Non-Conventional Roughages in Tropical and Sub-Tropical Asian-Australasian Countries* - Review -

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ABSTRACT : Non-conventional roughage (NCR) is shrub and tree fodders, crop residues and agroindustrial by-products which is not commonly used as livestock feed traditionally and commercially. Eventhough many sources of NCR is available, the farmers perceptions on NCR not only vary from country to country in tropical and sub-tropical Asian-Australasian countries, but also vary from region to region within the country. Chemical composition and nutritive value of NCR are not only vary from species to species but also vary between species within the genera, between provenances/cultivars within the species and such variations are affected by season, climatic zone, topography and land utilization. The nutritive value of NCR can be improved by physical, chemical and biological treatments and conservation. Feeding NCR to ruminant and non-ruminant is not only improve performance of the livestock but also economically feasible. Future direction of NCR is inventarization, exchange information through NCR information centre, integration with either agrisilvicultural, agrisilvipastoral or silvipastoral system, and use of genetic engineering to produce high quality NCR that ultimately become conventional roughage for agroindustry and agribissiness. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 3 : 449-459*)

Key Words : Non-Conventional Roughage, Agroforestry, Nutrient Composition, Treatment, Utilization, Livestock, Performance

INTRODUCTION

Non-conventional roughage (NCR) is defined as shrub fodder, tree fodder, crop residue and agroindustrial by-product which is not commonly used as livestock feed traditionally and as compound livestock ration commercially.

Perception of the farmer to NCR not only vary from country to country, but also vary from location to location. In some dryland farming area in India *Azadirachta indica* leaf has been fed to cattle during dry season; while in some dryland farming in Indonesia such Azadirachta leaf is not fed to cattle even other fodder is not available, since cattle will not consume such leaf. In Bali, Indonesia, in dryland farming area in the lower altitude *Gliricidia sepium* leaf can become the sole diet for ruminant during dry season; while in the wet land farming area in the higher altitude, farmers do not lop such leaf, since the ruminant will not eat it, in the prence and absence of other feeds.

In northern Australia, the leaf of a prickly weed which is protected by thorn is eaten by sheep but not by cattle; which is because the thick fleece of the sheep protect the sheep body so that it can goes through the branches of the prickly weed, while the cattle with its slick coat can not does such manouver. In tropical and sub-tropical Asian-Australasian countries some NCR have been considered as conventional roughages, while others still exist as NCR.

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This paper describes the present status, nutrient composition, treatment, response of the livestock, economic and future direction of NCR.

PRESENT STATUS OF NCR

NCR in agroforestry system

In the broadest sense, agroforestry is defined as any land use which includes both trees and agricultural production on the same piece of land (Mellink et al., 1991). The agroforestry system which has existed in the tropics for 100 years and has evolved through years of trial and error, has been successful not only as a way of increasing the timber, energy, feed and food productions, but also contributing to the conservation of the environment. Depending on the dominant and specific production of its components, agroforestry can be specified into may variants (figure 1).

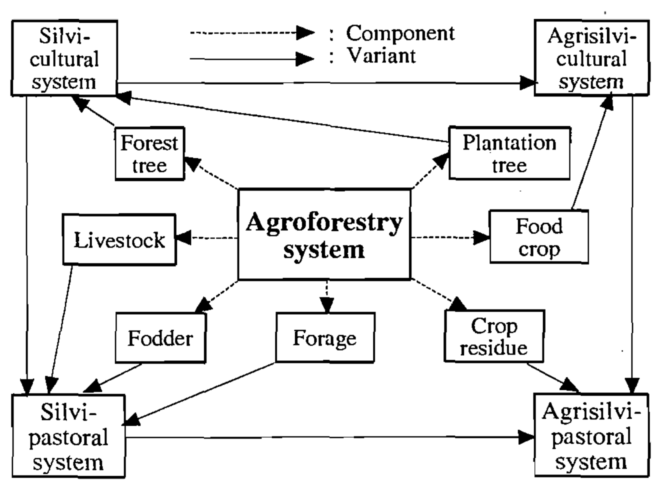

Figure 1. Non-conventional roughage (NCR) in the agroforestry system (Nitis, 1997)

In the silvicultural system where timber, wood and estate crop are the main production, the NCR can be in the from of tree leaves and pod peel. In the agrisilvicultural system where food crops are integrated, straw, stover and other food crop wastes/residues are another from of NCR. In the silvipastural system, where pasture is the main production, the NCR can be in the form of shrub and tree fodders and weed for the cattle, but may not be so for the goat and/or sheep and *vice virsa*. In the agrisilvipastoral system the NCR can be in the form of shrub and tree fodders, food crop waste/residue and weeds.

Source and availability of NCR

The source and availability of NCR can be as follows :

1. In the cereal crop, the NCR can be in the form of straw and hull; in the grain crop the NCR can be in the form of stover, husk and cob; in the bean crop the NCR can be in the form of straw and pod peel and in the tuber crop the NCR can be in the form of stem, tops and vines. These NCR are availability seasionally.
2. In the estate crop where shrubs and trees used as shade and climber, the NCR which is in the form of shrub and tree leaves and pod peels are available periodically. In the sugar cane plantation the NCR which is in the form of sugar cane top and bagasse are also available periodically. In the coconut and palm oil plantations, where NCR is in the form of leaf fronds and fruit husk are available anytime. In the banana plantation, the NCR which is in the form of leaf, pseudo-stem, corm and fruit peels are also available all the times.
3. In the forestry, where the NCR is in the from of shrub and tree leaves and timber pulp are available after logging.
4. In the pasture land, where the NCR is in the form of weeds are available year around for the perenial weeds and seasonally for the annual weeds.
5. In the fallow land and critical land, the NCR which is in the form of shrubs and tree leaves are available year around.

Farmers in Bali, Indonesia, lop more shrubs and trees during the dry season than during the wet season to anticipate the shortage of conventional roughages (table 1). Due to its bigger leaf canopy, tree fodder is lopped more than shrub fodder.

In the case of coconut frond, more is lopped because farmers climb the coconut every month to harvest the nut; while in the case of jack fruit (*Artocarpus integra*) leaf, farmers claim that the more it is lopped the more fruit is produced.

Utilization and preference of NCR

Traditionally the NCR is used only sparingly with the following considerations :

1. During dry season, when the conventional roughage is no more available.
2. As a supplement, when the supply of the conventional roughage is deminishing.
3. Not enough supply, because it grows seasionally. In the case of shrub and tree leaves because it is lopped periodically.
4. For some NCR, causing disturbance (e.g. go-off feed, constipation, diarrhea, poisoning) when fed in large quantity for certain livestock.
5. Priority for other uses, such as green manure, bedding and soil mulch. In the case of *Imperata cylindrica*, *Hyperhemia rufa* and coconut frond, they are mainly used for roofs.

Table 1. Lopping leaf yield of the NCR during the wet and dry season in Bali, Indonesia

Species	Lopping yield (kg DM/tree)[1]	
	Wet season	Dry season
Tree legume		
Erythrina orientalis	0.37	9.30
Erythrina variagata	0.92	11.57
Erythrina lithosperma	0.86	11.22
Non-tree legume		
Cocus micifera	12.09	17.16
Artocarpus integra	6.36	7.10
Ficus poacellii	2.23	11.93
Shrub legume		
Gliricidia sepium	0.95	1.90
Sesbania glandiflora	0.79	1.46
Calliandra errophylla	0.33	1.34
Non-shrub legume		
Zizynhus yuyuba	0.70	0.61
Hibiscus rosasinensis	0.20	0.97
Caecalpinia pulche	0.15	0.86

(Nitis et al., 1985)

[1] Amount lopped is total harvest for one season. Lopping is carried out every 2 months. The amount lopped is the quantity cut to be fed to livestock.

In Bali, Indonesia, goat is fed more shrub and tree leaves than cattle, while buffaloes is fed little amount of shrub and tree leaves (table 2). Rice straw, corn stover and banana stem are not fed to goat, but cassava top is fed when available. Cattle kept in the dryland farming area are fed more shrub and tree leaves than those kept in the plantation and rice field, in that order (table 3). Cattle in the rice field is fed rice straw, while those in the dryland farming area and plantation are fed corn stover and cassava top.

Table 2. Botanical composition (%) of roughage fed to livestock in Bali

Roughage species	Cattle	Buffalo	Goat
Grass	78	87	36
Ground legume	3	5	2
Shrub and tree leaves	15	1	61
Straw	2	3	-
Stem	1	1	-
Others	1	3	1

(Nitis et al., 1985)

Table 3. Botanical composition (%) of the roughage fed to cattle at different land utilization in Bali)

Roughage species	Rice field	Dryland farming	Plantation
Grass	85	70	60
Ground legume	1	2	1
Shrub and tree leaves	6	23	15
Straw	3	1	1
Stem	1	2	1
Others	4	2	2

(Nitis et al., 1985)

Acceptablity of different forage and fodder vary between the livestock (table 4). During the wet season, sheep and cattle do not eat trees and large bushes, while during the dry season sheep eat more trees and large bushes than cattle. Goat, on the other hand, eat much more trees and large bushes than sheep and goat both during wet and dry seasons.

Disease attacking NCR

Plant pest when properly managed will not cause extensive damage on the forage yield. However phsyllids

Table 4. Degree of acceptability (%) of different NCR by different ruminant

Species	Wet season[1]				Dry season			
	ML	D	A	NL	ML	D	A	NL
Sheep								
Trees and large bushes	-	-	-	100	-	5	11	84
Bushes	-	5	17	78	-	-	11	89
Dwarf bushes	-	23	15	62	-	12	35	53
Resistant grasses	5	86	5	4	82	9	9	-
Herbs	3	12	20	63	3	2	10	85
Annual grasses	10	74	16	-	8	74	13	5
Others	21	29	14	36	-	14	-	86
Goats								
Trees and large bushes	5	34	13	48	2	21	27	50
Bushes	6	22	33	39	-	11	33	56
Dwarf bushes	7	33	18	42	1	28	42	29
Resistant grasses	-	36	23	41	-	23	36	41
Herbs	4	24	32	40	-	4	16	78
Annual grasses	-	11	42	47	15	21	32	47
Others	14	50	14	22	15	22	-	63
Cattle								
Trees and large bushes	-	-	-	100	-	-	3	97
Bushes	-	-	6	94	-	5	12	83
Dwarf bushes	-	3	9	75	-	12	29	59
Resistant grasses	4	86	5	5	-	86	5	9
Herbs	3	5	13	79	3	2	10	85
Annual grasses	10	75	13	2	9	61	24	6
Others	-	36	-	64	-	7	14	79

[1] ML = much liked, D = desired, A = average, NL = not liked. (Luisgi, 1984)

Table 5. Chemical composition of the NCR

Plant species	Nutrient (% DM)				
	DM (%)	CP (%)	CF (%)	Ash (%)	GE (kcal/kg)
Tree legume leaf					
Erythrina orientalis	19.91	30.69	19.18	11.24	4,355
Erythrina variagata	18.59	29.22	21.68	9.65	4,344
Erythrina lithosperma	17.49	31.35	19.26	10.62	3,363
Non-tree legume leaf					
Cocus nucifera	37.79	8.30	27.10	8.13	4,648
Azadirachta indica	28.40	17.18	23.89	8.83	4,655
Ficus foacellii	27.49	13.59	29.89	10.49	4,613
Shrub legume leaf					
Gliricidia sepium	19.60	35.92	15.01	8.34	4,550
Sesbania glandiflora	19.92	27.45	16.11	8.22	4,468
Calliandra errophyla	18.53	23.02	16.38	6.72	4,821
Non-shrub legume leaf					
Zizynhus yuyuba	23.46	8.88	21.08	9.93	4,796
Hibiscus rosasinensis	16.13	26.31	12.12	14.21	3,813
Caecalpinia pulche	18.53	23.02	16.38	6.72	4,821
Crop residue					
Corn stover	26.65	11.45	23.13	11.47	4,127
Cassava top	21.90	27.52	14.95	8.89	4,819
Sugarcane bagasse	90.30	1.90	45.00	8.00	5,092
Weeds					
Imperata cylindrica	22.26	8.71	32.45	10.51	4,976
Nephrolepis spp	21.48	16.50	18.76	9.40	3,296
Eichornia crassipes	5.90	13.10	18.20	15.30	3,359

(Nitis et al., 1985; Bo Ghol, 1975)

Table 6. Effect of season on the chemical composition of leaf of some NCR

Species	Season	Nutrient (% DM)				
		DM (%)	CP (%)	CF (%)	Ash (%)	GE (kcal/kg)
Lannea corromandilica	Wet	21.78	20.26	17.34	8.46	4,598
	Dry	28.28	15.62	10.79	9.99	4,400
Schleichera cleosa	Wet	27.64	13.86	19.85	8.43	4,455
	Dry	37.49	12.75	18.34	4.50	6,500
Pisonnia alba	Wet	12.93	25.98	19.94	15.92	4,007
	Dry	16.66	24.72	12.81	13.14	3,822
Carica papaya	Wet	15.54	32.48	10.53	14.64	4.847
	Dry	18.58	20.38	20.84	16.57	4,112
Musa paradiciaca	Wet	16.85	19.00	22.81	11.28	4,263
	Dry	21.10	15.13	24.86	11.74	4,374

(Nitis et al., 1985)

(*Heteropsylla cubana*) outbreak was reported in Hawaii in 1984 and in Asia and Pacific regions in 1985 (NFA, 1989). Control measured using stable resistent Leucaena variety, effective predator, insecticides and management practises have been effective to a varying degrees.

In some areas in Indonesia, *Gliricidia sepium* is infested with aphid (*Aphis craccivora*) particularly at the onset of the rainy season, that causes blackening of the leaf surface and in severe cases causing the death of the leaf premordial and shedding of the young leaves (Nitis et al., 1989). The aphid exudate causes yellowing and even death of the *Cenchrus ciliaris* grown with the Gliricidia. Evaluation of the 16 provenances of *Gliricidia sepium* showed that 3 peovenances (G14, G17and N14) are quite resistant to aphid infestation (Nitis et al., 1991).

NUTRIENT COMPOSITION OF NCR

Chemical composition of NCR

Roughage is defined as plant materials containing high concentration of crude fibre and used as livestock feeds. From the 18 NCR listed, the CF content vary from 12-45% (vide table 7). The proximate composition of the NCR not only vary between species but also within species. The leaf of the shrub and tree legumes contain more CP than those of the non-shrub and non-tree legumes, which vary from 23.02-35.92% and 8.30-26.30% respectively (table 5). Within the 3 Erythrina species, the CP, CF, GE, and ash vary to 14, 7, 29, and 16% respectively. In the 3 crop residues listed, the DM, CP, CF, ash and GE vary from 21.90-90.30%, 1.90-27.52%, 14.95-45.00%, 8.00-11.47% and 4127-5092 kcal/kg, respectively.

Season affect the proximate composition of the NCR. DM of the 5 NCR listed during the wet season is lower while the CP is higher than those during the dry season (table 6). The lower CP during the dry season is not desirable, since during dry season more shrub fodder, tree fodder and crop residue are fed to livestock to anticipate the shortage of conventional roughages.

The proximate composition of the NCR is affected

Table 7. Effect of land classification on the proximate composition of leaf of Artocarpus integra during dry season

Land classification	Nutrient (% DM)				
	DM (%)	CP (%)	CF (%)	Ash (%)	GE (kcal/kg)
Topography					
Low laying area	29.13	13.05	21.23	23.18	3,980
Hill	30.08	12.76	20.62	13.86	4,006
Higher altitude	29.68	13.38	17.96	16.64	3,784
Land utilization					
Rice field	31.04	14.12	20.31	13.10	4,096
Dryland farming	32.02	14.14	19.22	13.25	4,041
Plantation	29.70	12.70	21.22	12.99	3,963
Soil surface condition					
Moist	30.38	12.35	22.51	13.77	4,038
Dry	29.70	12.70	21.22	12.99	3,963
Climatic zone					
B(9 mws/3 mds)[1]	28.31	14.91	20.51	13.31	4,239
C(8 mws/4 mds)	27.04	13.60	20.42	14.09	4,065
D (6 mws/6dms)	31.42	13.07	18.86	14.48	4,202
E (5 mws/7mds)	30.30	15.06	18.22	12.97	4,023
F (4 mws/8mds)	31.58	12.41	18.59	16.54	3,850

[1] mws = months wet season, mds = months dry season.

(Nitis et al., 1985)

Table 8. Major and minor elements of some banana (Musa paradisiaca) pseudo stem

Variety[1]	Major element (%)			Micro element (ppm)		
	Ca	P	K	Fe	Zn	Mn
Bali	0.36	0.33	10.40	400	65.9	68.7
Batu	0.97	0.22	8.06	467	53.0	112.7
Dangsaba	0.51	0.24	11.31	376	65.7	75.5
Dakgeremong	0.76	0.30	10.26	610	65.5	99.5
Daknangka	1.03	0.18	6.81	139	86.2	40.0
Daksaja	0.97	0.14	9.76	1,040	82.2	89.1
Kayu	0.26	0.31	7.09	513	69.1	12.6
Lumut	0.63	0.18	10.57	327	163.1	69.6
Masbali	0.29	0.14	6.95	1,176	36.8	34.3
Masbunga	0.48	0.32	6.43	2,958	77.8	34.4
Masudang	0.60	0.28	8.01	1,261	68.9	15.3
Padi	0.33	0.30	6.41	656	118.1	33.2
Sangkut	0.84	0.28	7.82	608	40.8	134.2
Susu	0.82	0.49	10.00	424	74.1	75.5
Suwala	0.77	0.30	11.72	400	65.9	68.7
Mean ± SD	0.64±0.26	0.25±0.10	8.77±1.87	758.3±187.5	74.7±31.3	66.4±37.0

[1] Local name. (Nitis et al., 1985)

by climatic zone, topography, land utilization and soil surface condition. Jack fruit (*Artocarpus integra*) leaf which is equally used during the wet and dry seasons (vide table 1) contained the highest CP when grown in climatic zone E and the lowest when grown in moist soil surface condition (table 7). For the CF content,the highest when the jack fruit is grown in moist soil surface conditon and the lowest when grown in the higher altitude. Jack fruit leaf therefore, is a good supplement or as a sole NCR during the dry season in dry land farming area (climatic zone E) as a source of protein for livestock.

The major and trace elements composition of the NCR also vary. Vercoe (1987) showed that the mineral content of 23 tree fodders (which is mainly legumes) grown in Australia vary from 0.05-0.18% P, 0.41-1.78% K, 0.29-3.52 % Ca, 0.21-1.13% S, 0.01-0.41% Na, 0.21-0.62 % Mg, 4-152 ppm Cu, 22 - 123 ppm Zn, 30 - 917 ppm Mn, 26-325 ppm Al and 0-9 ppm Ti. Nitis et al. (1985), showed that the major and trace elements of 15 varieties of banana stem in Bali, Indonesia vary from 0.26-1.03% Ca, 0.14-0.49% P, 6.41-11.72% K, 139-2958 ppm Fe, 40.8-163.1 ppm Zn and 12.6-134.2 ppm Mn (table 8). Therefore, banana stem is a good source of trace element Fe, Zn, and Mn.

Nutritive value of NCR

The nutritive value of NCR vary from species to species. In Nepal from the 18 NCR analysed the leaf dry matter digestibility (DMD) vary from 15.4-68.8%, while the leaf organic matter digestibility (OMD) vary from 23.3-69.6%) (table 9). The highest value both for the DMD and OMD is in *Artemisia vulgaris*.

The nutritive value is also affected by the stage of growth of the NCR. Except for Grewia, the leaf DMD at the late growth stage of the 4 NCR in India is higher than those of early growth stage (table 10). Similar trend is also observed for the digestible crude protein (DCP). This is important, since NCR is usually lopped later, to compensate for the shortage of feed during dry season.

Between the NCR species and between clones within the NCR species the nutritive value can vary. In Central America the leaf *in vitro* dry matter digestibility (IVDMD) of 4 Erythrina species vary from 44 52%,while its protein solubility vary from 32 56% (table 11). Between the 30 clones, IVDMD and protein solubility also vary, ranging from 32-55% and 20-60%,

Table 9. Digestibility of NCR

Species	As % DM		Species	As % DM	
	DMD (%)	OMD (%)		DMD (%)	OMD (%)
Albizia stipulata	27.8	23.3	*Grewia oppositifolia*	35.6	27.5
Artemisia vulgaris	68.8	69.6	*Litsea polyantha*	38.5	34.7
Artocarpus lakoocha	56.6	48.9	*Machilus odoratissima*	42.3	39.6
Bauhinia purpurea	49.1	39.8	*Michelia campaca*	64.9	64.2
Brassaiopsis hainla	65.5	56.1	*Quercus lamellosa*	15.4	33.2
Bridella ratusa	42.0	33.2	*Salix babylonica*	55.7	51.2
Dendrocalamus strictus	41.5	26.8	*Saurauia napaulensis*	55.1	55.8
Dalbergia sissoo	39.1	33.8	*Schima wallichii*	55.1	58.8
Ficus semicordata	55.6	44.2			
Ficus roxburghii	49.4	33.6			

(Compiled by Joshi and Singh, 1989)

respectively. This indicated that there is ample opportunity to select *E. poeppigiana* that has higher IVDMD and protein solubility among other species and clones of Erythrina.

Table 10. Nutritive value of leaf of NCR at different stages of growth

Species	Stages of growth	As % DM DMD (%)	DCP (%)
Grewia optiva	Early	76	15.8
	Late	67	13.6
Robinia pseudocacia	Early	39	9.8
	Late	56	11.5
Baulinia variegata	Early	43	6.8
	Late	56	7.9
Dendrocalamus hamiltonii	Early	68	10.3
	Late	76	10.8

(Negi, 1977)

Table 11. Nutritive value of the leaf of Erythrina species and clones (%)

	IVDMO		Protein solubility	
Species	Species	Clone	Species	Clone
E berteroana	49	42-55 (12)[1]	40	28-53 (12)
E. fusca	44	43-47 (7)	32	20-49 (7)
E. poeppigiana	52	50-54 (3)	49	44-60 (3)
E. costarricense	46	32-53 (8)	39	28-46 (8)
E. cocleata	47	(1)	35	(1)
E. lanceolata	50	(1)	56	(1)

(Pezo et al., 1989)

[1] Values in parenthesis are the ranges of mean values for clones within species.

Deleterious principle in NCR

The deleterious compounds that are found in some NCR are cyanoglucocides, fluoroacetic acid, tannin, frussic acid, mimosine, latex and oxalic acid (table 12). Some of the NCR such as *Bauhinia variegata*, may cause decrease in milk yield, *Bridella retusa* may cause dysphagia, *Albizia stipulata* may cause haematuria, *Ficus hispida* may cause abortion and *Schima wallichii* may cause hair loss and skin disease (table 13).

Table 12. Deleterious principles in NCR

Roughage	Deleterious principles
Acacia leaf	Cyanoglucosides, fluoroacetic acid, tannins (1.5%)
Banana leaf	Tannins
Cassava leaf	HCN (17.5 mg/100g)
Gliricidia leaf	Tannins
Leucaena	Mimosine (3-hydroxy-4 [1H]- pyridone)
Young leaf	2.1 6.8%
Mature leaf	0.3 3.7%
Stems	3.7%
Seeds	7.1%
Mesquite	Tannin (2.9%)
Water hyacinth	Oxalic acid (2.4% dry matter)

(Devendra, 1989)

Among other means and ways to overcome the anti-nutritive factors are supplementation, dilution, simple treatment, management and rumen microbial activity (Lowry, 1989). Memosine in the *Leucaena leucocephala* can be toxic to some ruminants if there is no 3,4 DHP-detoxifying bacterium in the rumen of such animal (Jones, 1986). To overcome the mimosine toxicity the sensitive ruminants can be innoculated artificially or in contact with resistant ruminants (Munoz and Seifert, 1991).

Table 13. Toxic effects of the NCR

Effect	Species
Decreased milk yield	*Bambussa spp., Bauhinia variegata, Boehmeria regulosa, Bredula retusa, Ficus auriculata, F. semicordata, F. hispida, F. glaberrina, F. roxburghii, Grewia tiliaefolia, Prunus Cerasoides, Quercus incana, Shorea robusta.*
Dysphagia	*Bridella retusa, Buddleja asiatica, Ficus lacor, F. roxhurbergii.*
Haematuria	*Albizia stipulata, Ficus semicordata, F. nemoralis, Osyris wightiana, Thysanolaena maxima.*
Abortion	*Bambusa spp., Bauhinia vahlii, Ficus semicordata, F. hispida.*
Hair loss, skin disease	*Ficus clavata, Macuna nigricans, Schima wallichii, Shorea robust.*
Photosynthesation	*Lantana camara.*
Death	*Dolichos lablab.*

(Joshi and Singh, 1989; Nitis et al., 1989)

TREATMENT OF NCR

Physical treatment

1) Wilting

Fresh *Gliricidia sepium* leaf produces astrigent ordour, so that some livestock will not eat such leaf (Nitis, 1985). Lopping the Gliricidia branches in the morning and letting the leaves to wilt during the day to reduce, if not get rid off, the astringent ordour would bring about the livestock to eat the leaves in the afternoon. Similar procedure can be followed by lopping the Gliricidia in the afternoon and fed them to the livestock the next morning.

2) Water soaking

According to Sharma et al. (1993) water soaking is assumed to affect the internal physico-chemical characteristic of the straw through swelling of the fibre, softening of the particles, loosening the linkages within structural carbohydrates and ultimately on palatability. Water soaked straw based diet lead to higher digestibility of DM, ADF and NFE than unsoaked straw. Ranjhan (1981) reported that soaking of straw overnight before feeding improved intake as well as digestibility by 5 units.

3) Water steaming

Wayman et al., (1972) reported that steam treatment of bagasse has been reported to increase voluntary intake and digestibility in cattle by degradation of cellulose and hemicellulose, through associated with the production of undesirable poly-phenolic compounds. Rangnekar et al. (1982) showed that low pressure steam treatment decreased in hemicellulose and increased in VFA and IVDMD of baggsse, rice and sorghum straws. It has been demonstrated that at any temperature and steam pressure, there is an optimum time, above which the digestibility decrease. This may be due to over-treatment leading to burning or charring of materials or loss of (hemi) cellulose (Sharma et al., 1993).

4) Chopping

A major aim of chopping in farmer practices may be to reduce the wastage (Doyle et al., 1986) and also to reduce the possibility for selective consumption (Wahed et al., 1990). Feeding of chopped or long rice straw did not affect DMI and DMD in sheep (Devendra, 1983), but consumption of chopped rice straw was higher than of long straw (Castillo et al., 1982). The effect of the chopping or grinding depend on the quality of the roughage, as the intake of crop residue is more than dried grasses, which may be due to increase rate of passage as well as better fermentation in the rumen (Sundstol and Owen, 1984).

5) Densification

Pelleting increased voluntary intake, but frequently depress digestibility (Greenhalgh and Wainman, 1972). Stevens (1981) summarized that pelleting of low grade roughage improved uniformity, density, dustiness, ease of handling and reduced wastage. Blaxter and Graham (1956) reported that pelleting increased faecal energy losses, but this has been compensated by lower losses of energy as heat and methane, with no significant effect on net energy. Except for the decrease in DCF, the effect of pelleting increased the utilizations of the other nutrients (Labuda et al., 1979).

Other form of densifications are cubes, briquettes, blocks and wafers. The DMD, DCF and DNFE of feed block made from unground rice straw were higher than those of ground rice straw (Kumar, 1998). The densification of feeds to wafers also depend on pressure applied, moisture content and plant characteristics (Singh et al., 1986).

6) Irradiation

X- rays irradiation improved digestibility of straw though breakage of the cellulose and hemicellulose bounds, resulting in the formation of olegosaccharides which can be utilized by the rumen microbes (Sharma et al., 1993). Gamma irradiation has been reported to improve the digestibility of carbohydrates in straw and other residues by rumen microbes (Ibrahim and Pearce, 1983). Since the process involves high cost and technology, it is not relevant for application to the farmers.

Chemical treatment

1) Alkali treatment

In reviewing the literature, Sharma et al. (1993) summarised that in the past the most widely applied chemical which produced good results, particularly for large scale treatment was sodium hydroxide (NaOH). However, the use of NaOH on small farms at village level was uneconomical and slightly dangerous. The use of ammonium hydroxide (NH_3OH) attracted the researches because it increased the nitrogen content, in addition to the digestibility and intake of straw. Because of the requirement of special equipment for transport and application of liquid and anhydrous ammonia, the use of ammonia is not feasible under small farm condition in Asia and Pacific. Another cheap alkali was calcium hydroxide ($Ca(OH)_2$), but due to its low solubility, imbalance Ca:P ratio and being a weak alkali, it has not been found to be very effective for *in vivo* animal performance.

In tropical and sub-tropical climates, urea has been found to be the most suitable source of ammonia for treating straws to increase feeding value, because of its ready availability, familiarity of farmers with its transport, storage and application as fertilizer in addition to its good effect on intake, digestibility, growth and milk production (Sharma et al., 1993). Many reports have been published on the importance of urea treatment in increasing the nutritive value of crop residue particularly straw, stover and bagasse in tropical and sub-tropical Asia-Australasian countries (Wanapat and Devendra, 1984; Doyle et al, 1986; Devendra, 1988; Guo Tingshuang 1993; Singh and Schiere, 1993; Chenost and Kayouli, 1997). Major factors affecting the degree of improvement of nutritive value of crop residue are level of urea treatment, temperature, curing period, moisture content, structure used and type of crop residue and even type of straw (Sherma et al., loc. cit.).

2) Oxidizing agent

Oxidizing reactions cause lignin solubilization and therefore improve nutritive value of crop residue (Chandra and Jackson, 1971). According to Sherma et al. (1993) bleaching powder was equally effective as NaOH in removing or solubilizing lignin, but at higher levels the residue chlorine in treated material may have been toxic to rumen microbes and thus *in vivo* digestion inhibited beyond 2% level of treatment. Sodium sulphite to break up lignin of cobs probably due to production of NaOH in the reaction.

Biological treatment

According to Gupta et al. (1993) biological treatments include the production of single cell protein from ligno-cellulosic wastes, used of straw left-over after mushroom production and the use of enzymes. Ligno-cellulosics are the most commonly and abundantly available organic compound in nature,while enzymes required for their breakdown have limited distribution and are mainly confined in micro-organisms. Though the required enzymes for breakdown of ligno-cellulose are mainly produced by microorganism. the decay of ligno-cellulosic materials is a normal phenomenon in nature and accomplished by organisms which mostly function through decomposition of various components of these materials. The fungi play a role in these processes are :

1. Brown rot fungi that preferentially attack the cellulose and hemicellulose, which are essentially fed to ruminants as an energy source, and leave behind brown residue.
2. Soft rot fungi that leave the attacked ligno-cellulosic material watery soft at the surface layer and that break down the lignin as well as cellulose and hemicellulose.
3. White rot fungi that are capable of breaking down the lignin without much attacking the cellulose and hemicellulose.

From the review of literature, Singh and Schiere (1993) summarized that the fungal treatment is consistently accompanied by dry matter losses, reduced DMD and TDN, increased DCP in the fermented product causing a net loss of nutrients. Furtherwork on solid state of fermentation, genetic improvement of microbes, or on scaling up of the process should be done by microbiologists, biochemists or bioengineers before the nutritionists continue to test a process for field application. The use of probiotics can be explored for improved feed conversion by animals.

Conservation

Some NCR are known to shed their leaves during dry season; the time when livestock feed is in a shortage of supply. By strategic and systematic lopping, the leaf shedding can be minimized, if not prevented, so that such NCR look green all the year around (TSFS Team, 1993). Such conservation *in situ* (standing green) is practised by lopping the branches of NCR twice during the 4 months wet season and twice during the 8 months dry season.

Table 14. Nutrient composition and nutritive value of hay and silage of Gliricidia sepium leaves

Constituent	AS% DM	
	Hay	Silage
DM (%)	77.81-88.63	19.00-24.66
CP (%)	17.99-23.69	16.74-20.06
Nitrogen (mg/100g)		
$N\text{-}NH_3$	0.011-0.022	19.46-53.26
N total	-	733.80-1018.73
Volatile fatty acid (%) :		
Lactic	-	9.09-21.48
Acetic	-	2.46-7.86
Butyric	-	0.01-2.79
Digestibility (%) :		
IVDMD	54.67-70.45	43.76-63.35
IVOMD	52.35-68.26	39.37-61.65

(TSFS Team, 1993)

Other method of conservation is by making hay and silage. Hay and silage made from 16 provenance leaf of *Gliricidia sepium* contained varying amount of DM, CP, $N\text{-}NH_3$; and the IVDMD and IVOMD also vary (table 14). In case of silage the lactic, acetic and butyric acid contents also vary. The hay contained more DM, CP, IVDMD, IVOMD but less $N\text{-}NH_3$ than the silage.

RESPONSE OF LIVESTOCK TO NCR

Cattle

In central Queensland, Australia 2 years old cattle grazing Heteropogon grass supplemented with Leucaena fodder gained 94% more live weight and had better carcass quality than those grazing grass only (Foster and Blight, 1993). Reynolds (1995) indicated that milk production of dairy cow increased 22-62% by supplementing Pennisetum or Brachiaria grass with Leucaena fodder. Bali heifer stall-fed a mixture of improved grasses, ground legume, shrub and tree fodders has 31% faster oestrus interval, 6% increased oestrus frequency, 4% longer oestrus duration and 20% less silent heat than those fed native grass only (Pemayun et al., 1996).

According to Haque and Saadullah (1983) calf fed untreated rice straw supplemented with water hyacinth (*Eichornia crassipes*) gained more live weight and produced heavier carcass dressing percentage than those fed untreated rice straw only. When urea-treated rice straw was used there was no differences on those parameters, indicating that water hyacinth can replace urea. Perdock et al. (1982) reported that local cow fed urea-treated rice straw supplemented with concentrate produced 40.9% more milk and the calf gained 41.9% more live weight than those fed untreated straw with concentrate supplement. Cow fed urea treated straw gained weight (93 g/day), while those fed untreated straw lost in live weight (266 g/day). Cattle fed sugar cane top cube supplemented with Leucaena fodder gained more live weight than those without Leucaena supplement (Lopez et al., 1981). Bali cattle fed a mixture of Leucaena fodder and banana stem (50 : 50 ratio) gained more live weight than those fed Leucaena only. Banana stem provided trace minerals and energy in the form of cellulose and hemi-cellulose.

Buffalo

Swamp buffalo fed rice straw lost in live weight, when supplemented with 1 kg dried Mimosa leaf the lost in weight was smaller (Wanapat, 1986). The higher the Mimosa supplement (2~3 kg) the smaller the live weight loss. Water buffalo fed rice straw supplemented with Gliricidia fodder produced more milk and better milk composition than those fed rice straw only (Van der Hock et al., 1988).

Goat

During the 3 months dry season in Bali, Indonesia, goat fed solely green Gliricidia or Ficus fodder gained live weight, while those fed solely dry grass lost live weight (Sukanten et al., 1996). Experiment in Bangladesh showed that Black Bengal goat fed 100% *Sesbania aculeata* fodder gained 45% more live weight and 38% heavier carcass dressing percentage than those fed 100% roadside grass (Alam et al., 1978). Experiment in the Philippines showed that native goat fed corn stover supplemented with Leucaena fodder gained more live weight than those fed corn stover only (Linggodjiwo, 1976).

Sheep

In cut and carry system sheep fed Pennisetum grass supplemented with Sesbania fodder gained 2.7~5.0 times more live weight than those fed grass only (Mathius and Van Eys, 1983). Sheep fed rice straw supplemented with Leucaena fodder gained more live weight than those fed rice straw only (Meevootisom et al., 1987).

Cattle lost weight, but sheep maintained weight when browse forage with nutritional value ranging from 0.25 - 0.46 feed units (Fu/kg DM); while goat gained weight even when the browse forage nutritional value is only 0.19 FU (Sarson and Salmon, 1978). This indicated that goat is more efficient in utilizing NCR than sheep and cattle in that order.

Swine

Pig fed basal diet supplemented with 5% bran and 5% Robinia leaf meal gained 13% more live weight and those supplemented with 10% bran gained only 2% more than those fed basal diet only (Zhao et al., 1975). This indicated than *Robinia pseudoacacia* leal meal can replace 5% of the bran. Pig fed basal diet supplemented with 10% Leucaena leaf meal gained 11% more live weight, while those supplemented with 20% Leucaena leaf meal gained 8% less live weight than those fed basal diet only, indicating that such leaf meal supplement should not be higher than 10% (Lizi, 1986).

Bali pig fed 60% rice bran + 40% banana stem gained more live weight than those fed 100% rice bran only. Such discrepancy is due to the lower Zn content of rice bran is compensated by the high Zn content of banana stem (vide table 7).

Poultry

Supplementing basal diet with 3% Leucaena leaf meal increased the egg production, egg weight and total egg mass compared with those without supplementation, while increasing the leaf meal supplement to 6 and 9% has no effect on such parameters (Young, 1988). Poultry layer supplemented with 6% Pinus leaf meal without vitamin supplement produced 11% less egg production than those fed basal diet with 5% vitamin supplement (Li and Yu, 1982). However, when the leaf meal was added only 2.5% vitamin supplement the egg production was 4% more than those supplemented with 5% vitamin. This indicated that Pinus leaf meal can replaced 2.5% of the vitamin. Poultry layer fed basal diet supplemented with Populus leaf meal produced 11% more egg production, while the egg fertility and hatchability were about the same as those fed basal diet only (Li and Zhou, 1982).

"Kampung" hens roaming the land planted with a food crop, improved grass-legume, fodder shrubs and trees in the Three strata forage system produced 56% heavier egg weight, 58% bigger egg size, 37% more eggs and had a 33% longer laying period than those roaming in the field with food crop only (Nitis et al., 1989). Such better response is probably due to the vitamins and minerals supplied by the improved grass-legume pasture, more plant protein from the seeds of the improved pasture and more animal protein from the white ants living on the plant debris.

ECONOMIC CONSIDERATION

In the Three strata forage system (TSFS) dryland farming area in Bali, Indonesia, the gross margin for cattle was 30.10% higher and the farm income was 29.55% higher than the traditional system (Nitis et al., 1989). Since the TSFS farmers have more time to do off-farm job, the farmer income was 39.78% higher. In the semi-arid tropic of western India, planting 400 trees/ha for wood and fodder on the bund of sugarcane fields, lead to 25 - 30% increased annual income of the farmers (Hegde, 1991). In the hot arid region of India, the net annual return from silvipastural systems was 50% higher than the net annual return from annual crops (Gupta, 1993).

Most, if not all, smallholders recognise the importance of fodder shrubs and trees in reducing their cash expenses. A case study carried out in a smallholder dryland farming area in Bali Indonesia showed that by integrating shrub and trees a farmer can save IDR 523,000/ha in the form of fodder (37%), fuelwood (20%, fruit (42%) and farm implement (1%) (Nitis, 1985). In a hypothetical illustration of fodder production from 5 trees planted on barren land and along the bund of a smallholder field, the benefit-cost ratio was 3.12 (Amir, 1989).

In the Philippnines, Trung et al. (1987) showed that dairy cattle fed 35% rice straw supplemented with 22.5% Leucaena leaf meal+22.5% dried poultry litter +20% concentrate increased income from milk production 17.3% more than those fed rice straw supplemented with 65% concentrate only. The 45% concentrate can be replaced with fodder and litter with better result that reduces the cost of the concentrate supplement. From the literature review, Kumar et al. (1993) summarised that dairy farmer in India generally fed their livestock rice straw supplemented with concentrate and green roughage. The on-farm trial showed that the annual benefit (treated rice straw/annual milk yield per cow) vary from INR 22-715, depending on the availability of green roughage and price of the rice straw.

FUTURE DIRECTION

To increase the quantity and quality of NCR and to increase the animal performance consumming such NCR the future direction suggested is as follows :

1. Inventarization of the availability, nutritive value and utilization of NCR by livestock in Asian-Australasian countries.
2. Exchange information by formation of Nasional NCR information centre in each countries and regional NCR information centre in the country most appropriate.
3. On-farm testing of the NCR potential for commercial production.
4. Integrate NCR with agrisilvicultural system in the intensive farming system, with agrisilvipastoral system the semi-extensive farming system and with silvipastoral system in the extensive farming system.
5. Use genetic engineering (tissue culture, transgenic) to produce high quality NCR that ultimately become conventional roughages for agroindustry and agribisnis undertakings.

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