SHRUBS AND TREE FODDERS OR FARM ANIMALS

PROCEEDINGS OF A WORKSHOP IN DENPASAR, INDONESIA, 24-29 JULY 1989
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Shrubs and tree fodders for farm animals

Proceedings of a workshop in Denpasar, Indonesia, 24–29 July 1989

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Abstract

This publication presents the results of an international meeting held in Denpasar, Bali, Indonesia, 24–29 July 1989, that focused on the use of shrubs and tree fodders by farm animals. Through 26 papers, the workshop addressed feed-resource availability, use by ruminants and nonruminants, processing methodology, economics, and development issues. These aspects and the current knowledge on shrubs and tree fodders were further highlighted by country case studies detailing prevailing situations and policy matters. A special session was held to discuss the successful development and results achieved in the three-strata forage system in Indonesia. The workshop concluded with important working group discussions on the priorities for further research and development, and on the potential for the wider use of shrubs and tree fodders in the developing world.

Résumé

Cette publication présente les résultats d’une rencontre internationale tenue à Denpasar, Bali, Indonésie, du 24 au 29 juillet 1989 et qui a porté sur l’utilisation des arbustes et fourrages végétaux par les animaux d’élevage. Les 26 communications qui y ont été présentées traitaient de la disponibilité des ressources alimentaires pour les animaux, de leur utilisation par les ruminants et les non-ruminants, des méthodes de transformation, des aspects économiques et des questions du développement. Ces sujets et les connaissances actuelles sur les arbustes et les fourrages végétaux ont ensuite été étudiés plus à fond dans le cadre d’études de cas de divers pays exposant les circonstances particulières de chacun et les questions liées aux politiques. Une séance spéciale a porté sur la mise en place et les résultats des systèmes de production de fourrages végétaux en trois strates en Indonésie. L’atelier s’est terminé par d’importantes discussions des groupes de travail sur les priorités de recherche et de développement pour l’avenir et sur les possibilités d’utilisation élargie des arbustes et des fourrages végétaux dans les pays en développement.

Resumen

Esta publicación presenta los resultados de una reunión internacional celebrada en Denpasar, Bali, Indonesia, del 24 al 29 de julio de 1989, y la cual centró su atención en la utilización de forrajes elaborados a partir de arbustos y árboles para alimentar a animales de granjas. En 26 trabajos presentados al seminario, los participantes abordaron temas tales como la disponibilidad de recursos alimentarios y la utilización de los mismos por rumiantes y no rumiantes, metodologías de procesamiento y cuestiones de economía y desarrollo. Estos aspectos y el conocimiento que se tiene actualmente sobre los forrajes de arbustos y árboles se vieron subrayados aún más por estudios de casos por países en los que se detallaron situaciones existentes y cuestiones de políticas. Se celebró una sesión especial para discutir el desarrollo y resultados exitosos alcanzados en Indonesia con el sistema de forraje de tres niveles. El taller concluyó con importantes discusiones de los grupos de trabajo sobre las prioridades existentes en el campo de la investigación y el desarrollo y sobre el potencial que encierra la amplia utilización de arbustos y árboles en el mundo en desarrollo.
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The use of shrubs and tree fodders by nonruminants

P.D. Limcangco-Lopez

Institute of Animal Science, College of Agriculture, University of the Philippines at Los Baños, College, Laguna, Philippines

Abstract — The trend of increasing prices for animal feed has compelled researchers from developing countries to direct their research to nonconventional feeds, with particular emphasis on protein substitutes. The use of plant leaves as possible sources of protein is one among many possibilities. Studies on shrub and tree leaves, leaf vines, grasses, and algae and other water plants showed that, on a dry-weight basis, leaves may contain 20 to 30% crude protein, 12 to 18% crude fibre, and 500 to 650 ppm xanthophyll. Plant leaves are commonly processed into leaf meals for nonruminant animals. If processed properly, leaf meals are good pigmenting agents because of the presence of several different xanthophylls of the general family of carotenoids. Among the leaf meals, leucaena (Leucaena leucocephala) and cassava (Manihot esculenta) leaf meals are most popular. Other leaf meals, such as Trema orientalis, Muros indica, Moringa oleifera, and Sesbania rostrata, are potentially useful, but more studies are needed to determine their availability and usefulness. The use of leaf meals as feed is limited by their high fibre content and, in some cases, the presence of toxic factors or metabolic inhibitors. Thus, the idea of extracting protein from leaves was conceived to obtain a product high in protein, low in fibre, and without residual toxins. This leaf protein concentrate has a higher feeding value and can be included at high levels as a substitute for soybean oil meal. Interest in the production of leaf proteins has been slow, mainly for economic reasons. Other shrub and tree leaves are used in small quantities as soilage for swine. Limited quantities are fed to poultry in confinement. Recently, there has been increasing interest in the use of shrub and tree leaves in herbal medicines for poultry and livestock.

Résumé — La tendance à l'augmentation des prix des fourrages a forcé les chercheurs des pays en développement à orienter leurs recherches sur des fourrages non conventionnels en s'attachant plus particulièrement aux substituts de protéines. Les feuilles des plantes ne sont qu'une des nombreuses sources possibles de protéines. Les études sur les feuilles d'arbustes et d'arbres, les vignes feuillues, les graminées, les algues et d'autres plantes aquatiques ont montré que, en poids sec, les feuilles peuvent contenir de 20 à 30% de protéines brutes, de 12 à 18% de fibres brutes et de 500 à 650 ppm de xanthophylle. Les feuilles de plantes sont généralement transformées en farines réservées aux non-ruminants. Si leur préparation a été bien faite ces farines constituent de bons agents de pigmentation parce qu'elles contiennent plusieurs xanthophylles différentes de la famille des caroténoïdes. Les farines les plus populaires sont celles de leucaena (Leucaena leucocephala) et de manioc (Manihot esculenta). D'autres farines, comme celles de Trema orientalis, Muros indica, Moringa oleifera et Sesbania rostrata, notamment, présentent des possibilités qui ne pourront être déterminées qu'après d'autres
Introduction

The high cost of protein sources for poultry and livestock is a perennial problem in many developing countries. Soybean oil meal (SBOM) and fish meal are still the major sources of protein in finished feeds. The increasing importation of these protein sources contributes to the financial drain in developing countries. Also, the rising cost of these feedstuffs is fast becoming prohibitive for feed millers and growers. This has lead researchers to direct increased attention to nonconventional feeds, giving more emphasis to protein substitutes.

The use of plant leaves as a source of protein is one possible alternative. Studies on shrub and tree leaves, leaf vines, grasses, and algae and other water plants have shown that, on a 90% dry-matter basis, their crude protein (CP) contents vary from 20 to 30%, crude fibre (CF) from 12 to 18%, and xanthophyll from 500 to
650 ppm. Although plant leaves are good sources of protein, their use by nonruminants is limited by the high fibre content and, in some cases, the presence of toxic factors or metabolic inhibitors.

Leaf meals

Plant leaves are commonly processed into leaf meals for nonruminants, particularly for poultry. A good-quality leaf meal must be free of stems, kiln dried, and dehydrated. It must not be sun dried because this treatment inactivates a high percentage of the carotenoids. None of these criteria are observed in countries with poor resources, where there is lack of drying facilities at the farmer’s level and where cost of energy for kiln drying is prohibitive. Thus, commercially sold leaf meals have varying amounts of stems and are sun-cured, with variable protein, fibre, and xanthophyll contents.

Leaf meals are included in poultry feeds primarily as pigmenting agents because of their low energy value (<6.25 MJ/kg) and low protein digestibility. The maximum level in broiler diets is about 3%, as high levels may decrease growth rates. Conversely, good-quality leaf meal is almost always used in feed formulations for layers, the usual upper limit being 5% by weight of feed.

In general, leaf meals are good pigmenting agents. This is due to the presence of several different xanthophylls of the general family of carotenoids. Xanthophylls are the hydroxy derivatives of carotene hydrocarbons; the hydroxyl (OH) group increases the solubility and metabolic absorption in the avian digestive system. Beta-carotene, per se, is not considered a pigment; however, after metabolic hydrolysis it becomes xeaxanthine, which is a pigment. The actual requirements for yellow-orange pigmentation of poultry meat or eggs are artificial standards governed by consumer preference, and consumer preference varies with location and ethnic origin.

Leucaena leucocephala

The most popular among the leaf meals is that of *Leucaena leucocephala* (Lam) de Wit. Known as ipil-ipil in the Philippines, leucaena is a leguminous shrub that grows very rapidly. It is resistant to drought, deep rooted, productive during the dry season, and tolerant to a wide range of soil pHs. With an average of 4.6 cuttings/year, rows 52.2 cm apart, and a seeding rate of 40.65 kg/ha, the annual green weight yield of leucaena is about 72 t/ha (Kinch and Ripperton 1962). The annual dry weight yield is 20 t/ha (green: dry = 3.6:1, at 10% moisture). In its fresh form, leucaena is a roughage feed for ruminants and, as leaf meal, it is commonly used in poultry and swine feeds.

Leucaena contains mimosine, a toxic nonprotein amino acid (Table 1). The highest mimosine concentrations are found in the leaves (5.3%), lower amounts are found in mature leaves, pods, and roots (1.36%), and none is found in the stems. Native leucaena leaves contain more mimosine (3.5%) than Hawaiian leucaena leaves (2.0%) (Carangal and Catindig 1955). Mimosine toxicity may be attributed either to its phenolic or alkaloidal properties or its inhibiting action on the metabolism of two aromatic amino acids: phenylalanine and tyrosine. Its effects
Table 1. The chemical and nutrient composition of *L. leucocephala* and *M. esculenta* leaf meals.

<table>
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<th><em>L. leucocephala</em></th>
<th><em>M. esculenta</em></th>
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</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>11.5</td>
<td>12.0</td>
</tr>
<tr>
<td>Crude protein (%)</td>
<td>22.8</td>
<td>23.0</td>
</tr>
<tr>
<td>Crude fibre (%)</td>
<td>12.7</td>
<td>11.7</td>
</tr>
<tr>
<td>Ether extract (%)</td>
<td>6.8</td>
<td>7.9</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>7.2</td>
<td>6.4</td>
</tr>
<tr>
<td>Calcium (%)</td>
<td>2.17</td>
<td>1.56</td>
</tr>
<tr>
<td>Phosphorus (%)</td>
<td>0.15</td>
<td>0.23</td>
</tr>
<tr>
<td>Xanthophyll (ppm)</td>
<td>600.0</td>
<td>566.0</td>
</tr>
<tr>
<td>Mimosine (ppm)</td>
<td>3.0</td>
<td>—</td>
</tr>
<tr>
<td>Prussic acid (ppm)</td>
<td>—</td>
<td>10.0</td>
</tr>
<tr>
<td>AME (kJ/kg)</td>
<td>—</td>
<td>3783</td>
</tr>
<tr>
<td>TME (kJ/kg)</td>
<td>1092</td>
<td>6079</td>
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<table>
<thead>
<tr>
<th>Component</th>
<th><strong>TAA</strong> (mg/g)</th>
<th><strong>TAAA</strong> (%)</th>
<th><strong>TAA</strong> (mg/g)</th>
<th><strong>TAAA</strong> (%)</th>
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</thead>
<tbody>
<tr>
<td>Phenylalanine</td>
<td>10.60</td>
<td>35.41</td>
<td>17.52</td>
<td>76.01</td>
</tr>
<tr>
<td>Valine</td>
<td>10.90</td>
<td>27.83</td>
<td>18.01</td>
<td>78.12</td>
</tr>
<tr>
<td>Threonine</td>
<td>9.29</td>
<td>22.98</td>
<td>15.46</td>
<td>73.40</td>
</tr>
<tr>
<td>Methionine</td>
<td>1.68</td>
<td>9.17</td>
<td>3.40</td>
<td>73.96</td>
</tr>
<tr>
<td>Arginine</td>
<td>12.54</td>
<td>36.46</td>
<td>18.42</td>
<td>78.58</td>
</tr>
<tr>
<td>Histidine</td>
<td>4.42</td>
<td>19.59</td>
<td>6.49</td>
<td>88.65</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>8.70</td>
<td>29.82</td>
<td>14.34</td>
<td>77.11</td>
</tr>
<tr>
<td>Leucine</td>
<td>16.07</td>
<td>23.68</td>
<td>27.91</td>
<td>27.03</td>
</tr>
<tr>
<td>Lysine</td>
<td>12.10</td>
<td>23.35</td>
<td>17.51</td>
<td>65.63</td>
</tr>
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</table>

Source: Lopez (1986).

Note: TAA (total amino acids), TAAA (total available amino acids), AME (apparent metabolizable energy), and TME (true metabolizable energy) were determined using 2-year-old cockerels and the method of Sibbald (1976).

...may also be associated either with its complex formation with pyridoxal phosphate, thus inhibiting the activity of pyridoxal-requiring transaminases, or its chelation with metal ions, thus inhibiting the activity of metal-containing enzymes.

Several studies have examined methods of detoxifying leucaena leaf meal (LLM). After observing a decrease in urinary mimosine and a simultaneous increase in fecal mimosine, Yoshida (1944) suggested adding iron salt to the LLM-containing ration. Matsumoto et al. (1951) reported that ferrous sulfate (FeSO₄) supplementation or high temperature treatment in the presence of moisture was effective in reducing mimosine. Likewise, Linggodjiwo (1976) claimed that heating the green leaves and immature pods in a moist environment at 70–100°C for 72 h will destroy 40–60% of the mimosine. The most recent work was done by Mendoza and del Rosario (1988). They examined four methods: sun drying fresh leaves; oven drying fresh leaves at 45°C; placing leaves in a plastic bag and immersing it in water at 70°C for 10 min followed by oven drying at 45°C for 24 h; and soaking leaves in water at 70°C for 10 min followed by oven drying at 45°C for 16 h. All four treatments resulted in a 65–85% reduction of mimosine in leucaena. Mendoza and del Rosario (1988) also reported that alkali treatment using 0.1–0.5 N NaOH reduces or eliminates mimosine (46–100%). Although heat treatment by extrusion lowered the mimosine level, microwave cooking did not appreciably...
reduce mimosine. However, mild heat and microwave treatments together produced the least change in the mono- and di-hydroxypyridine and total xanthophyll levels. Alkali and extrusion treatments reduced the pigments 10–50 times more than the other treatments.

Springhall and Ross (1965) reported that LLM supplemented with FeSO₄ during the growing stage of laying hens did not significantly alter egg production, egg weight, or feed-conversion efficiency. Although it took longer for the birds to reach sexual maturity, they had lighter body weights after 8 months of production. Similarly, when LLM supplemented with FeSO₄ was given to birds during the laying stage, no significant differences were found in egg production, feed conversion efficiency, or fertility; however the hens were lighter in weight and produced smaller eggs compared with the control hens.

Labadan et al. (1969) observed a linear depression in the growth of chicks when fed 0, 10, 20, 30, and 40% LLM in their diets. Mortality was also high for the chicks fed a diet containing 40% LLM. Significant reductions in average comb and testes weights of cockerels were also observed. Scott et al. (1969), claimed that leucaena inhibited the maturation of ovaries when included at the 30% level in isocaloric diets. This was supported by Alejar (1974), who observed zero egg production at 26 weeks of age in young pullets fed 30% LLM (equivalent to 1.2% mimosine in the diet). Both studies observed the development of comb and ovaries to be adversely affected. Directo et al. (1971) observed significant histopathological changes in the liver, kidney, and testes of cockerels given high levels of LLM. The most evident clinical responses they observed were low feed consumption, stunted growth, emaciation, and high mortality rate. Lopez et al. (1978) indicated that egg production was significantly decreased in birds fed 10% LLM. However, with FeSO₄ supplementation at 0.2 and 0.4% of the diet, egg production was comparable to treatment groups receiving no LLM (control) and 5% LLM. Furthermore, egg production at 5% LLM with or without FeSO₄ supplementation was comparable to the control diet (Table 2).

| Table 2. Average total egg production per bird during the first 5 months (140 days) of laying from molting. |
|-----------------|-----------------|-----------------|-----------------|-----------------|
| LLM (%) | 0.0% FeSO₄ | 0.2% FeSO₄ | 0.4% FeSO₄ | Mean |
| 0 | 105de | 105de | 106de | 105c |
| 5 | 107de | 109de | 103de | 106c |
| 10 | 92bc | 102de | 105de | 100b |
| 20 | 73a | 83ab | 96cd | 84a |
| Mean | 94a | 100b | 102b | |

Note: Values followed by the same letter(s) are not significantly different at the 5% level of probability (Duncan’s multiple-range test).

* LLM, leucaena leaf meal.
pigs weighing 50 kg or more could use higher levels of LLM better than younger or smaller pigs.

Early findings indicated that sows fed fresh leucaena failed to conceive after breeding for three or four cycles (Willet et al. 1945). This was confirmed by Wayman and Iwanaga (1957), who showed that with 15% LLM, the gilts had lower conception rates and smaller litter sizes and weights.

All these studies and the recommendation of Le Anh (1962) suggest that LLM should be limited to 5% in chick and 10% in pig diets.

**Extruded LLM**

Talamo (1987) evaluated the feeding value of LLM after it passed extrusion to determine if mimosine was destroyed or reduced. Talamo claimed that extruded LLM had more ether extract (EE) and nitrogen-free extract (NFE) and less CP and CF compared with nonextruded LLM. Birds fed 10% extruded LLM showed significantly higher body weight gain, feed consumption, feed conversion efficiency, and dressing percentage than those fed at the 20% level. Apparently, extrusion of LLM does not markedly improve its feeding value. Yellow pigmentation in the carcass increased with increasing levels of LLM.

**Manihot esculenta**

Lopez (1986) studied the chemical and nutritive value of cassava (*Manihot esculenta* Crantz) leaf meal (CLM) (Table 1). The potential yield of cassava leaves ranges from 10 to 32 t/ha. The major deterrent to the extensive consumption of cassava leaves by livestock is its content of prussic acid or hydrocyanic acid (HCN) (about 380 ppm). However, HCN is completely destroyed when the fresh leaves are processed into leaf meal. Nutritionally, the quality of CLM is higher than that of LLM, in spite of its deficiency in methionine and low digestibility (Eggum 1970; Lopez 1986).

Ross and Enriquez (1969) included graded levels of CLM in chicken and quail diets and noted a linear depression in growth. Khajarern and Khajarern (1986) reviewed the various studies on CLM and fresh cassava leaves fed to poultry and hogs. They claimed that, in both poultry and pigs, 20% CLM depresses live weight gain and feed conversion efficiency; the addition of sodium thiosulfate, methionine, molasses, or vegetable oil partially corrected this depression. They suggested that 5% CLM in broiler diets and 17% CLM in diets for replacement pullets, with proper supplementation, is appropriate. Vibulchai (1984) showed that young finishing pigs performed well on cassava silage diets containing 7% CLM (dry-weight basis).

Lopez (1988) incorporated CLM in six cassava-based broiler diets such that the cassava meal contained xanthophyll equivalent to that in yellow corn. The 7-week feeding trial showed that pigmentation of the skin, fat, breast, and shanks of broilers given cassava meal fortified with CLM was markedly less than with the yellow corn diet.

**Trema orientalis**

Castillo et al. (1981) used anabiong (*Trema orientalis* [Linn.]) leaf meal at 5, 10,
15 and 20% in the finisher diets of 5-week-old broilers and found no significant depression in growth. Supplementation with FeSO₄ at the 15 and 20% levels did not improve performance compared with broilers fed the same levels of LLM with FeSO₄ supplementation. Mashed and pelleted diets containing 20% anabiong leaf meal produced the same results in broilers. The body weights of broilers in all dietary treatments were, however, unsatisfactory (967–1 028 g).

In another experiment, Castillo et al. (1981) reported that the egg production of SCWL (single-comb white leghorn) layers decreased with increasing levels of leaf meal in the diet; however, the differences were not statistically significant. They also reported that 3–5% levels of good-quality anabiong leaf meal added to white corn, cassava, sweet potato, or sorghum diets produced egg yolks with a desirable yellow pigment, comparable to egg yolks of layers fed 40% yellow corn.

**Sesbania rostrata**

Sazon (1988) studied the chemical composition and feeding value in layer diets of *Sesbania rostrata* leaf meal (SLM). On a dry-weight basis, SLM has 29.7% CP, 7.6% EE, 15.3% CF, 27.6% NFE, 7.8% ash, 0.78% Ca, 0.23% P, and 467 ppm xanthophyll. Laying mashes were formulated to contain graded levels (0, 2.5, 5.0, 7.5, and 10%) of SLM. The 9-week study showed that the feed consumption of pullets decreased when the diet contained more than 5% SLM. Similarly, percent egg production and feed efficiency decreased with increasing levels of SLM in the diet. Body weight, egg weight, and egg quality were not significantly affected, even at 10% SLM. Yolk colour intensified as the leaf meal level increased.

**Moringa oleifera**

Leaves from malunggay (*Moringa oleifera*), a legume tree, have about the same CP and P levels as *Leucaena leucocephala* leaves (Cariaso 1988). When the leaf meal is fed to 1-week-old broilers up to a level of 5%, growth rate, body weight gain, feed consumption, and feed efficiency are not adversely affected. However, higher levels of leaf meal (7.5 and 10%) resulted in depressed growth rate, body weight gain, and feed efficiency, and increased feed consumption by the broilers.

**Muros indica**

Castillo et al. (1980), using 2–10% mulberry (*Muros indica*) leaf meal in broiler feed, reported that body weight gain and feed conversion efficiency decreased with increasing levels of the leaf meal. Furthermore, they reported that although 0.5% FeSO₄ improved the performance of broilers fed 9% LLM, broilers fed mulberry leaf meal with FeSO₄ supplementation did not show any improvement.

**Pisonia alba**

Rigon et al. (1983) prepared colis (*Pisonia alba*) leaf meal containing 18.5% CP, 15.8% CF, and 2.6% EE and added it to commercial broiler mash at 5, 7.5, and 10%. Performance of broilers decreased with increasing leaf meal levels.
Leaf protein xanthophyll concentrate

The idea of extracting protein from leaves surfaced at the beginning of the 20th century (Fig. 1). The purpose was to increase the feed's protein content to the level found in soybean oil meal (SBOM), decrease its fibre, and remove possible toxic factors. Leaf protein concentrate (LPC) has a higher feeding value and can, therefore, be used at a higher inclusion rate as a substitute for soybean oil meal and as a concentrate source of xanthophyll, compared with leaf meals. Despite the recent rising interest in the production of leaf protein, production on a commercial scale has been slow, primarily because of technological and economic factors. The yield of LPC is low, the quality of the product is variable, and the cost of

![Diagram]

Fig. 1. Leaf protein concentrate (LPC) production.
production is still far from being competitive with the price of traditional protein sources such as SBOM.

Cowlishaw et al. (1956) recovered 30–40% of leaf protein. Chayen et al. (1961) observed that, at the leaf stage, the yield and percent protein of the concentrate is optimum. When plants become stalky, as with flowering grasses, both yield and percent protein decrease. When the leaf begins to yellow and become fibrous, only 15–20% of its protein will be extractable, even if water and alkali are added.

Pirie (1971a) reported that, from 1 t of raw green matter with 20–22% dry matter, 90–100 kg concentrate and 100–110 kg by-products can be obtained. He reported that half of the leaf protein appears in the first extract and the rest is recovered in the second extract. Lopez (1979) showed that the percentage recovery of LPC from seven plant species varied from 4.4% for banana (Musa sapientum) to 23.6% for mixed weeds (Mikania cordata), based on the leaf material being 90% dry matter. The low yield of LPC, particularly with banana and acacia (Samania saman), is related more to the physical characteristics than to the protein content of the fresh leaf materials. Banana and acacia leaves are more fibrous, dry, and tough compared with other species used. When recovery is expressed in terms of CP of both the raw materials and final products, it varies from 5.5% (acacia) to 37.4% (leucaena). At this rate of recovery, the method of extraction is not satisfactory and needs to be improved to make LPC production more viable.

Legumes are the best sources of easily extractable and good-quality protein (Bryers 1961; Lopez 1986). Good results were also obtained with a few of the more common weeds, which yielded more CP than leaves from vegetable crops. It is impractical to use vegetable crops for this purpose, other plants, especially those posing as weeds or those that are a nuisance to crops as well as animals and humans, should be exploited.

Lopez (1979) studied the chemical composition and feeding value of LPC from seven plant species. On a 90% dry-matter basis, CP varied from 28.6% for acacia LPC to 41.6% for leucaena LPC, with an average of 34.5%. There were wider ranges in CF (9.8–26.6%) and ash (5.8–19.6%). Similarly, Ca content varied from 0.86–3.55% and P content from 0.16–0.43%. The xanthophyll concentration determined from fresh leaves of water hyacinth (Eichornia crassipes) ranged from 584 to 667 ppm; however, only 91 to 103 ppm was found in LPC. This suggests that about 85% of total xanthophyll was lost during processing. Results from chemical analyses of these LPC samples suggest that their quality was inferior compared with Pirie’s (1971b) suggestion that an acceptable LPC should contain 40–44% CP, 40–45% NFE, 2–4% fat, 1–5% CF, and 12–20% ash. All seven LPCs were higher in CF and lower in CP. The low CP of the product may be due to poor cell rupture and oversoaking of the ground leaves; the high CF may be due to poor separation of the juice from the pulp, which was done manually.

Data on total feed consumption of broilers showed that the acceptability of the different LPCs differed significantly (Lopez and Mania 1982). Cassava, banana, mixed-weeds, and acacia LPCs were preferred by broilers over water hyacinth, leucaena, and gliricidia (Gliricidia sepium) LPCs (Table 3). Except for cassava, all LPC-fed birds had lower feed consumption than the control (SBOM) diet ($P < 0.05$). Because LPC varies in CP, depending on the source, the amount added to diets will correspondingly be different. Apparently, acceptability of the LPC in terms of feed consumption is unrelated to CP level or the actual level of each LPC.
Table 3. Average total feed consumption and body weights of broilers fed different leaf protein concentrates.

<table>
<thead>
<tr>
<th>Protein source*</th>
<th>Avg. total feed consumption (g) (2-5 weeks)</th>
<th>Avg. body weight (g) (5 weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBOM (control)</td>
<td>1422a</td>
<td>726a</td>
</tr>
<tr>
<td>Acacia LPC</td>
<td>1269bc</td>
<td>551c</td>
</tr>
<tr>
<td>Banana LPC</td>
<td>1311bc</td>
<td>563c</td>
</tr>
<tr>
<td>Cassava LPC</td>
<td>1328ab</td>
<td>534c</td>
</tr>
<tr>
<td>Leucaena LPC</td>
<td>1147d</td>
<td>547c</td>
</tr>
<tr>
<td>Gliricidia LPC</td>
<td>1211cd</td>
<td>573c</td>
</tr>
<tr>
<td>Mixed-weeds LPC</td>
<td>1305bc</td>
<td>554c</td>
</tr>
<tr>
<td>Water hyacinth LPC</td>
<td>1139d</td>
<td>623b</td>
</tr>
</tbody>
</table>

Note: Values followed by the same letter(s) are not significantly different at a 5% level of probability (Duncan’s multiple-range test).

* Leaf protein concentrates (LPCs) 50% of the CP from soybean oil meal (SBOM); on a CP basis, 1 kg SBOM = 1.58 kg acacia LPC = 1.47 kg banana LPC = 1.19 kg cassava LPC = 1.12 kg leucaena LPC = 1.34 kg gliricidia LPC = 1.44 kg mixed-weeds LPC = 1.50 kg water hyacinth LPC.

in the diet. Similarly, a high CF content, such as in banana LPC, is unrelated to feed consumption.

Despite differences in feed consumption, broiler body weights at 5 weeks of age were not statistically significant, except for water hyacinth LPC (Table 3). Because all experimental diets were isocaloric and isonitrogenous, the poor performance of the birds may be related to the LPC source, which may be associated with toxic factors or metabolic inhibitors. Birds fed cassava LPC showed the lowest body weight. This was probably due to the presence of prussic acid in fresh cassava leaves. Similarly, fresh leucaena leaves contain a toxic amino acid, mimosine, and acacia leaves may contain a toxic alkaloid.

It is possible that combining LPC with SBOM may result in a better amino acid combination in the resultant diet. Water hyacinth LPC, for example, is better in combination with SBOM than the other LPCs. Sentheshanmuganathan and Durand (1969) found that Gliricidia sepium LPC contains 0.92% methionine, 2.48% lysine, and 0.72% tryptophan, comparable to the amounts of the same amino acids in SBOM. Cassava LPC contains too little available methionine and is marginal in tryptophan (Eggum 1970). The process of preparing leaf protein concentrates can destroy some essential amino acids or result in poor availability.

Birds on LPC diets had deep yellow skin, fat, breast, and shanks. The degree of pigmentation varied among LPCs: M. esculenta > L. leucocephala > M. cordata > M. sapietum > G. sepium > S. saman.

In another experiment (Lopez 1979), water hyacinth was studied more intensively in broilers using three feeding systems: "straight feeding" for 8 weeks of LPC-mixed diet; feeding of LPC-mixed diet from weeks 1 through 4 followed by the control diet (zero LPC) from weeks 5 through 8; and feeding of LPC-mixed diet from weeks 5 through 8 following 4 weeks of the control diet. The control diet consisted of a basal diet containing 20% SBOM, and the four treatment groups consisted of 7.5, 15.0, 22.5, and 30.0% water hyacinth LPC in the mixed diets equivalent to 25, 50, 75, and 100% substitution of CP in SBOM in the control diet. The study showed that feed consumption generally decreased as the level of water
hyacinth LPC increased (Table 4). The adverse effect was most noted for birds on straight feeding (LPC-mixed diet only). Although the decreasing trend on feed consumption was also observed in the other two systems, the effect was much less during the starter period, followed by the control diet in the finishing period.

Likewise, the average body weight of birds decreased as substitution of SBOM with water hyacinth LPC increased (Table 4). In the two feeding systems that involved alternate feeding of the control and water hyacinth LPC diets during the starting and finishing periods, body weight did not differ significantly ($P > 0.05$) at all levels of SBOM substitution. In the straight feeding system, however, the body weight of birds at the 50% level of substitution or higher was significantly lower ($P < 0.05$) than birds on alternate feeding.

The decreased body weight of broilers fed higher levels of water hyacinth LPC may be due to lower feed consumption and poor protein availability. Kohler and Bickoff (1971) explained that overheating the LPC from 80°C to as high as 100°C, in the process of either cooking or drying, may reduce the biological value and total digestibility by 5–6% and 10–20%, respectively. In this study, reduction in feeding value was higher than 20% when all the SBOM was substituted with water hyacinth LPC or when the LPC was fed during the finishing period or by straight feeding.

Feed conversion efficiency was highest for birds on the control diet. Substitution of SBOM with LPC decreased feed conversion efficiency. However, among water hyacinth LPC diets, there was no significant difference ($P > 0.05$) in feed conversion efficiency. Duckworth et al. (1961) reported that diets containing 10% dried LPC hindered growth but improved feed conversion efficiency. Hollo and Koch (1971) suspected that when green plant concentrate was added to the diet in

<table>
<thead>
<tr>
<th>Water hyacinth LPC (%)</th>
<th>System 1*</th>
<th>System 2*</th>
<th>System 3*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total feed consumption (g)</td>
<td>Body weight (g)</td>
<td></td>
</tr>
<tr>
<td>0.0</td>
<td>3315a</td>
<td>1454a</td>
<td>1454a</td>
</tr>
<tr>
<td>7.5</td>
<td>3033bc</td>
<td>1362abc</td>
<td>1362abc</td>
</tr>
<tr>
<td>15.0</td>
<td>2868de</td>
<td>1262de</td>
<td>1262de</td>
</tr>
<tr>
<td>22.5</td>
<td>3007c</td>
<td>1273cde</td>
<td>1273cde</td>
</tr>
<tr>
<td>30.0</td>
<td>2832e</td>
<td>1123g</td>
<td>1123g</td>
</tr>
</tbody>
</table>

Note: Values followed by the same letter(s) are not significantly different at a 5% level of probability (Duncan’s multiple-range test).

* System 1, control diet from weeks 1 through 4, LPC-mixed diet from weeks 5 through 8.
System 2, LPC-mixed diet from weeks 1 through 4, control diet from weeks 5 through 8.
System 3, 8 weeks of LPC-mixed diet.
high levels, certain accompanying substances may adversely influence feed efficiency.

Duckworth et al. (1961) reported that adding 7% dried LPC to a diet of barley–millet offal resulted in the same rate of growth and feed conversion efficiency as the standard diet in hogs. However, a hog starter diet containing 7 or 8% white fish meal and 10% dried LPC hindered growth but improved feed conversion efficiency. For a starter diet, 4–5% dried LPC had a beneficial effect when the rest of the hog’s supplementary protein was derived from ground seed meal.

Alcantara (1980) fed water hyacinth protein extract (WHPE) to growing pigs and reported decreasing growth performance and feed efficiency with increasing substitution of CP in the SBOM. Alcantara reported that a 25% substitution rate did not significantly affect the performance of growing pigs; however, at 50 and 75% levels, there was a significant drop in performance and in nutrient digestibility.

Fresh green leaves (soilage)

Leucaena leaves are not only extensively used as a leaf meal but are also gaining popularity as a green feed among local poultry and swine raisers. Dingayan and Fronda (1950) reported that, of the three kinds of fresh green leaves fed to chicks (leucaena, centrosema [Centrosema pubescens Benth.], and sweet potato [Ipomea batatas Linn.]), leucaena resulted in the heaviest chicks and the lowest mortality.

Apart from leucaena, tree legumes like G. sepium, Calliandra calothyrsus, and Albizia lebeckoides are widely planted in Indonesia to prevent erosion, enrich the soil, and provide wood for fuel and feed for animals. Mahyuddin (1983) assessed the nutritive value of these plants, which are high in nitrogen (3.5–4.5% N). Gliricidia was more acceptable to livestock than either A. lebeckoides or C. calothyrsus because of its low tannin content. These trees are promising as sources of leaf meal.

Winged bean (Psophocarpus tetragonolobus) is a legume grown almost exclusively in Papua New Guinea and Southeast Asia. Its leaves have one of the highest protein contents among tropical forage legumes (38% based on 90% dry matter) and have a great potential for use in poultry feed.

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