

Use of Trees by Livestock
QUERCUS

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R.T. Peterson



Development



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Contents

Foreword	
Genus <i>Quercus</i>	1
Summary	1
Description and distribution	2
Fodder characteristics	2
Anti-nutritive factors	6
Management	9
Alternative uses	10
References and further reading	12



Foreword

The importance of trees and shrubs in the feeding of animals in the tropics and sub-tropics has long been recognized by livestock owners. In arid areas where the growth of herbaceous plants is limited by lack of moisture, leaves and edible twigs of trees and shrubs can constitute well over 50% of the biomass production of rangeland. At high altitudes, tree foliage may provide over 50% of the feed available to ruminants in the dry season, branches being harvested and carried to the animals. Even in regions of higher rainfall where grass supplies the major proportion of the dry matter eaten by ruminants, tree leaves and fruits can form an important constituent of the diet, particularly for small ruminants.

In the last two decades interest in the planting of trees as a source of feed for livestock has been encouraged by workers in research and development, but in contrast to the hundreds of indigenous species which are used as fodder, attention has focussed on a limited number of introduced species. Thus there are many publications reporting the chemical composition of *Leucaena leucocephala* leaves and suggesting management

strategies for utilization of the tree for fodder, but it is more difficult to find information on alternative genera which might be equally, or more, appropriate.

The aim of this series of publications is to bring together published information on selected genera of trees which have the potential to increase the supply of fodder for ruminants. Each booklet summarizes published information on the fodder characteristics and nutritive value of one genus, with recommendations on management strategies, where available. Further, since the leaves of woody species frequently contain secondary compounds which may have an anti-nutritional, or toxic, effect, a separate booklet summarizes the effects of a number of these compounds. It is hoped that the booklets will provide useful resource material for students, research and extension workers, interested in promoting the use of trees as a source of fodder for ruminants

Further copies of this booklet or others in the series can be obtained by writing to Publishing and Publicity Services at the Natural Resources Institute.

Margaret Gill
Livestock Production Programme

Genus *Quercus*

Family FAGACEAE

Principal species *Quercus alba*
Q. calliprinos
Q. coccifera
Q. falcata
Q. gambelii
Q. glauca
Q. grisea
Q. havardii
Q. ilex
Q. incana
Q. lamellosa
Q. macrocarpa
Q. pubescens
Q. robur (syn. *Q. pedunculata*)
Q. rubra (syn. *Q. borealis*)
Q. semecarpifolia
Q. suber
Q. velutina (syn. *Q. tinctoria*)

Common name Oak

Summary

The leaves and acorns of many oak species are avidly eaten by cattle, sheep, goats, horses and pigs. Oak fodder contains relatively high levels of polyphenolic compounds and is not highly digestible but it is often available at times of the year when other fodder is in short supply. Its crude protein content is reasonable and it can be a useful supplement to poor-quality grazing or to cereal straw-based diets.

Oak toxicity occurs sporadically when animals consume too high a proportion of either leaves or acorns in their diets. Symptoms of toxicity appear within a few days and death follows rapidly. The provision of alternative feed, sometimes together with supplements of calcium reduce the incidence of poisoning.

Oak trees are used for many purposes including timber for tools, construction, ship-building and joinery. The wood is used for fuel and makes good charcoal. The bark provides tannins, inks and dyes for fabrics and leather work and cork for use in bottling, linoleum products etc. Acorns are sometimes eaten by humans and the leaves are used to feed silkworms and cochineal insects. They are important multi-purpose trees in many parts of the world.



Description and distribution

Quercus is a genus of some 600 woody, perennial species of diverse habit and leaf shape, ranging in size from shrubs to tall trees. Oaks are characterized by their fruit which takes the form of an acorn (Kingsbury, 1964), developing from a tricarpellate, inferior ovary and subtended by a cup formed by numerous overlapping scale leaves. The acorns mature over either one (white oaks) or two (black oaks) years. Trees may be either evergreen or deciduous but where they lose their leaves in autumn, they produce well developed winter buds.

The genus has a wide geographical distribution. In the Americas, it is found from the far north down into the tropical western parts of South America. It is also native to temperate and tropical Eurasia and both north and south Africa. Prior to widespread felling for agricultural purposes, oaks were a major component of many European forests. There appears to be natural hybridization, at least between some European species, and synonymy seems to have resulted from imperfect genetic isolation of species (Mabberly, 1987).

Many species have economic uses based either on

their strong, durable, close-grained timber or on the bark which provides cork and a range of extracts used for inks, dyes, leather tanning and medicinal purposes (Uphof, 1968; Willis, 1973). The acorns are commonly used as food for both humans and livestock and the leaves are fed to domestic animals, including silkworms (Uphof, 1968). Nevertheless, oak toxicity has been described in a range of animals, including cattle, buffaloes, horses, sheep, pigs, rabbits and dogs in a number of countries (Boughton and Hardy, 1936, in USA; Clarke and Cotchin, 1956, in UK; Kingsbury, 1964, in France, Germany and New Zealand; Nesor *et al.*, 1982, in South Africa; Shi, 1988, in China).

Fodder characteristics

The plant parts of oaks and the season in which they are most readily consumed by livestock both depend to a large extent on the growth habit of the particular species under consideration. In the southwest of North America where shrubby species such as *Q. grisea*, *Q. gambelii*, and *Q. dumosa* are common, leaves, buds and twigs are browsed avidly by goats and to a lesser extent by sheep and cattle (Ahmed, 1982;

Nunez-Hernandez *et al.*, 1989; Holechek *et al.*, 1990). In southern Europe, this is also true of *Q. ilex* and regrowths of *Q. pubescens* (Guerro and Boza, 1983; Meuret *et al.*, 1985; Meuret, 1988), while in Israel, leaves and young stems of *Q. calliprinos* are an important source of feed for cattle and goats (Perevolotsky *et al.*, 1993). The reported levels of voluntary intake of native oak browse by goats in France, Greece and Israel are higher than with the common oak species in North America at equivalent levels of digestibility and protein content. This may be attributable to the evolution of adaptive digestion behaviour over a much longer period in the Old World than has so far been possible in North America (Perevolotsky *et al.*, 1993). In India and Nepal leaves of a number of species such as *Q. incana*, *Q. semecarpifolia* and *Q. glauca* are harvested either for direct feeding of fresh material or for storage for use in times of fodder shortage (Lohan *et al.*, 1983; Bajracharya *et al.*, 1985). In such situations, the importance of acorns in animal nutrition is limited and oaks make their greatest contribution in the spring and summer.

In contrast to this, acorns from tall, mature trees of species such as *Q. robur* and *Q. alba* constitute the

major source of oak fodder in the northeastern part of North America (Kingsbury, 1964), northern Europe (Clarke and Cotchin, 1956) and South Africa (Neser *et al.*, 1982). Warm, dry summers tend to favour heavy crops of acorns. Autumn storms and winter snows can then lead to the simultaneous shedding of large quantities of fruits which can become an important source of feed when grazing and other browse may be unattractive, unavailable or scarce (Clarke and Cotchin, 1956; Holliman, 1985; Spier *et al.*, 1987) late in the year. In some areas, fallen leaves are also consumed from the litter on the ground under oak trees, but this material is not particularly attractive, being of poor quality and low digestibility (Forwood and Owensby, 1985).

Some typical data for the chemical analysis of leaves, buds and edible twigs of a number of oak species are shown in Table 1. On the basis of these data, *Quercus* spp. could be considered as relatively good sources of fodder, since in comparison with other commonly available browse species they show reasonably high levels of crude protein, moderate amounts of crude fibre and ether extract (fats) and low residues of ash (Bajracharya *et al.*, 1985).

In vitro dry matter digestibility (IVDMD) averaged



only 36.9% from mid-September to late October for *Q. macrocarpa*, and was only slightly better for a *Q. macrocarpa* hybrid (similar to *Q. alba*) with 42.6% (Forward and Owensby, 1985).

In general, however, *in vitro* analyses appeared to underestimate the digestibility of oak fodder when it was below about 60%, the discrepancy becoming greater at lower levels (Perevolotsky *et al.*, 1993). *In vivo* digestibility of a range of oak species from both Europe and North America appeared to fall in the range of 47-49% when measured in goats, although this could be increased by some 4-9% by the inclusion in the diet of high-quality meals made from lucerne (*Medicago sativa*) or soyabeans (Meuret, 1988; Nastis and Malechek, 1988). When fed as the sole dietary component to pregnant adult goats, *Q. calliprinos* was slightly deficient in protein, but provided adequate energy for maintenance (Perevolotsky *et al.*, 1993)

The inclusion of small proportions of *Q. gambelii* and *Q. grisea* in goat rations based on either lucerne or barley straw resulted in significant reductions of *in vivo* digestibility of the overall rations (Nastis and Malechek, 1981; Holechek *et al.*, 1990). This effect may be the result of the presence of anti-nutrive

factors in the oak fodder.

It has been noted (Nastis and Malechek, 1981) that where oak browse constitutes a large proportion of the ration, its low level of digestibility may reduce voluntary intake. This, in turn, may result in a diet which is deficient in metabolizable energy, especially if consumed together with native forage of poor nutritional quality. When used as a supplement at levels of intake below 25% of the diet, however, *Q. incana* is capable of increasing the digestibility and voluntary intake of wheat straw (Lohan *et al.*, 1983). It would appear that oak foliage is best used at relatively low levels of intake to supplement other, poor quality feedstuffs.

While not a common practice, the use of oak sawdust has been studied as the roughage component of diets for beef cattle on high-energy finishing rations (el-Sabban *et al.*, 1971). Sawdust could be successfully used at levels of up to 15% as fed, of a ration based on shelled corn and soyabean meal, without detrimental effects on growth rates or carcass characteristics. Coarse sawdust produced from a circular saw (modulus of fineness 4.56) was preferable to fine sawdust from a band saw (modulus of fineness 2.40), as the coarser material

Table 1 Analysis of edible leaves and twigs of *Quercus* spp.

Species	Crude protein	Crude fibre	Ash	Ether extract (% of dry matter)	NFE	NDF	ADF	Source
<i>Q. calliprinos</i>	6.5	25.9	5.5	4.4	57.8	52.1	45.4	1
<i>Q. glauca</i>	9.6		6.7	2.8				2
<i>Q. grisea</i>	10.6			9.1		44.3	35.1	3
	10.0			3.8		53.2	38.2	4
<i>Q. ilex</i>	7.8	36.4	6.0	3.2	46.6			5
<i>Q. incana</i>	11.6	35.9	5.0	3.7	43.8			6
<i>Q. lamellosa</i>	7.5		6.4	2.9				2
	11.9		5.2					7
<i>Q. lanuginosa</i>	5.6		2.5	1.4				2
<i>Q. semecarpifolia</i>	8.7		3.1	7.6				2
	14.6		2.9					7
	9.7	30.9						8
<i>Q. spicata</i>	8.7		8.0	2.9				2

Sources: 1 - Perevolotsky *et al.* (1993); 2 - Bajracharya *et al.* (1985); 3 - Holechek *et al.*; 4 - Nunez-Hernandez *et al.*;
5 - Guerrero and Boza (1983); 6 - Lohan *et al.* (1981); 7 - C. Wood (NRI), pers. comm. (1993); 8 - Roder, 1985.

Note: NFE - Nitrogen-free extract; NDF - Neutral detergent fibre; ADF - Acid detergent fibre.



appeared to improve rumen condition and reduce the incidence of liver abscesses.

Anti-nutritive factors

The poor digestibility of oak foliage is generally attributed to the high content of phenolics (including tannins) which is found in all species. Using the Folin-Denis reagent, Nastis and Malechek (1981) found 11.1% tannic acid equivalent of phenolic compounds in the immature leaves of *Q. gambelii* and 8.7% in the mature leaves, while Nunez-Hernandez *et al.*, (1989) and Holechek *et al.* (1990) found 7.9% in the immature leaves of *Q. grisea* and 5.4% in the mature leaves. From a single tree of *Q. robur*, Feeny and Bostock (1968) found that the total tannin content increased from less than 1% in early spring to 5% in late summer, the increase being largely due to an increase in the level of condensed tannin. These authors concluded that the period of heaviest insect attack (early spring) coincided with the lowest levels of total tannins and the near complete absence of condensed tannins in the leaves of *Q. robur* thus illustrating the protective role of tannins. In contrast, total phenolics were found to be highest in young

leaves of *Q. gambelii* (Nastis and Malechek, 1981) and *Q. havardii* (Dollahite *et al.*, 1966), the content falling with leaf maturity. In *Q. incana* the total phenolic content and protein precipitating capacity decreases with advancing leaf maturity while condensed tannins increase (Makkar *et al.*, 1988).

The total phenolic content of acorns varies with both the species of oak and the stage of maturity of the fruit (Basden and Dalvi, 1987). When extracted with Folin-Ciocalteu reagent, *Q. alba* (0.41-2.54%) contained less phenolics (tannic acid equivalent) than *Q. rubra* (3.72-4.47%) or *Q. velutina* (3.29-6.13%) when expressed as a percentage of air-dry weight of acorns with the cups removed. Green acorns contained from 1.5 to 3 times the phenolic levels of ripe acorns.

Bowns (1988) noted that many toxic species within a range of potentially poisonous plants, including *Q. gambelii* and species of *Prunus*, *Cercocarpus*, *Delphinium* and *Astragalus*, are considered by farmers to be good, or even excellent, forages with only beneficial effects on livestock for much of the year. Under certain conditions, however, animals may consume excessive amounts of these plants too rapidly. They then suffer the effects of toxicity, resulting in reduced productivity, or even death.

Although oaks may sometimes appear to be only nutritionally beneficial to livestock, the potential toxicity of both acorns and foliage has long been recognized. Few early reports adequately identified the toxic species of *Quercus*, but the physical symptoms of poisoning do not appear to vary significantly with either tree species or part of the plant ingested. As early as the 19th century, poisoning was attributed to the high tannin content of oaks (see Kingsbury, 1964). Dollahite *et al.* (1962) failed to produce symptoms of oak toxicity by the oral administration of large amounts of tannic acid to cattle, sheep and goats but repeated doses of either commercial tannins or extracts of oak leaves produced symptoms in rabbits that approximated natural oak poisoning. While it is often assumed that toxicity is due to tannic acid, gallic acid and pyrogallol (Basden and Dalvi, 1987) or to other, unspecified, low molecular weight compounds produced by the breakdown of hydrolyzable tannins in the gut (Shi, 1988), Nesor *et al.*, (1982) suggested that the possibility of a mycotoxin should not be ignored. Moulds are often observed on fallen acorns and these could produce the toxic principal responsible for the poisoning of livestock. The exact

cause of oak toxicity is still open to debate although the presence of potentially toxic compounds other than phenolics in oak leaves and acorns has not been reported.

The toxicity of oak is sporadic and reportedly low, even though buds and immature leaves are relished by cattle, sheep and goats. Harsh weather conditions including drought, high winds or heavy snow, are often associated with outbreaks of oak poisoning (Clarke and Cotchin, 1956; Nesor *et al.*, 1982; Spier *et al.*, 1987). Such weather can cause the simultaneous shedding of large quantities of acorns at times when other forage is scarce. The large buds may be the only browse available in late winter or early spring and under these conditions animals may consume excessive amounts of oak fodder. Toxicity symptoms appear after a few days and rapidly become acute. Symptoms, which are relatively consistent across animal species, include anorexia, constipation, rough coat, dry muzzle, abdominal pain, excessive thirst and frequent urination. Ruminant animals often also suffer rumen stasis. If death does not occur, foetid, haemorrhagic diarrhoea sets in, accompanied by subcutaneous oedema in the ventral part of the body. The pulse becomes thin and rapid and there may be a



brownish discharge from the nostrils. Severe hypocalcaemia and anaemia are noted and renal failure follows. High levels of blood urea can be measured and in both sheep and cattle: Holliman (1985) showed that animals with urea levels higher than 50 mmol/litre of blood rarely survived. Occasionally, death occurs within 24 hours of the onset of the symptoms but 3-10 days is more common.

Animals differ in their susceptibility to oak poisoning. In many countries acorns are collected for feeding to pigs as a supplement to their normal diets. Kingsbury (1964) speculated that the absence of negative consequences to this practice could be due either to the use of oak species with low toxic potential, the consumption of insufficient oak material to provoke toxicity, or to a greater tolerance of oak toxicity in pigs than in other animals. It is generally held that amongst domestic livestock, pigs and goats show greatest tolerance and cattle and buffaloes the greatest susceptibility. Sheep and horses are considered to be intermediate with regard to oak poisoning (Clark and Cotchin, 1956; Kingsbury, 1964; Nesor *et al.*, 1982; Holliman, 1985). Range cattle appear to be able to eat oak foliage at

levels of up to half of their diet on a dry matter basis without suffering ill effects (Kingsbury, 1964), while both Angora and dairy goats can consume 80-85% of their dietary dry matter as browse of *Q. gambelii* (Davis *et al.*, 1975; Nastis and Malechek, 1981), without showing either physical or physiological symptoms of toxicity.

In herds of cattle given free access to browse containing *Quercus* spp., there is a marked effect of age on susceptibility to poisoning. In the Ermelo region of South Africa, Nesor *et al.* (1982) reported that in a herd of 80 animals ranging in age from one to eight years, 22 animals suffered from poisoning and of these, 16 died. All the affected animals were less than two years old. In the Lake District of UK, in an outbreak of toxicity in 1984, confirmed cases included cattle ranging in age from three months to adult cows, and sheep ranging from fattening lambs to adult ewes. The most susceptible animals were the young cattle (Holliman, 1985). In California, in an outbreak resulting in the death of 2700 cattle in 1985, Ostrowski *et al.* (1989) noted that the most affected animals were calves weighing 100 - 180 kg.

Management

In most parts of the world, little attempt is made to manage oak trees specifically for the provision of fodder to ruminant livestock. Acorns and senescent leaves are generally seen as seasonal feeds which are utilized opportunistically as they fall to the ground, while accessible buds are browsed in a similar manner as they open and attract the attention of animals. Under ranching conditions, the major challenge to management is to ensure, in times of stress when other feeds may be in short supply, that the animals do not consume a diet too rich in oak forage. Poisoning has been avoided by *ad lib.* provision of alternative feed to reduce the intake of fodder from oak trees. Dollahite *et al.* (1966) recommended the use of well-balanced supplementary feed to which calcium hydroxide had been added at a rate of 15% by weight (reducing to a minimum of 10% if the higher rate resulted in acceptability problems) to counteract the characteristic hypocalcaemia associated with oak toxicity. In contrast to this, Spier *et al.* (1987) reported that when unseasonal snow in California in April 1985 denied animals their normal forage and cattle

ingested toxic quantities of buds of *Q. douglasii*, the immediate provision of hay, even in the absence of additional minerals, resulted in minimal stock losses. A total of some 2700 animals on 60 ranches died of oak toxicosis in the reported outbreak. Most of these received no supplementary feeding.

As noted above, cattle under two years of age appear to be at most risk from oak poisoning. It is therefore obvious that when conditions are such that excessive amounts of oak fodder may become available, young cattle should be removed to safe areas or provided with supplementary feed to reduce the risk of toxicity.

In Europe, it has been shown that leaves and twigs of *Q. ilex* can be used as a protein supplement for goats (Guerrero and Boza, 1983; Meurat, 1988). The plant material can be browsed or harvested and fed fresh, and is particularly valuable during winter, or in times of drought.

In India and Nepal, oak trees are of particular importance at higher altitudes where the number of browse species is limited. In this region, it is common practice to harvest oak leaves as animal fodder during the growing season, either for immediate use or for storage on the farm for use during times of



feed scarcity (Bajracharya *et al.*, 1985; Makkar *et al.*, 1986). It was originally thought that Indian oaks had no toxic effects on livestock (Chopra *et al.*, 1955) but more recent work has shown a reduction in the productivity of cattle fed moderate levels of *Q. incana* and the manifestation of toxicity symptoms when fed at higher levels (Lohan *et al.*, 1983; Makkar *et al.*, 1986). Sole feeding of oak leaves to yearling calves produced toxic effects within two days and one animal out of a group of four died within four days (Negi *et al.*, 1979). It would appear that the common perception of oak fodder is as a valuable resource to be used sparingly to supplement wheat straw or poor quality volunteer grasses during periods of feed shortages. This concept, resulting in the consumption of relatively low levels of oak leaves, would tend to maximize the efficient use of the scarce supplement and minimize the danger of stock losses due to poisoning.

Alternative uses

The many and varied economic uses of oak trees in their differing environments have been described by numerous authors including Smith (1882), Uphof

(1968) and Mabberley (1987).

The wood of many species is heavy, close-grained, strong, durable and of a pleasing colour. It is used in numerous countries of the Americas, Europe and the Far East for construction, agricultural implements and small tools, carriages, boat-building, furniture and interior finishes, cooperage, basket-making, railway sleepers, fences etc. Species particularly valued for timber include *Q. alba*, *Q. eduardi*, *Q. garryana*, *Q. ilex*, *Q. macrocarpa*, *Q. pubescens*, *Q. robur*, *Q. rubra* and *Q. virginiana*.

Several species, such as *Q. bicolor*, *Q. grisea*, *Q. macrocarpa* and *Q. nigra* are used for fuel, while *Q. incana* and *Q. marylandica* are reputed to make excellent charcoal.

In Japan, trunks of dead *Q. glandulifera* trees are used for the cultivation of edible mushrooms.

The bark of many oak species is utilized in industry. *Q. suber*, and occasionally other species such as *Q. pseudosuber* and *Q. occidentalis*, are cultivated for the production of cork, principally in Portugal and around the northern Mediterranean. *Q. denticata*, *Q. lusitanica*, *Q. prinus*, *Q. robur* and *Q. velutina* amongst others are used for tanning leather, while textile dyes are extracted from *Q. tauricola*, *Q.*

variabilis and *Q. velutina*. Powdered bark of *Q. alba*, containing about 10% tannin, is used medicinally as an astringent and a tonic. North American Indians used a decoction of the bark of *Q. lyrata* to treat dysentery and stomach ache.

Oak galls (commonly known as oak apples) are growths produced by perforations made by egg-laying insects on leaves and twigs. These callouses, known commercially in relation to the area of origin as Aleppo, Levant, Mecca and Turkish galls, contain 36-58% tannin (Mabberly, 1987) and are collected for use in leather processing, the manufacture of inks and dyes and in ointments and suppositories. *Q. infectoria* produces the best known commercial galls but other species such as *Q. tauricola* and *Q. robur* are also exploited for these purposes.

The acorns of many species, including *Q. cuspidata*, *Q. emoryi*, *Q. gambelii*, *Q. ilex*, *Q. glabra*, *Q. nigra* and *Q. persica* are eaten, either raw or cooked, by humans in many parts of the world. They may be roasted, boiled or sometimes made into a flour for baking. Species such as *Q. obtusiloba* and *Q. robur* are used as coffee substitutes. *Q. cerris* is a source of oak manna (*gaz* or *gazu much*) used to make a sweet-meat in Iran.

The leaves of *Q. obtusiloba* have been used as cigarette papers by North American Indians, while silkworms (*Antheroea pernyi*) are fed on leaves of *Q. fabri* and other oak species in China. *Q. coccifera* is used for feeding cochineal insects (*Coccus ilicis*).

Many oak species are handsome trees and much prized as ornamentals.



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