Der Tropenlandwirt, Zeitschrift für die Landwirtschaft in den Tropen und Subtropen
86. Jahrgang, Oktober 1985, S. 109 - 127

Mimosine – a factor limiting the use of Leucaena leucocephala as an animal feed

Mimosin – ein limitierender Faktor beim Einsatz von Leucaena leucocephala als Futtermittel

Von U. ter Meulen* und E.A. El-Harith**

1. Introduction

The uses of the tropic legume Leucaena leucocephala are quite versatile. These uses include its function as a source of firewood and timber, its role in soil erosion control, its ability to provide shade for other plants, its function in maintaining the fertility of the soil and its use as a nutritious forage for animal feeding.

Presently the greatest use of this plant in animal nutrition is its incorporation in cattle and sheep feed.
Leucaena leaf-meal with its rich protein, minerals and xanthophyll is becoming a popular ingredient in poultry feeds.

However the nutritive potential of this plant is still not fully realised partly due to reservations by nutritionists about the toxic alkaloid ß-N (3-hydroxy-4-pyridone) -α-amino propionic acid, known as mimosine, which is found in the plant. In livestock, as well as in experimental animals, mimosine is believed to induce alopecia, growth retardation, cataract, decreased fertility and mortality. This report discusses the significance of mimosine as a factor limiting the incorporation of Leucaena meal in animal feeds.

* Prof. Dr. U. ter Meulen, Thai-German Animal Nutrition Project, Faculty of Agriculture, Chiangmai University, Chiangmai / Thailand

** Dr. E.A. El-Harith, Institut für Tierphysiologie und Tierernährung der Universität Göttingen, Oskar-Kellner-Weg 6, D-3400 Göttingen

2. Nutritive value of Leucaena green meal:

Leucaena's forage compromises a source of nutrients and roughage and make an almost complete ruminant feed. The crude protein content, which is normally over 25 % of the dry matter (Table 1), has a high nutritional quality and its amino acids are comparable to those contained in Soyabean (Table 2).

Leucaena leaf-meal is a good source of ß-carotene; the ß-carotene in Malawi produced Leucaena leaf-meal amounted to 227-228 mg/kg DM (D'Mello and Taphin, 1978). Leucaena leaf-meal could be a ritcher source of vitamin K than Alfalfa (Medicago sativa) leaf-meal (Chou and Ross, 1965). Moreover Leucaena forage can also be considered a good source of calcium, phosphorus and some trace elements. The calcium content of 19 g/kg DM is very interesting especially with regard to the incorporation of Leucaena meal in poultry feeds (Table 3).

3. Performance of livestock fed on Leucaena meal:

In the recent decades Leucaena green meal has been incorporated in the feeds of several farm animals and has often led to satisfactory results. This subject has been already reviewed (D'Mello and Taplin, 1978; ter Meulen et al., 1979). The incorporation of Leucaena material in livestock feeds may cause several adverse reactions if the incorporated amounts exceed certain limits. The harmful dietary levels of the Leucaena meal obviously differ for the different species of livestock. A summary of the adverse effects on the performance of livestock due to the consumption of Leucaena meal is presented in Table 4. These adverse reactions include hair loss, retarded growth, fertility problems, development of goitres and general ill-health reactions which may lead to mortality.

Table 1: Crude protein and mimosine content in the seeds and leaves of Thailand grown Leucaena leucocephala (Given as percent of the dry matter)

	Leucaena leaves	Leucaena seeds
crude protein	26.14	33.44
mimosine	2.13	3.34

Sorce of data: ter Meulen, 1982 (unpublished)

Table 2(a) Amino acids and mimosine content in Leucaena leucocephala (seeds and leaves) compared with that in soyabean (values given in mg/g N)

amino acid	soyabean	leucaena	
		seeds	leaves
cystine	106	79	67
aspartic acid	756	643	864
serine	331	206	279
glutamic acid	1138	911	640
proline	300	222	305
glycine	275	285	278
alanine	275	205	311
thyrosine	238	162	208
mimosine	0	763	343
histidine	181	158	123

Source of data: ter Meulen et al.: 1979

Table 2(b): Essential amino acids composition in Leucaena leucocephala compared with that in soyabean (values given in mg/g N)

amino acid	soyabean	leucaena	
		seeds	leaves
methionine	88	64	98
threonine	244	138	266
valine	300	204	311
isoleucine	294	148	244
leucine	488	283	444
phenylalanine	319	197	283
lysine	388	324	339
arginine	463	493	277

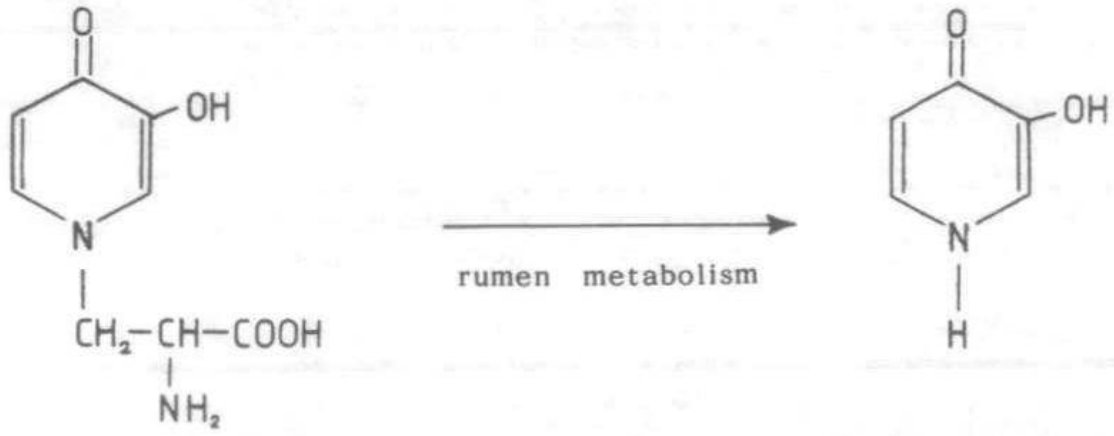
Source of data: ter Meulen et al.: 1979

Table 3: Concentration of certain minerals in Leucaena leaf meal from Malawi

major elements	(g/kg DM)
calcium	19,00
phosphorus	2,16
magnesium	3,35
sodium	0,16
potassium	17,0
trace elements	**(mg/kg DM)**
copper	11,4
iron	907,4
zinc	19,2
manganese	50,9

Source of data: D'Mello and Taplin, 1978.

Ruminants can tolerate the Leucaena material better than non-ruminants; in ruminants the rumen microflora convert mimosine into 3-hydroxy-4(IH)-pyridone a goitrogen which is less toxic than mimosine (Hegarty et al., 1964; Hegarty et al., 1976).



ß-N(3-hydroxy-4-pyridone)-α-aminopropionic acid

3-hydroxy-4-(IH) pyridone

Besides being a potent goitrogen in cattle, 3-hydroxy-4(IH)-pyridone is a potent antithyroid compound with thiouracil-type activity, is highly selective for the thyroid and is known to inhibit enzymes responsible for the metabolism of adrenalin and noradrenalin (Hegarty et al. 1979/80).

It has been noticed that whereas rabbits and goats can consume large amounts of Leucaena forage without showing signs of adverse reactions, pigs and poultry are more sensitive and adverse reactions are encountered if the Leucaena material is consumed at a dietary level of 10 percent or more.

Table 4: Adverse effects on the performance of livestock due to the consumption of leucaena green meal

animal species	level (% of diet)	adverse effect on performance	reference
rabbits	ad libitum	no reported adverse reactions; normal growth	Ruskin, 1977
chicken			
a) broilers	5 %	depression of both growth and feed intake	d'Mello and Thomas, 1978
	10 %	depression of growth, feed intake and feed efficiency	Labadan, 1969; Ross and Springhall, 1963;
	40 %	mortality	ter Meulen and El-Harith, 1981 (unpublished)
b) laying hens	20 %	decrease in egg production	Vohra et al., 1972; Gill, 1977
	30 %	no ovarian development	Scott et al., 1969
cattle	30 %	no adverse effects	Ruskin, 1977
	50 % fed for 6 months	retarded growth, development of goitres, loss of hair, reduced fertility	
sheep	ad libitum for 3 months	retarded growth, lambs born with low birth weights	Bindon and Lamond, 1966
goats	ad libitum	no reported adverse reactions	Ruskin, 1977
horses	?	hair loss	Owen, 1958
pigs	?	hair loss	Owen, 1958
	up to 10 %	no ill-health effects normal growth	Ruskin, 1977

4. Mimosine in Leucaena leucocephala:

Since mimosine is believed to be the main toxic ingredient in Leucaena leucocephala, this alkaloid has been a great concern to livestock nutritionists. The mechanism of mimosine toxicity is complicated in nature and it seems that some of its aspects are still unrevealed (ter Meulen et al., 1981; El-Harith et al., 1981).

Mimosine is known to inhibit a number of biochemical reactions. Mimosine acts as a tyrosine antagonist and competes with tyrosine to inhibit the activity of tyrosinase (Crounse et al., 1962). The decarboxylation of L-tyrosine, catalysed by the bacterial tyrosine decarboxylase, was slightly inhibited if mimosine was preincubated with the pyridoxal phosphate coenzyme (Grove et al., 1978). Supplementary tyrosine added to the diet of rats was reported by some workers to compensate the growth inhibition caused by mimosine (Lin and Tung, 1964).

However many other reports indicated that dietary supplementation with tyrosine was not successful in preventing the adverse effects of mimosine in experimental and farm animals (Hylin, 1969; Reis, 1975; ter Meulen et al., 1982, unpublished). Spectroscopic studies indicated the possibility of complex formation between tyrosine and mimosine, although tyrosine catabolism in rats was apparently not altered by inclusion of mimosine in the diet (Grove et al., 1978). The mechanism of mimosine toxicity is most likely multifactorial.

The different strains of the genus Leucaena vary considerably in their mimosine content (Brewbaker and Hylin, 1968). Mimosine ranges from 2 to 5 % of the dry matter of Leucaena seeds and leaves (Table 1). Breeding of low mimosine lines of Leucaena leucocephala appears promising from crosses with the Columbian strain of L. leucocephala or with the species L. pulverulenta. However the production of mimosine-less Leucaena is still relatively difficult.

Because mimosine is believed to be the main toxic ingredient in Leucaena leucocephala, and because the different strains of this species contain different concentrations of mimosine, in our view a new criterion for the evaluation of Leucaena leucocephala material as animal feed may be considered. Determination of the mimosine content in Leucaena material and the subsequent calculation of the consumed amount of the alkaloid by animals, expressed in g/kg body weight, represent an important parameter or "Mimosine-Criterion" in evaluating the nutritive value of the Leucaena material as an animal feed.

Recent studies undertaken in Bukavu-Zaire with 5 species of farm animals, and in our institute in Göttingen (Federal Republic of Germany) with chicken, were aimed at investigating the tolerable levels of mimosine in these animal species. The purpose of these studies was to estimate the maximum amounts of Leucaena meal which could be incorporated in the feed of these farm animals without causing adverse effects on their production performance. In these experiments the mimosine concentration in the consumed Leucaena meal was determined and from this the consumed amounts of mimosine were calculated and expressed in g mimosine/kg body weight of the special animal and per day (Table 5).

Table 5: Effects* of the consumption of different levels of mimosine on some farm animals in Zaire

animal species	maximal level of mimosine which has no effect on growth	level of mimosine that causes depression of growth
rabbits	0.21	> 0.21
chicken	0.19	> 0.19
goats	0.17	> 0.17
sheep	0.12	> 0.12
cattle	0.11	not determinded

all values given are expressed in g/kg body weight of the special animal per day

* other effects may include hair loss and fertility problems for both levels of mimosine mentioned.

The results presented in table 5 can be considered an attempt to mark the border line where the level of mimosine adversely affects growth which is an important production parameter. It is interesting to notice that generally animals with smaller body weights (e.g. rabbits and chicken) can withstand relatively higher doses of mimosine (expressed in g/kg body weight) without suffering from retarded growth or any other adverse effects. Larger animals (e.g. cattle) on the other hand can tolerate relatively smaller doses of mimosine.

5. Methods for solving the mimosine problem:

In order to make maximum use of the Leucaena material in animal nutrition, several relatively successful methods to reduce the deleterious effects caused by mimosine were reported. These include:

(a) Genetic method; whereby new hybrids of Leucaena leucocephala with lower mimosine content are produced as mentioned before.

(b) Chemical treatment of the Leucaena meal by addition of ferrous sulphate or aluminium sulphate. The detoxification of mimosine is believed to occur due to the formation of a metal ion-mimosine chelate complex (Tsai and Ling, 1973).

(c) Ensilaging method; washing or soaking in water of the Leucaena leaves considerably reduces their mimosine content without substancially influencing their raw protein content (Schülke et al., 1982).

6. Conclusions:

- The mechanism of mimosine toxicity is complicated in nature. It is not very likely that the main toxic mechanism of mimosine originates from the action of mimosine as a tyrosine antagonist.

- Leucaena leucocephala meal has a great potential as a good feed source. The risks of incorporating Leucaena meal in animal feeds are now - to a large extent - well known.

- A suggestion is put forward that the mimosine concentration in the Leucaena meal should be determined and the consumed amounts of mimosine per animal and day (expressed in g/kg body weight) should be estimated. These should not exceed certain levels for each of the farm animals in question. This method ensures the prior estimation of the levels of Leucaena leucocephala meal which can be applied in animal feeds without causing deleterious effects on the production performance.

7. Abstract

Leucaena leucocephala is a leguminous plant which is used for several purposes in the tropical and subtropical regions. Because of its high crude protein content (ranging from 25 to 35 % in the dry matter) and relatively well balanced amino acids content the plant could be considered a very suitable feed source. However the legume contains a toxic amino acid, ß-N(3-hydroxy-4-pyridone) -α-aminopropionic acid (mimosine), which seems to limit the incorporation of this legume in the feed of farm animals.

The different strains of Leucaena leucocephala vary considerably in their mimosine content. Determination of the mimosine content in the Leucaena material and estimation of the consumed amounts (expressed in g/kg body weight) of the alkaloid by livestock represent an important parameter for evaluating the nutritive value of the Leucaena material.

Zusammenfassung

Mimosin - ein limitierender Faktor beim Einsatz von Leucaena leucocephala als Futtermittel.

- Der Mechanismus der Mimosin-Vergiftung ist kompliziert. Es ist nicht wahrscheinlich, daß der Hauptmechanismus der Vergiftung des Mimosins von seiner Wirkung als Tyrosin-Antagonist ausgeht.

- Leucaena leucocephala-Mehl hat eine große Bedeutung als Futtermittelquelle. Die Risiken der Einmischung von Leucaena-Mehl in Futtermittel sind zum großen Teil gut bekannt.

- Es wird vorgeschlagen, daß die Mimosin-Konzentration im Leucaena-Mehl bestimmt und die aufgenommene Menge an Mimosin pro Tier und Tag (ausgedrückt in g/kg Körpergewicht) festgestellt werden sollte. Die aufgenommene Menge an Mimosin sollte für jede Tierart ein bestimmtes Niveau nicht überschreiten.

Diese Methode sichert die vorherige Bestimmung der Menge von Leucaena leucocephala die in das Futter eingemischt werden kann, ohne daß es zu unerwünschten Effekten auf die Produktionsleistung kommt.

References

1. Bindon, B.M.; Lamond, D.R., 1966. Examination of tropical legumes for deleterious effects on animal production. Proc. Aust. soc. Anim. Prod. 6, 109-116.

2. Brewbaker, J.L.; Hylin, J.W., 1968. Variations in mimosine content among Leucaena species and related Mimosacene. Crop Science 5, 348-349.

3. Chou, S.T.; Ross, E., 1965. Comparative vitamin K activity of dehydrated alfalfa and Leucaena leucocephala meal. Poultry Science 44, 972-974.

4. Crounse, R.G.; Maxwell, J.D.; Blank, H., 1962. Inhibition of growth of hair by mimosine. Nature 194, 694-695.

5. D'Mello, J.P.G.; Taplin, D.E., 1978. Leucaena leucocephala in poultry diets for the tropics. World Rev. Anim. Prod. 14 41-74.

6. D'Mello, J.P.G.; Thomas, D., 1978. The nutritive value of dried Leucaena leaf-meal from Malawi: Studies with young chicks. Trop. Agric. Trin. 55, 45-50.

7. El-Harith, E.A.; Mohme, H.; ter Meulen, U.; Bartha, Monika; Günther, K.D., 1981. Effects of mimosine on some serum enzyme activities and amino acid metabolism in the rat. Z. Tierphysiol., Tierernähr. u. Futtermittelkde. 46, 255-263.

8. Gill, I.M., 1977. Nutritive value of Leucaena leucocephala for laying hens. M. Sc. Thesis. University of Edinburgh.

9. Grove, J.A.; Ballata, P.D.; Eastmo, A.; Hwang, L.R., 1978. Studies on the metabolic effects of mimosine. Nutr. Rep. Inter. 17, 629-635.

10. Hegarty, M.P.; Schinckel, P.G.; Court, R.D., 1964. Reaction of sheep to the consumption of Leucaena glauca Benth and its toxic principle mimosine. Aust. J. Agric. Res. 15, 153-167.

11. Hegarty, M.P.; Court, R.D.; Christie, G.S.; Lee, Cp.P., 1976. Mimosine in Leucaena leucocephala is metabolised to a goitrogen in ruminants. Aust. Vet. J. 52, 490.

12. Hegarty, M.P.; Court, R.D.; Christie, G.S., 1979/80. Nitrogenous compounds in tropical pasture species and grain legumes. Tropical Crops and Pastures, Division of C.S.I.R.O. Divisional Report pp. 84 (C.S.I.R.O. Printing Unit, Melbourne).

13. Hylin, J.W., 1959. Toxic peptides and amino acids in foods and feeds. J. Agric. Fd. Chem. 17, 492-496.

14. Labadan, M.M., 1969. The effects of various treatments and additives on the feeding value of ipil-ipil leaf-meal in poultry. Philipp. Agric. 53, 302-401.

15. Lin, K.T.; Tung, T.C., 1964. Biochemical study of mimosine. I Effect of amino acids on the

growth inhibition of rats caused by mimosine. J. Formosan. Med. 63, 278-284.

16. Owen, I.N., 1958. Hair loss and other toxic effects of Leucaena glauca "Jumbey". Vet. Rec. 70, 454-456.

17. Reis, P.T., 1973. Effects of intravenous infusion of mimosine on wool growth of merino sheep. Austr. J. Biol. Sci. 28, 483-493

18. Ross, E.; Springhall, J.A., 1963. Evaluation of ferrous sulphate as a detoxifying agent for mimosine in Leucaena glauca rations for chickens. Austr. Vet. J. 39, 394-397.

19. Ruskin, F.R., 1977. Leucaena, promising forage and tree crop for the tropics. National Academy of Sciences. Washington D.C 20418.

20. Schülke, E.; ter Meulen, U.; Szyszka; M.; El-Harith, E.A., 1982. Untersuchungen zum Einfluss der Wässerung auf den Mimosingehalt von Leucaena Blattmaterial aus Zaire. Der Tropenlandwirt, 83, 43-48

21. Scott, M. L.; Labadan, M.M.; Ranit, G.D.; Resurreccion, R.S.; Abilay, T.A.; Rigor, E.M., 1969. Studies on the mechanism of the ovary-inhibitory action of ipil-ipil leaf meal. Poultry Science 48, 1868.

22. ter Meulen, U.; Struck, S.; Schülcke, E.; El-Harith, E.A., 1979. A Review on the nutritive value and toxic aspects of Leucaena leucocephala. Trop. Anim. Prod. 4, 113-126.

23. ter Meulen, U.; Günther, K.D.; El-Harith, E.A., 1981. Metabolic effects of mimosine on tyrosine in the rat. Z. Tierphysiol., Tierernähr. u. Futtermittelkde. 46, 264-269.

24. Tsai, W.E.; Ling, K.H., 1973. Study on the stability constants of some metal ion chelates of mimosine and 3,4-dihydroxypyridine. J. Chin. Biochem. Soc. 2, 70-86.

25. Vohra, P.; Herrick, R.B.; Wilson, W.O.; Slopes, T.D., 1972. Use of ipil-ipil (Leucaena leucocephala) in the diets of laying chickens and laying quail. Philipp. Agric. 56, 104-113.