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DETRIMENTAL COMPONENTS IN GRASSES AND GRASSLAND PRODUCTS, AND THEIR IMPACT ON FEED UTILIZATION

U. Simon

Technische Universität München, Lehrstuhl für Grünland
und Futterbau, 8050 Freising-Weihenstephan, B.R.Deutschland

ABSTRACT

Detrimental components in grasses and grassland products include epidermal structures such as hairs and denticles, cell-wall constituents (lignin, hemicellulose, silica), nitrate, alkaloids, glycosides, sterols, and plant pathogens. They may adversely affect the palatability, intake or digestibility of the plants in which they occur, or may be harmful to the health of domestic animals, or may be detrimental to animal performance and products. The expression and concentration of such components as well as their impact on feed utilization is described.

INTRODUCTION

The feeding value of grass and grassland products is determined by the three main factors viz. intake, digestibility, and amount of nutrients and other substances necessary for animal health and performance. In addition to the nutritional parameters which are analyzed in standard laboratory procedures, grasses may contain detrimental components in respect to the feeding value as well as to the health and performance of the consuming animal. Such substances include epidermal structures, cell-wall constituents, nitrate, alkaloids, glycosides, sterols, and diseased plant parts.

EPIDERMAL STRUCTURES

Grasses vary in the degree of roughness of the plant surface. Such roughness is caused by protrusions of the epidermis. There may be ± long or stiff hairs. Denticles of different number and size may protrude from the edge and from the vascular bundles of the leaf blade. Particularly the denticles which consist of solid silica have been associated with reduced palatability. Stählin (1969) mentions injuries of the mouth and intestinal mucosa with subsequent serious animal disorders. Among the grasses of limited palatability due to their hairiness are Avena pubescens and Holcus lanatus. Stählin (1969) considers the following species as unpalatable and health hazards because of their large number and size of denticles: Avena pratensis, Brachypodium pinnatum, Calamagrostis spp., Deschampsia caespitosa, Molinia coerulea, Nardus stricta. The high amount of denticles observed in Festuca arundinacea may be one of the reasons for the often reduced intake when compared with F. pratensis or Lolium spp. (Simon, 1972). In Dactylis glomerata, number and size of denticles differ considerably, and efforts have been made to reduce them by means of selection (Hertzsch, 1959).

CELL-WALL CONSTITUTENTS

The digestibility of forage is primarily determined by the inherent amount and composition of cell-wall constitutents. Since digestibility is closely related to forage intake, cell-wall constitutents affect also the amount of forage consumed. The structural components of grasses consist largely of polysaccharides which include cellulose, hemicellulose and pectic substances, and of lesser amounts of lignin, protein, and silica. Cellulose is almost completely digested by ruminants. Hemicellulose is composed of a mixture of different polymers which may have different digestibilities (Barnes, 1973). The most undesirable structural component from an animal nutrition point of view is lignin. Not only is lignin almost indigestible, but it interferes with the digestibility of cellulose and hemicellulose by physical incrustation, the formation of lignin-carbohydrate complexes, and of molecular bonds. Increasing plant age decreases total dry matter digestibility in two ways. The less digestible compounds accumulate at a faster rate, and their digestibility is more reduced than that of the more digestible components.

The role of silica in plants and animals has been reviewed by Jones and Handreck (1967). Soluble silica which is primarily found in the cell wall is associated with lowered digestibility. An average decline of 3.0 units of digestibility per unit of silica has been reported in the dry matter of grasses (Van Soest and Jones, 1968). Silica-rich forage can cause insuffucient intake, excessive wear of teeth, and the formation of opal uroliths. To avoid detrimental effects, the silica content in the dry matter should not exceed 2 %. Leaf blades contain more silica than the rest of grass tillers. Plant silica content increases in the primary growth with advancing maturity and is higher in the regrowth. Nitrogen fertilization reduces whilst, high temperature and excessive water increase the concentration of silica (Stählin and Tirtapradja, 1971). Considerable variation exists between and within grass species. Of the cultivated temperate grasses, the highest silica concentrations have been found in Festuca arundinacea.

NITRATE

Grass absorbs nitrogen primarily in the form of nitrate. Nitrate, therefore, is a naturally occurring substance in plant tissue. Adequate nitrogen nutrition is characterized by a nitrate content of 0.6 % NO_3 in the dry matter (van Burg, 1977). The NO_3-concentration may vary from less than 0.1 % to over 6.0 % (Kemp et al., 1978). Nitrate accumulates when NO_3 is taken up at a faster rate than its reduction to NH_3 in the plant. This may be caused by either an excessive supply of nitrate nitrogen i.e. over 100 kg/ha at a time, or by a retardation of grass growth due to insufficient supply of water, light, or other nutrients. Such conditions are likely to occur in early spring, and in late summer. Deinum and Sibma (1980) presented evidence that more nitrate is reduced in the root and stubble than in the leaves as long as sufficient soluble carbohydrate is present. They conclude from their findings that grasses with few large tillers contain more nitrate than grasses with many tillers and roots. Herbage from newly sown pasture has little stubble and root, and is therefore rich in nitrate. Likewise, short cutting intervals result in less nitrate accumulation. Reduced nitrate accumulation can be expected in profusely tillering species when cut at short intervals. Nitrate of grass tillers increases from top to bottom (Deinum and Sibma, 1980). Differences exist between grass species (Murphy and Smith, 1967) and varieties (Dotzenko and Henderson, 1964). In the rumen, nitrate is reduced to nitrite and further to ammonia by microorganisms. These compounds pass via the rumen-wall into the blood stream. Nitrite oxidizes haemoglobin to methaemoglobin. In contrast to haemoglobin, methaemoglobin is not able to carry oxygen. In ruminants 2 to 3 % of the haemoglobin is normally present as methaemoglobin (Kemp et al., 1968). If more than 50 % is converted to methaemoglobin disease symptoms such as drowsiness, muscular spasms, accelerated pulse and respiration, and staggering gait occur. Animals may fall down and die within a few minutes. Also sublethal animal disorders must be considered. According to Lotthammer et al. (1982) extended intake of nitrate-rich fodder may result in abortion. Kemp et al. (1978) showed that at high NO_3-intakes nitrate concentration in the milk can rise to about 60 mg NO_3 per liter.

Data on the acceptable doses of nitrate in the forage vary widely, e.g. from 10 g to 90 g NO_3 per 100 kg body weight (Kemp et al., 1978). The formation of methaemoglobin depends mainly on three factors viz. the nitrate concentration in the grass, the amount of nitrogen ingested within a certain period of time, and the speed of nitrate reduction in the rumen. Geurink et al. (1982) have shown that if grass in the form of hay and pre-wilted silage is ingested the nitrate in such material is reduced at a much faster rate than under grazing conditions. They determined as the maximum tolerable nitrate conentration in the dry matter: Pasture grass = 2.0 % NO_3; barn fed grass = 1.5 % NO_3; hay and pre-wilted silage = 0.75 % NO_3.

ALKALOIDS

21 grass species are known to contain alkaloids (Culvenor, 1973). Among the temperate forage grasses, alkaloids as the causative agents of animal disorders have been reported in tall fescue (Festuca arundinacea), canary-grass (Phalaris spp.), perennial (Lolium perenne) and Italian ryegrass (Lolium multiflorum), and cocksfoot (Dactylis glomerata). Alkaloids in these species have been associated with poor animal performance. It is most often noticed in summer. Clinical symptoms include rough hair coat, diarrhea, rapid respiration rates, and high rectal temperatures. The in vivo effect of the alkaloid fraction is the inhibition of microflora activity, particularly cellulytic avtivity, and subsequent decrease in the energy and nutrient availability to the animal. As the rate of digestion decreases, the rate of passage through the animal declines, and the intake of the forage by the animal is reduced (Bush and Buckner, 1973). Alkaloids in tall fescue have been reviewed by Bush and Buckner (1973) and Bush et al. (1979). Of 11 different types of alkaloids found in tall fescue, perloline is predominant (Gentry et al., 1969). Perloline levels of over 11 mg/g dry matter have been reported which can result in the ingestion of 50 to 100 g/day perloline. Perlolidine, an alkaloid related to perloline, also inhibits cellulose digestion. There is considerable variation in

perloline content due to environmental and genetic factors. Higher concentrations have been observed in mid-summer rather than in spring or autumn. Nitrogen fertilization increases perloline accumulation (Bush and Buckner, 1973). Perloline content is high in the tall fescue variety Kenwell, medium in Kentucky 31, and low in Alta (Gentry et al., 1969). Perloline content has been shown to be a highly heritable character. However, selection for low perloline increased two alkaloids of the pyrrolizidine type, N-acetyl and N-formyl loline, both of which are even more toxic and detrimental to animal performance than perloline (Boling, et al., 1983). Pyrrolizidine alkaloid accumulation in the plants is greatest in late spring and summer which coincides with poor performance of grazing animals. Water stress and a 21/25 ^{0}C temperature regime increased N-acetyl and N-formyl loline concentrations. Accumulation of these compounds was not positively associated with N-application. Recent research has presented strong evidence of a close relationship between poor performance of lactating dairy cows and steers, and high concentrations of N-acetyl and N-formyl loline with a greater degree of infection with the endophyte Epichloe typhina(Hemken et al. 1979). In the absence of the fungal endophyte, average daily gain of steers on tall fescue is high and similar to that on small grain pasture (Hoveland et al., 1983). The fungus can be present in tall fescue hay and seed as well. It is not known whether alkaloids are synthesized by the plant, the fungus or both. The causal agents of two other pathogenic conditions found in cattle grazing tall fescue viz.fescue foot and fat necrosis are not known. Marten (1973) reviewed the alkaloids in reed canarygrass. At least eight different compounds exist in this species, the most important of which appear to be gramine, hordenine, and tryptamines. Total alkaloid concentration is negatively associated with palatability which may lead to low intake and subsequent poor animal performance. Alkaloid concentrations ranging from 0.01 to 2.75 % of grass dry matter have been reported. Shading, moisture, stress, and heavy nitrogen dressing increase the alkaloid content which is largely confined to the leaf blades. Thus alkaloid concentration decreases with advancing maturity of the tillers; it is much higher in the regrowth than in the primary growth. Barker and Hovin (1972) found total alkaloid concentration to be highly heritable. Therefore, feeding quality can be improved by selection. In fact quality problems associated with alkaloids in reed canarygrass are now being overcome by the elimination of the tryptamine group and the development of low-gramine cultivars (Sachs and Coulman, 1983).

Frencel et al. (1979) found only small amounts of perloline in Italian and perennial ryegrass, none in red fescue, and up to 30 mg perloline per 100 g dry matter in meadow fescue and tall fescue. Six alkaloids have been found in Lolium perenne (Culvenor, 1973), the most prominent being perloline. This alkaloid has been associated with two cattle diseases in Australia and New Zealand, ryegrass staggers and facial eczema; it is not yet clear whether or not perloline is the causal agent. Perloline and two other alkaloids have been found in Lolium multiflorum but harmful effects are not on record (Culvenor, 1973). Ryegrass cultivars differ widely in their perloline content (Sachse, 1980).

GLYCOSIDES

Important glycosides occurring in grasses include cyanogenic substances, saponins, and oestrogenic constituents.
CYANOGENIC COMPOUNDS in Gramineae were reviewed by Tapper and Reay (1973). Toxicity of cyanogenic plants to animals appears to be greater the higher the level of cyanogenic glycoside in the plant and the more rapidly the plants are eaten. The hydrogen cyanide released in the rumen is rapidly absorbed through the wall of the rumen into the blood stream. The minimum lethal dose of hydrocyanide was found to be 2.4 mg/kg body weight in sheep. However, when ingestion of forage is relatively slow, as in normal grazing situations, sheep could well tolerate 15-20 mg HCN/kg body weight per day. Besides being potentially toxic, cyanogenic glycosides tend to have a bitter flavour and may affect the palatability of the fodder. Ample nitrogen supply increases the level of cyanogenic glycoside in grass. Limited amounts of cyanogenic glycosides are present in Glyceria fluitans, Glyceria maxima, Holcus lanatus, and Poa pratensis (Stählin, 1957), but no harmful effects on cattle have been reported. Extensive research on the toxicity of cyanogenic acid has been conducted in Sorghum spp. This group of plants contains the glycoside dhurrin. Young plants may contain between 120 and 1400 ppm HCN in the dry matter. Sorghum has often caused death of grazing cattle and is regarded dangerous to feed when the level in the leaves exceeds 500 ppm in the dry matter. However, cattle continuously grazing Sudan grass containing up to 1330 ppm HCN remained unaffected, whereas dairy cattle which ate rapidly were affected by lower levels of cyanide. Schieblich (1938) observed that HCN content decreases in wilting plant material and is negligible in hay. Silage making inactivates the

cyanogenic compound. The greatest glycoside accumulation is in the leaves and young plants. There is a diurnal variation with the highest glycoside concentration at noon. HCN potential decreases in autumn until frost, but significant increases in HCN potential occur within 1 to 6 days after temperature from 0 to -5 ^{o}C (Wattenberger et al., 1968).
SAPONINS in forage plants have been reviewed by Bondi et al., 1973. Among 300 investigated grass species, Lindner (1943) found saponins in 21, the only perennial ones of agronomic importance being Arrhenatherum elatius and Trisetum flavescens. Stählin (1957) attributes the reduced palatability of fresh Arrhenatherum elatius to its saponin content. Sole feeding of the species supposedly confers a bitter taste to the milk (Stählin, 1957).
COUMARIN is known to cause serious disorders in cattle after feeding sweet clover (Melilotus spp.). During spoilage coumarin is converted to the haemorrhagic agent, dicoumarol, by microbial action (Barnes and Gustine, 1973). The only European grass species of some agronomic importance containing coumarin appear to be Anthoxanthum odoratum and Hierochloe odorata. According to Stählin (1957) cattle do not like then because of the bitter taste exerted by the coumarin. Davis and Ashton (1969) found in Anthoxanthum 1.5 % coumarin in fresh grass d.m. and very little in hay.
PLANT OESTROGENS have been related to fertility problems in sheep and cattle on clover-rich pastures. Bickoff (1968) gives a comprehensive review of the subject. Little is known about oestrogenic compounds in grasses and their effects on animals. Stählin (1969) reports the following concentrations in forage grasses: Festuca rubra up to 13000 M.E., Lolium multiflorum 12300, Lolium perenne 7000, and Arrhenatherum elatius 6000 M.E. Occasionally very high concentrations, i.e. up to 60000 M.E. per kg plant dry matter, have been found in grass on heavily grazed pastures, and fertility disorders in cows on such pastures were observed.

VITAMIN D AND RELATED COMPOUNDS

Vitamin D and related compounds belong to the ubiquitous sterols. Vitamin D-like substances have recently attracted considerable attention because they have been detected as the active principles in plants causing calcification diseases in ruminants. Calcinosis is characterized by mineral depositions in the cardiovascular system, the lung and kidney, and by ulceration of cartilage of joints of limbs. Clinical signs include hesitant movement, refusal of forage intake, and subsequent loss of weight and reduced milk yield (Dirksen et al., 1970). The only grass hitherto found to contain a calcinogenic factor is golden oatgrass (Trisetum flavescens) (Dirksen et al., 1974). The calcinogenic activity of the plant is not affected by site, soil, climàte, fertilization or manuring, and is present in fresh grass as well as in hay or silage. Rambeck et al. (1981) detected vitamin D_3 and a vitamine D_3 metabolite as the active substances which accumulate primarily in the leaves. A doses-time-effect relationship between Trisetum intake and the manifestation of disease symtoms was established by Simon et al. (1978). The minimum level of toxicity is reached after the accumulated intake of approximately 500 to 1000 g golden oatgrass dry matter per kg body-weight which is equivalent to grazing a sward containing 20 % Trisetum for 10 weeks. The milk of Trisetum-fed sheep showed an increased vitamin D_3 level (Rambeck et al., 1980).

PLANT PATHOGENS

Grasses are hosts of a large number of pathogenic organisms. Some of these are known to reduce forage quality or, when ingested with the grass, may cause harmful effects in farm animals. In Dactylis glomerata, 9 % leaf area affected by Mastigosporium rubricosum resulted in 50 % loss of total soluble carbohydrates (Carr, 1962). Foliar diseases are detrimental to the content of crude protein, soluble carbohydrates, and reduce the digestibility in Dactylis glomerata and Lolium multiflorum (Isawa, 1982, 1983). The relationship between Epichloe typhina and poor animal performance in tall fescue is being mentioned elsewhere. The palatability of heavily rust-infected grass is reduced. Fusarium spp. and other fungi on Lolium spp. metabolize mycotoxins which are detrimental to fertility and performance o. domestic animals (Schumann et al., 1983). Ustilago longissima in Glyceria maxima and Ustilago echinata in Phalaris arundinacea have been related to the occurence of bloat (Stählin, 1957). Jenkinson (1958) assumed ergot-infected grass to be the cause of intestinal disorders of grazing cattle. Infestation by the nematode Anguina agrostis of the immature seeds of Festuca rubra has been associated with a fatal disorder in sheep and cattle (Reid, 1973).

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