Growth and Reproductive Performance of Small Ruminants under Integrated Livestock-Oil Palm Production System

A. S. Haji Baba, A. Azillah, T. K. Mukherjee and R. B. Abdullah
Institute of Biological Sciences, University of Malaya, 50603, Kuala Lumpur, Malaysia

ABSTRACT : The effects of supplementation with mixed fodder or concentrate were investigated on the performance of a) growth of male lambs and kids grazing extensively under oil palm trees and b) reproduction of ewes and goats stall-fed with native herbage. Supplemented kids and lambs had higher average daily weight gain than controls but the effect was only significant for those which received concentrate ($p < 0.05$). Final body weight was only significantly different from controls for lambs supplemented with concentrate ($p < 0.05$). The ages at puberty, first mating, first conception and first kidding of supplemented goats were about 110 days earlier than those for controls ($p < 0.05$ or better). Supplemented goats had first mating and conceived at lower body weights ($p < 0.01$) than those in control groups. Different feeding regimes had no effects ($p > 0.05$) on the reproductive performance of ewes apart from highest body weight of first lambing in animals supplemented with concentrate ($p < 0.05$). Native herbage available under oil palm trees of 5 years old was sufficient for growth and reproduction of sheep and goats. Concentrate was better than mixed fodder as supplement for enhancing the reproductive performance of goats but both appeared to have limited effects on the performance of reproduction in ewes and growth in male kids.
(**Key Words**: Sheep, Goats, Growth, Reproduction, Integration, Oil Palm)

INTRODUCTION

The area under tree or permanent crops including coconuts, oil palm, rubber and orchards in the South and Southeast Asia regions is estimated to total in excess of 20.3×10^6 ha (FAO, 1995). The availability of undergrowth as ruminant feed is estimated sufficient to support between 5-15 small ruminants/ha/year. Based on 10% readily available new grazing areas under crop plantation an estimated 20×10^6 small ruminants can be reared on top of the existing 24.1×10^6 small ruminants in the South and Southeast Asia regions. Substantial mutual benefits can be obtained from the livestock-tree crop integration. Preliminary studies with sheep grazing under rubber and cattle grazing under oil palm showed a saving of 17-36% (Abdul Karim et al., 1990; Tajuddin et al., 1990) and 20-40% (Gopinathan, 1991) respectively of the total cost of weed control besides the enhancement of animal productivity through the utilization of undergrowth and crop by-products (e.g. oil palm fronds (OPF), palm oil mill effluent (POME), palm kernel cake (PKC), copra, rubber seed meal). As such, integrated livestock-tree crop production system in the tropics offers great potential in small ruminant meat production in comparison to extensive and arable cropping production systems.

Adequate availability of undergrowth and other feed resources are necessary to ensure maximal livestock performance in the tree-crop plantation. Both growth and reproductive performance of animals under specific tree-crop production system must be assessed. The present studies have attempted to evaluate the feeding values of native herbage in oil palm plantation in the presence or absence of supplementation with mixed fodder (napier grass and *Leucaena leucocephala*) or concentrate on the growth and reproductive performance of goats and sheep.

MATERIALS AND METHODS

Location and background of project

The study was conducted in Sungai Sedu oil palm estate in the district of Hulu Selangor (latitude 101° 38′, longitude 3° 20′, altitude 0-10 m, mean daily temperature 26.5℃ (23° - 32℃), annual rainfall 1,500-3,500 mm), 50 miles South-West of Kuala Lumpur. The present report was based on findings from data collected from experimental trials carried out between March 1991-December 1994.

[1] Address reprint requests to A. S. Haji Baba.
Received July 14, 1997; Accepted April 13, 1998

Animal and plant management

Two elevated (4 feet high) goat and sheep sheds were constructed between the powerline rentices and the fringe of oil palm plantation. Animals were either brought in from the nucleus herd (Institute of Postgraduate Studies and Research, University of Malaya) or purchased from local suppliers. Animals were dewormed on arrival and every four months thereafter.

An area of approximately 3 ha under powerline rentices was cultivated with *L. leucocephala* and Napier grass (*Pennisetum purpureum*). Both forages were fertilized with liquid POME at the rate of 500,000 liters/ha/yr. The *L. leucocephala* fronds were harvested at six weeks of age whereas Napier grass was harvested on the fifth week from the previous cutting.

Native herbage thrived on practically all ground area under oil palm trees. The total area available for the growth of these and other herbage per ha was estimated to be about 6,300 sq. meter (Sivaraj et al., 1993) with the remainder unavailable for herbage growth because of tractor passage, herbicide-applied area around each tree (7 sq. meter; to facilitate collection of harvested palm fruits), and the presence of drains for irrigation. The yield, nutrient composition and *in vivo* feeding value of the undergrowth available under 5 years old oil palm trees were initially evaluated and reported (Sivaraj et al., 1992).

Dried POME, PKC and molasses were purchased locally, mixed in 3:1:0.2 ratio, made into pellet and offered to the animals within one month of preparation. Nutritional values of feed samples were estimated by proximate analysis by the method of AOAC (1984). Dry matter (DM) digestibility was determined in a feeding trial (Sivaraj et al., 1992) and metabolic energy (MJ/kg DM) was estimated from conversions of digestible organic matter (DOMD; MJ/kgDM) values (Barber et al., 1984) i.e. ME (MJ/kgDM) = 0.0157[DOMD].

Growth performance of Katjang kids and Malin lambs under oil palm plantation

Lambs (n=36) and kids (n=36) of indigenous breeds Malin and Katjang respectively (both between 5-8 months old) were each divided randomly into three groups. Animals were housed together in a shed and were allowed to graze undergrowth available in an area of 20 ha of oil palm plantation trees (4-5 years old) from 11:00 hr to; 17:00 hr. The animals were herded back to the main shed and penned according to feeding groups. Animals in the control groups (undergrowth only; UG) were not given any supplements. Animals were supplemented with either mixed fodder (undergrowth and mixed fodder; UGF) or concentrate (undergrowth and mixed concentrate; UGC) at 2% of body weight (BW) in dry matter (DM). All animals had free access to mineral blocks and fresh water in the shed. Live body weights were weighed every two weeks. Animals were kept in the shed throughout the day whenever the undergrowth was flooded due to heavy rain. During these occasions (a total of 8 weeks) undergrowth were offered to the animals (manually cut and carried to the shed) at approximately 3% of BW in DM. Animals were weighed for final body weights after 12 months of feeding trial. Results are expressed as means ± s.e.m. Least significant difference at $p < 0.05$ was compared between the means of UG, UGC and UGF.

Reproductive performance of small ruminants

Female Dorset-Malin crosses (n=22, 6-7 months old) weighing between 17.5-30.5 kg and female Jermasia goats (n=24, 6-7 months old) weighing between 14.5-17.5 kg were used in this study. The animals were randomly divided into three groups and fed throughout the experimental period with either one of the following dietary regimes: a) control (4% of body weight (BW) of native herbage only in dry matter (DM)); b) concentrate supplement and native herbage each at 2% BW in DM; and c) mixed fodder supplement (Napier grass: *L. leucocephala*, 1:1) and native herbage each at 2% BW in DM).

Oestrus detection was carried out twice daily and those in oestrus were mated with either Dorset-Malin ram or Jermasia buck. After parturition, the offsprings were allowed to suckle their dams but were weaned early at 60 days old. Weighing was done once fortnightly and the feed rations were adjusted according to the body weight. Parameters recorded include age and weight at first estrus (puberty), first mating, first conception, and first lambing/kidding. Analysis of variance was done by comparing the treatment means using F-test and D-MRT (Snedecor and Cochran, 1967).

RESULTS

A total of nine males (12.5%) and seven females (15.2 %) died during the course of the study for various reasons. All females died due to either pneumonia or bloating whereas males died due to wild dogs attacks or accident (drowning in the irrigation drain) or pneumonia. The proportion of plant species of native herbage available under the 5 year old palm trees varied substantially between harvest (table 1) and contributed to considerable variation in nutrient values (table 2) available to experimental animals. The nutritive values of other feeds

Table 1. Botanical composition of the native herbage under 5 years old oil palm trees (data adapted from Sivaraj et al., 1992)

Plant species	Dry matter yield[#] of undergrowth in 5 years old plantation			
	Harvest I	Harvest II	Harvest III	Mean*
Asystasia sp.	57.0	163.8	0	73.6
Ottochloa sp.	76.6	0	116.1	64.2
Mikania sp.	28.7	0	18.8	15.8
Pueraria sp.	28.9	0	4.7	11.2
Adriantum sp.	0	28.6	0	9.5
Lipocarpha sp.	0	0	8.9	3.0
Paspalum sp.	0	0	3.4	1.1
Cleome sp.	0.4	0	0.8	0.4
Total	191.6	192.4	152.7	178.8

[#] (g/sq m).
* Mean from 3 harvests (5 replicates/harvest).

(Napier grass, *L. leucocephala* and concentrate) offered were more consistent.

Growth performance of kids and lambs under oil palm plantation

Sheep tend to have higher ($p > 0.10$) average daily weight gain (23.14 g/day) than those recorded for goats (21.96 g/day) (table 3). Both goats and sheep with supplementary feeding showed higher average daily gain compared to unsupplemented animals. The effect was greatest in sheep supplemented with concentrate (31.71 g/day) which was higher than those recorded for goats supplemented with concentrate (26.40 g/day). The differences in average daily weight gain for goats and sheep supplemented with fodder were also higher than their respective controls (26.18 vs 23.13, lambs; 25.55 vs 21.96, kids) but the effects were not significant ($p > 0.05$). The initial body weights between groups were not significantly ($p > 0.10$) different for each species (table 3).

Table 2. Nutritive value of native herbage, cultivated forages and palm-based concentrate

Parameter	Native herbage	Napier grass	L. leucocephala	Concentrate
Dry matter (%)	15.5 ± 2.5	15.3 ± 0.8	25.3 ± 0.78	89.3 ± 0.63
Organic matter (% DM)	82.3 ± 3.8	85.7 ± 1.3	92.8 ± 1.0	80.3 ± 0.3
DM digestibility (%)	59.3 ± 3.2	68.6 ± 1.1	59.2 ± 0.8	54.3 ± 1.9
Energy, ME (MJ/kg)	9.8 ± 2.4	10.1 ± 1.1	11.8 ± 0.8	10.3 ± 0.4
Crude protein (%)	11.4 ± 3.0	17.3 ± 0.6	26.4 ± 0.9	14.5 ± 0.5
Calcium (g/kg)	2.7 ± 1.8	3.5 ± 0.1	10.2 ± 0.3	1.67 ± 0.03
Phosphorus (g/kg)	1.2 ± 0.8	2.0 ± 0.6	1.4 ± 0.6	0.32 ± 0.05

Table 3. The effect of grazing undergrowth ± supplements on growth performance in malin sheep and katjang goats

Animal	Undergrowth grazing Only (Control)	Undergrowth + Fodder	Undergrowth + Concentrate
	Average daily body weight gains (g/day)		
Malin sheep	23.13 ± 1.96[a] (n=12)	26.18 ± 2.48[a] (n=12)	31.71 ± 2.75[b] (n= 8)
Katjang goats	21.96 ± 1.71[a] (n= 9)	25.55 ± 2.38[a] (n=12)	26.40 ± 3.68[b] (n=10)

[a,b] Means within row having different superscripts differ ($p < 0.05$).

	Changes in live body weights (kg)		
Sheep (Initial B.W.)	11.41 ± 0.70 (n=12)	10.89 ± 0.53 (n=12)	12.50 ± 1.57 (n=12)
Sheep (Final B.W.)	17.53 ± 0.68 (n=13)	17.94 ± 0.38 (n=12)	21.42 ± 1.76* (n= 8)
Goat (Initial B.W.)	11.15 ± 0.81 (n=12)	11.16 ± 0.78 (n=12)	11.25 ± 0.98 (n=12)
Goat (Final B.W.)	11.49 ± 0.77 (n= 9)	19.14 ± 0.81 (n=12)	18.37 ± 0.81 (n=10)

Data are presented as mean ± s.e.m. * $p < 0.05$ compared to control.

The final body weights of supplemented goats and sheep were not significantly ($p > 0.10$) different compared to their respective controls. An exception to this was the final body weight of sheep receiving concentrate as supplementary feeding which had average final body weight (21.42 kg; $p < 0.05$) higher than those recorded in unsupplemented sheep (17.53 kg).

Reproductive performance of small ruminants

Table 4 shows the effects of different feeding regimes on the age (days) of the first sign of sexual maturity, first conception and parturition in goats. Mixed fodder and concentrate supplemented animals became sexually matured (detection of first oestrus) at earlier age (220.5 days; $p < 0.05$) compared to unsupplemented animals (355.5 days). As a result, supplemented animals conceived and kidded approximately 110 days ($p < 0.05$) earlier than control animals. There were small differences in the reproductive performance of goats supplemented with concentrate and fodder. Significant differences ($p < 0.05$) between the two were only observed for age at first mating (210.71 days vs 243.88 days). Differences between the two supplemented groups diminished with respect to age at first conception and first kidding. Animals in both supplemented groups however arrived at first conception and kidding at earlier ages than those in control groups. As shown in table 4, does fed with concentrate attained puberty and were ready for first mating at a significantly ($p < 0.05$) lighter bodyweight than those on mixed fodder (16.71 kg vs 20.50 kg). The mean body weight of does

Table 4. Effects of supplementation on the age (days) and body weight (kg) of goats at sexual maturity, conception and kidding

		UG (Control)	UGC	UGF
First oestrus	Age	276.50^{a} ± 15.94 (n=6)	272.6^{a} ± 14.76 (n=7)	295.6^{a} ± 13.81 (n=8)
	BWt	28.00^{a} ± 1.91 (n=6)	27.26^{a} ± 1.77 (n=7)	26.75^{a} ± 1.65 (n=8)
First mating	Age	339.0^{a} ± 28.77 (n=6)	287.6^{a} ± 26.63 (n=7)	334.8^{a} ± 28.77 (n=6)
	BWt	30.17^{a} ± 2.38 (n=6)	28.97^{a} ± 2.20 (n=7)	27.87^{a} ± 2.38 (n=6)
First conception	Age	360.5^{a} ± 31.46 (n=6)	320.4^{a} ± 29.13 (n=7)	370.7^{a} ± 29.13 (n=7)
	BWt	30.75^{a} ± 2.70 (n=6)	31.54^{a} ± 2.50 (n=7)	29.29^{a} ± 2.50 (n=7)
First lambing	Age	497.8^{ab} ± 34.29 (n=6)	449.4^{a} ± 29.70 (n=8)	542.3^{b} ± 29.70 (n=8)
	BWt	28.68^{a} ± 2.59 (n=6)	35.11^{a} ± 2.24 (n=8)	30.16^{ab} ± 2.24 (n=8)

Note: UG: Undergrowth only UGC: Undergrowth + Concentrate UGF: Undergrowth + Mixed fodder.
^{a,b}: Means of parameters with different superscripts within a row were significantly different ($p < 0.05$).

Table 5. Effects of supplementation on the age (days) and body weight (kg) of sheep at sexual maturity, conception and lambing

		UG (Control)	Supplementation			Mean difference ± Standard error	
			UGC	UGF	Supplementation (Average)	UGC vs UGF	UG vs Supplementation (Average)
First Oestrus	Age	355.50 (n=8)	207.71 (n=7)	231.75 (n=8)	220.53 (n=15)	−24.04 ± 14.4	−134.97** ± 28.80
	BWt	24.37 (n=8)	16.71 (n=7)	20.50 (n=8)	18.73 (n=15)	−3.73 ± 1.25	−5.64 ± 1.68
First mating	Age	373.57 (n=8)	210.71 (n=7)	243.88 (n=8)	228.40 (n=15)	−33.16* ± 13.69	−141.17** ± 27.59
	BWt	25.46 (n=8)	17.14 (n=7)	20.75 (n=8)	19.07 (n=15)	−3.61 ± 1.26	−6.39 ± 1.58
First conception	Age	385.57 (n=7)	292.00 (n=8)	251.17 (n=6)	274.50 (n=14)	40.83 ± 37.52	−111.07** ± 36.87
	BWt	25.64 (n=7)	21.81 (n=8)	21.17 (n=6)	21.54 (n=14)	0.64 ± 2.98	−4.11 ± 2.33
First kidding	Age	531.43 (n=7)	436.00 (n=8)	395.17 (n=6)	418.50 (n=14)	40.83 ± 38.00	−112.93** ± 37.20
	BWt	33.12 (n=7)	31.16 (n=8)	27.86 (n=6)	29.89 (n=14)	3.30 ± 2.49	−3.23 ± 2.24

Note: UG: Undergrowth only UGC: Undergrowth + Concentrate UGF: Undergrowth + Mixed fodder.
* $p < 0.05$ ** $p < 0.01$.

consuming supplementary feed attained puberty at significantly ($p < 0.05$) lower bodyweight than those which consumed undergrowth only (18.73 kg vs 24.37 kg). Body weight at first conception and first kidding between the two supplemented groups (UGF and UGC) were not significantly different ($p > 0.05$).

First lambing in concentrate supplemented group occured 48 days earlier ($p > 0.05$) and at significantly ($p < 0.05$) higher body weight than those in control group (35.11 kg vs 28.68 kg; table 5). No significant differences ($p > 0.05$) were observed between treatment groups for other parameters investigated although better service per conception was obtained i.e. 4 of the 6 ewes conceived at first mating for the control group.

DISCUSSION

Adequate supply of protein and energy is necessary for optimum growth and reproductive performance in young animals (AFRC, 1993). For integrated livestock-tree crop production system to be sustainable, sufficient feed must be readily available both in the form of undergrowth and supplements. Canopy shade under 5 year old oil palm trees which has suitable growth conditions for about 30 different species of native herbage (Chen and Shamsudin, 1991) is normally dominated by the growth of several species including *Asystasia intrusa*, *Ottochloa sp*, *Mikania sp* and *Pueraria*. It was estimated that the yield of dry matter, organic matter, gross energy and crude protein of native herbage/ha, 1,132 kg, 1,006 kg, 10.4 MJ/kg DM and 158 kg respectively (Sivaraj et al., 1993), are sufficient to support a stocking rate of at least 5.7 small ruminants/ ha per year. Stall fed sheep and goats under cut and carry system consumed about 57.5 and 87.8 gDM/ $kg^{0.75}$ /day respectively (equivalent to 3.8 and 7.0 MJ/day and 60.1 and 105.9 g protein/day respectively; Sivaraj et al., 1993). The actual daily DMI by small ruminants grazing extensively under oil palm plantation in the present studies however is not known but is expected to be greater than those under stall feeding since more palatable parts of herbage are available for selective grazing/browsing. Findings from the present studies demonstrated that native herbage under 5 year old oil palm trees provided sufficient nutrients to meet the growth potentials of extensively grazed kids and lambs since growth was not remarkably enhanced upon supplementation with either mixed fodder or concentrate (table 3).

The potentially available undergrowth as roughage under coconut (640 kgDM/ha; Moog et al., 1993) and mature rubber (767 kg DM/ha; Chong et al., 1992) are less than those available under oil palm (1,132 kg DM/ha; Sivaraj et al., 1993). In cases whereby nutrients value is low supplementation with either concentrate or fodder can stimulate higher growth rate than those in unsupplemented. This is illustrated in the similar degree of improvement with PKC/POME as concentrate for lambs in the present studies with those seen in PKC supplemented Sumatran lambs (from 38 to 50 g/day) reared in rubber plantations (Batubara and Subandriyo, 1990). Supplementation with moderate level (300-900 g fresh weight/animal/day) of *L. leucocephala* and *G. sepium* also resulted in higher growth rate than those in unsupplemented animals (Johnson and Djajanegara, 1989). Present studies however showed that concentrate is a better choice than forage for the purpose of supplementing small ruminants especially sheep. Small growth response to forage supplements seen in the present studies probably arise from larger intake of native herbage from abundant sources of DM under oil palm plantation compared to those available under coconut and mature rubber trees.

Malin sheep and Katjang goats were used in the present studies to evaluate the growth performance of indigenous small ruminants integrated with tree crops plantation. Findings from the present studies however suggest that livestock-oil palm treee integration using Malin sheep and Katjang goats, even with fodder or concentrate supplementation gave limited benefit with respect to final body weight (mature body weight of 25-30 kg at 24 months old). Supplementary feeding to faster growing breeds is expected to enable heavier final body weight to be achieved. Four months old Dorset Horn × Malin lambs were shown to weigh an average of 24.3 kg after six months grazing on *Setaria splendida* pasture with concentrate supplementation (2% body weight; Basery et al., 1992).

The age at the attainment of sexual maturity is related to the body weight (Lees, 1979); the quicker the body weight reaches a certain threshold level of about 40-70% of the adult weight, the earlier would be the onset of puberty, thereby enabling early reproductive life. Poor body condition as a result of undernutrition has been associated with delay or suppression of oestrus and with a high return-to service rate (Gunn and Domey, 1975; 1979). Other studies have shown specific negative effects of low level of feeding on reduced reproduction performance via delay and suppression of oestrus, reduction in the ovulation rate/ incidence of multiple ovulation, and the loss of embryos (Mani et al., 1992). Under intensive production system, goats stall-fed with undergrowth was only able to reach reproductive maturity at 11 months old and first kidding was delayed to 17 months old. This indicates insufficient nutrient level intake when only native herbage was offered. Supplementation with fodder or concentrate ensured higher provision of energy and protein resulting in improvement in reproductive performance (table 4). Studies in grazing Savanna Brown goats showed that cottonseed cake (CSC) and maize supplemented animals reached puberty earlier than goats which grazed only or those which also received lower level of supplements (maize or CSC; Fasanya et al., 1992a). CSC supplemented groups also exhibited postpartum oestrus much earlier than those in other groups did (Fasanya et al., 1992b). Further studies should be carried out to determine the optimum level of fodder and/or concentrate supplement since it is not advisable in the long run to make the animals to reproduce at an age less than 9 months old and at body weight less than 25 kg.

The ovulation and lambing rates have been shown to be dependent on the pre-mating food intake (Gunn and Doney, 1975; Rhind et al., 1985) as well as on the body condition at mating (Gunn and Doney, 1979). Supplementation with fodder or concentrate were anticipated to help meet the requirement of sheep and goats for reproduction activity. In contrast to goats, ewes gave poor response in the improvement of reproductive performance when supplemented with fodder or concentrate (see table 5). This may be partially explained by adequate protein and energy requirement for maintenance and growth that can be obtained from grazing undergrowth. Earlier studies on DMI of sheep stall fed with chopped native herbage (57.5g / $kg^{0.75}$; Sivaraj et al., 1993) indicate that the quality of undergrowth available as feed approaches that of good forage (e.g. sheep DMI of temperate grass 62 g/ $kg^{0.75}$, Thornton and Minson, 1973). Similar observation i.e. small or negligible improvement in overall reproductive performance, were also observed in ewes supplemented with urea and molasses (Mulholland and Coombe, 1979; Depeters et al., 1985).

Present studies demonstrated that sheep and goats can be successfully reared in oil palm plantation of 5 years old which provides sufficient and readily available native herbage to be used as animal feed. The availability of palm-based concentrate, produced from the by-products of oil palm processing plants, as feed supplements help to increase the performance of growing goats and sheep for meat production. The use of cultivated fodder such as Napier grass and *leucaena* may be less attractive in view of additional labour required for planting, fertilizer application and harvesting. Recently, chopped oil palm fronds has been reported to be practical and nutritionally suitable ruminant roughage (Abu Hassan et al., 1995) although substantial initial investment required for the purchase of chopper may camouflage the advantages given by this approach to some farmers.

Besides providing important primary data on the growth and reproductive performance, present studies have explored the characteristics of intensive and semi-intensive livestock rearing in association with oil palm plantation. Limitation/ advantages and the decision for the adoption of either method is dependent on factors including capital investment, labour costs, natural predators, soil quality for the cultivation of improved fodder and efficiency of the plantation's irrigation system to minimize risk of flooding. Intensive livestock farming, which is labour intensive largely due to requirement for cut and carry feeding system, can minimize risks associated with free grazing in the plantation such as stray dogs attack, accidents (e.g. drowning) and infestation with diseases and parasites (present studies, Symoens et al., 1993). For small farmers, whereby livestock rearing is a side income activity, semi-intensive is more commendable than intensive farming because the availability of native herbage as feed is sufficient for small number of animals.

CONCLUSION

Native herbage available under oil palm plantation of 5 years old can support growth and reproduction of sheep and goats. Supplementation with fodder gave limited response whereas growing male sheep and reproducing goats performed best with palm-based concentrate.

ACKNOWLEDGEMENTS

The authors wish to thank International Development Research Center (IDRC) for providing financial support and cooperation given by the Golden Hope Plantation Sdn. Bhd.

REFERENCES

AOAC. 1984. Official Methods of Analysis (14th Ed.) Assoc. of Official Anal. Chemists. Arlington, VA pp. 151-169.

AFRC. 1993. Energy and protein requirements of ruminants. Ed. G. Alderman and B. R. Cottrill CAB International, Wallingford, U.K.

Abdul Karim, K. 1990. Sheep rearing - FELCRA progress and experience. Proc. 3rd. Ann. Conf. Malaysia Society of Animal Production. pp. 256-259.

Abu Hassan, O., M. Ishida and Z. Ahmad Tajuddin. 1995. Oil palm fronds (OPF) technology transfer and acceptance- A sustainable *in-situ* utilization for animal feeding. Proc. 17th Ann. Conf. Malaysian Society of Animal Production. 28-30 May, 1995, Penang.

Barber, W. F. B., A. H. Adamson and J. F. B. Altman. 1984. New methods of feed evaluation. In *Recent Advances in Animal Nutrition* – 1984, Eds. Haresign, W., & Cole, D. J. A., pp. 161-176, Butterworth.

Basery. M., J. B. Liang, A. R. Darus, R. Moh Salleh and K. Musaddin. 1993. Prime lamb production: Carcass composition of Dorset Horn × Malin ram lambs under intensive and semi-intensive systems. Proc. 16th Ann. Conf. Malaysian Society of Animal Production. pp. 138-139.

Batubara, L. P. and Subandriyo. 1992. Research highlights in the integration of small ruminants and rubber in Indonesia. In Advances in Sustainable Small Ruminant-Tree Cropping Integrated Systems. Ed S. Sivaraj, P. Agamuthu and T. K. Mukherjee. Proc. Workshop on Development of Sustainable integrated Small Ruminant-Tree Cropping Production Systems, 30 Nov.-4 Dec. 1992, University of Malaya, Kuala Lumpur.

Chen, C. P. and A. B. Shamsuddin. 1991. Limitation of forage availability on cattle productivity under oil palm. In Utilization of nature forages for animal production in S. E. Asia. FAO Regional Forage Working Group Workshop. Manila, Philippines. 26 Feb.-5 March

Chong, D. T., T. Ismail and A. S. Mohd Salleh. 1992. Performance of sheep on natural and improved pasture in rubber plantation. In Advances in Sustainable Small Ruminant-Tree.

Cropping Integrated Systems. Ed S. Sivaraj, P. Agamuthu and T. K. Mukherjee. Proc. Workshop on Development of Sustainable integrated Small Ruminant-Tree Cropping Production Systems, 30 Nov.-4 Dec. 1992, University of Malaya, Kuala Lumpur. pp 125-128.

Depeters, E. J., M. R. Dally, A. A. Alwash and P. Therkelson-Tucker. 1985. J. Range Management. 38:291-295.

Fasanya, O. O. A., E. C. I. Molokwu, L. O. Eduvie and N. I. Dim. 1992a. Dietary supplementation in the Savanna Brown goat. 1. Effect on attainment of puberty in the doe. Animal Reprod. Sci. 29:157-166.

Fasanya, O. O. A., E. C. I. Molokwu, L. O. Eduvie and N. I. Dim. 1992b. Dietary supplementation in the Savanna Brown goat. 2. Gestation and postpartum activity in primiparous does Animal Reprod. Sci. 29:167-174.

Gopinathan, N. 1991. Cattle rearing under oil palm. The Planter. Incorporated Society of Planters, 67:598-605.

Gunn, R. G. and J. M. Doney. 1975. The interaction of nutrition and body condition at mating on ovulation rate and early embryo mortality in Scottish Blackface ewes. J. Agric. Sci. 85:465-470.

Gunn, R. G. and J. M. Doney. 1979. Fertility in Cheviot ewes I. The effect of body condition at mating on ovulation and early embryo mortality in North and South country Cheviot ewes. Anim. Prod. 29:11-16.

Johnson, W. L. and A. Djajanegara. 1989. A pragmatic approach to improving small ruminant diets in the Indonesian humid tropicss. Journal of Animal Science. 51:3068-3079.

Lees, J. L. 1979. Factors affecting puberty and mating behavior in sheep. In Miller, J., ed Management and Diseases of Sheep. Commonwealth Agric. Bureux, London. pp 124-151.

Mani, A. Y., W. A. C. McKelvey. and E. D. Watson. 1992. The effects of low level of feeding on response to synchronization of estrus, ovulation rate and embryo loss in goats. Theriogenology. 138:1013-1022.

Moog, F. A., L. T. Trung, N. B. Velasco, L. P. Palo and A. Coloico. 1993. Forage and small ruminant production in coconut cultivation. Eds. S. Sivaraj, P. Agamuthu and T. K. Mukherjee. Proc. Workshop on Dev. Sustainable Integrated Small Ruminant-Tree cropping Production Systems 30 Nov.-4 Dec, 1992. pp 76-83.

Mulholland, J. G. and B. Coombe. 1979. Aust. J. Exp. Agric. Anim. Husb. 19:23-31.

Rhind, S. M., I. D. Leslie, R. G. Gunn and J. M. Doney. 1985. Plasma FSH, LH, prolactin and progesterone profiles of Cheviot ewes with different levels of intake before and after mating, and associated effects on reproductive performance. Anim. Reprod. Sci. 8:301-313.

Sivaraj, S., P. Agamuthu and T. Shamsudin. 1993. Botanical composition and nutritive value of native herbage in an oil palm plantation. In Advances in sustainable small ruminant-tree cropping integrated systems. Eds. S. Sivaraj, P. Agamuthu and T. K. Mukherjee. Proc. Workshop on Dev. Sustainable Integrated Small Ruminant-Tree Cropping Production Systems 30 Nov.-4 Dec., 1992. pp 69-75.

Snedecor, G. W. and W. G. Cochran. 1967. Statistical Methods. 6th ed. Ames. Iowa. Iowa State University Press.

Symoens, C., P. Dorny, R. Alimon, A. Jalila, J. Hardouin and J. Vercruysse. 1992. Productivity of goats in smallholdings of Peninsular Malaysia. In Advances in sustainable small ruminant-tree cropping integrated systems. Eds. S. Sivaraj, P. Agamuthu and T.K. Mukherjee. Proc. Workshop on Dev. Sustainable Integrated Small Ruminant-Tree Cropping Production Systems 30 Nov.-4 Dec., 1992. pp 129-136.

Tajuddin, I., L. A. Najib and D. T. Chong. 1990. Status report on RRIM commercial sheep project, Internal Report, Kuala Lumpur, Rubber Research Institute of Malaysia.

Thornton, R. F. and D. J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake and apparent digestibility of legume and grass diets in sheep. Aust. J. Agric. Res. 42:889-898.