



Crop Residues for Animal Feed

Especially in stall-feeding



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Crop residues for animal feed

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Foreword and acknowledgements

The idea for this booklet on straw feeding emerged some years ago during a meeting, while discussing an Agrodok on dairy cattle husbandry. That Agrodok was to have a chapter on animal feed, especially fodders such as grasses and crop residues. However, this would have meant squeezing too much information into a few pages, which would not have done justice to the vast amount of information available on feeding straws. A separate Agrodok was needed on the subject.

Pressure on grazing lands continues to increase and in many parts of the world livestock will continue to provide an important supplementary source of income for many resource-poor farmers. In addition, straws play an important role in the sustainable management of the soil.

It is even more likely that competition between the various ways in which straws are used will increase as urban demand for energy, packaging and roofing materials continues to grow, resulting in a decrease of the amount of straw available for animal feeding.

Crop residues for animal feed emphasises the different ways of using a wide variety of straws, especially for stall-feeding. It is based on information collected by Hans Schiere from farmers and researchers in different parts of the world, as well as on practical experience and on a large body of scientific literature.

Adri Vink
Wageningen, 2015

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1 Introduction

1.1 Crop by-products

Farm crops are grown for one or more main product: for example grain, pulse, sugar and oil. Straw and crop leftovers after harvesting and after processing are ‘by-products’ of the main crop. Whether left in the field or harvested, these by-products have value and farmers have traditionally used them in many ways. Sometimes the by-product is even more important than the crop itself, especially for mixed crop-livestock farmers in semi-arid regions.

‘Crop by-products’ is a general term used to refer to both fibrous by-products (e.g. straws, mature grass and tree leaves) and crop residues that are richer in nutrients, such as broken grain, bran, oil and seed cakes.

1.2 Straws

Fibrous crop by-products – also referred to as crop left-overs or crop residues – come in different forms and have different names. Grain crops yield either slender straws (barley, rice, rye and wheat) or coarse straws (maize, millet and sorghums). But sugar cane tops may also serve as animal feed, as can banana leaves and bean ‘straws’, all of which are also fibrous crop by-

products. In some countries maize, sorghum or soybean stalks are referred to as 'stover'. The stalks or stems left over from peas, beans or potatoes are known as 'haulms'.

For the sake of simplicity this Agrodok uses the word 'straws' for all fibrous crop by-products, defining them as *fibrous parts of crop biomass, excluding the roots but including the weeds and immature or fallen grain from failed harvests, as well as spontaneous crop re-growth (ratoon)*.

Common traditional uses of straw include:

- Mulch: straw left in the field to protect the soil and reduce wind and water erosion.
- Compost: crop leftovers turned into compost to maintain or improve the soil, in the household garden or in the field.
- Thatching, roofing and building material: for example sorghum stalks for shelter or chopped straw in mud bricks.
- Cooking fuel: if firewood is scarce and other kitchen fuels are unaffordable.
- Animal bedding: straw in pens used to keep cows, buffaloes, goats or sheep.
- Animal feed: the topic of this Agrodok.

More recent uses of straw/crop leftovers include:

- packaging and/or papermaking
- bio-fuel
- digesters for biogas production
- raw material for synthetic fuels.

Using straw in rural areas saves money in local communities: it helps maintain and improve soil quality, and enables farmers to reduce expenditure on external animal feed, roofing materials and so on. Selling straw to urban areas, as animal feed or for modern uses, gives quick cash returns but removes valuable materials from the rural areas. Thus short-term cash gains may come at the expense of long-term sustainability in farming areas.

Burning is an easy way to dispose of straw but the idea that burning adds nutrients to the soil is wrong. What actually happens is that organic matter and valuable nutrients such as nitrogen and sulphur go up in smoke. Not burning straw can thus save money on fertiliser (Chapter 7). Burning crop leftovers in the field, a traditional practice in some farming communities, should be strongly discouraged.

1.3 Straws as animal feed

Not all farm animals are able to digest straw fully. Farm animals with just one stomach (monogastrics), such as pigs, poultry, donkeys, horses, rabbits and guinea pigs, cannot digest straws as well as ruminants, such as buffaloes, cows, goats and sheep. Ruminants have four specialised stomachs, enabling them to extract more nutrients from low-quality feed. Straw as feed for ruminants in stall-feeding is the main topic of this Agrodok, though some information on grazing is included.

1.4 The structure of this guide

Chapter 2 discusses definitions and provides basic information on animal nutrition and crop by-products, including their nutritive value.

Chapter 3 describes straw types, straw availability and storage, as well as ways in which farmers can restructure their farms to optimize their crop and animal farming.

Chapter 4 discusses using straws ‘as they are’ for feed, with and without supplementation.

Chapter 5 describes methods to improve digestibility and/or the nutritive value of straws.

Chapter 6 gives a brief review of straw-based grazing systems.

Chapter 7 discusses the economics and sustainability of the different ways of using straw. The advantages and disadvantages of using straws as feed or as composting material are briefly described here, as well as the greenhouse gas emissions caused by using straw.

In the appendices you will find a glossary, a list of useful addresses and suggestions for further reading.

2 Straw and animal nutrition

2.1 Straw and other crop leftovers

Straws can be an important part of the total crop value, especially in up-land, semi-arid and/or rain-fed lands. In these regions, grains with coarse straws are more common than those with slender ones. Straws are also important in densely populated areas and in cropping systems where little grazing land is available.

The nutritive value of coarse straws is usually higher than that of slender straws, and coarse straws tend to command similar or higher prices. Coarse grains have a higher straw/grain ratio than fine grains, so their straws make up a greater part of total crop biomass. Because of this combination – higher price, higher proportion of straw in the total crop biomass and somewhat better nutritive value – straw represents a larger amount of total crop value in maize, sorghum and millets than in rice, wheat, barley and rye (Table 1).

Readers can use the table to estimate the value of straw as part of the total crop value for conditions in their own area. In high-potential areas, where green fodder and/or concentrates are readily available, straw can be a nuisance, making cultivation more difficult, so its value is low. In low-

potential areas, straws may have a high value if they make a difference between a farm surviving or collapsing. If the main crop fails, the relative value of straw becomes high. This is more likely to happen where millet is the crop rather than rice.

Table 1: Straw value as part of total crop value: a case from Southern India

	Rice (slender straw) high-potential area	Finger Millet (coarse straw) low-potential area
Grain yield (kg/ha)	5,000	1,000
Straw yield (kg/ha)	8,000	3,000
Straw/grain ratio	1.60	3.00
Grain price (Rs/kg)	5.00	2.00
Total value of grain (Rs)	25,000	2,000
Straw price (Rs/kg)	0.40	0.60
Total straw value (Rs)	3,200	1,800
Total crop value (Rs)	28,200	3,800
Value of grain as % of total crop	89	53
Value of straw as % of total crop	11	47

Note: Values based on fieldwork [by Hans Schiere] during the 1994/95 season in South India. Rs = rupees

Tree leaves, grass cut from roadsides and erosion control bunds, crop re-growth (ratoon), banana stems/leaves, and sugarcane tops can all serve as animal feed, as can crop residues such as press cakes (Box 1). Indeed, where straws are found there are often also other types of animal feed. Therefore, they are often used in combination with other feed, or they are not used at all because better feed is available. Also, animals grazing on stubble fields tend to browse on weeds, ratoons and fallen grains.

If straw is the only feed available, its main value is that it can help animals survive the dry season. Straw does not permit high production levels. Nutritionists speak of maintenance or sub-maintenance when referring to animals that are just ‘staying alive’, even though they are losing weight.

Straws are sometimes fed to highly productive animals, but only in a very special case (see Section 7.2).

Animal productivity can refer to milk or meat production of an animal, its bodyweight, animal draught power or number of offspring (reproductive potential). Usually a high milk yield also implies that an animal will have a potentially high gain in bodyweight, and good work capacity and reproductive potential, as long as the animal is healthy. Diet is more critical for milk production however than for meat. As a simple rule of thumb one can say that:

- 10 Litres milk daily equals 1-2 kg bodyweight gain.
- Dairy cows (of 350 kg bodyweight) yielding 10-16 litres milk/day are good producers; those giving 5-10 litres milk/day are medium producers (Agrodok 14 Dairy husbandry).
- For smaller and larger animals (goats, sheep, buffaloes) you can use the bodyweight ratio. A goat weighing 35 kg (heavy for many tropical areas) eats and produces 10% of the amount that a 350 kg cow does; a goat weighing 17.5kg counts for 5%, and so on.

2.2 Terminology

People use different terms to refer to the by-products of different crops:

Box 1: Crop by-products – some definitions

Husks

The coarse outer skin of grains, particularly rice. Husks are not suitable as feed; they are useful as mulch, fuel, packaging or bedding for farm animals, including poultry.

Bran

The soft outer skin of grains, removed by milling and polishing. Part of the bran is the 'sprout' or 'germ' of the grain, often separated from the grain by industrial processing (Figure 1). The germ can be used as feed, especially after extraction of germ-oil. Bran comes in different qualities with more or less fibre. It is a valuable feed for ruminants, pigs and poultry, but of medium quality, especially when compared with full grain.

Oil seed cakes

The residues left when oil has been extracted from oilseed crops such as coconut, oil-palm seed, sunflower, soya bean, and also from rice, maize, wheat bran and germ. In general, they have much higher nutritive value than straw (Table 3) because sugars and proteins are left in the residue after the oil has been pressed out. Seed cakes need to be conserved well to avoid them becoming rancid.

Concentrate feed

Feed concentrates can be produced locally by farmers themselves as well as by commercial enterprises; they tend to be a mix of grain and residues like cakes. Concentrates have a higher concentration of nutrients than green or dry fodder.

Tree leaves

The generally nutritious leaves from trees in agro-forestry systems and/or home gardens, such as breadfruit, bananas and legume trees. Tree leaves can be collected and dried, and fed as a supplement to a diet of straw in the dry season.

Ratoon

Ratoon is the regrowth of a harvested crop, for example, rice, sorghum or sugar cane. It is generally green and fresh, unlike straws, which are usually yellow, brown and dry. Ratoon tends to be a more nutritious animal feed than straw. It is almost as good as grass and green maize, though not quite as good as cakes or weeds. Some ratoons can be poisonous and must be wilted before use (Chapter 3.3). Ratoon mostly develops after harvest, just above the roots.

Kitchen waste, or peelings and leftovers from restaurants

A very variable mix of feeds, generally nutritious, which can supplement straw. There are some risks including transmission of diseases and the occasional presence of lost sharp kitchen utensils, which are harmful to animals and humans.

All products mentioned in Box 1 can be crucial supplements to straw feeding (Chapter 4.3). While it is difficult to give accurate estimates of the volumes of by-products available, there are some rules of thumb, bearing in mind that local conditions will influence these. 100 kg paddy (threshed rice) yields 25-35 kg husks, 5-10 kg bran and 60-70 kg grains. And 100 kg oil seed yields about 60-80 kg cake, depending on the amount of oil extracted.

This Agrodok uses basic terms for animal nutrition that farmers also use (for some scientific terms see Section 2.3):

- ‘Sweetness’ is a measure of the nutritive value of straw. More sweetness means a better nutritional value.
- ‘Greenness’ signals a higher content of protein, minerals and vitamins, of which protein is generally the most important.
- Sweetness and greenness tend to go together: if sweetness increases, so does greenness.
- ‘Intake’ is the amount of feed an animal is actually eating. Intake is linked to palatability, the ‘tastiness’ of the feed: the more palatable feed is, the more an animal will eat.
- Dry matter of feed is everything it contains that is ‘not water’. Fresh green grass and leaves contain about 15-25 kg dry matter per 100 kg fresh material. 100 kg of straws can contain more than 90 kg dry matter, if they are harvested in dry conditions and are properly stored. All calculations in this Agrodok are based on dry matter.

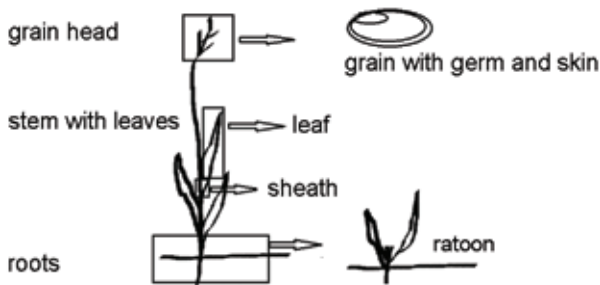


Figure 1: Main body parts of plants, in particular of cereal crops. In general, the nutritional value of stems is lower than that of leaves (except in rice). Leaves consist of a leaf- and sheath part; the leaves have more nutritive value than the sheath, except in rice. The leaves of pulses are more nutritious than the straw, but the brittle leaves are easily lost during harvesting and handling.

2.3 Nutrition

Straw can be used as animal feed if the following points are taken into account:

- Only ruminants can eat straw.
- Straw is low-quality feed, to be avoided if possible in favour of grasses, tree leaves and/or concentrated feeds made from grain waste, bran, oilseed cakes (if affordable).
- Straw can be useful, in specific conditions and/or for specific livestock, for example when there is a shortage of better feed, for low-production animals, or as special feed for highly productive animals.

Nutritive value

Farmers and academics assess nutritive value (sometimes called ‘feeding value’) and usefulness of straw in different ways. Whereas farmers in general focus on maximizing the total income of all their farm activities, academics tend to focus on maximizing the productivity of a single farming activity. Farmers discuss straw quality in terms of price, labour needs, colour (greenness) and sweetness. Technicians, scientists or researchers focus on fibre, digestible proteins and energy content.

Nevertheless, farmers and scientists also agree on a set of principles (see Table 2):

- They agree that low nutritional value of straws leads to low levels of animal productivity.
- They also agree on the importance of the intake and the amount consumed.

Nutritive value is only relevant if animals actually eat the feed that is available to them. This is where ‘palatability’ comes in. Palatability is a controversial notion, but rice straw and sugar cane tops with edges that feel like sandpaper do not make for very palatable feed. Intake of straws with low palatability can be increased by chopping or soaking them, or by supplementing the straw with tastier ingredients such as molasses or salt (Chapters 4 and 5).

Farmers and animals often have ‘to learn together’ how to feed and eat straws, especially if the animals have not eaten straws before. Start feeding small amounts of straw with green grasses before shifting to higher quantities. Animals used to tough grass can start eating straw directly.

Nutritive value in farmers’ terms

Farmers measure feed quality in terms of price, ease of handling, colour, leafiness, stem-thickness, sweetness and dustiness or mouldiness. Another aspect of feed quality is the effect of feed on animal health, especially if animal reproduction suffers from feeding poor quality straw for a long period of time. This can lead to lack of vitamin A and imbalance of minerals such as calcium and phosphorus. Mould, scrap iron (e.g. nails or iron wire used to bale the straw) or toxic weeds mixed in with straws can also present problems. Overall, however, straws can be used as feed and rarely have negative effects on animal health if supplemented with some green feed, and/or concentrates or kitchen waste.

Table 2: Nutritive value in farmers’ and academic terminology

Farmers’ terminology	Academic language
Sweetness	Many sugars still in the straw, generally indicating poor ripening and low grain yield, but good and relatively easily digestible straw.
Greenness	Leaves and stems are green, indicating that some nutrients such as proteins are still available in the straw.
Stay green	Many nutrients in stem and leaves, indicating high digestibility and many sugars.
Leafiness	Leaves are usually more digestible than stems (except in rice straw); so leafy straw tends to have better nutritive value. Farmers sometimes adjust cutting height when harvesting; low cutting yields more straw of lower quality (more stems); a higher cut yields less straw but more leaves.
Mouldiness	Fungi imply the presence of mycotoxins.

Box 2: Sweetness, fibre and digestible nutrients: some technical information

Sweetness depends on the amount of contents in the cells of the plant material. More cell content implies less fibre; more fibre is an indication of less cell content. Fibres are cell walls and consist of sugars tightly strung together, called NDF (Neutral Detergent Fibre). These sugar strings are hard to digest: they are broken down by bacteria in the rumen, the first stomach of ruminants.

The total amount of digestible nutrients (mainly sugars) in the plant cells is called TDN (Total Digestible Nutrients), which is roughly the same as the amount of sweetness (= 'sugars') in the straws. Roughly speaking, 40% TDN means 0.4 kg sweetness in 1 kg dry matter feed, as is found in very poor quality straw. Grasses and legumes can have over 60% TDN, i.e. per kg dry matter they contain more than 0.6 kg of those more easily digestible sugars! As a rule of thumb, the TDN can be converted into ME (Metabolisable Energy, which is the energy generated for the animal's body) using the following formula:

1 kg TDN = 3.6 Megacalories ME (1Megacalory = 1000 Kilocalories).

Nutritive value of potential feeds is not the only aspect that farmers take into account. This is shown by the following observations of farmers in India and the decisions they take.

Farmers in Haryana, Northern India carefully collect and conserve wheat straw, although it is not as good quality as rice straw, which they burn or sell. Wheat straw becomes available at the start of the dry season when there is no other feed and not much farm work. Rice straw, with slightly more 'sweetness' and 'juice', becomes available when farmers have hardly any time to collect and store it, and plenty of other green feed is available. The availability of labour and other feed is more important than differences in feeding value.

In a similar vein, a farmer in West Bengal asked, "Why should I waste my oil seed cakes on feeding animals when I can use them as fertiliser for my crops?"

Cell walls and cell contents: more information

Plants are made up of cells, which are composed of cell walls and cell contents (Figure 2). Cell walls are made of tough fibre, consisting of woody

materials mainly composed of tightly strung sugar strings (Box 2). Cell walls serve as a structure to support the plant's life processes: growth, flowering, and setting seed through storage of nutrients (sugars, proteins, minerals) in seeds, tubers or bulbs for the next generation (Box 2 and 3).

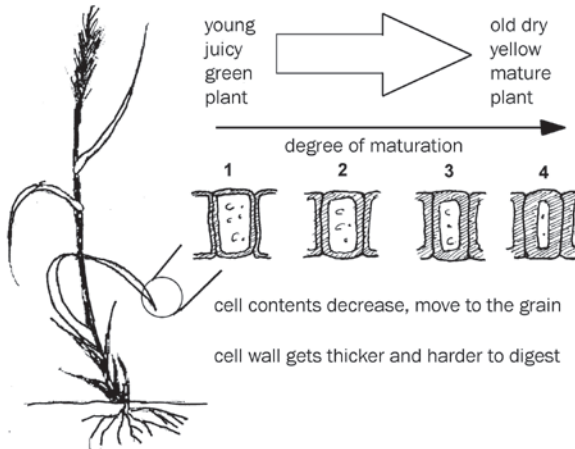


Figure 2: The plant, showing how its cell walls and cell contents change as the plant matures

Ideally, in a good harvest, most if not all cell contents have moved to the grain, leaving only the structural parts in the stems of the plant, which thus become the straw.

Fibrous materials are difficult for animals to digest, whereas the cell contents are easy for them to digest. Cell contents consist mainly of digestible sugars, proteins and minerals. Fresh plant material, such as green grass, tree leaves and legumes, has cells with thin walls that are filled with soluble and easily digestible contents. Thus, they are 'sweet' and have relatively high levels of protein. More sweetness in straws and grasses also tends to imply more greenness and better digestibility.

Cell walls thicken as plants mature: they become woodier and more difficult to digest (Figure 2). As plants grow and mature, the cell contents

move from stem and leaves into the seed, where they are stored as sugars, starches, proteins and some fat for a new plant to grow. In a grain crop the seed (grain) is usually the main reason for cultivating that crop. The farmer wants to achieve a high grain yield, accepting that the straw will be of low straw quality because that indicates that most of the cell contents have been effectively stored in the grains. A failed harvest implies that not all cell contents have moved to the grains, thus yielding straw of relatively good quality.

Box 3: The structure of straw fibres

Chemically speaking cell walls consist of cellulose and hemicellulose. These fibres form a kind of flexible, reinforced sheath, cask or hull around the cell's contents. The resulting material is held together with lignin, a material both tougher and more flexible than steel. Lignin is a small, but very strong component of cell walls and fibres (strings of cell walls stuck together). If broken, it sticks together again because the parts of lignin act like small magnets.

Just as reinforced concrete only needs a few well-placed steel rods to strengthen it, straw only needs a little lignin to be tough and flexible. Lignin production requires a lot of energy from the sun, but nature prefers to use this for building the 'next generation': the seeds. Nature does not waste energy on building materials.

Cellulose and hemicellulose are densely packed and interconnected strings of different sugar molecules. This makes it even harder for animals to extract energy from fibre during digestion. The way in which the strings of molecules are stacked and connected differs between straws of grains, pulse and sugar cane. Thus the best way to treat and feed different straws varies, as it does between straws and haulms.

Well-matured crops have less 'sweet' and 'green' fibrous crop residues (i.e. less straw). Some crops, however, leave better straw and/or they stay greener than others due to different genetics, plant management or weather conditions (Chapter 3). Sometimes grain crops are inter-planted with legumes or young grass with less cell walls and more cell contents, yielding good feed (Figure 3 and Chapter 3).

When conditions are arid or semi arid, farmers might even be left with a crop where the partially filled grains are not worth harvesting. In such conditions, farmers choose their grain type and adjust their management practices to balance the risk between grain and straw yield (Section 2.4).

Lack of sweetness, low feed intake and maintenance

Straws are hard to digest, even for ruminants. To compensate for the lower feed quality of straw animals should eat more, but in reality they eat less. They tend to eat only 1.5 % of their bodyweight when given straws, instead of the normal 2-3% of bodyweight when given fresh green feed (the percentages refer to dry matter).

As an example:

An animal weighing 350 kg can eat 1.5% of 350 kg = 5.25 kg straw (dry matter). If fed fresh green fodder it can eat 8.75 kg dry matter (being 2.5% of their body weight). An animal weighing 250 kg can eat 3.75 kg dry matter from straws and 6.25 kg from fresh green feed.

The problem of low nutrient intake from straw is two-fold:

1. Digesting fibre is hard, even for ruminants, in spite of help from microbes in the rumen; much fibre passes through the animal and leaves as manure.
2. Lack of cell contents (= lack of digestible nutrients) causes reduced rumen functioning, because the microbes in the rumen also need nutrients to help digestion.

Ruminants are animals that ‘chew the cud’, such as buffaloes, cows, goats and sheep. They have four stomachs, and the first in particular, the rumen, is full of microbes, very small organisms that help to digest fibre. But these microbes need nutrients as well. If the straw is of very poor quality (low cell content and high fibre content) the microbes do not get enough nutrients to do their digestive work. Instead of eating more low-quality straw to compensate for its low nutritive value, the animals eat less because they cannot digest it.

Table 3: Combined effect of sweetness and intake of feeds that vary in nutritive value

	Sweetness per 100 kg feed	Total feed intake per 350 kg bodyweight	Intake sweetness per 350 kg bodyweight	Intake minus maintenance requirement	Milk **	Multiples of maintenance requirement
	A	C	D = A x C	E = D-2.8*	F = E/0.350	G = (D/2.8)
	[kg]	[kg]	[kg]	[kg]	[litres]	
Very low quality straw	40 (35-45)	5.25	2.10	-0.70	-2***	0.75***
Good quality straw	50 (45-55)	7.00	3.50	0.70	2	1.25
Medium grass	55 (50-60)	8.75	4.81	2.01	5.7	1.72
Good tropical forage	60 (55-65)	10.50	6.30	3.50	10	2.25
Good temperate forage	65 (60-70)	11.38	7.39	4.59	13.1	2.64
Tree leaves & legumes	65 (60-70)	11.38	7.39	4.59	13.1	2.64

All data refer to dry matter and requirements of animals of 350 kg weight. Feeding values are reasonable estimates (with range in brackets). See also Chapter 3.

Note: Sweetness is about the same as digestibility, and the same as TDN (total digestible nutrients).

* Maintenance requirement = 2.8 kg per 350 kg bodyweight.

** Approximately 0.350 kg sweetness is needed to produce 1 liter of milk, thus with any extra 2.8 kg of sweetness 8 liters of milk can be produced.

*** An animal fed very low quality straw will produce -2 litres milk (= nothing) and only 0.75 times its maintenance level. In practical terms this means that a cow may produce some milk, but at the expense of her own bodyweight (and condition) since she does not get enough nutrients from the feed. The bodyweight that she loses is equivalent to the amount needed to produce 2 litres of milk!

To satisfy its nutrient requirements (Table 3) an animal should eat more low quality straw than it would have to eat from more easily digestible feeds (green grass, leaves, grains, cakes). But feed intake decreases with decreasing feed sweetness and greenness, as explained at the start of this section.

This lower feed and nutrient intake can be overcome in the following ways:

- By adding nutrients to the feed that help the rumen's microbes to function better.
- By accepting the low quality of straws and using the feeding strategies described in Chapter 4, including use of supplementary feeds.
- By using physical or chemical methods to 'improve' straws (Chapter 5).
- By growing other crops in-between to obtain a better mix of feed (Chapter 3).

Feeding requirements

To stay alive an animal needs a minimum quantity of feed. This is called its maintenance requirement (M). In addition, animals need energy to move, to restore their strength after being used for traction or transport, to grow, to produce milk or offspring. We can compare the amount of feed they need for all these functions with the amount of feed they need for maintenance only, expressing the extra quantity as a multiple of that maintenance requirement.

The heavier the animal, the higher its maintenance requirement, and vice versa. In theory, animals fed on straw supplemented with large amounts of concentrate can eat 3x as much as they need for maintenance (3M). For a cow of 350 kg this is enough to produce 16 litres of milk, because an animal weighing 350 kg needs 1M for maintenance and about 1M for every 8 litres of milk it produces. This figure of 3M is an approximate rule of thumb for all farm ruminants.

The term 'multiples of maintenance' can make it easier to understand feeding value (Box 4). As stated, animals can hardly extract enough nutrients from straw to satisfy their maintenance needs. When fed a straw-based ra-

tion + supplement or good quality fodders, animals can eat about 3x maintenance at most. If the animals have to be more productive (e.g. because they are used for draught power, calving or milk production, or their body mass needs to grow) they need better quality feed and special management.

Box 4: Feeding value in more detail

Animals need nutrients to survive. These are called 'maintenance requirements': what is required for them to stay alive, chew, walk, stay warm, keep their heart beating so the blood circulates, for breathing, etc. To gain weight, and to produce offspring and milk, animals need to eat more feed than they need just for survival. The main nutrients animals need are energy ('sweetness'), protein ('greenness') and minerals, e.g. calcium and phosphorus for bones, iron for blood, iodine, vitamins and other nutrients for other functions. This Agrodok uses 'multiples of maintenance' to give an indication of the production level that can be achieved using straws of different qualities (see also Table 3). Maintenance requirement is written as 1M.

Animals getting enough 'sweetness' to survive are eating about 1M. It is important to know that the heavier the animals are, the more feed they need just for maintenance. Therefore heavier animals also need a higher volume of sweetness to produce milk.

This is explained as follows:

- Animals that get less feed than they need for survival (i.e. less than 1M) lose weight and may eventually die.
- The amount of 'sweetness' a 350 kg animal needs for maintenance (1M) is about the same as the amount of sweetness it needs to produce 8 litres of milk.
- To produce 5-10 litres of milk a cow needs about the same amount of nutrients as it needs to produce 1 kg of meat. (This varies depending on the fat content of the milk, because to produce milk with a high fat content, the cow needs more 'sweetness').
- In tropical conditions cows cannot eat more than 3x the amount of kgs required for maintenance, 3M (1M for maintenance + 2M for milk). This means that a 350 kg cow cannot produce more than 16 litres/day.
- A goat or sheep weighing 35 kg weighs 10 times less than a 350 kg cow. Thus, in terms of feed requirements, 10 goats or sheep are roughly the same as 1 cow.

As a rule, straw alone is rarely sufficient for an animal, even just for maintenance. If the proteins and minerals that animals need are included in the

calculations shown in Table 3, the calculations are a little more complex, but this does not radically alter the picture.

Poor quality straw provides only 0.9x maintenance (0.9 M): in this case animals lose weight and body reserves (about 100 g/day, i.e. 30 kg in 3 months for a 350 kg animal). Many animals – both in temperate and tropical countries – are used to periodic loss of bodyweight. This can make economic sense, if feed is cheap in the lush season when the loss in bodyweight can easily be recouped. On high-input farms, highly productive animals are not used to underfeeding and they would suffer much more from low quality feed.

If animals are able to select the best parts of (coarse) straws, they can manage to eat just a little more than the amount of nutrients they need for maintenance (Table 3).

2.4 Straw quality: a second look

Though straws are generally considered low-quality feed they can be valuable in various ways in special cases:

- When no other feeds are available straws help animals through the period of feed scarcity.
- If other feed is too good for the animal's needs. Feeding legumes and very fresh grass provides nutrients for more than 2x maintenance. If farmers have a lot of green fodder and low-production animals (buffaloes, draught animals or cows yielding a few litres of milk per day) they can use straws to economize on feeding costs, without suffering a loss of productivity.
- To maintain good rumen function in farm animals on high-concentrate diets, such as those kept on farms around cities where grasses are not grown because there is a lack of land and where grain or oil mills provide a cheap supply of high quality feed. In these cases straws are sometimes transported over long distances to urban areas.
- Leaving straw and stubble on the field after harvest contributes to soil protection: straw can serve as mulch to avoid wind erosion.



Figure 3: Top: low-yielding cows and goats fed on straws in the Pakistani Punjab, producing manure and milk, and serving as draught animals. Centre: a straw market near Khartoum (Sudan) where the coarse straw of maize and sorghum is sold for livestock feeding in and around the city. Straw is a valuable source of fibre for good rumen function, not primarily a source of nutrients. Bottom: tall straw-stubble in areas with reduced grazing to avoid wind erosion.

Straws are more than just a by-product. In uncertain climates farmers tend to weigh their options carefully. They either go for high grain yields with straws as a by-product, or they balance grain for cash and food with straw for feed. These different options have implications for their crop choice. Straws from coarse grains and/or with 'stay-green' quality are preferred in semi-arid regions where their feed value is important. In high-potential regions grain yield is important and straw quality is less relevant.

3 Availability of straws: types, quantities and use

3.1 Introduction

How much straw is available and what can a farmer do with that straw? How can farmers manage their farms to serve the needs of their crops and their animals in the best way?

Choosing whether to feed straw, and how to feed it, depends on the farming system, the straws available and their cost. Feeding straw can be very useful but often it is a second choice. Better feed may be available at an affordable cost, and straws may be too expensive, or might be wet or mouldy. Straw used as feed must be well stored. Dry straw that is well stored can be kept for years without loss of feeding value. Badly stored straw quickly loses its value.

The same reasoning applies to the ‘how’ question: there are many ways of feeding straws. Feeding poor straws keeps animals alive, but at best at maintenance level only. Chopping straw (Chapter 5) is useful if labour is cheap and other feed is scarce or expensive. Allowing selective consumption (Chapter 4) presupposes an ample feed supply. Urea treatment (Chapter 5) is useful at medium (milk) production levels only, if there is a function-

ing local milk market and if the cost of treating straw is no more than half the cost of concentrates.

3.2 Types of straw

Slender and coarse straws

Differences between slender and coarse straws are summarized in Table 4. Coarse straw tends to be available primarily in upland areas with low potential, where cash for supplementation and/or straw treatment is scarce and livestock survival is the main goal. Coarse straws allow for better selective consumption (see Section 4.4) than slender straws. Normally one finds more slender straws in areas where higher yielding crops are grown and they generally contribute less to the total crop value than coarse straws do.

Cheap and expensive straws

The price of straw is crucial in determining how or whether to use it as an animal feed. If straw is plentiful and cheap, the farmer can use additives to help digestion and make it more effective, apply selective feeding, and/or treat the straw with urea (Chapters 4 and 5). In this case the animals receive plenty of feed (straw) and the way of feeding can make them eat more. However, when straws are scarce and expensive the most appropriate feeding methods are chopping, soaking or using moderate to high levels of supplementation. In such cases straw only makes up a small part of the ration, only limited amounts of straw are used and its quality becomes less important because it serves mainly as a source of fibre.

Green, yellow and brown straws

The difference between green, yellow and brown straws is similar to the differences between young and old straws. Often, brown straw has not been stored properly, while yellow suggests that straws have been well kept. 'Green' straw refers to the straws of some grain crops which stay green. Since 'green' implies more protein and minerals, 'staying green' usually indicates a better nutritive value. Plant breeders and farmers know the extra value of the green colour. Some farmers pay more for 'stay-green' straw.

Certain rice varieties can also ‘stay green’, and ‘straw’ of beans and/or pulse can also stay green for a long time.

Table 4: Differences between slender and coarse straws

Aspects	Slender straws (wheat, rice, barley, oats)	Coarse straws (sorghum, millets, maize, beans)
Agro-ecologies & farming systems	High potential areas, low-land, often irrigated.	Lower potential areas, semi-arid to arid, upland.
Nutritional characteristics	Allowing for selective consumption not easy. These straws have a lower nutritive value and chemical treatment may be useful.	Nutritive value is often higher because, in upland growing conditions, less grain fill implies better straws. Selective feeding is easier. Chemical treatment is less useful.
Farmer’s production goals	Main goal is grain, straw is a distant second.	Straw is a substantial part of the total crop yield.
Price ratio grain/straw	The grain has a far greater value; the value of straw is quite low (Table 1).	The value of the straw adds substantially to the value of the harvest (Table 1).
Political interest	Important for feed supply in urban areas, supplied by farmers from high potential areas.	Important for life in more remote rural areas; no direct impact on city life.

A special case of ‘green straw’ is the coarse straw of maize or sorghum that is harvested before the seed is fully mature. The feed value of this kind of green straw (for example after picking young unripe cobs) is higher than that of yellow straws and it can be sold and fed as green fodder of medium quality (1.7M, see Table 3). Green feed can also be harvested from growing maize by stripping and/or thinning (see Section 3.4). When harvesting before full seed maturity, whether through early picking of corn-cobs or stripping, farmers have to balance cost and value of green feed against loss of grain yield.

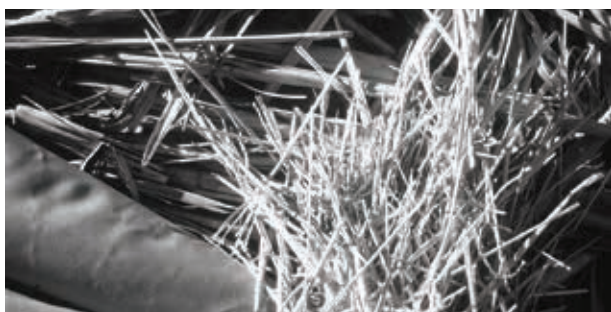


Figure 4: Top: bundled slender straw, well kept and not mouldy, central hills Nicaragua. Centre: the coarse (green) maize straw at the back is a better feed than the slender (yellow) rice straw in front, Bangalore, India. Bottom: fine straw in foreground, and better coarse sorghum straw at the back, Khartoum, Sudan.

Re-growth of a crop after harvesting (ratoon) is a very special type of green feed. Coarse straw ratoon can be cut and taken to the farm, for direct feeding or drying and storing. Slender straw ratoon is harder to cut because it tends to be shorter. Letting animals graze it is the best way to use it.

Weeds and non-grain crops

Weeds can be used as feed and green weeds are very useful feed, better than dry yellow or brown straws and stubbles. They can be grazed or collected to feed stabled animals. Some weeds are toxic but farmers are well aware of these risks in their own area.

Non-grain crops yield fibrous crop leftovers resembling straws. These include haulms from pulse and sugar cane leaves, but also dry grasses, vegetable leaves (beware of chemical residues from spraying though) and leaves of crops such as jute. Green leaves from groundnut, cassava and sweet potato resemble fresh grass, and their feeding value is enough for up to 2M. Farmers are well aware of the difference of the various straws and other green feeds. They use quality criteria such as stem thickness, juiciness, leaf content and degree of mouldiness. The major crops that yield fibrous by-products are listed below.

Sugar cane

Sugar cane holds about 20-30% of the total plant mass in its leaves. ‘Cane tops’ can be classified into leaves (not very good), sheath (bad) and pure cane top (valuable). Feeding plenty and allowing animals to select is the best way to feed them; do not chop cane tops too short (< 10 cm) as this prevents animals from being able to select. Treating cane tops with ammonia/urea has little or no effect on their nutritive value. Conservation by ensiling is possible only if the cane tops are chopped and compacted.

Bagasse is the fibrous mass remaining after the cane juice is pressed from the cane. Bagasse consists of cell walls only and is best used as fuel in the sugar factory or for soil improvement. ‘Exploding’ sugar cane fibres by steam treatment (only practical if you are near a sugar factory) is technically possible, but bagasse is not an important ingredient in animal feed, except as a source of fibre in high concentrate rations.

Molasses is another by-product of cane production at farm level. Molasses has many uses (for example, for making alcohol) and this makes it an ex-

pensive feed. In smaller quantities it can be used to sweeten straws, increasing palatability. Molasses can also be sprayed over straws as a carrier of other ingredients such as urea, minerals or medicines, for example for deworming. Molasses is a basic ingredient in urea-molasses licks and lick blocks (Table 7). Feeding molasses in large quantities as a concentrate is technically possible but uncommon in livestock farming because of its alternative uses.

Pulses

Pulses or legumes (beans) produce ‘straws’ that can be used as good feed. Here too, there are differences between the separate parts: stems (low nutritional value, about 1M) and leaves (medium to good quality, 1-2M). The leaves have the highest nutritive value, but they must be properly harvested and stored to keep them as intact as possible. Often they are brittle and crumble in the field, leaving the farmer with just the stems. Urea treatment has no effect on the nutritive value of bean straws.

Green haulms and leaves

Green haulms and leaves are often dirty and soiled, increasing risk of moulds. If clean, haulms and leaves, such as those of cassava and sweet potato vines, and from trees, have a similar nutritive value (2M) as that of green grasses. They are very nutritious but may be toxic (e.g. containing prussic acid), as in the case of cassava leaves and sorghum ratoon.

Dry grasses

Dry grasses resemble coarse straws (with a nutritive value of about 1M). They can be cut and stored but grazing them is often easier. Urea treatment has only a slight effect so this is not recommended. Selective feeding is an option if there is plenty of dry grass. Probably the best option is to feed them as they are, dry and untreated, if they are in good supply, or chopped and/or soaked if they are not.

3.3 Straw quantity, some details

Nutritive value

The straw from 1 ha of a grain crop can feed one cow for a year at just below or about maintenance level (0.9-1M). But straws are often not sweet and green enough to keep an animal alive over extended periods of time. Some weight loss might be acceptable, but feeding only slender straws for several months would affect animal health, and productive and reproductive capacity. Coarse straws, if collected and stored well, can provide just enough nutrients to keep animals at maintenance level or slightly higher, especially if straw is plentiful and the animals can select the better parts.

Straw quantity

Straw quantity is best measured on the spot but it can also be estimated. Exact ratios are best based on data collected in the field, as figures will differ depending on weather conditions and harvesting practices. As a rule of thumb, a yield of 4000 kg (fine) grain can roughly be associated with 6000 kg straw. Grain yields of sorghums and millets can be lower, but because these crops produce more straw per kg of grain, the total amount of straw harvested is often about the same.

Box 5: Calculating straw quantities from grain crops

Straw/grain ratios can easily be measured in the field but some rules of thumb are useful.

Slender straws

For slender straws and good harvest conditions the straw/grain ratio is mostly lower than 1.5:1. In other words, the farmer gets no more than 1.5 kg straw/ kg of grain.

Coarse straws

For coarse straws, the straw/grain ratios tend to be higher, even greater than 2:1, i.e. over 2 kg straw/kg of grain, especially where growth and harvest conditions are bad. Under such conditions the straw/grain ratio is very high because there is little grain.

Harvest index

Another way to estimate the amount of straw is to use the harvest index: the proportion of grain (in %) of the total biomass above the surface. Basically the harvest index is the straw grain ratio upside down. Harvest indexes are usually around 30–50%, which means straw/grain ratios of 2:1 (or higher). If the straw/grain ratio is 1.5:1 then a grain yield of 4000 kg/ha per season can result in 6000 kg of straw if cut at ground level and handled well.

Animals can eat up to 1.5% of their bodyweight in straw. That means that a cow with a bodyweight of 350 kg will eat about $0.015 \times 350 = 5.25$ kg straw per day, or nearly 2000 kg per year. Thus a harvest of 6000 kg straw is roughly sufficient to feed three 350 kg cows for one year, if all the straw is harvested and stored well! In practice, straw yields per hectare per year may be higher or lower, with higher or lower grain yields, or there may be two harvests per year.

Straw losses

Straw is often burnt or left to decompose in the field. A light burning makes it easier for grazing animals to select leftover grains and weeds. Burning saves labour, it may reduce incidence of disease and pests and it can help cultivation of the field, but this is at the expense of soil fertility and soil life (Chapter 7.3). Fierce burning of straws can destroy the ratoon and weeds but fierce burning is uncommon. Most straw is left spread around or in rows and it burns fast.

Letting animals graze straw is easier than collecting, transporting and storing it, but it is hard to guess how much the animals really eat during grazing. They trample a lot of the straw, making it unpalatable and reducing the amount available. Stabled animals waste feed by selecting the better parts (leaves and tops) and leaving the stems. Straw is lost also if it is not harvested dry and stored properly.

Ratoon

Grain crops usually produce some ratoon, the green, nutritious re-growth after harvesting and with a nutritive value close to that of grasses. Farmers

may choose grain varieties that yield more ratoon. The amount of ratoon harvested depends on the level at which the crop is harvested (cutting the crop at ground level just above the roots, or at a much higher level). This also has an effect on the quality of the ratoon, because the lower parts are usually tougher and dirtier.

Ratoon can easily amount to a quarter of the main crop; 500-1000 kg ratoon per ha is realistic for sorghums and millets, depending on variety, rainfall, time after harvest and cutting height. Fine grains yield less ratoon, but 3000 kg straw per ha + 10% ratoon (i.e. 300 kg) is worth harvesting!

Some ratoons may be poisonous especially from sorghum, and perhaps some millets. A lush sorghum regrowth in particular can be poisonous, as happens when a dry spell is followed by good rains. The risk is real, but it can be easily overcome by wilting green ratoon shoots in the sun for a day or so. In some countries it is common practice only to start using sorghum ratoon when it has grown taller than 50 cm.

Grazing of stubble and ratoon, including weeds and fallen grain may form a significant feed source. Much duck keeping in the paddy fields of South-East Asia, and sheep grazing in Australia and the Middle East is based on fallen grains. Farmers may manage grazing in such a way that they ensure that more productive animals get a better graze – more grains, ratoon and weeds – than less productive ones.

Weeds

In many poor rural areas labourers take home weeds and/or straws as part of their daily wage. Feeding green weeds to animals as part of a straw ration can be very beneficial, even in small quantities, as weeds are a good source of minerals (nitrogen and phosphorus) and vitamins (especially vitamin A, which is necessary for good fertility).

Failed crops

Straw quantity and quality of (partly) failed crops due to drought is usually higher than normal. A failed crop (little or no grain) has a higher straw/

grain ratio than a successful crop. The straw of a failed crop also contains grain that was not harvested, so it has a higher nutritive value. Moreover, stems and leaves of a failed crop are sweeter and greener because less sugars and proteins have shifted into the grain. Finally, a failed harvest due to drought means the straw will store better. Failed crops due to floods tend to yield larger, juicier and greener straw and weeds, but harvesting and storing them is difficult. The crop can be ensiled or treated, though both these are complicated processes (Chapter 5).

Dry matter content

Fresh grass, weeds or tree leaves tend to have a dry matter content of approximately 20% or less, so 10 kg fresh feed will yield 2 kg dry matter. Most straws are almost dry on harvesting; they usually contain about 90% dry matter, so in general 10 kg straw = 9 kg dry matter.

3.4 Straw types and cropping practices

Farmers can use straws of different quality to feed their livestock more efficiently and to compensate for lower nutritive value of other feed sources. However, other factors including climate and crop practices such as planting distances, mixed cropping, thinning, weeding, harvesting and storage are likely to have a greater influence on straw quality than differences in the types of straw. Farmers cannot change the weather, but they can take some measures to reduce its effects (e.g. wind breaks, shade crops, timing of cropping patterns). They can also influence many aspects of soil quality (e.g. soil structure, soil fertility, organic matter content, drainage capacity, plant coverage, contour ploughing). Finally they can choose the type of grains to grow and their crop husbandry practices.

Influences of climate

In wet climates, collection and dry storage of straws is difficult, but in these regions green feed is often available, unless straws are in high demand either because of high population density, where farm plots are small, or because intensive cropping patterns make it difficult to find sufficient green feeds.

In wetter areas slender straws are more common, whereas coarse straws tend to be found in semi-arid areas with rather unpredictable weather and frequent harvest failures. In such regions the demand for animal feed (and the price of straws) tends to be higher due to the lack of green feed, for example, to feed working animals at the onset of the rainy season. In many regions straw quality depends mainly on proper post-harvest management.

Choice of straw type

Farmers can base their choice and management of grain crops on the potential grain yield, and the quality and quantity of straw they want to produce. Different types of grain crop produce different quantities and qualities of straw, but it is important to remember that even the same crop variety does not always produce straw of the same quality and quantity. Using more fertiliser and creating more favourable growing conditions will lead to increases in the volume and quality of the straw produced.

Some straws stay green longer and retain their nutritive value better than others. In comparison to the (slender) straws of rice and wheat, coarse straws from maize, millets and sorghums tend to be better quality and fetch a higher price. Especially in areas with highly variable weather conditions, farmers who are accustomed to harvest failures often want to be sure that they can at least harvest enough good straw. They tend to prefer (coarse) grains that yield more and better straw.

Some 50 years ago, high yielding varieties (HYVs) were introduced, and this affected the quantities and quality of straw produced. Many people think that newer, short-stem grain types yield less and poorer quality straw than the older varieties. Although at the level of an individual plant HYVs produce relatively less straw and more grains, HYVs as a crop produce a much higher yield in tons per hectare. Therefore, not only the total grain yield is higher, but also the total quantity of straw. Moreover, new HYVs tend to have less stem and more leaf, resulting in better overall straw quality, with the possible exception of rice.

Crop husbandry

Cropping practices that affect straw quantity and quality include:

- planting density
- stripping
- intercropping
- harvesting
- post-harvest practices

None of these practices can be seen in isolation. They are all related to other issues such as cropping patterns, choice of grain, soil tillage, labour input, use of farm machinery and farm economics. Farmers may want to harvest close to the ground to get more straw, but a lower cutting height might be impractical. Others consider the upper part of the straw better than the lower sections. Local custom often determines harvesting practices such as cutting height and storage, even though the reasons may be out-dated and counterproductive.

Planting density

Planting density refers to the number of plants per unit area. High density means denser crops, thinner stems (less woody, ‘thus’ juicier) and fewer weeds. The higher costs of seed and labour must be offset by higher grain and straw yields. Local conditions determine whether higher planting density will be worthwhile and farmers should calculate the costs and benefits. Uncertain rainfall, local soil types and the presence of vermin also affect sowing/planting practices.

Stripping

Stripping, or ‘thinning’, is the practice of picking early, lower leaves, which are still green but starting to yellow as plants mature. Upper, younger leaves are left to produce sugars for the grain while the lower, maturing leaves are picked and fed directly, or dried for later use. Stripping is labour intensive and it affects grain yield; farmers have to balance labour input, crop yield and the needs of their animals.

Intercropping

Intercropping and relay cropping are variations on what is often called mixed cropping. It is a matter of re-designing the farm to achieve a better combined yield from crops and animals. There are a number of options:

- It is possible to increase the fodder yield from straw by planting legumes towards the time that the main crop starts to ripen. The legumes overgrow the standing straw, improving its nutritive value. This provides animal feed of better quality, unless poor management or high humidity causes mould.
- By sowing a mixture of grains, all of which ripen at different times, a farmer can ensure at least some harvest when conditions are uncertain. It also means (more or less) green straw will be available for a longer period, improving the total nutritive value.

Other forms of mixed planting also help provide (green) feed besides straw, including:

- Alley cropping, a variation of intercropping where, for example, maize or sorghum are planted in rows at a distance of 1-2 m and soil cover is ensured by planting lower crops, e.g. beans or sweet potato, between the taller crops. This way a steadier supply of green feed becomes available.
- A fodder crop such as mustard or berseem clover can be planted when grains do not do well (as is done in the northern plains of the Ganges and the Nile delta). These fodder crops may also be useful as rotation crops, adding nutrients or suppressing weeds, pests or diseases and thus helping the main crop.

Harvesting time and method

Harvesting time of straw depends on how a crop ripens and on the grain yield expected. These in turn depend on the weather and the availability of labour and alternative feeds. Each stage of growth involves particular choices, depending on local weather conditions, markets and traditions. For example:

- Early in the growing season a farmer with crops and (grazing) livestock can decide to graze; a light graze even encourages the crop to re-sprout (tiller) better while the animals get valuable feed.

- Later in the season, if rains make a good grain yield likely, the farmer may focus on grain. If there is little rain the farmer may choose to go for straw.
- Straw harvested in rainy conditions is more likely to turn mouldy than straw harvested in dry weather. Leaving straw in the fields decreases its feed value, e.g. rain will wash away nutrients in the straw; plant sugars remain in the plant so moulds can grow.
- Height of cutting affects the quality and quantity of straws harvested. A high cut saves work and may yield better straw. Although this leaves less straw for feeding, it may mean there is more straw and ratoon left for grazing in the field.
- Of a different order, cutting height and/or grazing are becoming issues in erosion control. In south-west Australia and the Middle East, grazing has been reduced and taller stubble left standing to reduce wind erosion (see also Chapter 7).

Traditional systems allow animal owners, often from elsewhere, to graze straw and stubble. But around the world, crop farmers increasingly want to use their own straw, and pastoralists are finding it harder to pursue their roaming lives.

3.5 Post-harvest practices

Post-harvest practices include straw gathering, transportation and storage. Straw for feed should be removed from the field as soon and as cleanly as possible so that it can be properly stored on the farm. Sun and rain both have a negative effect on sweetness. Rain washes out nutrients and causes mould. Fungi affect palatability; they may also cause dry matter loss and affect animal health. Mouldy straw is unfit for feeding; it can only serve as animal bedding or mulch.

Proper storage should protect the straw from sun, rain, roaming animals and vermin such as rats, mice and insects. Rats and mice love to breed in stacked straws from (partly) failed crops that still contain some grain.

Basics of good stacking

- a. Stack dry and clean straw so that it is not in contact with the ground, to avoid moisture and vermin getting into the stack.
- b. Prevent rain from entering by ‘combing’ the sides of the heap and by providing a cover.

Combing the sides means using well bundled straw: packed tightly and with no straw sticking out. The stack can be covered with a tarpaulin, plastic sacks, palm leaves or zinc sheets, for example.

Straws (haulms) from pulse crops such as beans, grain or soybeans have brittle leaves that easily shed when handled and become mouldy when stored. If they are good quality and are dried well, their higher nutritive value may mean it is worthwhile storing them in bins or sacks in a dry place.

Some farmers simply ‘store’ straws on the roof of their house or stable, keeping them safe from roaming animals but exposed to sun and rain. This is definitely not good for the nutritive value of the straws but it may be the easiest solution in practice.

4 Straw in stall-feeding

4.1 Different feeding systems

Animals are kept in various ways depending on climate, culture, cropping patterns and markets. Generally farmers use three different practices to raise ruminants:

- **Stall-feeding**

The animals are kept and fed in a stable most of the time or continuously.

- **Mixed**

The animals roam around (or are herded) outside for part of the day (or year), returning to the stable at night – or in the dry season – to consume additional (straw) feed.

- **Grazing**

The animals are herded to areas where grass grows after the rains or where there are crop leftovers, stubble, ratoon or weeds.

Which feeding methods farmers choose depends to a large extent on the type of farming system they are practising. Resource-rich farmers generally use a higher level of inputs, because they can afford to buy feed and fertilisers and can alter the amount of feed they give to their animals. Resource-poor farmers have to make do with the few resources they have

access to; they have to 'live with poor conditions', which may include low-quality straw.

Box 6: Living with low production levels

Resource-rich conditions

Under resource-rich conditions farmers can afford to buy the best quality feed and can thus achieve high production levels from their animals. Resource-rich farmers within or near towns have access to good fodder (often green maize and sorghum straws from rural areas), leaving the lower quality slender straws to farmers in the countryside.

Resource-poor conditions

Under resource-poor conditions farmers are not easily able to buy better feeds, so they adjust production levels to the feed available, taking weight loss of their livestock or lower milk yields for granted. If they sell their better quality straws to richer farmers, the quality of straws available for their own livestock decreases.

Adding concentrates to feed can compensate for the poor quality of the straw being fed: if all other conditions are favourable, cows can produce 1-1.5 litres more milk per kg concentrate that is added to their feed. If 1 kg concentrate costs less than the selling price of 1 litre milk, supplementation is profitable; if it costs more it is not.

'Living with feed as it comes' and thus accepting that production will be low can be a wise decision, certainly where the cost of increasing production would be too high. Feeding animals only straw may cause them to lose weight, but it keeps them alive until the rains arrive (Table 5).

The same reasoning applies to animals fed for live weight gain or for use as draught power. However, there are differences. Weight loss due to underfeeding can be compensated for by the accelerated growth that happens when normal feeding is resumed. Sometimes, when farmers can sell sheep at high prices during religious feasts, buying feed supplements to fatten their sheep can be profitable. But it is important to know that underfeeding during a lactation period not only lowers milk yields during that period but also during later lactation periods. Therefore concentrate feeding might pay off, if the farmer wants to maintain future production levels.

4.2 Using straws ‘as they are’

Methods for using straws as feed for animals kept in stalls, based on straw quality ‘as it is’, include:

- ‘Living with it’: i.e. adjusting animal production to available feed.
- Supplemental feeding: adding missing nutrients in increasing amounts.
- Permitting selective consumption.

A farmer can adjust to a feed shortage (quantity and/or quality) by:

- Choosing adapted livestock, lower-producing but hardier animals, zebu or zebu-crosses rather than exotic breeds. Exotic cattle suffer much more from feed shortage and low feed quality.
- Choosing small livestock (goats or sheep) rather than cows, especially when feed quality is adequate but supply is limited. Remember, a 35 kg goat eats and produces roughly one tenth of what a 350 kg cow eats and produces.
- Feeding strategically, giving the best feed to the best animals (pregnant or lactating ones) while allowing weight loss in the other livestock. At the start of planting, which is often at the end of the dry season, the supply of animal draught power in particular can be critical. But this is usually also when feed scarcity is most severe. Feeding the draught animals might then be given priority.
- Accepting temporary weight loss and using straws as cheap feed for survival purposes. Higher live weight gains and/or milk yields can be achieved in periods when there is plenty of cheap feed (Table 5).
- Adjusting the time and/or frequency of calving/lambing to coincide with feed availability.
- Moving pregnant and lactating animals to places with more and better feed. It is common for animals to be milked in or near cities and returned to the countryside to recover and calve.
- Culling or selling animals, often at (very) low prices, in periods of feed scarcity. Straw together with tree leaves and kitchen leftovers allow the remaining stock to survive. As a farmer from arid western India put it: ‘We have no feed shortage, we sell our animals before the dry season gets severe!’

Table 5: Methods of herd adjustment in response to different availability of straws and concentrates over seasons and places, with basic feeding strategies

Feeding situation	
Seasonal quality differences, but always at least plenty poor quality feed	Constant lack of quality and quantity
Herd adjustment strategies	
Choice of animals and herd size	High yielders (meat and milk): goats, sheep and cows, using little straw and a lot of supplements
Adjusted calving and kidding, combined with seasonal culling	Raising/rearing of young stock in other regions with enough feed and no markets
Large herds; low yield per animal; manure has value	None of the herd adjustment strategies are useful
Feeding strategies	
Value of straws and poor grasses for survival	Small amounts of straws and grasses used for good rumen function, not as bulk feed
Main feeding strategies	Moderate or even substitution supplementation, + straw mainly as source of fibre for rumen function
Examples of such feeding systems	Areas with good access to markets, usually near big towns and harbours

4.3 Supplementation

Low feeding value of straws – as they are – can be overcome by supplementation; that is by adding nutrients, such as bran, cakes, grain, or green leaves. We distinguish three levels of supplementation (Figure 5):

1. **Catalytic supplementation** – Adding supplements in small amounts (10-15% of the total feed) to boost digestion by improving rumen functioning.
2. **Moderate supplementation** – Adding missing nutrients in modest amounts (15-60% of the total feed).
3. **Substitutional supplementation** – Using supplements as a replacement for the low-quality feed, at levels above 60 % and even up to 70% of the ration.

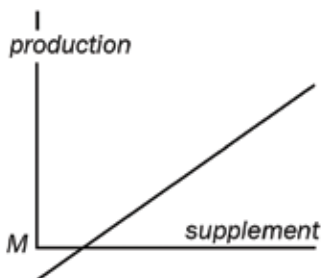
Catalytic supplementation

Ruminants digest straw in their first stomach (the rumen) with the help of microbes, which cannot function properly on straw alone; microbes need nutrients as well. Small quantities of critical nutrients help to ‘quick start’ the animal’s rumen. Catalytic supplementation aims to supply small quantities of those critical nutrients.

Catalytic supplementation to improve feed intake and digestibility is used in three well-known feeding methods (see Table 6):

- lick blocks
- licks
- spraying straw with urea

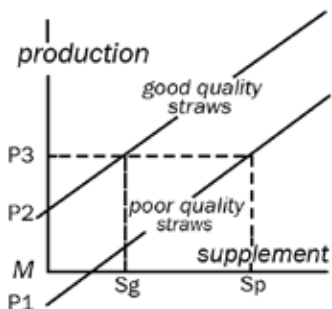
Many small farmers use tree leaves or kitchen waste in small amounts (5-15% of total feed) as a catalytic supplement. Above 15% of total feed, the supplementation becomes ‘moderate’ and the catalytic effect might be lost; it then becomes moderate supplementation, where there is no booster effect.



A: The effect of supplementation on animal production

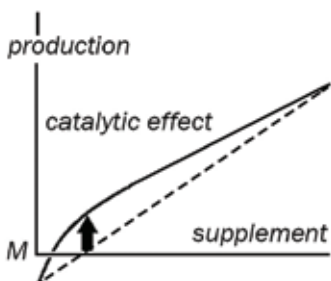
Production (vertical axis) increases in a straight line as the amount of supplement increases (horizontal axis).

M = maintenance level (in practice the curve is not straight, see Figure C and D).



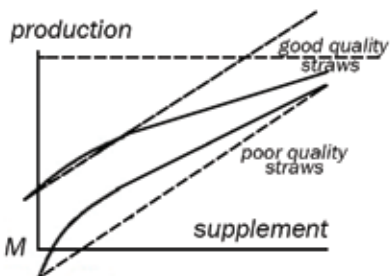
B: The effect on production of feeding poor quality straws and of feeding good straws/grasses

Animals fed only on poor straws lose weight. P1 is less than maintenance. The animals need supplements to maintain weight. They can gain some weight (P2) however when fed good quality coarse and/or treated straws. To achieve the same level of production (P3) using only poor straws, more supplements (Sp) need to be added than when fed better quality (or treated) straws (Sg).



C: The effect of catalytic supplementation

Low (catalytic) supplementation levels can disproportionately (see arrow) increase the amount of production achieved from feeding poor quality straws and grass. Broken line represents the solid line in Figure A.



D: The effect of substitutional supplementation

In this case, supplements make up most of the ration. Difference in quality between poor and good straws becomes less important and the effects in terms of production approach each other. Broken lines represent the solid lines in Figure B.

Figure 5: Effect of three levels of supplementation on animal production

Table 6: Different ways of providing catalytic supplementation

Method	Urea molasses lick blocks	Urea molasses licks (roller drums)	Urea sprayed on straw
What	Molasses + hardening materials + urea (nitrogen) + any of the following: minerals, deworming medicine, small amounts of special feed e.g. fish meal, cotton seed cake	Urea + other nutrients dissolved in molasses, with or without mineral supplements and/or medicines	A 2% solution (2 kg urea in 100 liter water per 100 kg dry straw)
Advantages	Enhances use of plentiful poor roughage. Licking = slow and steady intake of catalytic nutrients to stimulate rumen (and to avoid toxic levels of urea intake)	Licking = slow and steady intake of catalytic nutrients to stimulate rumen (and to avoid toxic levels of urea intake)	Spraying ensures urea is evenly distributed over straw. Animals cannot eat the sprayed straw fast enough to ingest dangerous quantities of urea. Molasses can be used instead of water to improve straw intake.
Disadvantages	Irregular intake increases risk of animals consuming chunks of the block. Too much urea is toxic.	High intake of 'soft' licks can easily become moderate supplementation rather than catalytic supplementation.	Beware of ants if using molasses. Take care animals do not drink the urea solution!
Where used	Rangeland grazing	Rangeland grazing	Stall feeding

NOTE: All these forms of catalytic supplementation to increase straw intake are useful only if there is plenty of straw. If there is not, the feeding stocks will be exhausted before the end of the season.

Catalytic feeding is useful if it means the difference between starvation and survival, if the catalyst is cheap and if there are plenty of straws or low-quality grasses available, such as in rangeland grazing.

Catalytic feeding is counterproductive if it is used to increase intake when straw supply is restricted, because it leads to a greater feed shortage towards the end of the lean season.

Moderate supplementation

Moderate supplementation is a way for farmers to add missing nutrients while making maximum use of straws and grasses to feed their cattle. Between 20 and 60% of the total ration consists of the supplement, depending on what the main (or staple) form of feed is. If this is lush and young grass, with high sweetness and low fibre content, up to 50% of the total ration will consist of the supplement. For coarse straws with high fibre and much less sweetness, the supplementation is likely to be closer to 60% or even 70%. In moderate supplementation where every 10 kg of feed contains 2-6 kg of supplement, the animals' response to the supplement is fairly constant (see the straight line in Figure 5B).

Starchy supplements, such as bananas or cassava rejects, have a similar protein content to that of straws. They can only be used as animal feed if protein is added, e.g. in the form of legume leaves or cakes. Supplements such as (broken) grains or bran have medium levels of protein (8-14 %), but oil seed cakes can contain 20-40 % protein.

The aim is to obtain the maximum effect from all the feed (total ration = main/staple ration + supplement), accepting that adding some kind of concentrate will decrease the amount of straw the animals eat and therefore also the amount of nutrients they gain from this.

Substitutional supplementation

Some farmers in 'resource rich' conditions feed beyond 50-70% supplement in their rations, e.g. near cities where concentrates are cheap and straws expensive. Some straw is needed to prevent acidosis caused by high concentrate levels. Acidosis is a rumen disorder (see Glossary).

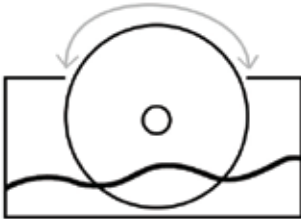


Figure 6: Top: an old tyre used as a feeding trough to feed a mix of molasses, mineral medicines or protein-rich concentrate such as cotton seed cake (not urea mixture!). Centre and bottom: a photo and diagram of a rolling drum placed in a trough. This enables the animals to lick the molasses-urea mixture in small quantities, ensuring steady intake but avoiding urea poisoning. (Photo source: <http://cadfor.com.au/murraygreys>)

Table 7: Suitability of the three supplementation strategies

Supplementation strategies	Catalytic supplementation	Moderate supplementation	Substitutional supplementation
Function of straws	Cheap staple feed	Cheap staple feed	To prevent rumen disorders
Level of production	Survival and (sub-) maintenance	Moderate 1-3x maintenance	High 3x maintenance or more
Examples of feeding systems	Rangeland, stall-feeding. Use of lick blocks (on rangeland) and/or urea spraying (in stall-feeding).	Grazing and stall-feeding for high-input systems with good access to buying concentrates and selling produce (milk, meat).	High input systems with stall-feeding under resource-rich conditions near cities.

4.4 Selective consumption

Selective consumption is a management practice that farmers can use to actively influence the quality and quantity of straw eaten by their animals, while not treating the straws in any way. If there is sufficient straw available, it is good practice to allow animals to select the better parts to eat, such as leaves. Selective consumption is a widely used practice, but is often not well understood.

Both farmers and animals play a role in selecting feed, which is the basis of selective consumption. Farmers can decide to select the type of feed they give to specific animals as in ‘strategic feeding’. Farmers can also decide to feed either in a ‘plentiful’ or ‘stingy’ way. In ‘stingy’ feeding (e.g. when there is only a limited straw supply) an animal has to eat whatever it gets, and selection is not possible. In this case straws can be chopped, or mixed thoroughly with other feeds to ensure that the amount of feed that is refused is kept to a minimum. In ‘plentiful’ feeding (when there is plenty of straw available) the animals select themselves, choosing between

leaves and stems or between green and dry or tough straws. In this case it is counter-productive to chop straws.



Figure 7: Example of selective consumption: cow has to survive on coarse straw stems but is allowed to select; the leftovers are for the bulls.

Selective consumption is a particularly relevant practice for coarse straws. If animals are given large amounts of feed they will refuse to eat some of it. This can amount to more than 30% of the total feed, so the straw that is left over can be chopped and fed to unproductive animals, or used as bedding, mulch or manure. Goats and sheep are very good at selective consumption; cows and buffaloes are not so good at selecting leaves and stems, even from slender straws. Selective consumption from coarse straws is easier than from slender straws.

Animals always select their feed unless prevented from doing so. Chopping and thoroughly mixing the straw forces animals to eat the poor-quality parts as well. But total intake goes down if animals are forced to eat the poor quality parts.

5 Straw treatments

5.1 Introduction

Farmers may decide to treat straws rather than feeding it ‘as it is’ to their animals. The decision will depend on the price of feeds and the production levels of the animals. Straws, whether green, yellow or dry, can be treated in several ways to increase sweetness, greenness, intake and/or palatability.

The main treatments are:

- **Physical treatments** – chopping, soaking, grinding, pellet-making, steaming;
- **Chemical treatments** – using caustic soda or ammonia compounds (especially urea);
- **More complex treatments** – using fungi, enzymes or other agents.

Some of these treatments are well known and practical; others are ineffective, impractical or too costly. Chopping and/or soaking methods have been used for many centuries. Chemical treatments have been used for the last fifty years. Some chemicals, while they are likely to be impractical in field conditions, are mentioned here simply for the sake of completeness.

Remember: no treatment or feeding method is suitable in all conditions. Economic considerations vary depending on the availability (and cost) of straw, labour, chemicals, and other feed, and on income from animal production. The most practical kinds of treatment are chopping, soaking and treatment with urea. Other methods are only slightly useful, if at all. They are mentioned briefly because people in the field may have heard about them.

5.2 Physical treatments

Chopping and soaking

Chopping and soaking are traditional farmers' practices; their main objective is to increase intake of a feed the animals would not otherwise eat. Chopping straw is labour-intensive and farmers need to use knives, choppers or larger equipment to reduce straw particle size, generally to 2-5 cm. Soaking is a less labour-intensive way to increase straw consumption.

Soaking and chopping are often combined, i.e. by soaking chopped straw in a container with plenty of water or in the feeding trough (not longer than overnight). In that way the animal gets its drinking water at the same time. Longer soaking can cause straw to rot and water-soluble sugars are lost when the water is drained off.

Chopped straws can also be mixed with other feed, such as concentrates, molasses or salt. Increased palatability is probably the main effect, as the hard, silica-rich edges of (especially rice-) straws are softened in this way. Chopped straws are easier to mix well with other feed, thus reducing hardness, dustiness and wastage.

Another objective is to stretch straw supply by preventing selective consumption: animals are forced to eat parts they would otherwise refuse. Tall, bushy grasses are also chopped to ensure that animals eat stems as well as leaves. In this way chopping and/or soaking can stretch limited feed supplies. But if enough feed is available, the best way to increase intake is to feed plenty and let the animals select the better parts.

The effects of chopping and soaking on digestibility (= sweetness) have not been studied in detail, but they are probably not significant. There are exceptions however: in some places the well water is so alkaline that soaking causes a kind of chemical treatment (Chapter 5.3). Chopping straws finely, to less than a centimetre in size, can increase both intake and the rate of passage through the animal. But faster passage also means that less digestion takes place and fewer nutrients are absorbed, so extra work on finer chopping or grinding can be counterproductive.

Some harvesting and threshing methods can cause straw to break into small parts. Examples are bhoosa (short wheat straw from Northern India), finger millet straws in Southern India, straws from mechanical harvesting, and the crumbled brittle (but nutritionally valuable) leaves and stems of beans and pulse.

Steam treatment

Steam treatment can be a practical method of improving straw quality where there is access to steam and steam technology, e.g. near sugar-cane mills that are also a source of bagasse. Bagasse fibres are very tightly packed and therefore do not react to caustic soda and/or ammonia. Steam treatment involves heat and pressure, which ‘explode’ the fibres, making them more brittle and therefore more easily available to rumen microbes.

Steam treatment costs resources and money: for steam equipment, fuel and transport. Some dry matter is lost in the process as well, so costs have to be weighed against benefits. It is only really feasible under very specific economic and technological conditions. It is not practical to carry out steam treatment on a small farm. Even if the bagasse can be taken from the sugar mill back to the farm on the carts or lorries that collected the cane from the farmers’ fields this is an expensive and time-consuming process.

Steam-treated bagasse can be marketed near larger towns where commercial dairy farmers may buy it for its fibre. Treated bagasse should not cost more than locally available straws because its nutritive value hardly exceeds

that of straws. Moreover, bagasse has other profitable uses, for example in papermaking or as fuel for sugar-mill boilers. Bagasse, treated or not, is even exported for dairy cattle that are fed high amounts of concentrate, but this is beyond the scope of this Agrodok.

Other physical treatments

Other physical treatments such as grinding, pelleting, extrusion and/or pressure are not very relevant in rural areas.

Grinding straw into very small pieces (much smaller than 1 cm) involves costs for machinery and energy. The small particles pass through the rumen quickly and are not well digested, so this treatment is counterproductive.

Pellets can be made in very low, medium or high densities. Pelleting ensures good mixing, so animals cannot consume selectively. It reduces straw volume and thus also transport costs. Medium-density pellets, also called briquettes, are a few centimetres in size and the individual particles stick together. High-density pellets are one centimetre or less in size. They are produced in large, costly machines that require much energy and special technology. Consequently they are not practical for field conditions and resource-poor farmers.

Baling, which produces bales of low density, is not really a method of pelleting. It does however considerably reduce the volume of straw without having any effect on nutritive value or intake. Baling can be done by machines on larger farms and/or by traders. Resource-poor farmers can make bundles or use efficient stacking methods to keep the straw dry and vermin-free, or to sell it if they wish.

Pressure and/or extrusion involve applying high pressure followed by a sudden release of the pressure to explode the straw fibres.

Pressure, steam and pelleting can be useful ways of producing specialist feedstuffs for rabbits, poultry or calves, or special concentrate mixes, but they are not relevant techniques for resource-poor farmers.

Table 8: Suitability and effects of physical treatments (excluding pelleting, bailing and pressure)

Effects of treatments on:	Treatments		
	Chopping	Soaking	Steaming
Intake	Animals are forced to eat what may not be very nutritious	Animals are forced to eat what may not be very nutritious	Intake of steamed feed is higher than of untreated feed
Sweetness (digestibility)	No effect	No or little effect, except if the water is very alkaline	Some effect
Greenness	No effect	No effect unless the water contains special nutrients	No effect on protein or mineral content
Usefulness & special requirements:			
	Stretches feed supply in low input systems; ensures even intake of the mix of straws and other feed (also in high input systems). Much labour required	Useful to stretch feed resources, to soften the feed, to enhance palatability, to avoid selective consumption. Can be combined with supply of drinking water	Only useful near sugar cane mills with access to steam (technology) and bagasse. Unsuitable for poor farmers; could be used as source of fibre in high concentrate rations



Figure 8: Different ways of using straws as feed. Left: a set-up for steam-treating sugar cane bagasse in India. Right: two farmers in Sri Lanka treating straw with urea.

5.3 Chemical treatments

The most common chemicals used to improve straw quality are caustic soda (sodium hydroxide) and ammonia. Caustic soda is effective but not practical in tropical conditions: it is hard to obtain and hazardous to handle. Urea is easier and safer than caustic soda, and is a good source of ammonia (nitrogen), mainly because it is usually available as fertilizer.

Terminology and processes

Chemical straw treatments are often called ‘ensilage methods’ but ‘treatment’ and ‘ensilage’ are quite distinct processes. Treatments are chemical methods to improve nutritive value of the feed. Ensilage is a way of storing green grass, maize or sorghum fodder and it means putting grass or straw into a ‘silo’, starting a microbial fermentation.

Box 7: Chemical treatment to conserve and improve feed: a little history

Alkali treatment to soften fibre was first developed about 100 years ago in the paper industry. Later on, these treatments were applied in animal nutrition. The first chemical used for this purpose was caustic soda (also called lye, chemical name sodium hydroxide, chemical formula NaOH), a toxic substance that can lead to a sodium imbalance in the animals. Using water to rinse excess sodium out of straw leads to loss of organic matter and water pollution.

Over time, caustic soda was replaced by ammonia, which in the tropics is mainly derived from urea. Treating straw with urea does increase intake and digestibility, though less so than caustic soda.

Ammonia treatment was particularly successful in Scandinavia because it helped to avoid loss of moist straw. Straw does not dry well in the cool and wet climate there. Chemical treatment during the cold winters became a conservation practice rather than a specific way to improve the nutritive value of feed.

Attempts to conserve wet straw with urea were not successful in the hotter climates of South Asia. There, treatment is used to improve straw quality within a period of one or two weeks (Urea-ammonia treatment, below). It is not a conservation method, since straw quality tends to decline again if treated straw is kept for longer than a few weeks.

Other chemicals have been tried, e.g. lime (with or without urea), lye from ashes, and even urine. Although lime treatment has been tried extensively, it has hardly been used at all in practice; even less than urea. Using wood ash from kitchens or wood burning is problematic, as is the use of urine. The main challenge is how to collect enough ash and urine, and how to calculate the alkali concentration in these substances. None of these chemicals has proved practical; nor has the use of more exotic chemicals such as hydrogen peroxide, ozone or acids shown positive results.

Table 9: Differences between ensiling green fodders and urea treatment of straws

	Grass ensilage	Straw treatment
Basic process	Microbiological fermentation	Chemical reaction
pH during process	Low (acid)	High (alkaline)
Addition of urea	May be harmful	Essential
Purpose of process	Conservation of feed	Increase in feeding value
Duration	Many months or longer	One or a few weeks
Effect on nutritive quality	Negative	Positive
Loss of feed dry matter	Often more than 10%	Much less than 10%
Name of 'structure'	Silo, pit or clamp	Silo, pit or clamp
Use of 'structure'	One large batch per season	Repeated use of a few small batches (silos) per season
Cost of 'structure'	More expensive	Less expensive
Need for air tightness	Essential	Not essential
Purpose of sealing	To keep air out	To keep ammonia in
Name of process	Ensilage	Treatment

Urea-ammonia treatment

Urea is the best source of ammonia that is available for treating straws in the tropics. It is easy to store, safe to use and the treatment benefits from high temperatures. Globally, urea treatment is only used on a very small scale but its technical effectiveness is beyond doubt. It is a practical process that uses a robust chemical, and working with it requires no special skills or equipment. Much is known about urea-treated straws and there are many 'recipes', which provide information on urea quantity, treatment duration and its effect on nutritive quality.

For small-scale farmers a well-tested way to treat straw is:

- Collect enough dry and clean straw to feed the animals for a specific period of time.

Quantities can be estimated using a simple calculation:

For example: a cow can eat 2% of its bodyweight of treated straw per day, so a cow weighing 350 kg needs $0.02 \times 350 = 7$ kg (dry matter!) treated straw/day, or 49 kg/week. A farmer with a herd of 5 cows will need $5 \times 49 = 245$ kg treated straw per week (dry matter!).

- One week is a practical length of time for the urea straw treatment.
- 100 kg straw has a volume of around 0.20 m^3 . Therefore treating 245 kg straw for one week requires a pit of almost 0.5 m^3 .
- If farmers construct a pit above ground (also called a clamp or silo, as shown in Figure 9) that is 2.00 m long and 0.50 m wide (so they can cover the pit with plastic sheets that are 1.00 m wide), the pit should be 0.50 m deep. Other dimensions are possible and pits should be made to suit local conditions. Digging a pit in the ground might seem a good way to save money, but this is impractical because these pits cave in, collect water and are difficult to empty.
- To measure the quantity of straw, it can be weighed into bundles of 10 kg each. The urea quantities given below should be adjusted for higher or lower quantities of straw.
- Use 4 kg urea per 100 kg dry straw. Using less urea will not be effective; more urea costs more, and it has no extra effect, while in the long run it will have a negative effect on animal reproduction.
- Mix the urea with 60-100 litres of water, depending on the humidity of the straw. Too much water has been used if water collects in the bottom of the pit, or if the bottom layers of straw get brown and pasty.
- Spray the urea solution evenly over the straw, and then trample the straw to make sure it is compact. Complete compaction, as is done when silage is made for conservation, is not necessary.
- Keep the treated straw covered during treatment; use plastic sheets, urea bags or other reasonably airtight material to prevent the ammonia from escaping (Figure 9.2 - 9.5).

- Allow the process to work for one week (seven days) before feeding. The seven-day period is an easy one for farmers to remember: treatment day will always be on the same day of the week. Four days is the minimum amount of time for treatment, but treatment for longer than one week is also possible.
- Start feeding the treated straw after one week (Figure 9.2) and make sure it has all been used within two weeks. Treated straw could be kept for longer but this increases cost and might lead to spoilage.
- When feeding your livestock from pit A, reload and treat straw in pit B, so this is ready for feeding once pit A is empty (Figure 9.3).

This method is easy to follow, and the small difference in practice between air dry (+/- 90% dry) and completely dry (100% dry) straw is too small to affect the process, so 4 kg urea per 100 kg 'dry' straw is good enough for practical purposes. Also, a little more or less water, as well as small variations in the quantity of urea used (3.5- 4.5%), does not make a great difference. Farmers might only be able to measure approximately using homemade measures (e.g. tin cans, water cups) rather than weighing scales, but this does not matter.

Note 1:

Local conditions differ and farmers should use their own experience as guide. Reasonable assumptions are:

1. Intake of treated straw (dry matter base) is 2 kg/100 kg bodyweight.
2. Intake of untreated straw (dry matter base) is 1.5 kg/100 kg bodyweight.
3. Intake of 2 kg/100 kg bodyweight assumes that no large quantities of other feed, such as green fodder, are being fed, as this would reduce the usefulness of feeding treated straw.
4. After feeding treated slender straws not much residue is left, unlike selective consumption of coarse straws.

Note 2:

Animals must be prevented from eating the urea or drinking the urea-water solution. If they do, it will lead to convulsions and rapid death.

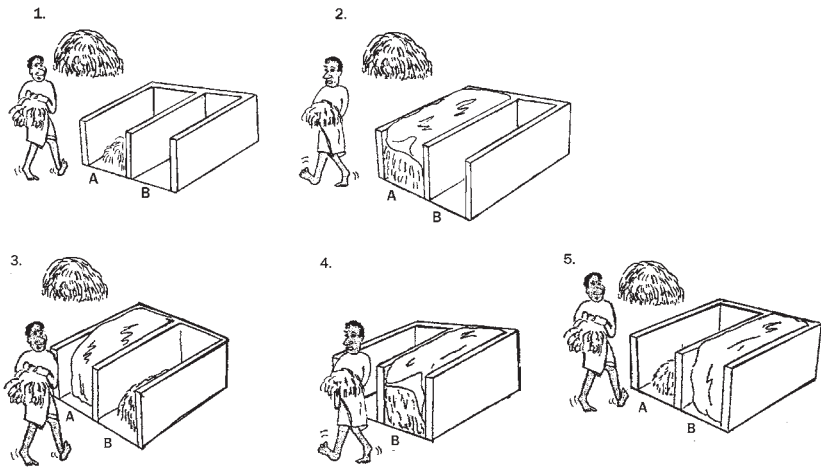


Figure 9: The two-batch treatment as developed in Sri Lanka. Materials used to construct the aboveground pits will vary, depending on what is available locally. (Source: Palitha Handunge)

Straw treatment with urea has three positive effects on the nutritive value of feed:

1. it increases sweetness (= digestibility);
2. it increases intake;
3. it increases greenness (= protein).

The importance of increased intake, however, also means that treatment only makes sense if there is enough straw: farmers should not let their animals eat more if straw is in short supply. Increased digestibility alone is not a sufficient reason to apply the treatment.

Table 10: Combined effects of increased digestibility and feed intake on the intake of nutrients: the case of slender straws

	Untreated straws	Treated straws	Increase in nutrient intake compared to untreated straws
Sweetness (total digestible nutrients, kg/kg straw)	0.45 kg	0.50 kg	~ 11%
Intake (kg feed/100kg bodyweight)	1.50 kg	2.00 kg	~ 33%
Intake (kg feed/ 350kg animal)	5.25 kg	7.00 kg	~ 33%
Intake of 'sweetness' (kg/100kg bodyweight)	2.30 kg	3.50 kg	~ 45%

Note:

Treatment of coarse straws, bean straw or cane tops is generally less effective since:

- their initial nutritive value is higher (resulting in lower effect of treatment);
- they stack and compact less easily, resulting in less effective treatment;
- bean straw and cane tops are not affected by urea.

Treatment also has disadvantages:

- Urea should be available at a cost that can be covered by the increased productivity of the farmer's animals: this could mean increased health, or the income generated by the volume of milk that can be sold.
- Clean water must be available.
- Plastic or other materials must be available to cover the stack.
- Although the process is simple, it requires work and foresight by the farmer, who needs to develop a routine of weekly treatment and feeding schemes.
- Animals (and farmers) may have to get used to this way of feeding. Especially if the animals are not used to straws the transition to the new feed should be stepwise, for example mixing the straw with some palatable green feed.

Feeding urea-treated straw tends to be profitable:

- if (treated) straws are a large part of the ration: at least 50% or more;
- if animals produce at levels of at least 1-1.5 x Maintenance (4-12 litres milk for a 350 kg cow);
- if other feed such as green fodder is not available, and if there is a good market for milk;
- if 1 kg of concentrates costs more than twice as much as 1 kg of dry treated straw; otherwise it would be cheaper to feed extra concentrates than to feed treated straw.

Feeding urea-treated straw is useful in specific conditions. Health effects are positive compared with starvation and/or feeding untreated straw. Feeding levels of treated straw are comparable to those of feeding medium quality grasses: feed plenty and – as a general guideline – add 1 kg of concentrate as a supplement for every 1.5 litres of milk yielded over 2-4 litres. Local conditions and farmers' 'eyes' are the final determinant of what is good enough. Generally speaking, 1 kg urea saves roughly 7-8 kg concentrate feed.

Treatment does have side effects, which may cause problems in particular situations:

- Dung becomes sticky, a potential drawback when preparing dung cakes for fuel.
- People will initially blame all problems on feeding urea-treated straw
- Ammonia evaporation into the air is a loss, and is not good for the environment.
- If farmers' access to urea is limited, the urea used to treat straw cannot be used on crops .

Table 11: Suitability and effect on nutritive value of different chemical treatment methods¹

Chemical treatment ¹	Sodium hydroxide	Ammonia ²	Urea
Improvement in nutritional quality			
Increase in digestibility % increase	Considerable +/- 20%	Medium (+/-10%)	Medium (+/-10%)
Digestibility after treatment of straw (starts at 45%)	50 - 54%	+/-50%	+/-50%
Increase protein content	Nil	High	High
Start	+/- 4-6%	+/- 4-6%	+/- 4-6%
End	still 4-6%	> 10%	> 10%
Increase in intake % increase	Considerable 30-40%	Medium 20-30%	Medium 20-30%
Intake after treatment (kg/100kg bodyweight)	1.5-2.1	1.5 - < 2.0	1.5 - < 2
Suitability for tropical conditions			
Availability/Handling of chemical	Very difficult	Very difficult	Easily available in many places. Not dangerous if handled well.
Suitable if:	Not suitable	Not suitable	<ul style="list-style-type: none"> • are easily available • is cheap • is less than half the cost of concentrate • is medium (1.5-2 M)
<ul style="list-style-type: none"> • Straw and water • Urea • Cost treated straw • Production level of cows 			

¹ Treatments with (wood-) ash, lime or urine are not included because they are not sufficiently effective or practical.

² Ammonia here refers to aqueous and anhydrous ammonia, both unsuitable for small farms in the tropics.

The way straws respond to urea treatment depends on the type of straw and its condition. Sometimes there is very little result or none at all. It is important to know that treating dirty, moist and mouldy straws is a waste of time and energy. Treating coarse straws (maize, sorghum, millets) or straws from broadleaved plants like beans, pulse gram or cane tops is not recommended either. Slender straws, on the other hand, should respond well to treatment, with an increase in intake from about 1.5 to 2-2.5 kg/100 kg bodyweight and a rise in digestibility from about 45 to 50%.

Complex methods

Other straw treatment methods, whether chemical (using acids or hydrogen peroxide) or biological (using micro-organisms, enzymes or fungi), are complicated, costly, and may be toxic. These are industrial processes that can be effective, but have no place in small-scale farming in rural tropical areas.

6 Grazing

6.1 Introduction

There are surprising similarities in the way farmers worldwide cope with feed shortages (Box 8). Many farmers leave their animals to graze the fields after harvest, or let other people's animals graze there. During rainy seasons, animals are mostly kept at home, tethered under a tree, or in the stable. Thus, animals are often relatively underfed in the wet season unless they have access to good feed under trees, or on public lands and roadsides.

Animals also can graze 'waste lands' such as bush and rangeland where their feed consists of leaves, weeds and grasses or herbs. These can be green and lush in one season and dry and mature in other seasons. The nutrient value of mature grasses is similar to that of straw, but the difference is that animals can select the better parts of grass, which is really 'standing hay'.

Box 8: Grazing on rangelands and croplands

All over the world animals graze on straws, stubble, ratoon, weeds and fallen grains to some degree. Often, rangeland grazing is combined with stall-feeding, sometimes using high-quality feeds such as grain. Such systems can be found in densely populated South and South-East Asia as well as in the cold and thinly populated regions of Northern Asia (Mongolia, western China) and in the semi-arid regions of the Mediterranean and Africa. These systems also occur in the Americas and Australia, while some farmers in western Europe feed straw (if cheap) to animals in winter.

Where climates are becoming wetter and where populations are growing, cropping intensity is rising. Whereas livestock traditionally moves from dry to wet areas in rangeland grazing, this type of grazing has become less common as the use of crop residues for feeding becomes more popular.

In West Africa herders trek with their animals from one region to another, making their livestock graze wherever there are green grasses and/or crop residues, depending on the season and market opportunities. In Australia, some grazing practices resemble those of pastoralists in Africa. For example, different animals are put to graze in different areas, depending on the type of animal, the season and crops. Goats and sheep can graze more easily on small, tender grass shoots than large ruminants. Pregnant and lactating animals need greener and juicier feed than bulls and non-lactating animals. Each category of animal has its own needs and grazing habits, and taking these into account are all ways of carrying out 'strategic feeding' (see Section 4.2 for a list of ways of adjusting to feed shortages).

Grazing is becoming less common and stall-feeding is on the increase due to pressure on rangelands and forests, and increasing use of land for growing crops. Traditionally, pastoralists have understood how to handle animals and grazing lands in a sustainable way, in harmony with the environment. But pastoral production systems are increasingly making way for the animal husbandry practices of town-dwelling cattle owners, and these practices often are not in tune with the ecology and local cultures and therefore harmful for the environment. Nevertheless, we briefly consider grazing here because of its similarities and overlap with stall-feeding.



Figure 10: Grazing crop residues in the Mediterranean (Syria), where the cool rainy winters are the growing season. Left: a flock of sheep, led by a goat and a shepherd. Right: a grazed-off grain field with shepherds' tents.

6.2 Grazing straws and other crop residues

Only low to moderate levels of production can be expected from all types of grazing system: at best between $< 1x$ and $2x$ maintenance, or between a slight weight loss and (at most) perhaps 6-8 litres milk from a 350 kg cow. Generally speaking, dairy animals do not thrive in grazing areas because they expend a lot of energy walking large distances to find feed. Moreover, it is hard to sell milk in remote areas, unless it has been made into butter or cheese. It is possible to earn a moderate income from young stock (cattle, lambs and kids) but these animals are usually moved to feedlots near cities, where better grass and/or concentrates are available for fattening them before sale.

Grazing systems can be categorised as follows:

- Regions with green, lush feed, often with some residual soil moisture (and/or rains). These have plenty of 'sweet' straws and stubble, as well as green ratoon, weeds and grasses. Under these conditions herders will have no worries about feed if they know how to let their animals select the better parts of what is available so they get enough nutrients. Yields can be between 1 and $2x$ maintenance, especially if some concentrate is fed.
- Dry arid regions with plenty of straws and dry grass. These 'standing hay' conditions are where 'animals starve in a sea of plenty': they eat large amounts, so their stomachs are full, but the feed is too poor to

be digested well. Catalytic supplements can help here (Section 4.4), creating conditions where animal production is just below or slightly above maintenance. Herdsmen can supply catalytic feed, preferably well spread over the day, when animals are resting near the camp. In some rangeland grazing areas, e.g. in Australia and Southern Africa, the use of hard lick blocks can be profitable. Other options are accepting temporary weight loss, or culling animals if there are markets where meat can be sold.

- Regions where croplands can be grazed down after the harvest and there is also good grazing land nearby, for example under coconut trees. These conditions result in a variety of pastoralist grazing strategies and livestock management systems, ranging from culling and strategic feeding to transhumance and migration. When nothing is left for the animals to graze on the land, bagasse or straw is sometimes brought in from elsewhere as an emergency measure. A range of other fodders, from whole wheat (parcice in Australia) to paper soaked in molasses (tried in Kenya), can help animals through a dry season, but advice will be best when local conditions are taken into account.

6.3 Grazing and stall feeding

There are similarities between grazing and stall-feeding practices: for example both use forms of strategic feeding, catalytic supplementation and cull excess animals. In both cases farmers have an active interest in their animals and see them as an important source of income. However, if that interest is based on tradition alone, as it tends to be in grazing systems, it might be wise to reconsider existing practices, production goals and ways of life. The time has passed when a large flock was a sign of wealth. Stall-feeding of fewer animals on crop leftovers, rather than herding many animals, is becoming increasingly predominant in regions where land is becoming scarce and where growing crops is becoming more important.

7 Feasibility and sustainability of feeding straw

7.1 Introduction

Farmers keep animals and grow crops to make a living. After harvesting, all crops yield leftovers such as straws, and after processing there are residues such as bran and seed cakes. These leftovers and residues are part of the total crop and they have potential value. Ideally they should not be burned but they should be used in better ways, e.g. for soil improvement or for feeding purposes as described in this Agrodok.

7.2 Simple economics

A simple way to assess costs and benefits of straw feeding is to compare the unit cost of nutrients and the cost-benefit of rations.

Theoretically the cost of grass growing ‘free on the roadside’ is nil, and so is the cost of straw that would otherwise be burnt. But ‘free’ grasses or straws have to be collected, stored and taken to the animals, or the animals have to be taken to the grass and straws. Utilising the ‘free’ grass or straw thus requires labour, either supplied by family members or hired labourers, and transport. Don’t forget though, there may even be a market for straw.

The basic economics of straw feeding can be assessed by simple calculations, as in the example given below. Costs and prices are expressed in ‘Shillings’, to be converted by readers into their own currency. All quantities refer to dry matter, and ‘sweetness’ is expressed in Total Digestible Nutrients (TDN), the technical term for sweetness. Calculations for protein (greenness) are beyond the scope of this Agrodok.

Box 9: Nutritive value of straws and other feeds

Feed quality in terms of sweetness (Total Digestible Nutrients, TDN) and greenness (see Box 2 for more detail).

- Slender straws, e.g. rice, wheat, barley:
about 45% sweetness (= 0.45 kg TDN/kg feed)
- Coarse straws, e.g. maize, millet, sorghum:
about 50% sweetness (= 0.5 kg TDN/kg feed)
- Mature grasses: about 55% (= 0.55 kg TDN/ kg)
- Fresh grasses and legumes: 60-70% (= +/- 0.65 kg TDN/ kg)
- Bran: 65-75% (= +/- 0.7 kg TDN/kg feed)
- Grains and concentrates: 80% (= 0.8 kg TDN/kg feed)
- Pure sugar and starch: 100% sweetness (= 1.0 kg TDN/kg feed in theory)
- Woodchips: low concentrations of sweetness

Cost of feed and nutrients: a few examples

Slender straw at 1 Sh/kg seems cheaper than bran at 1.20 Sh/1 kg. But let us compare the amount of TDN in slender straw with that in bran:

- 1 kg slender straw contains 0.45 kg TDN, so 1 kg TDN derived from straw costs $1/0.45 = 2.2$ Sh.
- 1 kg bran contains 0.65 kg TDN, so 1 kg TDN derived from bran costs $1.2/0.65 = 1.8$ Sh.

Conclusion: *feeding the more expensive bran is actually the cheaper option*, because animals need to eat only 1.54 kg bran ($1/0.65$) to take in 1 kg of TDN, while they need to eat 2.22 kg ($1/0.45$) slender straw to achieve the same TDN intake.

Coarse straw at 0.50 Sh/kg seems cheaper than (inferior) bran at 1.20 Sh/kg. But the calculation should be made to check:

- 1 kg coarse straw contains 0.5 kg TDN, so 1kg TDN derived from straw costs $0.5/0.5 = 1.0$ Sh.
- 1 kg inferior bran contains 0.6 kg TDN, so 1 kg TDN from bran costs $1.2/0.6 = 2.0$ Sh.

Conclusion: feeding the coarse straw is the cheaper option.

However, the cost of 1 kg TDN is only one of many factors that have to be weighed up in farm management. Nutrient intake from straws is barely sufficient to keep an animal alive, even if selective consumption from coarse straws is allowed. Fed on straw alone, an animal cannot gain weight, produce much milk or offspring (calves, kids, lambs), or do work. To ensure productivity some nutrient-rich supplement has to be fed in addition to the straw. Better feed is more expensive than straw, so the farmer must balance higher feeding costs against the financial benefits that higher production offers.

Many small-scale farmers feed concentrates in moderate amounts. Normally, 1 kg concentrate above maintenance feeding level can yield up to 1-1.5 litres more milk if conditions are reasonable. Feeding concentrate pays off, if that extra 1-1.5 litres milk sells for more than the cost of 1 kg concentrate (assuming that straw feeding costs are low). This calculation ignores the positive effect of supplements on animal health. See Chapter 2 for more details on whether or not it pays to feed concentrate, or whether the farmer is wiser to 'live with' low quality straws during the lean season.

Feeding untreated or treated straw

The benefit of feeding untreated or treated straw can be calculated using the graph in Figure 11, and the results can then be compared with the cost of feeding green grass (or any better feed other than straws).

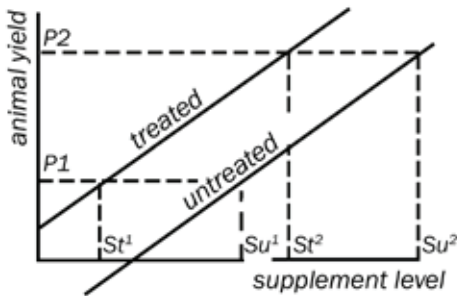


Figure 11: Level of production (vertical axis) represents response to increased supplementation and different qualities of staple feeds (treated and untreated straws), based on figure 5 (S = supplementation level, P = production level)

For example: production level P1 (vertical axis) can be achieved by combining treated straw with St¹ amount of supplement, or by combining untreated straw with Su¹ amount of supplement. The cost of achieving production P1 by feeding either treated or untreated straws can then be calculated and compared.

Quantities and prices of straw and supplements have to be known to be able to perform locally relevant calculation, and it should be kept in mind that:

- animals may lose weight and cannot produce milk when fed untreated straw only;
- animals can gain weight, produce milk and/or offspring when fed treated straw;
- the response to supplements is fairly similar for both treated and untreated straw (unless catalytic supplementation is used with untreated straw, see Figure 5C).

A large set of calculations on the usefulness of feeding treated straw was done in Sri Lanka (Schiere and Nell 1993, see Further Readings). They concluded that feeding treated straw only makes sense if:

- straws of good quality are easily available compared with other feeds. The straws should not cost more than medium-quality grass;
- there is a ready market for animal products: milk and meat;

- the price of straw, urea and water (and labour) needed to produce treated straw (expressed as per kg dry weight) is not more than 50 % of the cost of concentrates;
- cows produce at a level between 0.5 and 1.5M, i.e. 4-12 litres milk for a cow of 350 kg bodyweight.

Straw feeding and animal health

The economic effects of straw feeding on animal health and reproduction can be summarised as follows:

- Straw has a less positive effect on health and reproduction than grasses and tree leaves have, mainly due to the lack of vitamin A (from carotene) in straw. Straw's lack of protein and phosphorus (greenness) is not good for animal health and reproduction, while its lack of sweetness causes weight loss and exhaustion.
- Feeding good (treated) straw (and/or allowing selective consumption) maintains animal health and reproduction. The higher level of greenness and sweetness in urea-treated straws (or in the selected greener and sweeter leaves) helps maintain an animal's condition and enables some production of milk or meat.
- Feeding of 10-20% straw to animals on a high concentrate diet (substitution supplementation, see Chapter 4) helps maintain good rumen function. It avoids acidosis, a rumen disorder caused by high concentrate levels, which results in low feed intake, low production and poorer health.
- Feeding young calves some straw (or, better, some hay) improves rumen development.

In general there are no risks associated with feeding straws, though farmers tend to blame straw for all kinds of problems if straw feeding is new to them. Long-term straw feeding can weaken an animal and make it more susceptible to infections. However, straw feeding can be an alternative when starvation is a real threat. Deficiencies of vitamin A and minerals can be overcome by adding a few handfuls of green leaves, and by making

saltlicks available. Allowing temporary weight loss is also a long-standing practice in livestock husbandry.

Specific feed-related animal health and reproduction issues, including toxic ratoon and toxic weeds, have been discussed in previous chapters.

Box 10: Urea, risks and benefits

In ruminant feeding the greenness (= protein content) of the feed is related to its nitrogen content. Nitrogen nearly always makes up around 16% of the protein in feed. Microbes in the cow's rumen convert nitrogen into protein and vice versa. Animal urine contains nitrogen, mainly in the form of urea: it is a normal substance in the animal's body.

A lack of protein can be overcome by adding fertiliser urea, or even urine and chicken manure. Feeding chicken manure or urea are practical ways to feed protein: if this is done properly there are no health risks, nor undesirable residues left in milk or meat. But farmers must be careful to keep to the levels of urea that ruminants can handle safely. If there is less than 2% urea in the feed (or in the concentrate) there is no risk, provided intake is slow. Urea or chicken manure should be fed evenly over the day. Straw treatment or supplementation with urea is absolutely safe provided these precautions are taken.

7.3 Other straw feeding considerations

Straw feeding has a socio-economic impact. Using straws to feed low- or medium-yielding animals generates a low income, but at low cost, and with potentially high nutrient use efficiencies in farming systems that are based on recycling. Feeding straws to their own livestock also enables resource-poor farmers to extract value from their straws as opposed to selling them and letting outsiders benefit from their value.

Whether straw is used for animal feed or for soil improvement implies a choice. However, there is not a great difference, in terms of costs or yield, between applying straw directly for soil improvement or feeding it to an animal first. The proportion digested by ruminants is roughly the same as the proportion that quickly degrades when straw is left in the field. If spe-

cialised production is preferred, the following guideline is useful: 1kg urea fertiliser saves about 7 kg concentrate if used for straw treatment, because the animals will eat a larger amount of treated straw than untreated straw. If used as fertiliser on crops, 1 kg urea will yield about 30-50 kg additional grain. If resource-poor farmers have to choose between using urea as feed or fertiliser, it helps to calculate the expected benefit of both options and compare the results.

Environmental considerations are increasingly relevant in discussions about the sustainability of animal husbandry. Although environmental issues are largely beyond the scope of the intended audience of this Agrodok, farmers should be (made) aware of the increasing problems of greenhouse gas emissions, such as carbon dioxide (CO₂) and methane, and their effects on climate. Small-scale farmers play a minor role in terms of the amount of their emissions (e.g. through burning wood or straw as fuel, or through the methane emissions of their cattle). On the other hand, many farmers in developing countries are already suffering from the consequences of climate change, such as irregular rains, severe dry spells and flash floods. That is why these environmental issues are briefly mentioned here.

Box 11: Use of straw and environmental issues

Clean water is rapidly becoming a scarce resource. Estimates of water needs for high-quality fodder produced with irrigation run from 300 litres to well over 1000 litres water/kg, implying that 300-1000 litres water are needed to produce 1 litre milk. And 5-10 times more water is needed to produce meat. Using straws to feed medium yielders involves no irrigation or fertiliser use, making straws a low-cost by-product.

Mixed farms using straws as a basis for production represent efficient forms of animal production. In these systems animals are seen as converters of waste rather than users of prime resources.

People often say that animals produce nutrients via their excreta (dung and urine). But the nutrients in excreta are not 'produced'; they already exist and have been recycled. Care has to be taken to keep these nutrients in the cycle, e.g. by not burning straw that has been used as bedding, by collecting ni-

trogen from urine, or by using manure or urine in other ways to maintain soil fertility. The amount of urine excreted over a period of one year by a 350 kg animal easily contains the equivalent of two bags of urea, if not more.

Straws have a low nutritive value and burning is an easy way of disposing of straw that might hamper soil preparation or carry plant pests and diseases. While burning may save time, it robs soils of organic matter, and the amount of nitrogen lost in the smoke can be as much as the equivalent of two bags of urea/ha/harvest). The sulphur contained in straws also goes up in smoke: a public nuisance and polluting. Burning straw also emits the greenhouse gas carbon dioxide (CO₂) into the atmosphere.

Straw used for soil improvement is best applied on upland fields. Flooded paddy fields retain their organic matter reasonably well and do not need additional organic matter such as straw to maintain soil quality.

The contribution to soil quality of organic matter in straws, stubble and roots is limited but not unimportant. These help maintain the level of organic matter in the soil.

Grazing of stubble in dryer areas should be reconsidered as it can lead to increased damage from wind erosion.

7.4 Concluding remarks

All crops produce some form of 'straw', or haulms and/or leafy parts that are not the main crop (grain, beans, sugar, etc.). Farmers can consider various options for using these fibrous by-products that are usually of low feeding value:

- Often these by-products are simply burned so it is easier to prepare the land for sowing or for planting the next crop. But burning makes the most important nutrients in the straws 'go up in smoke', and it may damage or destroy the soil's organic matter. This option should be avoided in sustainable farming.
- Resource-poor farmers can sell straws to rich cattle farmers in or near cities, where cattle are raised on large amounts of concentrates (grains, brans and oilcakes) and where some fibre is needed for good rumen function. If the choice is made to sell, a potentially useful crop residue

benefits the city farmer instead of the rural farming community (apart from yielding short term cash).

- Straws may simply be left in the field as organic matter and/or mulch, but the beneficial effect will be minimal. If soil improvement is the objective, mixing straws into the compost heap and/or farmyard manure is a better option. The compost can be worked into the soil when the next crop is sown or planted. Using straws for mulch can help to protect soils from exposure to heavy rains, winds or strong sunlight.
- Straws mainly consist of fibre, which is not very nutritious, but especially ruminants (cows, buffaloes, sheep and goats) can eat them and thus extract sufficient nutrients to survive the lean season.

The main message of this booklet is clear: do not burn or throw away the straws that are a natural by-product of your grains and pulse crops. Think of these residues as a useful asset and treat them accordingly!

Further reading

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Useful addresses

Feedipedia: an on-line encyclopedia of animal feeds

Feedipedia is an open access information system on animal feed resources that provides information on nature, occurrence, chemical composition, nutritional value and safe use of nearly 1400 worldwide livestock feeds. It is managed jointly by INRA, CIRAD, AFZ and FAO.

www.feedipedia.org

Food and Agriculture of the United Nations (FAO)

Department of Animal production

FAO's programme focuses on sustainable development of dairy, beef, pig and poultry as well as small ruminants production and draught animals. It takes into account, among others, animal health and welfare related issues, the responsible use of animal genetic resources, sustainable animal nutrition and feeding. FAO provides advocacy, awareness raising, information, knowledge, guidance and technical support to help produce high quality animal products, safely, efficiently and responsibly, while improving their people livelihood and meeting citizens' demands.

www.fao.org/animal-production/en/

International Livestock Research Institute (ILRI)

ILRI works to improve food security and reduce poverty in developing countries through research for better and more sustainable use of livestock.

www.ilri.org

Practical Action

Practical Action's technical information service offers free downloads on a range of topics related to food and agriculture.

www.answers.practicalaction.org

Glossary

Acidosis	Rumen disorder caused by over-feeding concentrates. Acidosis causes low appetite, reduced health, low production and low milk-fat content. Feeding some straw or roughage, so that it makes up at least 30% of the total feed ration, prevents this.
Ammonia	A form of nitrogen found in all animals, usually in the form of urea, formed by protein digestion. Supplementing the diet of ruminants (e.g. by adding fertiliser urea, less than 2% of total feed) can provide them with more protein and improve productivity.
Bran	Grain husks, which are removed during milling, and contain some starch and protein. Rice husks or groundnut hulls are not useful as feed.
Bodyweight	Live weight of an animal, as opposed to carcass weight. Abbreviation: BW
By-product (also 'residue')	What is left over, e.g. straws, grains and press cakes, after main product, such as grain, pulses or sugar juice, has been removed.
Cake	The remains of oil seeds left after the oil has been extracted, by pressing or otherwise, in the form of a 'cake' with relatively high levels of protein.
Cell wall	The woody (and difficult to digest) part of a plant (also called 'fibre') that serves as the 'container' for the plant's juicy and nutritious cell-contents.
Cell contents	The juice in a plant, containing almost all the digestible sugars, proteins, minerals.
Chopping	Reducing the size of straw parts, usually with knives or 'choppers' to somewhere between 2 and 10cm.
Coarse straw (and coarse grain)	Straws from crops that produce coarse grains, such as maize, millet and sorghum.
Concentrate feed	Feed with a high concentration of digestible nutrients (sweetness and protein). Most concentrate feeds contain

	one or more of the following: grains, grain leftovers, brans, oil-seed cakes. They may be fed alone, mixed on farm or bought ready mixed from commercial feed mixers (then they are usually called compound feeds).
Digestible energy	The energy that can be digested (= used) by animals to survive, to move and to produce milk, meat and offspring. In this Agrodok it is called ‘sweetness’.
Fibre	Woody material (‘strings’) in plants, giving them their structure and enabling the transport of nutrients in the green plant. Generally not readily digestible (in practice mostly cell walls).
Slender straw	Straw from crops that produce fine grain, such as barley, oats, rice, rye and wheat.
Feed, fodder	General name for materials used to feed animals, such as straws (poor quality), fodders (medium to good quality) and concentrate feeds (see above).
Germ	The part of the grain that starts to grow after germination.
Greenness	A characteristic of straws: that they ‘stay green’, i.e. do not turn yellow. Greenness is associated with a slightly better feeding value and protein content.
Greenhouse gas	Gases, such as carbon dioxide and methane, which escape from ruminants during digestion (through burping and farting) and contribute to climate change.
Haulm	‘Straw’ from pulses or legumes.
Hull (or husk)	The hard ‘skins’ of grains, such as rice, and pulses (e.g. groundnuts).
HYV (high yielding varieties)	Grain varieties developed since the 1970s, with relatively more grain and less straw.
Maintenance	Nutrients needed by an animal to stay alive.
Monogastric	Animals, such as chickens and pigs, with only one stomach (see ‘ruminant’).
Node	The hard part of a grain stem from where a leaf grows. The part of the stem in between the nodes is called ‘internode’.

Prussic acid	A poisonous substance found in certain plants, often after lush growth (e.g. during rains following droughts). It is found especially in sorghum (re-) growth and in some cassava roots. This acid quickly degrades after wilting or after exposing the sliced tubers to the air (drying).
Ratoon	The green, nutritious re-growth in the field after the grain has been cut.
Residue	See by-product.
Resource-poor farmer	Farmer who owns few assets and has little access to resources.
Resource-rich farmer	Farmer who owns quite some assets and has good access to resources (money, labour, land, equipment, infrastructure, facilities).
Rumen	Main stomach of a ruminant, (one of its four stomachs, each having a different function for digestion). Microbes in the rumen break down fibrous feeds for further digestion.
Ruminant	Any animal with four stomachs, e.g. sheep, goats, buffaloes and cattle.
Selective consumption	Selecting the better parts from its feed by the animal, e.g. leaves instead of stems or grains from a mix of fodder and concentrates.
Sheath	The hard (lower) part of the leaf that links the leaf with the stem, generally less nutritious than the leaf itself.
Silage	Feed generally made from (excess, lush) green fodders, compacted and covered with plastic to keep it airtight. It is left to ferment and to become acid, thus, preserving it for the seasons when feed shortages are expected to occur.
Slender straw (and fine grain)	Straw from barley, rice, rye, oats, wheat (and their associated grains).
Strategic feeding	Feeding the best parts of the feed to the most productive animals (lactating and/or pregnant cows or working bullocks).

Straw	The combined plant parts that are NOT the grain, including stem, sheath and leaf.
Supplementation	Use of special feeds to make up for shortages of nutrients, e.g. use of grains, brans, cakes or even urea fertiliser.
Sweetness	In this Agrodok the ‘sweetness’ of straws refers to the sugar content, and thus the nutritive value.
Stripping	Cutting green leaves from straws (especially coarse ones) to obtain feed of relatively good nutritive value. Stripping may result in a somewhat lower grain yield.
TDN (total digestible nutrients)	The part of the plant biomass that can be digested, usually expressed as a percentage of the total feed, or as kg/100kg feed.
Thinning	Picking of seedlings/young plants deliberately planted densely to increase the chances of germination, and allowing some green fodder to be harvested.
Tillering	The sprouting of a grain or grass crop at the foot of the plant.
Urea (treatment)	The use of (fertiliser) urea to improve the nutritive quality of straws.

The Agrodok series

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27.	Establishing and managing water points for village livestock	P, F, E
28.	Identification of crop damage	P, F, E
29.	Pesticides: compounds, use and hazards	P, F, E
30.	Non-chemical crop protection	P, F, E
31.	Storage of agricultural products	S, P, F, E
32.	Beekeeping in the tropics	P, F, E

33. Duck keeping in the tropics	P, F, E
34. Improving hatching and brooding in small-scale poultry keeping	S, P, F, E
35. Donkeys for transport and tillage	P, F, E
36. Preparation of dairy products	P, F, E
37. Small-scale seed production	P, F, E
38. Starting a cooperative	S, P, F, E
39. Non-timber forest products	P, F, E
40. Small-scale mushroom cultivation	K, P, F, E
41. Small-scale mushroom cultivation – 2	P, F, E
42. Bee products	K, P, F, E
43. Rainwater harvesting for domestic use	P, F, E
44. Ethnoveterinary medicine	P, F, E
45. Mitigating the effects of HIV/AIDS in small-scale farming	P, F, E
46. Zoonoses	P, F, E
47. Snail farming	P, F, E
48. Entering the organic export market	P, F, E
49. The Rural Finance Landscape	P, F, E
50. Packaging of agricultural products	P, F, E
51. Improving lowland rice cultivation	F, E
52. Backyard grasscutter keeping	F, E
53. Crop residues for animal feed	F, E
54. Edible insects in Africa	F, E

Straw has been used for feed and other purposes around the world for as long as humans have kept animals and grown crops. Straw is still important for many farmers, especially those who have few resources. At the same time, growing urban demand for raw materials and fuel is putting pressure on the demand for straw and the various ways it is used in rural areas. This Agrodok Crop residues for animal feed is intended for extension workers, advisors and farmers who want to know more about the different ways in which straw can be used for sustainable farming and rural development, and especially as feed for ruminants. It reviews experiences from around the world and discusses in depth how straws can continue to play an important role in livestock feeding and sustainable farming.

No specific knowledge of animal nutrition is assumed. Scientific terminology on nutritive value is condensed into terms that farmers use, such as 'sweetness' and 'greenness'. For readers wanting further information some technical background has been included in separate text boxes.

Agrodoks are a series of publications on small-scale agriculture. The booklets are aimed at people who work directly with small-scale farmers in the South. Each provides a theoretical background on a particular topic and then explains its practical applications extensively. All Agrodoks are published in English and French and many also in other languages. They can be ordered from Agromisa and CTA and are also available in PDF format.

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