# *Mulberry: an exceptional forage available almost worldwide!*

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## *Summary*

Mulberry (*Morus* spp), the traditional feed for the silk worm, has been selected and improved for leaf yield and quality in many environments and is spread throughout the world. Mulberry leaves are highly palatable and digestible (70-90 %) to herbivorous animals and can also be fed to monogastrics. Protein content in the leaves and young stems, with a good essential amino acid profile, varies from 15 to 28 % depending on the variety. Mineral content is high and no anti-nutritional factors or toxic compounds have been identified. The establishment of this perennial forage is through stakes or seed, and it is harvested by leaf picking or cutting whole branches or stems. Yields depend on variety, location (monthly temperature, solar radiation and rainfall), plant density, fertilizer application and harvesting technique, but in terms of digestible nutrients, mulberry produces more than most traditional forages. The leaves can be used as supplements replacing concentrates for dairy cattle, as the main feed for goats, sheep and rabbits, and as in ingredient in monogastric diets.

## *Introduction*

Mulberry (*Morus* spp.) leaves have been the traditional feed for the silk worm (*Bombyx mori*). There is evidence that sericulture started about 5,000 years ago (Huo Yongkang, South China Agricultural University, personal communication) and hence the domestication of mulberry. Mulberry has been selected and improved for leaf quality and yield for a long time. Through silk production projects, mulberry has been taken to countries all over the world, and it has now spread from the temperate areas of northwest and central Asia, Europe and North America, through the tropics of Asia, Africa and Latin America, to the southern hemisphere (southern Africa and South America). There are mulberry varieties for many environments, from sea level to altitudes of 4,000m (FAO, 1990), and from the humid tropics to semi-arid lands, like in the Near East with 250mm of annual rainfall and southwest of the U.S.A. (Tipton, 1994). Mulberry is also produced under irrigation. Although the majority of silk production projects have had limited duration due to silk processing constraints and limited market opportunities, mulberry trees have remained in most places where they had been introduced.

The main use of mulberry globally is as feed for the silk worm, but depending on the location, it is also appreciated for its fruit (consumed fresh, in juice or as preserves), as a delicious vegetable (young leaves and stems), for its medicinal properties in infusions (mulberry leaf tea), for landscaping and as animal feed. In Peru, the multiple uses of mulberry have been recognised (Zepeda, 1991). There are several places where mulberry is utilised traditionally as a feed in mixed forage diets for ruminants, like in certain areas of India, China and Afghanistan. In Italy there has been several studies on the use of mulberry for dairy cows and other domestic animals (Vezzani, 1938; Maymone *et al*, 1959; Bonciarelli and Santilocchi, 1980; Talamucci, and Pardini, 1993) and in France there was a research project to introduce mulberry in livestock production (Armand, 1995). But it was only in the eighties that specific interest in the intensive cultivation and use of mulberry as animal feed started in Latin America. It is surprising, that a plant which has been improved for leaf quality and yield to feed an animal, the silk worm, which has high nutritional feed requirements, received limited attention by livestock producers, technicians and researchers.

Like several significant breakthroughs in science and technology, the discovery of the value of mulberry as a high quality feed in Latin America happened serendipitously. A Costa Rican farmer of Chinese origin, whose silk project failed, fed mulberry leaves to his goats and was impressed by its palatability and by the performance of his animals. He communicated his observations to scientist of the Tropical Agriculture Research and Training Center (CATIE), who were receptive to the farmer's news and smart enough to include mulberry in their tree fodder evaluations and later in agronomic and animal performance trials (J. Benavides, personal communication). In Africa, the International Centre for Research in Agroforestry (ICRAF) in Kenya and the Livestock Production Research Institute in Tanzania, have conducted successful agronomic and animal trials by themselves, apparently without being aware of the interest elsewhere.

## *Genetic resources*

Mulberry belongs to the Moraceae Family (Subtype Angiosperms; Class Dicotyledons; Subclass Urticales) and there are several species: *Morus alba*, *M. nigra*, *M. indica*, *M. laevigata*, *M. bombycis*, etc. which have been used directly, or through crossings and induced mutations, for the development of varieties to support silk worm production. The diploid *M. alba* (2n=2x=28) is the species most widely spread, but polyploid varieties, which originated in various research stations in Asia, show greater leaf yields and quality. In general, polyploid varieties have thicker and larger leaves with darker green colour, and produce more leaves. There is a large variation in leaf production and in leaf quality (e.g. protein content) among the many species and in the varieties and cultivars grown at different locations under a wide range of soil and environmental conditions, indicating the huge potential for identifying suitable germoplasm for most sites. Many of the references on mulberry in the literature do not specify which species or varieties were used. Often, names are given based on leaf features. In many cases locally grown varieties (native or "criolla") seem to perform adequately, since they are probably well adapted to local conditions.

## *Composition and nutritive value*

Results of chemical composition of mulberry fractions from various authors are presented in Table 1. Crude protein content in leaves varies from as low as 15% to 28% depending on the variety, age of the leaves and growing conditions. In general, crude protein values can be considered similar to most legume forages. Fibre fractions are low in mulberry leaves compared to other foliages. Shayo (1997) reported lignin (acid detergent lignin) contents of 8.1% and 7.1% for leaves and bark, respectively. A striking feature of mulberry leaves is the mineral content, with ash values up to 25%. Typical calcium contents are around 1.8-2.4% and phosphorus 0.14-0.24%. Espinoza *et al*. (1999) found potassium values of 1.90-2.87% in leaves and 1.33-1.53% in young stems, and magnesium contents of 0.47-0.63% for leaves and 0.26-0.35% for young stems.

Table 2 shows the digestibility of mulberry. As can be seen, leaf digestibilities *in vivo* (goats) and *in vitro* are very high (>80%) and total digestibility is equivalent to that of most tropical forages. The degradation characteristics of mulberry, determined by the nylon bag technique, are presented in Table 3. Leaves would be completely degraded if they remained in the rumen for enough time (Maymone *et al* 1959).

**Table 1.** Chemical composition (% of dry matter) of mulberry

| Variety | CP | CF | NDF | ADF | EE | Ash | Ca | P | Reference |
|---|---|---|---|---|---|---|---|---|---|
| **Leaf** | | | | | | | | | |
| Hebba[1] | 15.9 | 12.6 | | | 7.1 | 15.9 | 2.42 | 0.24 | Narayana & Setty, 1977 |
| Izatnagar[1] | 15.0 | 15.3 | | | 7.4 | 14.3 | 2.41 | 0.24 | Jayal & Kehar, 1962 |
| Palampur[1] | 15.0 | 11.8 | | | 5.1 | 15.5 | | | Singh *et al.*, 1984 |
| Parbhani[1] | 22.1 | 5.9 | | | 3.9 | 13.4 | 3.3 | 1.43 | Deshmukh *et al.*, 1993 |
| Kanva-2 | 16.7 | 11.3 | 32.3 | | 3.0 | 17.3 | 1.80 | 0.14 | Trigueros & Villalta, 1997 |
| Mpwapwa[1] | 18.6 | | 24.6 | 20.8 | | 14.3 | | | Shayo, 1997 |
| Dominican | 20.0 | | | 23.1 | 4.0 | 4.5 | 2.70 | | ITA#2, 1998 |
| Criolla | 19.8 | | | | | | 1.90 | 0.28 | Espinoza *et al.*, 1999 |
| Tigreada | 21.1 | | | | | | 2.74 | 0.38 | |
| Indonesia | 20.1 | | | | | | 2.87 | 0.33 | |
| **Leaf & young stem** | | | | | | | | | |
| Tigreada | 27.6 | 13.2 | | | | 10.4 | | 0.20 | González *et al.*, 1998 |
| Indonesia | 24.3 | 15.3 | | | | 11.2 | | 0.29 | " |
| Criolla | 27.6 | 16.9 | | | | 11.8 | | 0.26 | " |
| Acorazonada | 25.2 | 14.1 | | | | 13.4 | | 0.15 | " |
| Koruso 21[2] | 11.0 | 10.0 | 22.0 | 20.6 | 5.9 | 13.9 | 3.13 | 0.37 | Casoli *et al.*, 1986 |
| Koruso 21[3] | 8.0 | 11.8 | 24.7 | 24.5 | 5.3 | 19.3 | 4.76 | 0.37 | " |
| **Young stem** | | | | | | | | | |
| Criolla | 11.3 | | | | | | 1.33 | 0.29 | Espinoza *et al.*, 1999 |
| Tigreada | 11.7 | | | | | | 1.38 | 0.33 | |
| Indonesia | 11.9 | | | | | | 1.53 | 0.43 | |
| Dominican | 4.7 | | | 48.2 | 1.7 | 1.3 | 1.61 | | ITA#2, 1998 |
| **Stem** | | | | | | | | | |
| Dominican | 3.8 | | | 50.2 | 1.0 | 1.8 | 1.10 | | ITA#2, 1998 |
| Mallur | 11.5 | 34.0 | | | 2.7 | 9.32 | 1.56 | 0.20 | Subba Rao *et al.*, 1971 |
| **Bark** | | | | | | | | | |
| Mpwapwa | 7.8 | | 46.8 | 36.9 | | 6.1 | | | Shayo, 1997 |
| **Whole plant** | | | | | | | | | |
| Dominican | 11.3 | | | 34.4 | 1.6 | 1.9 | 2.10 | | ITA#2, 1998 |

[1] Names of places where local varieties were used.
[2] September 1982. [3] November 1983.

**Table 2.** Digestibility of mulberry

| Method | Fraction | Digestibility (%) | Reference |
|---|---|---|---|
| *In vivo* (goats) | Leaf | 78.4 – 80.8 | Jegou *et al.*, 1994 |
| | | | |
| *In vitro* | Leaf | 89.2 | Araya, 1990 cited by Rodríguez *et al.*, 1994 |
| | Leaf | 80.2 | Schenk, 1974 cited by Rodríguez *et al.*, 1994 |
| | Leaf | 89 - 95 | Rodríguez *et al.*, 1994 |
| | Stem | 37 – 44 | " |
| | Total | 58 – 79 | " |
| | Leaf | 82.1 | Shayo, 1997 |
| | Bark | 60.3 | " |

**Table 3.** *In sacco* degradation of mulberry (ITA#2, 1998)

| Fraction | Parameter | | | | Reference |
|---|---|---|---|---|---|
| | a | b | a + b | c | |
| Leaf | 35.7 | 64.0 | 99.7 | 0.0621 | ITA#2, 1998 |
| Whole plant | 30.4 | 46.2 | 76.6 | 0.0667 | " |
| Leaf & young stem | 27.8 | 48.95 | 76.8 | 0.0300 | González *et al.*, 1998 |

The average amino acid composition and N content of 119 mulberry varieties grown experimentally in Japan (Machii, 1989) are presented in Table 4. Tryptophane was not included in the analysis. As can be seen from the data, essential amino acids are over 46 % of total amino acids. It can be calculated from the table that the average nitrogen (N) is 16.6% of the total molecular weight of the mulberry amino acids (plus ammonia), and thus the converting factor from N to mulberry protein is 6.02. The 204.3 mg of amino acids per g of protein is equivalent to 3.47% N, which is 80% of total N in mulberry leaves. Once tryptophane is subtracted, the difference, a non-protein fraction, is likely to be composed of nucleic acids and other unidentified N compounds.

**Table 4.** Average amino acid composition and N content of mulberry varieties (Machii, 1989) and soybean meal (NRC, 1984).

| **Compound** | **Soybean meal** | | **Mulberry** | | |
|---|---|---|---|---|---|
| | **Content (mg/g DM)** | **%[1]** | **Content (mg/g DM)** | **SD** | **%[1]** |
| Non essential amino acids | n.a.[2] | | 108.93 | | 53.3 |
| Essential amino acids (EAA): | | | | | |
| Lysine | 32.92 | 6.7 | 12.33 | 2.58 | 6.0 |
| Methionine | 7.30 | 1.5 | 2.99 | 0.61 | 1.5 |
| Threonine | 20.34 | 4.1 | 10.52 | 1.75 | 5.2 |
| Valine | 26.29 | 5.3 | 12.83 | 2.17 | 6.3 |
| Isoleucine | 26.85 | 5.4 | 10.04 | 1.88 | 4.9 |
| Leucine | 39.55 | 8.0 | 19.45 | 3.10 | 3.1 |
| Tyrosine | 14.38 | 2.9 | 7.40 | 1.39 | 3.6 |
| Phenylalanine | 25.51 | 5.2 | 12.26 | 2.06 | 6.0 |
| Histidine | 12.92 | 2.6 | 4.61 | 0.82 | 2.3 |
| Trytophane | 6.97 | 1.4 | n.a.[2] | - | - |
| Total EAA | 213.03 | 43.1 | 92.43[3] | - | 45.3 |
| Ammonia (NH3) | n.a.[2] | | 2.89 | 0.54 | 1.4 |
| Total (AA + NH3) | 494.38 | 100 | 204.25 | | 100 |
| Nitrogen (%) | 7.91 | | 4.36 | 9.63 | |

[1] Percentage of the amino acid in the total sum of amino acids (plus ammonia).
[2] Non available
[3] Without Tryptophane

The most important protein in mulberry leaves, as in most leaves, is ribulose-1,5-bisphosphate carboxylase (RuBisCO) whose active site is responsible for carbon fixation (Kellogg & Juliano, 1997). Nitrogen in RuBisCO can be 43% of the total nitrogen in mulberry (Yamashita & Ohsawa, 1990).

**Palatability**. One of the main features of mulberry as forage is its high palatability. Small ruminants avidly consume the fresh leaves and the young stems first, even if they have never been exposed to it before. Then, if the branches are offered unchopped, they might tear off and eat the bark. Cattle consume the whole biomass if it is finely chopped. There is a report (Jegou *et al*., 1994) of *ad libitum* dry matter intake of 4.18% of liveweight (average of three lactating goats), which is much higher than in other tree fodders. Jayal and Kehar (1962) reported dry matter intakes of mulberry leaves of 3.44% of body weight in sheep under experimental conditions. Animals initially prefer mulberry over other forages when they are offered simultaneously, and even dig through a pile of various forages to look for mulberry (Antonio Rota, FAO Barbados, personal communication). In a comparative study, Prasad and Reddy (1991) reported higher daily dry matter intakes of mulberry leaves in sheep than in goats (3.55 vs 2.74 kg DM/100kg body weight).

## *Agronomy*

**Establishment**. The most common planting method worldwide is by stem cuttings, but in certain places seed is preferred. As is the case with other tropical perennial forages for cut-and-carry systems, planting by seed assures deeper roots with greater capacity to find water and nutrients which eventually results in higher biomass production and greater longevity. Seeds might be the most acceptable way of transporting, quarantine and store selected materials. The advantages of stem reproduction (cloning) are certainty of production characteristics, practicality in obtaining the material and easiness of planting. Male plants might be preferred when introducing foreign germoplasm to new locations since this prevents involuntary expansion (Morgan P. Doran, University of California, Davis, U.S.A., personal communication). As in most perennial forages, the time and the establishment cost (mainly for land preparation, planting and weed control) are the critical aspects of the successful introduction of mulberry.

**Cultivation**. Mulberry is cultivated for fruit as isolated trees or in orchards; for small scale silk worm rearing along the edges or along food crops in mixed farming systems; for large silk projects or for intensive forage production in pure stands; and also for forage in association with N-fixing legumes (Talamucci and Pardini, 1993; González and Mejía, 1994). Mulberry is also found mixed with other trees in natural forests or plantations.

**Fertilisation.** All the required nutrients for mulberry growth must come from the soil, since it does not fix atmospheric nitrogen. In pure stands, mineral and organic fertilisers (animal and vegetable manures) must be used to replenish the nutrients removed with the foliage in order to maintain a sustainable production. The association with legumes with effective N-fixing rhizobium can reduce N inputs and may be the most desirable combination for some farms, but even when recycling nutrients in animal manures, extra chemical fertilisers are required for maximum yields (J.E. Benavides, personal communication). Responses of mulberry to N fertilisers have been clearly demonstrated, both in inorganic and organic forms, with better responses to the latter (Table 5). According to Kamimura *et al*. (1997), the nitrogen level in soils is the major factor for mulberry growth.

**Harvest and preservation**. For silk worm feeding, individual leaf picking, shoot harvesting and whole branch cutting are practised, depending on the feed requirements of silk worm larvae stages and on harvesting costs (FAO, 1988). For silk worms leaves are offered fresh, but some other forms of feeding are being developed. For ruminant feeding, the preferred method has been branch cutting by hand, although one could envisage that mechanical harvesting could be employed in the future for direct feeding of fresh material on a large scale, for processing or for drying. Forage conservation by ensiling has been successfully achieved (Vallejo, 1995; González, 1996; cited by Benavides, 1999) and there have been some preliminary studies on leaf drying (Ojeda *et al.*, 1998). Leaf blades dry within hours under full sun but more time is required for petioles and stems. Some conditioning (e.g. passing them through rollers) may help to reduce water content and minimise the deterioration of leaf quality by over exposure. Diploid varieties dry faster since they tend to have more stomata per unit of leaf area (Govindan *et al.*, 1988).

**Table 5.** Effect of goat manure or ammonium nitrate application on total dry matter yields during three consecutive years (Benavides *et al.*, 1994).

| Year | Level of manure (ton DM/ha/year) | | | | $NH_4NO_3$ |
|---|---|---|---|---|---|
| | 0 | 240[1] | 360[1] | 480[1] | 480[1] |
| 1[2] | 23.0c | 24.4bc | 26.6b | 31.1a | 26.7b |
| 2 | 21.3c | 25.2b | 27.6ab | 33.4a | 29.7b |
| 3 | 22.9d | 28.2c | 32.6b | 38.2a | 29.2b |

[1] kg of N/ha/year.
[2] Values with the same letter horizontally do not differ (p>0,001).

**Yields**. The production of leaf and total dry matter per hectare of mulberry depends on the variety, on the location, on plant density, on fertiliser applications and on harvesting techniques. Table 6 presents the yields of mulberry in various locations. Total biomass yield and the leaf proportion vary with species and varieties. Climate (moisture and solar radiation) and soil fertility are determining factors on productivity (Espinoza *et al.*, 1999). Increasing planting density increases leaf yields (Gong *et al.*, 1995).

**Table 6.** Examples of mulberry yields

| Location | Variety | Fraction | Yield (tons/ha/year) | | Reference |
|---|---|---|---|---|---|
| | | | Fresh | DM | |
| Karnataka, India | M-5 | Leaf | 40 | | Mehla *et al*., 1987 |
| | | Stem | 52 | | |
| Mpwapwa, Tanzania | Local | Leaf | | 8.5 | Shayo, 1997 |
| | | Stem | | 14.1 | |
| | | Bark | | 2.7 | |
| San José, Costa Rica | Tigreada | Leaf & young stem | | 11.0 | Espinoza *et al*., 1999 |
| | Indonesia | " | | 8.7 | |
| Puntarenas, Costa Rica | Tigreada | " | | 13.4 | |
| | Indonesia | " | | 12.5 | |
| Matanzas, Cuba | Tigreada | Total biomass | 30 | | González *et al*., 1998 |
| | Acorazonada | " | 33 | | |
| | Indonesia | " | 26 | | |
| | Local | " | 30 | | |
| Cuyutla, Guatemala | Local | Total biomass | 37 | | Rodríguez *et al*., 1994 |
| | | Leaves | 16 | | |
| Zhenjiang, Jiangsu, China | Shin Ichinose | Leaves | 32 | | Gong *et al*., 1995 |
| | | Branches | 28 | | |
| | | Stems | 8 | | |
| Kalimpong, W. Bengal, India | Local | Leaves | 22 | | Tikader *et al*., 1993 |
| | BC 259 | " | 20 | | |
| | TR 10 | " | 19 | | |
| | C 763 | " | 19 | | |

Fresh leaf yields of 40 ton/ha /year (approximately 10 tons of dry matter) have been reported in India (Mehla *et al*., 1987) and in Costa Rica (Espinoza, 1999). Maximum dry matter yields of edible material (leaves and young stems) and total biomass were 15.5 and 45.2 tons/ha/year, respectively. Total leaf dry matter yields of less than 10 tons could be expected under less intensive production.

## *Animal performance with mulberry*

**Ruminants.** Although the feeding value of mulberry for dairy cattle has been recognised for some time in Italy (Vezzani, 1938; Maymore *et al*., 1959) and it has been traditionally used in Himalayan countries, the research on mulberry for ruminants has been rather limited. Jayal and Kehar (1962), based on the high digestibility values of *M. indica* leaves, suggested that they could be used as supplements for lower quality forages. Mulberry was used to replace grain-based concentrates in lactating cows with excellent results (Table 7). Yields did not significantly decrease when 75% of the concentrate was replaced with mulberry. Milk production increased with the levels of mulberry offered to goats on a King grass diet (Rojas and Benavides, 1994) as shown in Figure 1. At CATIE (Turrialba, Costa Rica), a module of two dairy goats (Saanen x Toggenburg) being fed exclusively with forage from 775 $m^2$ of mulberry (17,000 plants/ha), in association with *Erytrina berteroana* (5,128 trees/ha) just as green manure, and from 425 $m^2$ of King grass, produced an average of 4 litres per day, equivalent to over 12,000 litres per ha/year (Oviedo *et al*., 1994).

**Table 7.** Substitution of concentrates by mulberry in lactating Holstein cows grazing Kikuyu grass (*Pennisetum clandestinum*) (Esquivel *et al*., 1996)

| Parameter | Concentrate : Mulberry | | |
|---|---|---|---|
| | 100 : 0 | 60 : 40 | 25 : 75 |
| Milk yield (kg/d) | 14.2 | 13.2 | 13.8 |
| Intake (kg MS/d): | | | |
| Concentrate | 6.4 | 4.2 | 1.9 |
| Mulberry | 0 | 2.8 | 5.5 |
| Kikuyo grass | 9.3 | 7.8 | 6.2 |
| Total | 15.7 | 14.8 | 13.6 |

Also in Costa Rica, liveweight gains of bulls belonging to the Romosinuano breed (a criollo type) fed elephant grass, increased to over 900g/d when mulberry was offered as a supplement at 1.7% of their body weight on a DM basis (González, 1996 cited by Benavides, 1999). Table 8 presents the results of an experiment in Guatemala with growing Zebu x Brown Swiss steers being fed increasing levels of mulberry as supplement to a sorghum silage diet (Velázquez *et al*., 1994). Although the growing rates with the highest mulberry level are not impressive (195g/d), most likely due to the poor quality of the silage, this trial shows the high nutritive value of the supplement. Total intake and weight changes improved with the amount of mulberry offered reflecting its higher nutritive value compared to the basal diet. Daily gains of female calves (0-4 months) were not affected when mulberry leaves were offered *ad libitum* and the commercial concentrate reduced to 25% of the amount traditionally used (González y Mejía, 1994). In lambs, gains reached 100g/d when King grass was supplemented with 1.5% DM of mulberry (Benavides, 1986).

**Table 8.** Effect of mulberry supplementation level on intake and weight changes of Zebu x Brown Swiss steers fed on sorghum silage (Velázquez *et al, 1994*).

| **Parameter** | **Mulberry level (% BW[1])** | | | |
|---|---|---|---|---|
| | **0** | **0.5** | **1.0** | **1.5** |
| Dry matter intake (% BW/d) | | | | |
| Total | 2.26 | 2.39 | 2.64 | 2.88 |
| Sorghum silage | 2.26 | 1.91 | 1.68 | 1.51 |
| Daily gains (g/d) | - 128 | - 29 | 164 | 195 |

[1] BW = Body weight

**Monogastrics.** The silk worm has a relatively simple digestive system, in certain ways it is comparable to that of the monogastric animals, thus, in theory, mulberry leaves could also be used at least as one of the ingredients in monogastric diets. In a trial with growing pigs in which a commercial concentrate was replaced by up to 20% by mulberry leaf (Trigueros and Villalta, 1997), the best level of substitution was 15%. It increased daily gains from 680g/d, with only concentrates, to 740g/d and also gave the best economic results. In rabbits, the reduction of concentrate offered daily from 110g to 17.5g with *ad libitum* fresh mulberry only reduced gains from 24 to 18g/d, but decreased to more than half the cost of the meat produced (Lara y Lara *et al*., 1998). The combination of mulberry and *Trichantera gigantea* leaves, as the protein source, and blocks made of molasses, cassava root meal and rice bran, as the energy source, gave better reproduction and growth performance than a diet of commercial concentrates and grass (Le Thu Ha *et al*., 1996). Singh *et al*. (1984) supplemented Angora rabbits, receiving pelleted diets, with mulberry leaves *ad libitum* and obtained intakes of mulberry equivalent to 29-38% of the total intake. This level significantly reduces feed cost. Deshmukh *et al*. (1993) fed mulberry leaves as the sole ration for adult rabbits. They found daily intakes of 68.5g for dry matter, 11.2g for crude protein and 175kcal for digestible energy (equivalent to 2.55Mcal of digestible energy per kg). The digestibility values were 74% for crude protein, 59% for crude fiber and 64% for dry matter. The authors concluded that mulberry leaves provided enough nutrients for maintenance. Narayana and Setty (1977) found better egg yolk colour and increased egg size and production with the inclusion (up to 6%) of shade-dried *M. indica* leaf meal in the mash of laying hens.

Other small herbivores, like guinea pigs, iguanas and snails, could also be fed mulberry leaves. In fact, wild green iguanas (*Iguana iguana*) came to feed on recently established mulberry fields in Costa Rica (J.E. Benavides, personal communication).

## *Livestock production systems*

The traditional way of using mulberry as animal feed in silk producing areas is by providing ruminants with the residue left by the silk worm. A model of sericulture and milk production has been proposed by Mehla *et al*. (1987), in which dairy cows receive mulberry residue and concentrates. The generation of edible protein and employment are much greater than with food grains. This refuse material is added to fishponds for herbivorous carps in the Chinese dyke-pond system, which is one of the most intensive agricultural low-input systems in the world, and generates food and outputs for a large number of people (Korn, 1996). In these silk areas, as well as where mulberry grows wild, cut-and-carry systems are practised and it is the most obvious way of utilising mulberry for livestock, either from pure stands or from associations with legumes (Benavides *et al*., 1995). Mulberry foliage can constitute the supplement to low quality forage (grass) based diets or as the main component of the ration.

A natural association of mulberry and livestock occurs in regions (e.g Near East and Central Asia) where mulberry trees are kept for fruit production. Fallen leaves in the autumn are consumed by domestic animals. Since fruit ripening happens in late spring or early summer, it may be possible to harvest leaves for forage one or more times before the winter.

The only suggestion of utilising mulberry for direct grazing came from Talamucci and Pardini (1993) who proposed a complementary association with clover (*Trifolium subterraneum*) for sheep and cattle grazing in Tuscany (Italy). Mulberry benefits from the N fixation by the clover and contributes with high quality forage during the summer. The association produces more forage over a longer period than the individual pure-stands.

## Conclusion

The net result of long selection and improvement of mulberry has been that it is comparable or better than many other forage plants in terms of nutritional value and yield of digestible nutrients per unit of area, specially in tropical environments. Yield, quality and availability worldwide, make mulberry a very important option to intensify livestock systems, especially in those places where enough nutrients can be applied to obtain maximum response in biomass production. The high mineral content of mulberry foliage should be specifically taken into account in nutrient recycling and fertilising schemes to prevent loss of soil fertility.

Considering its high quality and palatability, mulberry should be relatively more valuable as a feed, the smaller the animals are. Under equal circumstances, stock with higher nutrient requirements (per kg of liveweight), should be given preference when feeding mulberry.

The greatest immediate impact of mulberry in animal production would be in tropical areas if introduced as supplement to lactating cows and as feed to growing calves. It could be grown near stables where simple harvesting and manuring practices could be implemented.

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