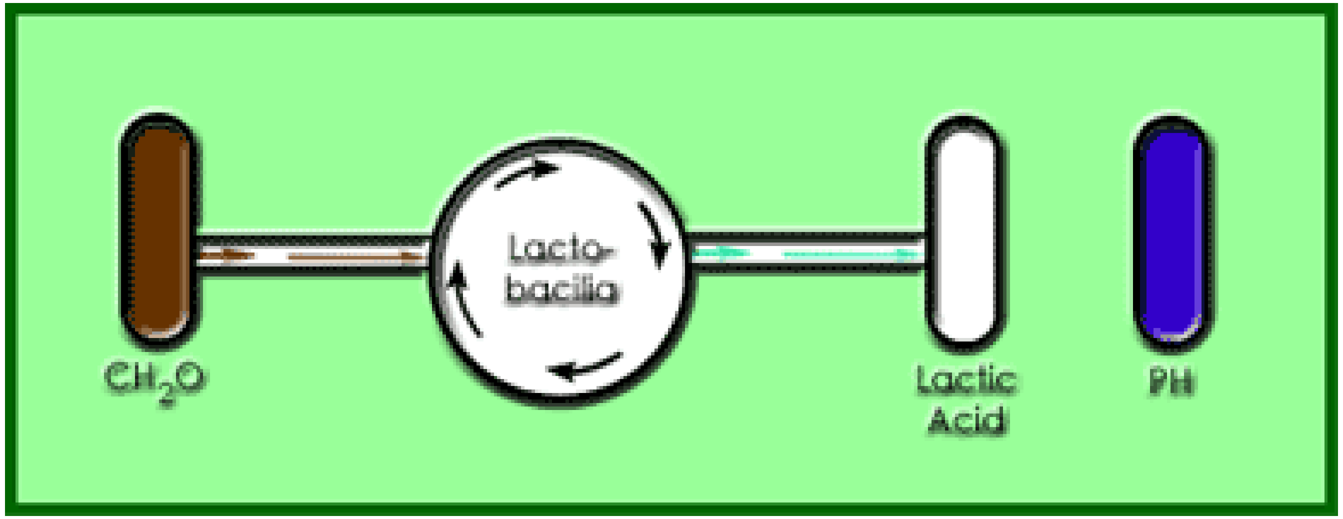
Respiration = Sugar + O_2 → CO_2 + Heat + $H_2 0$

➔ Respiration of sugar: loses in energy, dry matter, food for lactic bacteria

➔ Respiration = waste

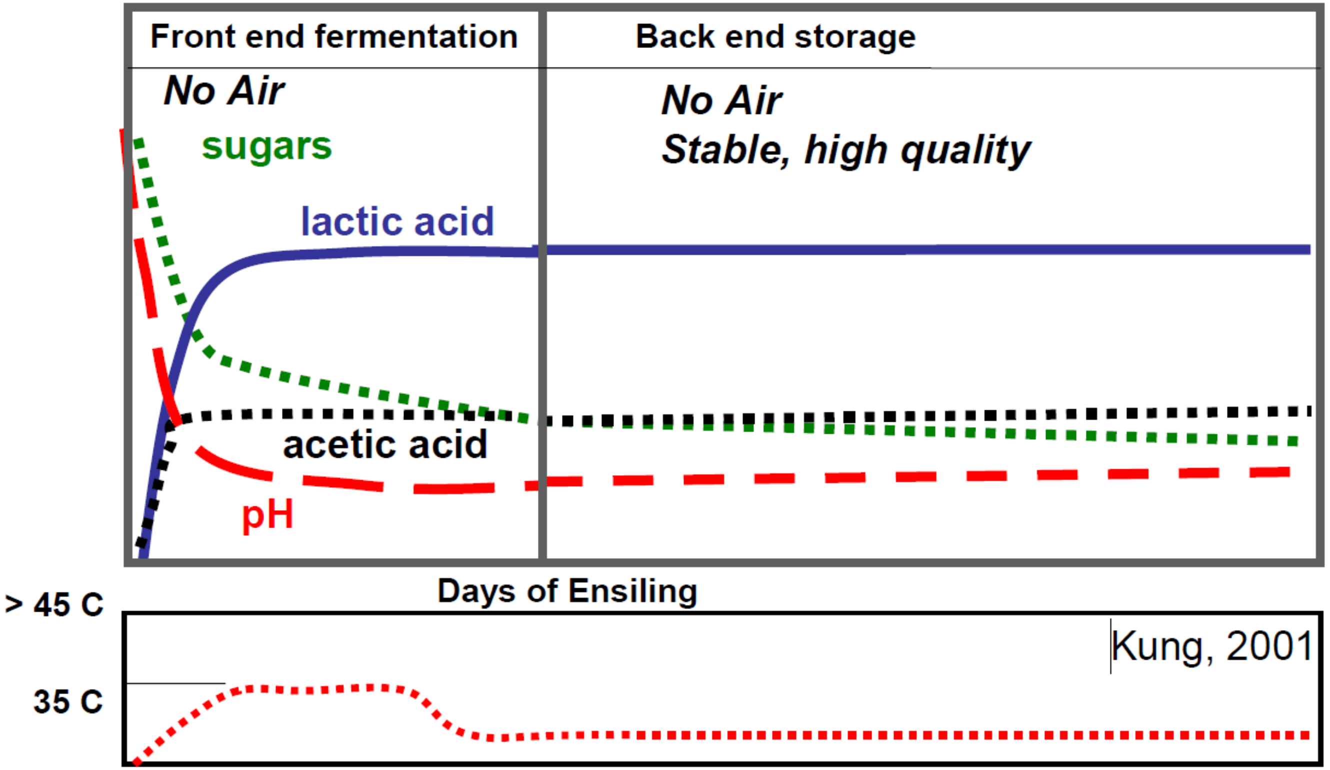
6.3 Respiration Cont'd…

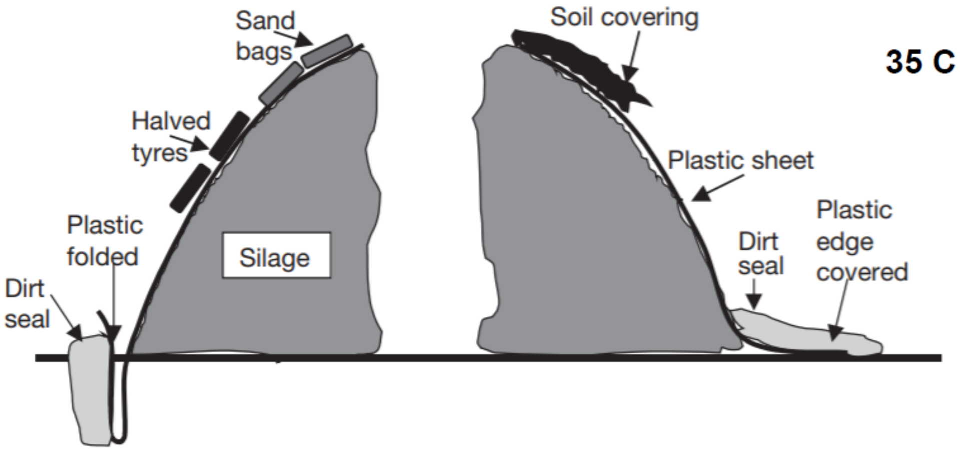
- Once oxygen is depleted in the forage mass, fermentation begins.
- Fermentation process is the lowering of the pH (acidity) in the forage to a point where no organism (mould or bacteria) can function.
- The pH is lowered by lactic acid which is a by product of lactobacillus bacteria. The lactobacillus bacteria are on the forage when it is mowed/harvested and multiply rapidly until the forage is fermented.



7. Anaerobic fermentation

- In the absence of air, lactic acid bacteria ferments sugar in the biomass to lactic acid which acidifies the forage material (this results in a drop in pH).





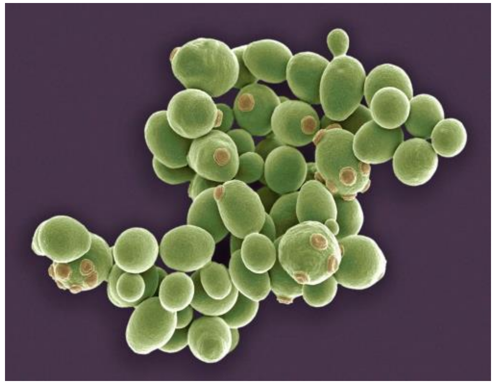
7.1 Anaerobic fermentation Cont'd…

- Lactobacillus bacteria consume carbohydrates in the forage (grass or maize) for their energy source and excrete lactic acid.
- The lactobacillus bacteria continue to produce lactic acid and lower the forage pH (acidity) until they cannot function anymore.
- At this pH level, the forage is fermented and can exist unchanged for many years as long it is not exposed to air (oxygen).

7.2 Fermentation is micro-organisms at work

Good organisms

- Lactic acid bacteria
  - heterofermentative
  - homofermentative



Bad organisms

- Yeasts
- Moulds
- Clostridia
- Enterobacteria

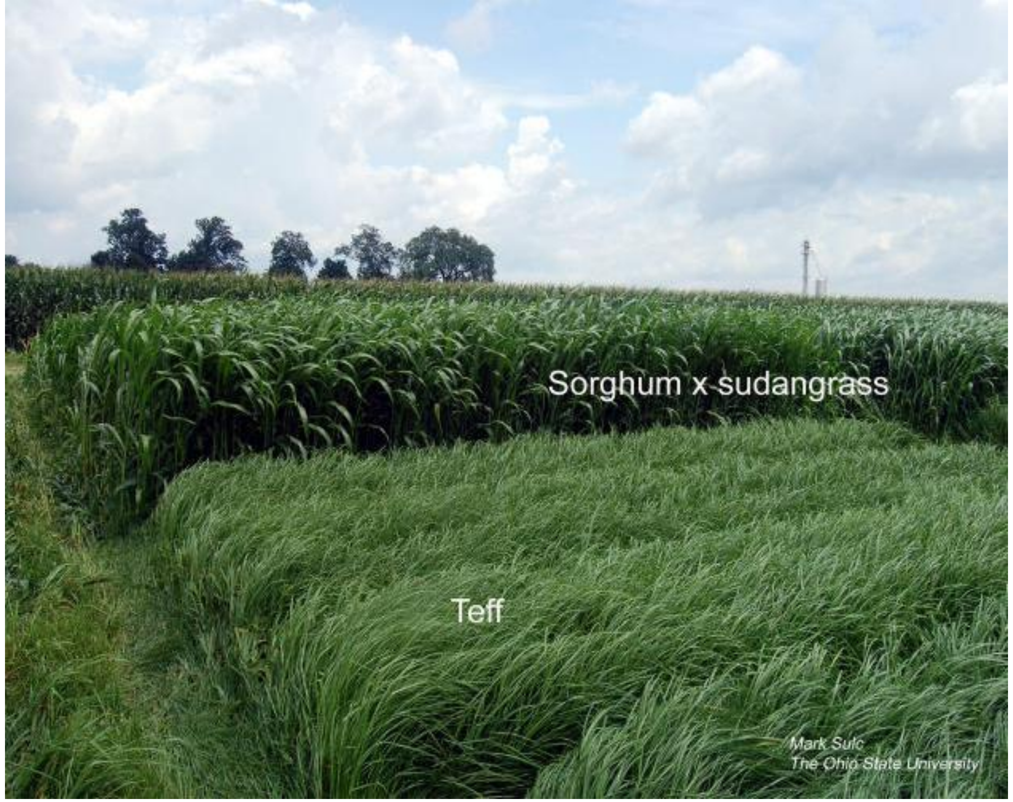
8. Water soluble carbohydrates in forage material/biomass

- Availability of water soluble carbohydrates (sugar) in forage material or biomass depends on:
  - Species
  - Variety
  - Stage of maturity
  - Time of day
  - Climate
  - Drought
  - Nitrogen (N) fertilization
  - Rainfall
  - Lower under poor wilting conditions
  - Management

9. Water soluble carbohydrates in forage crops

- Availability of water soluble carbohydrates (sugar) in selected forage crops:

Forage crop	Water soluble carbohydrates as % of DM
Maize silage	10-20
Forage sorghum	10-20
Sudan grass, Sorghum-Sudan	10-15
Oats, wheat	8-12
Alfalfa	4-7
Star grass	2-4
Paspalum (Bahia grass)	<5

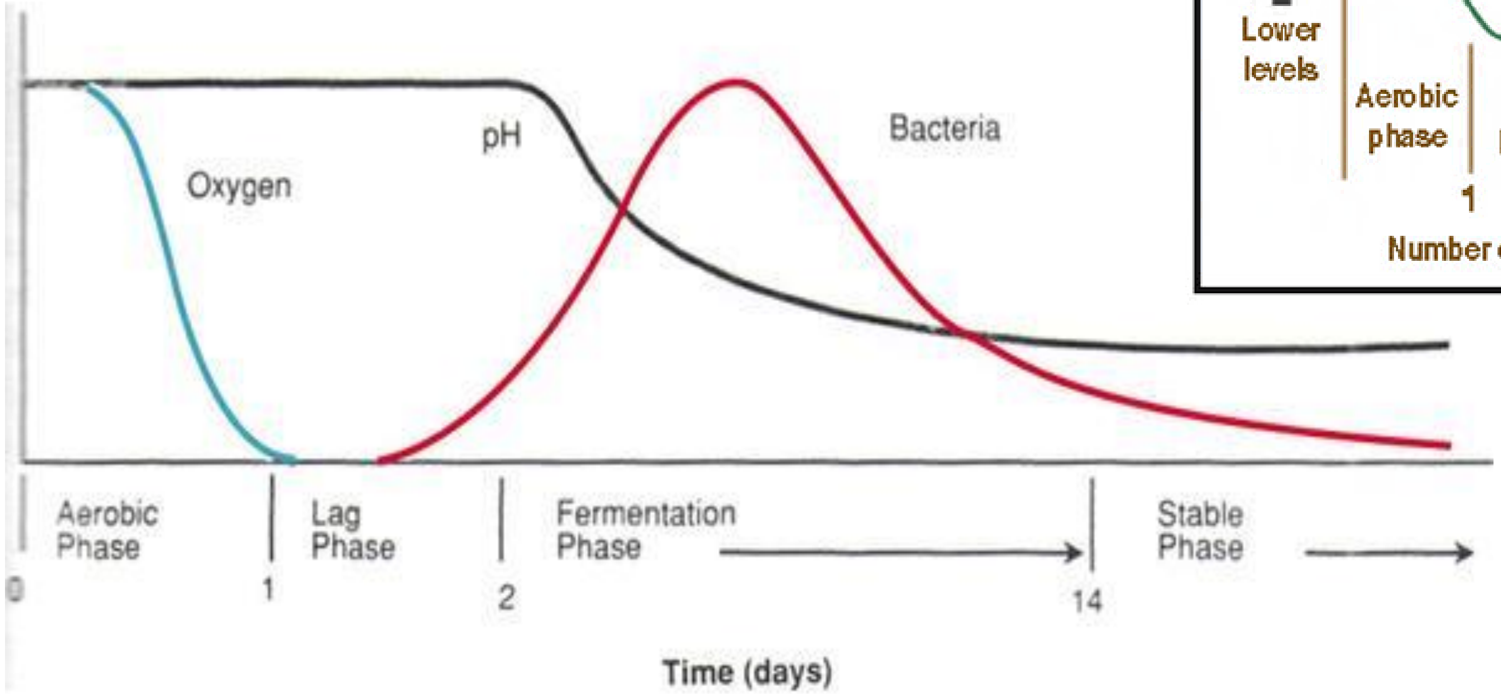


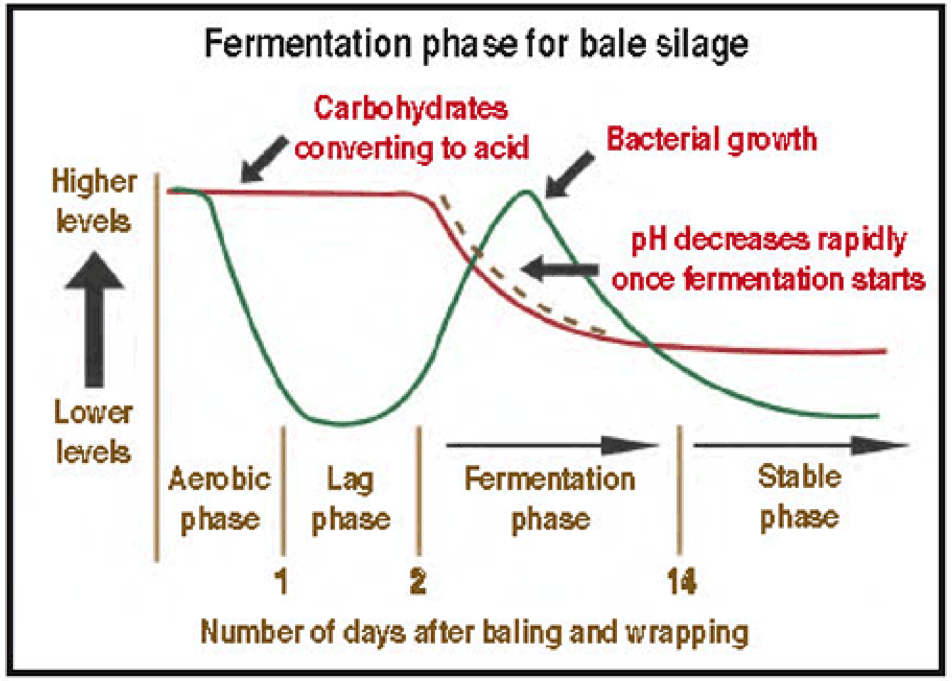
10. Population of micro-organisms on plants before

Group	Population (cfu/g)*	Population (log cfu/g)*
Total aerobic bacteria	>10,000,000	>7
Lactic acid bacteria	10 - 1,000,000	1-6
Enterobacteria	1,000 - 100,000	3-6
Yeast & yeast like fungi	1,000 - 100,000	3-5
Moulds	1,000 - 10,000	3-4
Clostridia (spores)	100 - 1,000	2-3
Bacilli (spores)	100 - 1,000	2-3
Acetic acid bacteria	100 - 1,000	2-3
Propionic acid bacteria	10 - 100	1-2
*cfu colony forming unit		

Source: Phalow et al 2003

11. Fermentation phases in silage





Source: Pitt et Sniffen, 1985

11.1 Good fermentation

- Good fermentation is dominated by lactic acid bacteria.
  - Good silage made from tropical forages has a pH less than 5.0.
  - Nitrogen from ammonia (NH_3) as a percentage of Total Nitrogen is less than 15%.
  - Lactic acid is >50% of the total organic acids.
  - Butyric acid content is <0.5% of the total dry matter.

11.2 Fermentation process phase I: Aerobic phase

Aerobic phase: Phase I (1-2 days)

- The (chopped) plants continue their respiration and as a result of this activity, CO_2 is produced.
- Inside the silage mass, the temperature starts to rise above 20°C and the pH is around 6-6.5.

11.3 Fermentation phase II: Lag phase

Lag phase or hetero-fermentative phase: Phase II (1-3 days)

- Anaerobic fermentation starts; organic acids (acetic acid, lactic acid) and ethanol are produced.
- Temperature reaches 30-32°C.
- The pH decreases gradually to 5°C and lactic acid bacteria start flourishing.
- At times, if natural occurring bacteria are more than 10,000 CFU/g*, it may limit the growth of lactic acid bacteria, especially of bacterial innoculants.

* Colony Forming Units/ gram

11.4 Fermentation phase III: Homo-fermentative phase

Fermentation phase or homo-fermentative phase: Phase III (3-5 days)

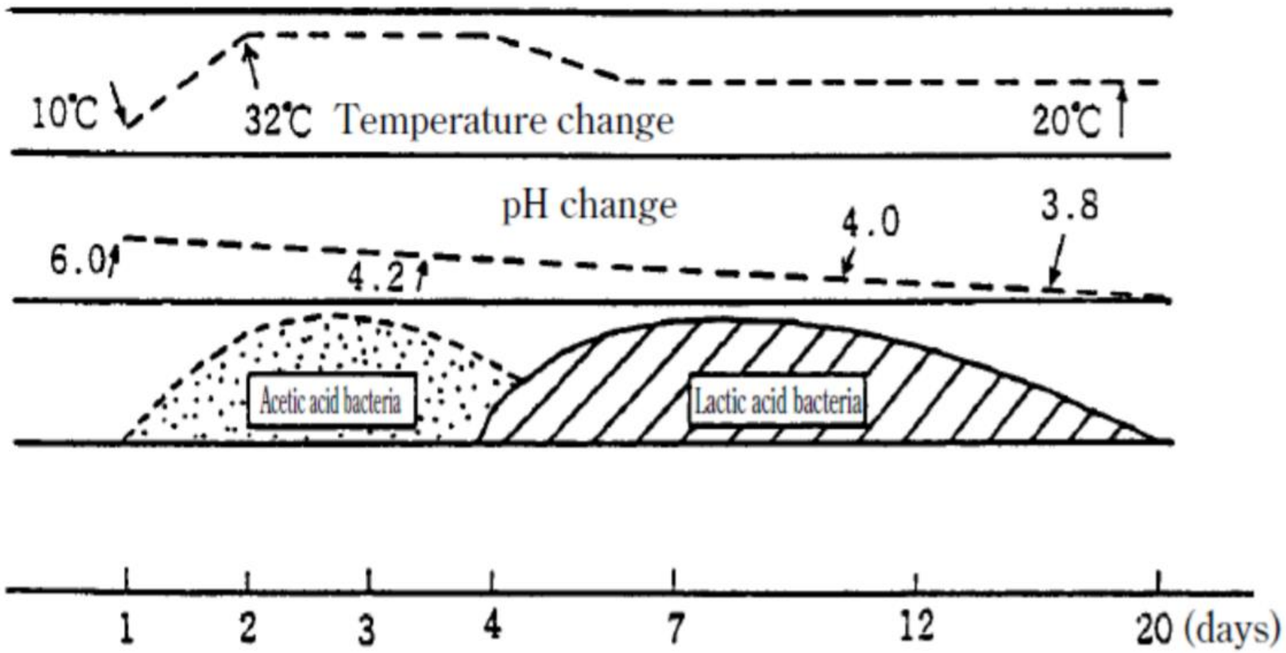
- The fermentation is almost exclusively lactic acid.
- pH drops to 4.
- By the end of this phase silage mass starts to cool down.
- Under tropical climate, it is important to achieve pH 4-5 early in order to prevent hot fermentation in silage, which makes it favourable for mould and yeast to grow within the silage mass.

11.5 Fermentation phase IV: Stable phase

Stable phase: Phase IV (15-21 days)

- All kind of fermentations are almost shut down.
- pH is stabilized at around 4.
- The temperature inside the silage mass should be more or less the same as the environment (outside - night) temperature.

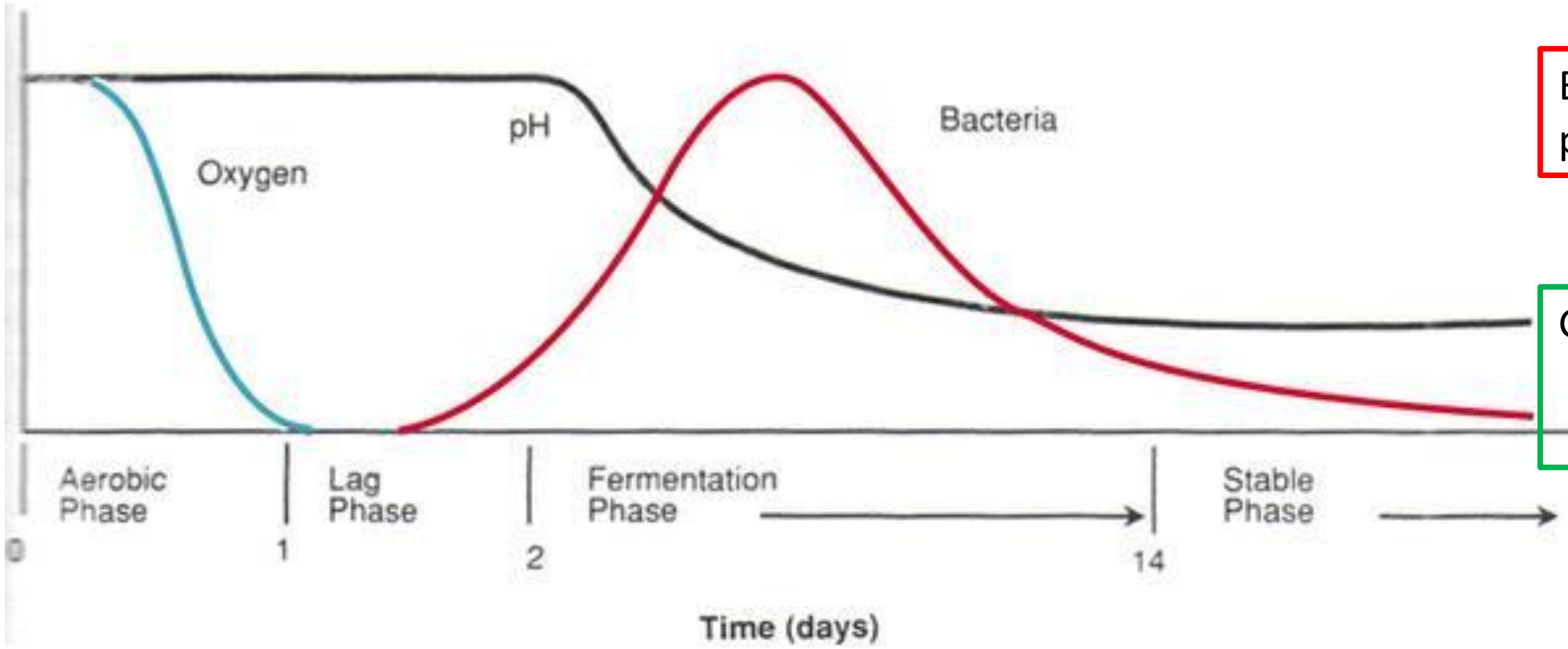
11.6 Temperature and pH during fermentation process



A hand feeling the temperature in silage (chopped material)

Source: T.C. Da Silva. 2017

11.7 Fermentation phases: Good vs Bad silage



Bad silo management, pH > 6

Good silage
pH: 3.8-4,0
Temp : < 25 °C

Source: Pitt et Sniffen, 1985

12. Factors influencing fermentation

- DM content: ideal 30-35% DM.
- Chopping length: ideal 0.28-1.25 cm.
- Compaction increases density (600 kg/m³)
- Sealing closes off the biomass from oxygen.
- Covering ensures any air still inside is removed.

13. Important note

This module is continued in Part II…

- PROCEED TO PART II -