II. FORAGE TREATMENTS

Forage treatment consists of technological treatments aimed at rendering the parietal constituents of low quality forages more accessible to the digestive enzymes of the rumen's microorganisms so as to improve both their digestibility and intake.

There are three broad categories of treatment: physical, biological and chemical.

Physical and biological treatments are only briefly mentioned to refresh the memory. In fact, except for mowing, physical treatments are too onerous and their execution requires availability of complex machinery. As regards biological treatments, these still remain technically delicate to put into practice.

The two chemical treatments most commonly put to practical use consist of treating the forages with either ammonia or urea and in contrast, these will be placed into context and described in detail in the following two chapters.

2.1. Physical treatment techniques

These modify the physical structure of the forages. They involve *mechanical* treatments such as chopping, laceration or defibering and grinding, together with *thermal* treatments using *steam*. There are also treatments using *radiation* techniques (with gamma rays, ...) which are only mentioned in passing as they are too difficult and delicate to use in practice.

2.1.1. Mechanical treatment

The objective of mechanical treatment is to reduce the size of the blades of straw:

- **chopping** (by machines with knives or flails) cuts the blades of straw into relatively long sections (from 1 to 10 cm). This is not truly a treatment but more of a technique for improving the presentation of long and somewhat tough forage matter, easing its manipulation and handling by the animal. Chopping is useful, for example, when feeding long maize stalks.
- **laceration**, also called defibering (achieved with a type of flail mill but which has no concave sieve) gives shorter but variable sections due to bursting the stalk along its length. This technique, which increases the absorptive capacity of the forage, is used in developed countries to form a carrier for liquid feed supplements such as molasses and whey.

- **grinding** (with a hammer mill) produces forage particles which are less than a centimetre in length.

The particles resulting from mechanically treated forage are usually agglomerated so as to reduce their volume and ease handling. Agglomeration is achieved in a continuous press which produces condensed fodder in pellets. Agglomeration can also be achieved without any prior grinding, either in a continuous press (designed to make compacted fodder or cobs), or in a ram press (which makes compacted fodder or wafers). This type of treatment reduces the size of the particles even if there is no grinding undertaken.

Amongst mechanical treatments for straw which have been studied, grinding has received the most attention (DEMARQUILLY and JOURNET, 1967; WAINMANN and BLAXTER, 1972; MELCION and DELORT-LAVAL, 1972,...); it is also the most common mechanical treatment in current use.

Mechanically treated forage which has been condensed, compacted or compressed is normally ingested by ruminants in quantities which are 60 to 80 % superior to that of untreated forage which is more voluminous. This phenomenon occurs because the rumen is able to physically process and rid itself of the reduced size forage particles more quickly, hence physically regulating the ruminant's appetite. There are however, some negative effects, as this accelerated passage through the digestive system allows insufficient time for action by the microorganisms and causes a reduction to the digestibility. Despite this decrease in digestibility, the net energy value of ground forages is, with the exception of grasses, rather similar to that of untreated forages due to a number of factors which are favourable to a better utilization of the digestible and the metabolic energy (at least for fattening): less energy is used for digestion and rumination, less methane is produced in the rumen, a reduced concentration of acetic acid in the rumen (due to a lower pH), etc.

Although these industrial type treatments are interesting, they are generally costly in energy consumption. They are now less frequently used, particularly since the development of more efficient chemical treatments.

2.1.2. Thermal treatment by steam

High pressure steam treatment provokes a swelling of the fibres and acidity of the environment through freeing acetyl groups, the production of furfural and derivatives of phenol and a fairly significant destruction of the hemicelluloses. Steam treatment is used above all to improve the nutritive value of timber waste products (BENDER, HEANEY, BOWDEN, 1970) and also that of bagasse, the pulp residue byproduct left after sugar cane juice extraction. As bagasse is used as fuel in the sugar refineries, this treatment system is self sustainable from an energy point of view. Surplus bagasse can therefore be judicially transformed at low cost, transforming untreated matter with a mere 30 % digestibility, to a treated feed with 70 % digestibility. Such treatment is undertaken in certain sugar refineries in Mauritius, India and Brazil.

2.2. Biological treatment

Because biological treatment constitutes a topic for ongoing research, only the fundamental principles are summarised below. A recent "state of the art" review has been collated by COUGHLAN and AMARAL COLLACO (1990).

Biological treatment consists of using the forage as a substratum and cultivating fungi such as white or brown decomposition rot which enable the enzymes to break or loosen the bonds between the lignin and the parietal carbohydrates, hence and above all, decompose the lignin itself.

The fungi or mould growth is detrimental to the amount of energy stored in the substratum and overall nutritional interests are not compensated for by the increased protein content which results from this growth. This aspect, together with the difficulties in controlling these cultures means that these techniques cannot yet be applied on a practical scale.

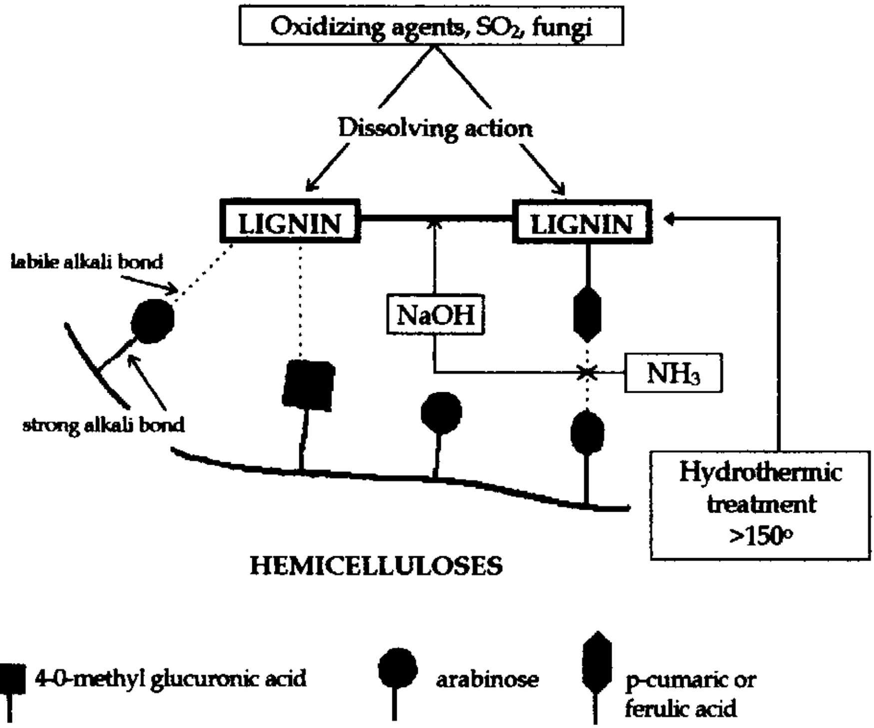
2.3. Chemical treatment

It is this category of treatment techniques which has attracted the most attention both from a research and development point of view. These treatments are in fact very efficient and indeed some of them, as will be emphasised below, extremely easy to put into practice. They form the basis for numerous review articles, amongst which the most significant are by GUGGOLZ, McDONALD, WALKER *et al.* (1971); JOUANY (1975); JACKSON (1977 and 1978), and complete treatises whereby the most comprehensive is that by SUNDSTOL and OWEN (1984).

The Principles

These treatments call upon one or other of the following chemical agents:

***Figure 10:** Diagramatic representation of the lignin-hemicellulose complex and the manner in which various treatment methods act (Chesson, 1986).*



- oxidizing agents (peroxyacetic acid, acidified sodium chloride, ozone, etc.) which decompose fairly efficiently the lignin,
- strong acids such as those used in the paper industry.
- alkali based agents (lime, potassium, **caustic soda** either alone or in association and, more recently, **ammonia**), which are able to hydrolyse the chemical bonds (see **Figure 10**) formed between the indigestible lignin and the parietal polysaccharides (cellulose, hemicellulose) which respectively, are completely digestible or partially digestible.

It is clear that no toxic residues must be left by these substances either for the ruminant which is consuming the treated forages nor for the microbes residing in the rumen.

The combined effect of these reactions is to cause a significant reduction in the rigidity of the cell structures and a swelling of the cell walls, so allowing their penetration by the electrolytes and cellulolytic enzymes from the rumen microbes. These microbes can thus colonise more rapidly the vegetal matter, decomposing it more quickly and intensively because hydrolysis has already taken place.

Oxidizing agents are prohibitively expensive and have not been used in practice. Alkalis have been the most frequently used agents and caustic soda has seen practical use made of the technique.

Treatment with caustic soda

This treatment was introduced by the Norwegian, BECKMANN, towards the end of the last century. Straw was soaked in a 2 % solution of caustic soda, then thoroughly washed and dried out in the open. This constitutes a wet treatment and requires vast quantities of water and causes a certain amount of sodium pollution to the environment.

The Danes have progressively simplified the treatment, so reducing the amount of water needed which varies in a ratio of 1 to 30, depending on technique. The amount of caustic soda used in the treatment is in the range of 40 to 60 g/kg of forage to be treated.

Three distinct types of treatment are used these days:

- *semi-wet treatment*: a caustic soda solution is prepared to a concentration of between 1.6 and 5 % and mixed with the straw at a rate of between 1 and 3 litres per kg of straw. The straw can then be fed to the animals either 24 or 48 hours later or as an alternative, conserved as silage.
- *semi-dry* treatment: two private companies in Denmark (Taarup and JF) have developed a trailed machine operated through the tractor power take-off shaft which chops the straw and mixes it with a 12 % solution of caustic soda at a rate of 0.4 litres per kg of straw. The treatment action takes about 8 days and the straw can be dried in the open air.
- *dry* treatment: this is a technique used on an industrial scale. A more concentrated solution of caustic soda (16 %) is mixed with chopped straw at a rate of 0.3 litres per kg of straw; it is then passed through a continuous press. Because of the high temperature and pressure used in this continuous process, the beneficial action of the caustic soda is very quick, only taking between 20 seconds and a minute.

Both semi-wet and semi-dry treatment techniques were put to wide practical use during the 1970's, particularly in Scandinavia. They were also introduced in Tunisia (Project FAO/SIDA/TUN/-10; KAYOULI; 1979).

Treatment with ammonia

Because of both the cost and the potential dangers involved in treatment with caustic soda, these techniques have now been almost entirely abandoned **in favour of treatment with ammonia**. This is particularly the case since the 1978 proposal (SUNDSTOL, COXWOTH and MOWAT) for the farmer to inject anhydrous ammonia into the straw by himself, using a very simple piece of equipment.

Ammonia treatment does however present one inconvenience in that it needs a supply of industrially produced ammonia together with a distribution network. If ammonia is not available or the distribution network is unsatisfactory, an **alternative** may be found by treating the straw with a solution of urea which then hydrolyses and produces ammonia within the straw mass.

These two groups of treatments will now be studied in greater detail as they constitute the only practical possibilities at farm level for treating straw or other bulk forage matter.