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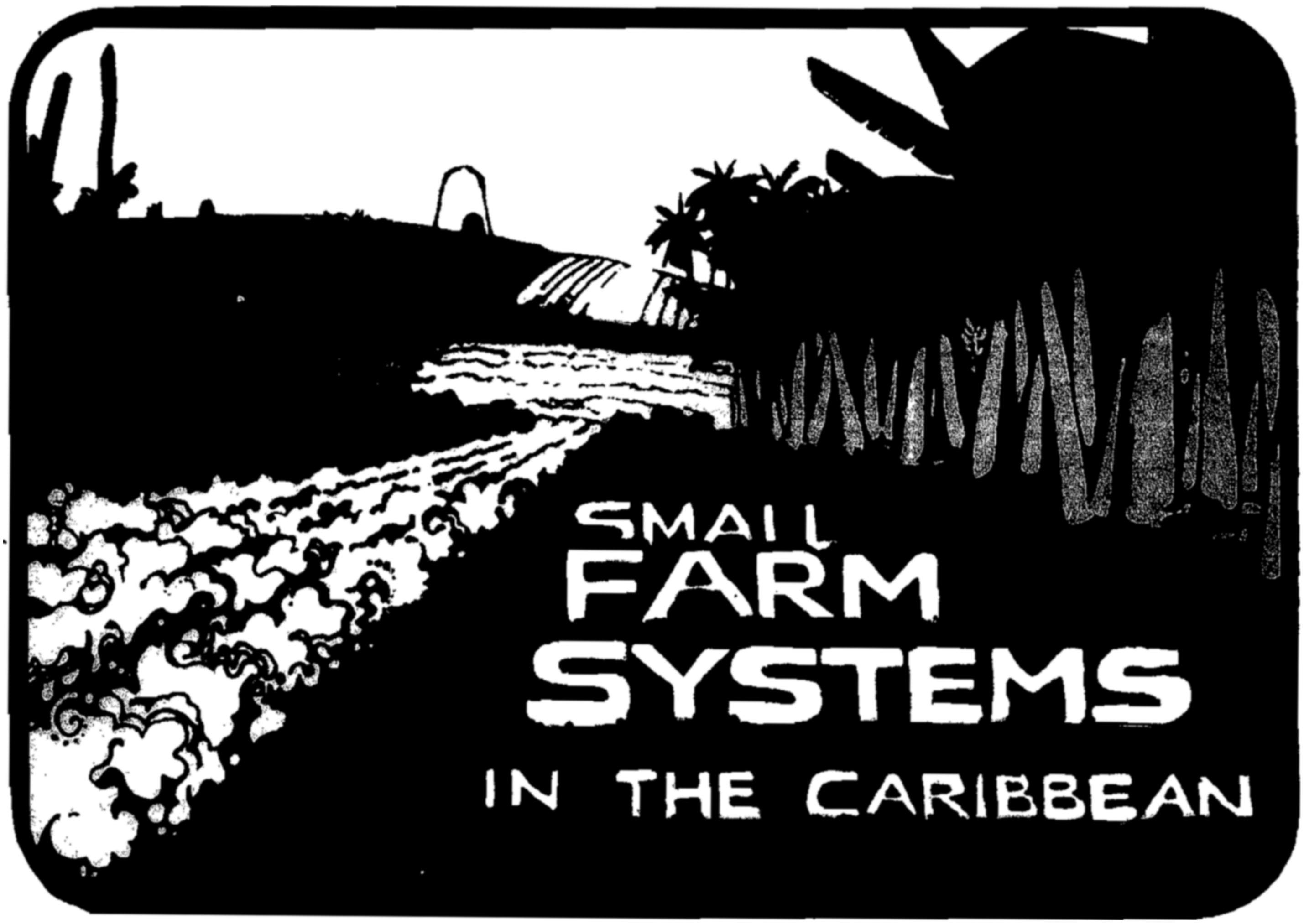

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Leucaena as a Protein Source

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The ubiquitous weedy form of *Leucaena leucocephala* (Lam.) de Wit is capable of producing 1,000-2,000 kg/ha/yr of good quality protein. Its production capacity responds to elevation. rainfall, and soil type in addition to imposed management practices. The cultivars 'El Salvador' and 'Peru' produce 1,000-4,000 kg/ha/yr under similar treatments. Leucaena protein is high in nutritional quality. Amino acids are present in well-balanced proportions. Information from tropical and subtropical regions is sparse as to location and extent it is used as human food. Leaves, flowers, fruiting pods and seeds at various stages of maturity are consumed either cooked or uncooked. Various plant parts are eaten separately or as components in salads or soups. Highly proteinaceous foods such as "botok," "toge," and "tempeh lamtoro" are made from leucaena. Leucaena is of limited value as a food source in widely scattered regions of the tropics and subtropics. Despite the known detrimental effects of leucaena, its consumption as food probably exceeds that which is recorded in the literature. Leucaena is unsurpassed as a renewable source of high quality protein for food and feed.
Keywords: *Leucaena leucocephala* (Lam.) de Wit; Protein production; Protein quality; Food; Feed.

Leucaena provides a renewable and sustaining source of protein for both mankind and his livesrock. Multifarious uses are made of leucaena which include a source of energy, food, feed, fuel, and biomass. This paper addresses some aspects concerning the protein production potential of leucaena and its use as a protein source both for human food and livestock feed. First, in view of the nature and purpose of this meeting the producrion of protein by leucaena and its use as food will be considered. At the same time we must not neglect its use in livestock feed. Most of the leucaena literature concerns the production and utilization of the crop as a source of feed and protein for livestock.

Protein Production

Leucaena leucocephala (Lam.) de Wit is the best known and most widespread in distribution of the ten leucaena species recognized by Brewbaker (1978). The so-called ubiquitous, weedy form of *L. leucocephala* known as the "Hawaiian ecotype" has been evaluated and utilized as a forage crop more extensively than other leucaena species or other lines of *L. leucocephala* largely because of irs widespread distribution and availability. Other lines of *L. leucocephala* and leucaena species have entered forage evaluation trials in recent decades, however. The Hawaiian ecotype has come to be known as the line by which all others are compared in yield trials.

Highly variable protein yields of *L. leucocephala* are reported from different locations throughout the rropics and subtropics. The Hawaiian ecotype, for example, produced only 454 kg/ha/yr in Australia (Hutton and Bonner, 1960). Yields of 3,136 and 3,584 kg/ha/yr are also reported for this same ecotype when grown in Australia (Anon., 1969; Hills, 1963). The cultivar 'Peru' produced 2,464 and 3,603 kg/ha/yr in Queensland, Australia (Hutton and Bonner, 1960) whereas the cultivar 'El Salvador' produced 1,915 kg/ha/yr (Hutton and Bonner, 1960). The yield of an Australian line, C.P.I. 18228, was 1,479 kg/ha/yr (Hutton and Bonner, 1960). The Hawaiian line ranged from 932 to 4,264 kg/ha/yr in a 58-inch rainfall belt in Colombia (Herrara, 1967).

When the Hawaiian line was grown at different elevations in Hawaii, the yields ranged from 550 to 3,233 kg/ha/yr (Gueverra et al., 1975; Takahashi and Ripperton, 1949; Takahashi et al., 1943). When the Hawaiian line and the cultivar 'El Salvador' were grown at 110 m elevation in Hawaii, protein yields were 550 and 460 kg/ha/yr respectively (Gueverra et al., 1975). Takahashi and Ripperton (1949) reported three-year yields of the Hawaiian ecotype to be 3,233 kg/ha/yr when grown at a lower elevation. Brewbaker et al., (1972) evaluated the yield potential of 104 leucaena lines, including the Hawaiian ecotype as the control, in Hawaii. Yields of most lines in these trials exceeded those of the Hawaiian type. Average yield of the top three lines (K8, K29, K67) was 4,838 kg/ha/yr or about rhreefold that of K63, the Hawaiian ecorype control. Yields of 2,352 to 3,080 kg/ha/yr are reported from orher Hawaiian trials involving the Hawaiian ecotype (Takahashi et al., 1943).

The Hawaiian ecotype produced 1,904 kg/ha/yr when grown in a 60-inch rainfall belt in Mauritius, and 3,024 kg/ha/yr in India (Savur, 1953).

Mendoza er al., (1976) report protein yields of 3,346 to 3,733 kg/ha/yr for the cultivar 'Peru' from rhe Philippines.

A two-year mean yield of 2,511 kg/ha/yr of the Hawaiian line is reported from Taiwan (Luh et al., 1961). Slick and Harris (1971) obtained 672 kg/ha/yr from the Hawaiian line grown in south Texas.

Here in the Virgin Islands, the socalled weedy form produced 1,671 kg/ha/yr in one field trial (Oakes and Skov, 1962) and a five-year average of 2,005 kg/ha/yr in a second trial (Oakes and Skov, 1967). These trials were conducted on Fredensborg clay, capable of producing 89,000-90,000 kg/ha/yr of sugarcane. The trials were unfertilized and conducted in a 40-inch rainfall belt. Experimental plantings of eight lines of *L. leucocephala* produced 1,477 to 2,856 kg/ha/yr. The cultivars 'El Salvador' and 'Peru', which produced 2,589 and 2,119 kg/ha/yr respectively, were among the four lines which were superior in yield. All yields reported from the Virgin Islands are from cutting trials.

In summary, the lowest reported protein yields of the Hawaiian ecotype of *L. leucocephala* are those from Queensland, Australia and Texas, which are 454 and 672 kg/ha/yr respectively. The highest is that of 4,838 kg/ha/yr of top-yielding lines in Hawaii. Other yields from Australia, Colombia, Hawaii, India, Mauritius, Philippines and the Virgin Islands are intermediate between these extremes. All available yield data indicate that the ubiquitous weedy form of *L. leucocephala* is capable of producing 1,000-2,000 kg/ha/yr of good quality protein. The cultivar 'Peru' is capable of producing 1,000-4,000 kg/ha/yr, as is the cultivar 'El Salvador.'

Protein Quality

Leucaena protein is high in nutritional quality. Amino acids are present in well-balanced proportions and are very similar to alfalfa (Meulen et al., 1979): Leucaena leaves provide a rich source of B-carotene, xanthophyll and vitamin K and can be an excellent source of calcium, phosphorous and other dietary minerals. Calcium appears to be an important constituent of the mineral content of the plant; it occurs up to 19 g/kg on a dry matter basis. Leucaena leaf meal is very rich in xanthophyll pigments, estimated in the range of 741-766 mg/kg. The vitamin A content of leucaena leaf meal is fourfold that of alfalfa meal, whereas the carotene content is twofold that found in alfalfa.

There is no exact information about regions of Africa, Australia, the Caribbean, Central and South America, Indonesia, Malaysia, Mexico, Philippines, Taiwan, Thailand, and Viet Nam in which leucaena is used in the human diet. There is also a paucity of reliable information from these areas regarding the percentage of population consuming leucaena as a food and the quantities they utilize. The people in areas where leucaena is consumed as food aware of its undesirable side effects. In view of this knowledge, and yet in spite of it, leucaena is probably consumed as food in quantities far in excess of that which is recorded.

Young leaves and young seeds form a regular part of the diet in New Guinea, Mexico and Thailand, according to Jones (1977). Leaves and immature fruits are reportedly edible uncooked (Dalziel, 1937; Dragendorff, 1898); they are cooked and eaten, according to Morton (1962). Young pods are most commonly used as food (Martin and Ruberte, 1975). Young pods and ripe, but not mature, seeds are eaten raw with rice (Benthall, 1933; Perkins, 1907; van Veen, 1966; Walandouw, 1952). Young pods are commonly used in soup (Benge, 1977; van Veen, 1966) and as a vegetable in Malaysia (Corner, 1940; Walker, 1954), the Philippines (Holdridge, 1942; Walker, 1954) and the West Indies (Hosaka and Ripperton, 1944; Morton, 1962).

Young pods, leaves and flower buds are used as vegetables in Hawaii (Takahashi and Ripperton, 1949). Mature but still succulent seeds are eaten with rice. The food called "botok," described from the Dutch East Indies, is also used in Hawaii. Even the young seedlings are mixed with dry fish and grated coconut and eaten.

Leucaena flowers are used in salads according to Benge (1977). The flowers are less commonly eaten with rice according to Martin and Ruberte (1975).

The slightly bitter leaves are added to soups and stews, according to some sources (Benge, 1977; Martin and Ruberte, 1975; van Veen, 1966). In addition, leucaena leaves are eaten fresh, dipped in sauces, and eaten as a side dish. Children in Thailand pluck the tender young leaves from leucaena hedges and relish them.

Full grown but unripened seeds are dried and eaten uncooked (Benge, 1977; Martin and Ruberte, 1975). Immature seeds are also palatable and eaten as a vegetable, and when pulverized and dried, they are made into dried seed cakes (Benge, 1977). The mature seeds are also eaten after they are parched or roasted (Anon., 1962; Martin and Ruberte, 1975; Morton, 1962; Takahashi and Ripperton, 1949; Walker, 1954). I have observed Mexicans eating immature seeds shelled from the pods at lunch along with fish and rice. Indeed, leucaena pods are sold in the open markets of many towns and cities throughout Central America and Mexico. The immature pods are collected daily and taken to the market. In various parts of Mexico, pods of *L. esculenta* (Moc. and Sesse) Benth. are preferred to those of *L. leucocephala*. Along the roads and highways in many areas of Mexico, one can observe the mutilation of trees caused by indiscriminate pod collection. Some families build and maintain ladders in order to collect pods from trees growing around the home. This is done in order to minimize the damage to the trees. The precise stage of maturity of the pods appears of utmost importance to some people. By collecting the pods at the desired stage, some people store them in their refrigerators until needed. Apparently, storage under these conditions slows the maturation process sufficiently, at least to the satisfaction of those who follow this custom.

A food called "botok" is made from leucaena seeds in Java. It is made by mixing half ripe seeds with grated coconut and fish or meat, wrapping the mixture in a banana leaf and cooking it. It is also used as a side dish with rice. Seeds of partially mature pods are eaten, either raw or cooked, as a delicacy. Ripe, mature seeds are eaten with rice after they are roasted and pounded into a meal. People of east and central Java also make "roge" from the young seedlings; in addition, the seedlings are eaten mixed with dry fish and grated coconut. Ochse and Bakhuizen van den Brink (1931) summarized the use of leucaena in the Dutch East Indies by stating that it has "varied but limited use as a food crop."

Monrias (1978) wrote a thesis on her study of the use of ipil-ipil (*L. leucocephala*) flour in the preparation of cookies.

"Tempeh" is a fermented food made from leguminous seeds; *e.g.*, leucaena and soybeans. The commercial product is usually made from soybeans and is popular in Indonesia because it can be fermented there the year-round without artificial temperature control. Tempeh is mild flavored; it is served with a variety of spicy or sweet sauces, in soups, curries, and after frying (Shurtleff and Aoyagi, 1980). Soybean tempeh is called "Tempeh kedele" in Java. "Tempeh lamtoro," which is more flavorful than soybean tempeh, is made from leucaena seeds. Incidentally, lamtoro is the name for leucaena in Indonesia.

At least four procedures have been described in making Tempeh lamtoro; *i.e.*, those of Raintree (1980), Shurtleff and Aoyagi (1980), Slamet et al., (1982), and Whiting (1982). The procedures described by Slamet et al. and Whiting in making Tempeh lamtoro are essentially the same, both requiring three to four days. Both Tempeh kedele and Tempeh lamtoro are served in a similar manner. A sample of leucaena tempeh, described by Raintree, contained 50% protein, 38% carbohydrate, and 11% fat on a moisture-free basis.

It is important to eliminate the mucilage envelope which surrounds the cotyledons and separates them from the testa in the preparation of tempeh. This is accomplished by repeated trampling and washing the seeds (Whiting, 1982). An inoculant, *Rhizopus oliosporus*, is also required in the fermentation process. The palatability and digestibility of leucaena seeds is increased and the mimosine content decreased in the process of making tempeh. Fortunately, mimosine is either destroyed or metabolized during the washing, soaking, boiling, steaming, and finally, during fermentation, according to Whiting (1982). Slamet et al. (1982) indicate that the entire procedure of processing the seeds reduces the mimosine to 1/1125 of the initial content. At this extremely low level of mimosine, Tempeh lamtoro consumption should be considered safe.

Additional research on the technology of processing leucaena seeds to separate testa from cotyledons and removing the mucilage is being carried out by the University of Hawaii. Nutrient values of Tempeh lamtoro are being studied at the Nutrition Research and Development Center in Bogor, Java. Biological testing with laboratory animals will provide greater assurance of the safety of Tempeh lamtoro for general consumption. Meanwhile, however, it is being made and utilized in Indonesia.

The limitations imposed on leucaena as a food and feed crop by the presence of the toxic amino acid mimosine are well known. They are not a part of this paper, however. Instead, we must consider acceptability, palatability, digestibility, and nutritive value of leucaena as a food crop for man. Similar considerations should be addressed to leucaena as a feed crop for livestock. Leucaena is hard to surpass as a renewable and sustaining source of food and feed.

The livestock acceptability of leucaena in almost any form is very high. All types of ruminants and non-ruminants relish the plant in its green and dried state. Fowls, including ducks, quail, turkeys, guineas, and partricularly chickens thrive on green leucaena in addition to leucaena meal. The acceptability of leucaena by all types of livestock and fowls poses no problem whatsoever. Indeed, the danger is in the opposite direction by their consuming the plant in excessive amounts to their own detriment. The palatability of leucaena for cattle is excellent and speaks for itself, judged by their feeding on the plant in its various forms.

The nutritive value of leucaena forage is comparable to that of alfalfa. Incidentally, leucaena has been referred to as the "alfalfa of the tropics." The whole leaf contains both nutrients and roughage which makes a ruminant feed comparable to that of alfalfa forage.

Rosas et al., (1980) report nutrient analyses of leucaena from Panama in which they concluded that leucaena is equivalent to that of alfalfa and pigeon pea. Lee (1981) reports the nutrient composition, proximate analysis, trace minerals and amino acids in four leucaena lines grown in Taiwan. Three of these lines include the Hawaiian type and the cultivars 'El Salvador' and 'Peru.' His data indicate that leucaena seed meal and stem and leaf meal are higher in protein and lower in fiber than that of meal of the whole plant. The iron content of the stem and leaf meal of the two cultivars was 3 to 14 times that found in the Hawaiian type.

A comparison of the nutritive value of leucaena leaf meal with that of alfalfa, the legume by which all other legumes are usually compared, is of interest. The nutritive value of leucaena is superior to that of alfalfa (Work, 1938; 1946). Studies indicate the superiority of leucaena leaf meal over that of alfalfa in protein content, B-carotene and vitamin A, in addition to a higher TDN value (Gantt, 1958). Data of Kinch and Ripperton (1962) emphasize the comparative carotene content of leucaena leaf meal and alfalfa; *i.e.*, alfalfa 205 ppm, leucaena 523 ppm. The high carotene and xanthophyll content of leucaena justifies the use of leucaena leaf meal in poultry diets. This is because carotene is suitable for pigmenting the meat of chickens and particularly the egg yolks. The TDN content of leucaena is comparable to that of alfalfa (Henke, 1958; Work, 1946). The forage components, coarse stems, fine stems, and leaves are listed in ascending order of protein content (Kinch and Ripperton, 1962). Dehydration does not affect the protein content of leucaena forage (Oakes, 1968).

Digestibility trials indicate leucaena is equivalent or superior to that of alfalfa (Gantt, 1958; Henke, 1958; Work, 1938: 1946). TDN digestible coefficients for leucaena vary from 51 to 70% whereas those for digestible crude protein (DCP) vary from 12 to 17% on a DM basis (Singh and Mudgal, 1967; Upadhyay et al., 1974). The range of UF energy values has been reported to be 0-220, where UF is a unit of forage equivalent to the nutritive value of one kg of barley (Compere, 1959). MJ metabolizable energy/kg dry matter values of 2.74-2.83 are reported by D'Mello and Thomas (1978); 17.0-20.1 MJ gross energy/kg dry matter (Vietmeyer et al., 1977); and 4.06 MJ/kg dry matter (Dingayan and Fronda, 1950).

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