

**EVALUATION OF MAJOR PULSE
BYPRODUCTS OF NORTH KARNATAKA
BY *IN VITRO* AND *IN VIVO* METHODS**

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**KARNATAKA VETERINARY, ANIMAL & FISHERIES SCIENCES
UNIVERSITY, BIDAR**

AUGUST – 2005

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*Thesis submitted to the Karnataka Veterinary, Animal & Fisheries Sciences
University, Bidar, in partial fulfillment of the requirement for the*

Degree of

MASTER OF VETERINARY SCIENCE

In

ANIMAL NUTRITION

By

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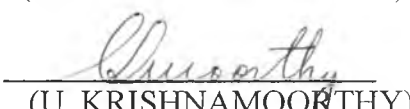
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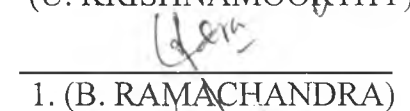
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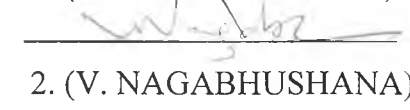

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AFFECTIONATELY DEDICATED

TO

MY BELOVED PARENTS, SISTERS, BROTHERS

AND

TEACHERS

ACKNOWLEDGEMENTS

*It gives me immense pleasure to express my deep sense of gratitude and reverence to the chairman of my advisory committee **Dr. S. Mallikarjunappa**, Professor and Head of Animal Nutrition, Veterinary College, KVAFSU, Bidar for his excellent guidance, constant encouragement and everlasting patience throughout the course of my work.*

*I am equally indebted to **Dr. U. Krishnamoorthy**, Associate Professor of Livestock Production and Management, Veterinary College, Hebbal, Bangalore for having kindly served as co-chairman of my advisory committee and for providing laboratory facility to carry out my research work in his department.*

*I express my esteemed and profound sense of gratitude to **Dr. B. Ramachandra**, Assistant Professor, Department of Animal Nutrition, Veterinary College, Bidar, **Dr. V. Nagabhushana**, Assistant Professor, Department of Animal Nutrition, Veterinary College, Bidar, and **Dr. U. S. Biradar**, Associate Professor, Department of Livestock Production & Management, Veterinary College, Bidar, for having acted as members of my advisory committee and for giving critical comments and valuable suggestions during the course of my work.*

*I avail this opportunity to express my sincere thank to a dynamic, dedicated, kind hearted, cooperative and a person of outstanding caliber **Dr. Suresh S. Honnappagol**, Ph.D. FISSAR, FNAVSC, Registrar, KAVFSU, Bidar for his constant encouragement during my study.*

*I heartily express my special thank to **Dr. D. Gopalakrishna Rao**, Dean, Veterinary College, KVAFSU, Bidar for providing me timely help and facility to complete this work in stipulated time period.*

*My sincere thanks are due to **Dr. V. B. Shetter**, Assistant Professor, Department of Animal Genetics & Breeding, Veterinary College, Bidar, for extending his help in Statistical analysis of the data. I also place on records my sincere thanks to **Dr. G. K. Shivaraman**, Assistant Professor, Department of Animal Genetics & Breeding, Veterinary College, Bidar, **Dr. Mohd. Amanullah**, I/c. Associate Professor, Department of Biochemistry, Veterinary College, Bidar, and **Dr. D. Dilipkumar**, Assistant Professor, Department of Surgery & Radiology*

Veterinary College, Bidar, for lending necessary help and encouragement throughout my work.

*I owe my special thanks to **Dr. Thirumalesh**, Ph.D scholar, Assistant Professor, Dept. of Animal Nutrition, Agricultural College, Bijapur, UAS, Dharwad and **Dr. Kiran D.**, Dept. of LPM Veterinary College, Bangalore for their untiring, inspiration and encouragement during the course of my research.*

*I heartily express my special thanks to **Dr. D. H. Hugar**, Captain, RVC, Meerut, **Dr. M. S. Gananahalli**, Veterinary Officer, Thamba, Dist. Bijapur for their valuable moral support and worm companionship in completing my postgraduate work.*

*I am grateful to my postgraduate colleagues **Dr. Kiran**, **Dr. Kendesh**, **Dr. Sanjeevkumar**, **Dr. Mallinath**, **Dr. Das**, **Dr. Vijay**, **Dr. Satish**, **S. P.**, **Dr. Sharanu**, **Dr. Manju**, **S. S.**, **Dr. Satish B. M.**, **Dr. Mahesh**, **Dr. Hegga**, **Dr. Manju**, **S. M.** and **Dr. Manju G. L.** I would also like to thank my junior postgraduate friends **Dr. Mahantesh**, **Dr. Sanjaya** and undergraduate friends.*

I feel inadequacy of words from the dictionary, to form suitable phrase to pay regard to my parents who had to sacrifice many things in their lives to nurture my ambition. The constant encouragement and love offered by my brothers, sisters and sister-in-laws helped me a lot to achieve this goal.

*I wish to place on records my sincere thanks to **Mr. U. S. Jadhav**, Asst. Librarian, **Mr. Khadri**, **Mr. Aravind** and other library staff for their help in library work.*

*My heartfelt thanks are also due to **Mr. Ramachandra Reddy**, Senior Assistant, Dept. of LPM, Veterinary college, Bangalore, **Mr. Ganganna**, Lab Assistant, **Mr. Breezesh**, **Mrs. Nagamma**, Attender and **Mr. Ramappa**, Attender for their help in the departmental work.*

I finally thank all my well wishers.



Bidar

(S. G. BIRADAR)

August, 2005

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LIST OF ABBREVIATIONS

ADDM	Apparent digestible dry matter
ADF	Acid detergent fibre
ADL	Acid detergent lignin
AOAC	Association of Official Analytical Chemists
BNG	Bengal gram
BLG	Black gram
CF	Crude fibre
CFM	Compound feed mixture
CP	Crude protein
DE	Digestible energy
DM	Dry matter
DMI	Dry matter intake
DOMD	Digestible organic matter in dry matter
EE	Ether extract
GE	Gross energy
GNG	Green gram
MBP	Microbial biomass production
ME	Metabolizable energy
NDF	Neutral detergent fibre
NDS	Neutral detergent solubles
NE	Net energy
NFE	Nitrogen free extractives
OM	Organic matter
PEG	Polyethylene glycol
PF	Partitioning factor
PVP	Polyvinyl pyrrolidone
RDG	Red gram
RIVIGP-24	Rumen <i>in vitro</i> incubation by gas production for 24 h
SEDS	Summation equation by detergent system of feed analysis
SF	Stoichiometric factor
TA	Total ash
TDN	Total digestible nutrients
TDOM	True digestible organic matter
TMR	Total mixed ration

INTRODUCTION

I. INTRODUCTION

Major pulses grown in north eastern transition and north eastern dry zone, the two agro-climatic zones of North Karnataka are bengal gram (*Cicer arietinum*), black gram (*Vigna mungo*), green gram (*Vigna radiata*) and red gram (*Cajanus cajan*) . The byproducts, mainly the straws and chunnies of these pulses are not efficiently used for livestock feeding, particularly for small ruminants. Chunnies of all these pulses and only the straw of red gram are being regularly used for large ruminants feeding. The straws of rest of the pulses are often burnt or ploughed back into the soil.

Small ruminants especially Bidri goats constitute eighteen per cent of total livestock population of Bidar district (6.8 lakhs). Eventhough, large quantities of pulse byproducts are available in this region, feeding of these byproducts to goats is not the practice until now.

However, due to increase in cultivable land and multitude of measures adopted to conserve forests, the traditional grazing and browsing tracts are on the decline. Therefore finding alternatives to sustain the goat population is a necessity because of their widely perceived role as the most valuable animal products. Therefore, finding ways to utilize pulse straws and chunnies for small ruminant production can be useful both from the point of animal production and the environment.

The limited information about the chemical composition and nutritive value of pulse byproducts limits their inclusion in livestock feeding.

Knowledge about the energy values and their effect on rumen fermentation is of greater importance for exploiting the

usefulness of pulse byproducts into valuable products through the small ruminants. The conventional digestion trial to determine TDN or DE values are labour intensive, time consuming, require large quantities of feed and a large number of animals. Hence, attempts have been made to predict energy values with the help of prediction equations using analytical values obtained from chemical analysis. However, such prediction equations differ for different categories of feedstuffs (Minson, 1979) and it is generally believed that the prediction equations developed for temperate feedstuffs may not hold good for tropical feedstuffs (Khan, 1991 and Ranjhan, 1993).

In an attempt to evaluate tropical feedstuffs by Rumen *in vitro* incubation by gas production (RIVIGP) (Menke *et al.*, 1979), it was reported that the energy value of conventional Indian feedstuffs could be predicted with an accuracy of $\pm 15\%$ of the values reported in the literature (Krishnamoorthy *et al.*, 1995). Further studies to compare energy values obtained by RIVIGP and summative equations of detergent system of feed analysis (SEDS) (Goering and Van Soest, 1970 and Van Soest, 1971) revealed similarities in energy values for conventional feedstuffs but not for unconventional feedstuffs (Krishnamoorthy, 1992). These observations led to question that which of these estimates are best related to *in vivo* estimates of DE or ME. Energy estimation by SEDS has the advantage of easy adaptability of detergent system of feed analysis and not having the need to maintain a rumen fistulated animal.

Therefore, considering the enormous production of pulse straws and other byproducts in and around Bidar district and many of the disadvantages associated with the *in vivo* digestibility trials, this study was taken up to assess the potential of RIVIGP

and SEDS to obtain estimates of energy values and compared to those determined by *in vivo* digestion trials.

In addition to energy evaluation, evaluation of pulse byproducts for their efficiency of rumen microbial biomass synthesis (partitioning factor) as an information on rumen fermentation pattern on these unconventional feeds is also attempted.

The objectives of the study are;

1. To estimate the nutritive value by digestion trial.
2. To estimate the energy value of selected feedstuffs by rumen *in vitro* incubation by gas production (RIVIGP).
3. To fractionate feed nutrients using detergent system of feed analysis and to predict energy values by summative equations of detergent system (SEDS) of feed analysis.
4. To compare energy values obtained by RIVIGP and SEDS with energy values obtained by digestion trial.
5. To evaluate the feedstuffs for efficiency of rumen microbial biomass synthesis (partitioning factor).

*REVIEW OF
LITERATURE*

II. REVIEW OF LITERATURE

Evaluation of feeds for available energy is done by digestibility studies, balance studies and production studies. While, digestibility studies measure extent of digestibility, balance studies (balance of energy or matter) measure extent of nutrient retention and production studies measure performance of animals. Therefore, with reference to feed energy evaluation, digestibility studies give estimates of DE, whereas the balance studies and production studies give estimates of ME and NE respectively.

2.1 Expression of digestible energy

The basic principle in digestibility study is to account for the loss of nutrients from the feed as it passes out of digestive tract, which is taken as an index of digestibility. The digestibility is expressed in different ways:

- Dry matter digestibility (DMD)
- Organic matter digestibility (OMD)
- Digestible organic matter in dry matter (DOMD)
- Total digestible nutrients (TDN)
- Digestible energy

DMD, OMD and DOMD can differ in magnitude by up to seven units. Therefore, to make these units comparable different factors and/or equations are recommended for conversion of digestibility parameters to DE (Table 2.1).

Table 2.1 Recommended factors and/or equations to derive digestible energy from digestibility

Digestibility parameters (kg)	DE (MJ)	Reference
DOM	$0.0124 \text{ CP (g/kg DM)} + 17.3$	Minson (1979)
DOM	18.41	Morgan (1974)
DOM	19.00	Van Es (1978)
TDN	18.45	NRC (1989)

2.2 Conversion of DE to ME

Feed evaluation and feeding system introduced in recent years include ME system and NE systems. For storage and dissemination of data about nutritive values in data banks, ME is recommended as more appropriate than NE from the point of exchange of information at the international levels (Pigden *et al.*, 1979).

For basic experimental purposes the direct determination of ME requires measurement of the energy content of faeces, of expired methane and of urine. Estimates of ME can, however be derived from DE, DOM or DDM by the use of conversion factors, which are sufficiently accurate for advisory purposes and for much applied experimentation (Pigden *et al.*, 1979).

ME is reported to be a constant proportion of DE, although the factors used varied among the authors (Minson, 1979). The most widely used factor is 0.81 (Armstrong, 1964b). However,

for which a factor of 0.84 was suggested. For tropical feedstuffs, Graham (1967) proposed a factor of 0.807, whereas Gill *et al.* (1976) reported this to be 0.822. However, the NRC (1989) reported that the ME as a proportion of DE varies linearly from 80 per cent at 50 per cent digestibility to 88 per cent at 80 per cent digestibility and recommended the following equation to derive ME from DE.

$$\text{ME (MJ/kgDM)} = -1.8828 + 1.01 \text{ DE (MJ/kg DM)}$$

2.3 Chemical composition

Bhadane *et al.* (2004) reported, the arhar straw contained 94.0, 11.8 , 2.7 , 48.5 and 8.0 % OM , CP , EE , NFE and lignin, respectively.

The arhar and gram straw contained 6.2 and 8.2 % TA ; 14.2 and 11.2 % CP ; 2.4 and 2.9 % EE ; 47.2 and 52.6 % NDF ; 31.3 and 32.6 % ADF ; 22.8 and 23.9 % cellulose ; 7.9 and 8.2 % lignin respectively (Rekhate *et al.*, 2004).

The CP for bengal gram chunni , red gram chunni , black gram chunni , and green gram chunni were 14.06 , 13.25 ,15.29 and 14.90 %, respectively (Annonymus, 2003).

2.4 Laboratory methods for estimating digestibility

Sen *et al.* (1978) reported that in India, the most commonly used method for estimating digestibility is the conventional digestion trial method and the digestibility is expressed as the total digestible nutrients (TDN). A number of techniques such as RIVIGP, SEDS, *In situ*, RUSITEC and enzymatic methods have been established which give a high degree of correlation with *in vivo* digestibility measurements.

2.4.1 Chemical analysis

Proximate analysis and detergent system of feed analysis are the two important systems of chemical analysis widely used in ruminant feed evaluation. The proximate analysis does not give an estimate of digestibility of feedstuffs. In detergent system of feed analysis (Van Soest, 1967) the components of feed dry matter are classified according to their potential digestibility as illustrated below (Van Soest, 1982).

Fraction	Component	Availability
1. Neutral detergent soluble (NDS)	Lipids, sugar, water soluble pectin, starch, NPN, soluble protein	Almost completely digested
2. Neutral detergent fibre (NDF)		
a. Acid detergent soluble (ADS)	Hemicellulose, fibre bound protein	} Partially digestible according to the degree of lignification
b. Acid detergent fibre (ADF)	Cellulose, lignin	

Further, it was recommended that by making use of these analytical estimates in summative equation, dry matter digestibility (Goering and Van Soest, 1970) and TDN (Van Soest, 1971) can be predicted for roughages. The TDN is converted to DE (MJ) by using the factor 18.45 (NRC, 1989) and DE is converted to ME by a factor of 0.82 (Gill *et al.*, 1976).

Thus, one kg TDN = 15.15 MJ of ME. For compound feed mixtures (CFM), Giger-Reverdin *et al.* (1994) predicted the equation of ME as illustrated below.

Roughages

$$\begin{aligned} \text{TDDM} &= (\text{NDS} \times 0.98) + [\text{NDF} \times ((147.3 - (78.9 \log_{10} ((L + \text{BS}) \times 100 / \text{ADF}))) / 100)] - (\text{SS} \times 1.4) \\ \text{ADDM} &= \text{TDDM} - (365.7 - 0.275 \text{TDDM}) \\ \text{TDN} &= \text{ADDM} - (\text{TA} - \text{TS}) + 1.25 \text{EE} + 19 \end{aligned}$$

CFM

$$\text{ME} = 13.38 + 0.0118 \text{EE} - 0.00547 \text{NDF} + 0.0065 \text{ADF} - 0.0378 \text{ADL} + 0.00291 \text{CP}$$

Where, ME is metabolizable energy (MJ/kg DM); TDDM = True digestible dry matter; ADDM = Apparent digestible dry matter; TDN = Total digestible nutrients; EE = Ether extract; NDS = Neutral detergent solubles; NDF = Neutral detergent fibre; BS = Biogenic silica; SS = Sand silica; TS = Total silica; TA = Total ash; CP = Crude protein; ADL = Acid detergent lignin. All constituents are expressed as g/kg DM.

Conrad *et al.* (1984) in an attempt to improve the precision of energy estimation by summative equation suggested a different set of equations by incorporating the concept of the ratio of NDF surface to lignin surface area influencing the extent of digestibility of cell wall. The equations are,

$$\text{TDNm} = 0.93 P (1+F-A-P-\text{NDF}) + 0.82(\text{NDF}-L) \times (1-L^{2/3}/\text{NDF}^{2/3})$$

Where, TDNm = TDN at maintenance

The TDN value of a given feedstuff varies with the level of intake, which is said to be due to change in the output of metabolic secretions and the rate of digestion of NDF fractions. The decline in digestibility is said to be about four units of TDN per unit of intake above maintenance for mixed rations (NRC, 1989).

TDN at three times maintenance, (TDN_{3m})

$$\text{TDN}_{3m} = 0.93 P + 0.92 (1+F-A-P-\text{NDF}) + 0.75(\text{NDF}-L) \times (1-L^{2/3}/\text{NDF}^{2/3})$$

Where, TDN = 4400 Kcal/kg; P = per cent protein; F = per cent lipid; A = per cent ash; L = per cent lignin

Girard and Dupuis (1988) attempted to combine the effect of chemical composition, digestion and passage kinetics and intake on digestibility into one model to evaluate forages for the DDM.

$$\text{DDM}_m = 0.98 \text{ NDS} + 0.95 \text{ PDF} - 14.2 \text{ (} r^2=0.99, P<0.01 \text{)}$$

$$\text{DDM}_{4m} = 0.91 \text{ NDS} + 0.79 \text{ PDF} - 14.2 \text{ (} r^2=0.99, P<0.01 \text{)}$$

Where, DDM_m = digestible dry matter at maintenance;
 DDM_{4m} = digestible dry matter at four times maintenance level;
 NDS = Neutral detergent solubles; PDF= potentially digestible fibre per cent

$$\text{PDF} = (\text{NDF} - \text{L}) (1 - \text{Q} (\text{L} / \text{NDF})^{2/3})$$

Where NDF = neutral detergent fibre; L=Lignin; Q= structural co-efficient, where Q values are assumed constants for feeds belonging to a cluster group, values of Q vary from 0.05 (grains) to 1.85 (corn silage).

The detergent system of feed analysis to be sufficiently accurate requires considerable quantum of chemical analysis that may not be economical and practical at time. Therefore to make the system easier and economically applicable attempts were made to develop regression equations to predict energy content using only some analytical estimates (Minson, 1982), although, the prediction equations based on multiple components are better, specially when applied to varieties of feedstuffs. Some of these equations are presented in Table 2.2.

2.4.2 *In vitro* methods

In vitro methods have the advantage not only of being less expensive and less time consuming, but they allow to maintain experimental conditions more precisely than do *in vivo* trials. The *in vitro* methods are based on quantification of substrate degraded or microbial protein produced using internal or external markers and of gas or short chain fatty acids (SCFA) produced in

Table 2.2 Equations for predicting organic matter digestibility and metabolizable energy from chemical analysis

Feedstuffs	r	RSD
Gieger Reverdin <i>et al.</i> , 1994 Compounded feeds:		
a. $DOM = 81.2 - 0.0300 \text{ CF} + 0.0159 \text{ CP}$	0.42	4.26
b. $DOM = 88.3 - 0.0258 \text{ NDF}$	0.54	3.92
c. $DOM = 85.1 - 0.0237 \text{ ADFd}$	0.35	4.37
d. $DOM = 87.9 - 0.258 \text{ ADLd}$	0.81	2.77
e. $DOM = 87.9 - 0.202 \text{ L}$	0.81	2.77
f. $DOM = 91.8 - 0.0333 \text{ NDF} + 0.0417 \text{ ADFS} - 0.247 \text{ ADLS} - 0.0396 \text{ EE}$	0.87	2.39
a. $ME = 0.710 \text{ GE} - 0.071 \text{ ADLd}$	0.82	0.51
b. $ME = 12.62 + 0.159 \text{ EE} - 0.0398 \text{ ADLd} + 0.0364 \text{ CP}$	0.82	0.51
c. $ME = 0.709 \text{ GE} - 0.0343 \text{ L}$	0.81	0.52
d. $ME = 12.71 + 0.016 \text{ EE} - 0.0311 \text{ L} + 0.0032 \text{ CP}$	0.82	0.52
e. $ME = 5.49 + 0.456 \text{ GE} - 0.00583 \text{ NDF} + 0.0072 \text{ ADFS} - 0.0422 \text{ ADLS}$	0.87	0.45
f. $ME = 13.38 + 0.0119 \text{ EE} - 0.00547 \text{ NDF} + 0.0065 \text{ ADFS} - 0.0378 \text{ ADLS} + 0.0021 \text{ CP}$	0.86	0.46
Morgan, 1974; MAFF, 1975 (cited by Minson, 1979) 47 grass hays		
$ME = 17.07 - 0.0222 \text{ MADF}$	-	±0.18
$ME = 13.51 - 0.01548 \text{ ADF} + 0.0138 \text{ CP}$	-	±0.17
$ME = 0.84 - 0.0138 \text{ IVD}$	-	±0.15
$ME = 0.46 - 0.0126 \text{ IVD} + 0.0126 \text{ CP}$	-	±0.13
(Armstrong, 1964b) 16 grasses		
$ME = 7.57 + 0.027 \text{ CP}$	-	±0.158
$ME = 19.41 - 0.035 \text{ C}$	-	±0.137
$ME = 14.73 - 0.062 \text{ L}$	-	±0.127
$ME = 17.57 - 0.024 \text{ CF}$	-	±0.109
$ME = 16.99 - 0.026 \text{ H}$	-	±0.103

All constituents are expressed as g/kg OM, ME = MJ/kg OM. ADLd= Acid detergent lignin by direct method; ADFS = Acid detergent fibre sequential; ADLS = Acid detergent lignin sequential; CF= crude fibre; CP= crude protein; DOM= Digestible organic matter; EE= ether extract; IVD= organic matter digestibility *in vitro*; L=Lignin, NDF= neutral detergent fibre; C= cellulose; H= Hemicellulose; ADFd= Acid detergent fibre by direct method;

an *in vitro* rumen fermentation system (Menke *et al.*, 1979). This method does not require sophisticated equipment or the use of a large number of animals (one or preferably two fistulated animals are required) and helps selection of feeds or feed constituents based not only on the dry matter digestibility, but also on the efficiency of microbial protein synthesis (Makkar, 2000).

2.4.2.1 Rumen inoculum

“Two stage *in vitro* technique” (Tilley and Terry, 1963) is the most widely used *in vitro* method for the evaluation of ruminant feedstuffs. Using this technique a good correlation ranging from 0.82 to 0.95 between *in vitro* and *in vivo* digestibility were reported by many workers (Marten and Barnes, 1979)

Goering and Van Soest (1970) proposed the use of neutral detergent solution as a substitute for acid pepsin in the second stage of the Tilley and Terry (1963) method.

Van Soest and Robertson (1979) compared methods of Tilley and Terry (1963) and Goering and Van Soest (1970) and concluded that the latter provides a better estimate of digestibility. Both techniques have the disadvantages of lack of satisfactory reproducibility because of the day to day variation in quality of rumen inoculum. Apart from this, the difference between observed and solubilized dry matter is regarded as an estimate of digestibility. However all that is solubilized need not necessarily be digestible and absorbable. Therefore, the technique which measures solubilized dry matter may over estimate digestibility.

In an attempt to improve the method of evaluating feedstuff for digestibility, Menke *et al.* (1979) developed a technique of measuring gaseous end product as an index of digestibility. A

check on day to day variation in quality of rumen inoculum was kept by incubating standard reference sample (hay meal and maize starch) along with feedstuffs to be evaluated. Gas production in 24 h from 200 mg feed dry matter was found to have a high correlation with digestibility of organic matter *in vivo*. Using data from proximate analysis and gas production technique predicted equations were developed to estimate energy content of feedstuffs. Having found this technique quite promising a wide range of feedstuffs subjected to *in vivo* digestion trial were tested by this technique and appropriate equations were developed to predict energy content of different categories of feedstuffs (Menke and Steingass, 1988). Some of these equations are presented in Table 2.3.

Inclusion of crude protein, crude fat and N-free extracts in the evaluation makes the estimate more accurate than the “Two stage *in vitro* technique” (Tilley and Terry, 1963), cellulase method and chemical analysis as reported by Menke and Steingass (1988).

Khazaal *et al.* (1993) reported that the gas production technique can be used as good as the nylon bag technique to predict feed intake and apparent digestibility as long as the antinutritional factors do not interfere in gas production. Because of the simplicity of the technique and its superiority over other *in vitro* methods it was suggested that gas production technique has the good potential for routine feed evaluation.

Krishnamoorthy *et al.* (1995a) recorded the ME (MJ/kg DM) for grains, byproduct feeds, cultivated fodders and nonlegume straw by RIVIGP were 11.8 to 13.9, 6.0 to 13.7, 7.1 to 9.4 and 5.7 to 7.7, respectively.

Table 2.3 Equations for estimating metabolizable energy (MJ/kg DM) of feedstuffs (Menke and Steingass, 1988)

Equations	R ² %	Sy.x%
<u>Compounded feeds (N=150)</u>		
ME=2.04+0.1448GP+0.0036CP+0.024EE	82	2.49
ME=- 2.69+0.0868GP+0.0132CP+0.0331EE+0.0105NFE	90	1.85
<u>Compounded feeds and components (N=200)</u>		
ME=15.14+0.0130EE- 0.0195 CF-0.0163TA	67	6.72
ME=0.04+0.1639GP+0.079CP+0.0239EE	92	3.34
ME=-2.30+0.1335GP+0.0121CP+0.0281EE+.0055 NFE	95	2.75
ME=1.06+0.157GP+0.0084CP+0.0220EE-0.0081TA	94	2.92
<u>Dry roughages (N=100)</u>		
ME=2.43+0.1206GP+0.0069CP+0.0187EE	95	3.91
ME=1.47+0.1152GP+0.0084CP+0.0164EE+0.0024NFE	95	3.81
<u>Roughage feeds (N=100)</u>		
ME=14.07+0.0206EE-0.0147CF-0.0114TA	77	8.32
ME=2.0+0.1298GP+0.045CP+0.0303EE	93	4.62
ME=0.98+0.1049GP+0.0088CP+0.0268EE+0.0038NFE	94	4.20
<u>All feed stuffs(N=400)</u>		
ME=14.27+0.0143EE-0.0148CF-0.0121TA	81	7.73
ME=1.24+0.1457GP+0.0070CP+0.0224EE	94	4.20
ME=0.46+0.1181GP+0.0088CP+0.0247EE+.0036	95	3.78
ME=1.68+0.1418GP+0.0073CP+0.0217EE	95	4.10
-0.0028TA		
ME=1.39+0.1457GP+0.0075CP+3.14CP+0.0119EE+0.00008	95	4.12
311EE		
ME=1.92+0.1143GP*+0.0003233GP ² +0.0072CP+0.0230EE	94	4.21
ME=0.72+0.1559GP*+0.0068CP+0.0249EE	95	3.93

GP* = 9.9 + 0.77 GP dry roughage

GP = Gas production (ml/200 mg DM)

CF = Crude fibre

CP = Crude protein

EE = Ether extract

NFE = Nitrogen free extractives

TA = Total ash

(All constituents expressed as g/kg DM)

Ramachandra and Krishnamoorthy (2000) studied the effect of urea treatment of the chopped finger millet straw (FMS) for ME content. The ME (MJ/kg DM) content was significantly higher in untreated (7.91 ± 0.08) compared with FMS treated with urea (6.97 ± 0.14).

Kiran (2004) observed mean ME (MJ/kg DM) of 10.15, 12.60, 5.14 and 8.04 for protein supplements, energy supplements, other byproducts and roughage by RIVIGP respectively.

Nagabhushana *et al.* (2005) observed ME values (MJ/kg DM) of 5.52, 5.92 and 5.67 in wheat straw supplemented with cobaltous chloride, cobaltous sulphate and cobalt acetate, respectively, by Hohenheim gas test.

ME (MJ/kg DM) for finger millet straw (FMS), sugar cane bagasse (SCB), tamarind seed hulls (TSH) and bengal gram husk (BGH) by RIVIGP were 6.50, 5.80, 4.60 and 9.60, respectively, as observed by Krishnamoorthy *et al.* (2005).

Addition of tannin complexing agents such as polyvinyl pyrrolidone (PVP), polyvinyl polypyrrolidone (PVPP) and polyethylene glycol (PEG) to the *in vitro* gas system resulted in higher gas production from tannin rich feeds (increase varied from 0-135%) (Makkar *et al.*, 1995). The PEG was the most effective tannin complexing agent followed by PVP and PVPP. Addition of tannin binders, known to inactivate tannins, for use in rumen incubation studies are recommended to assess the potential interference of such tannins in nutrient availability from tannin containing feedstuffs (Makkar *et al.*, 1995).

Sreerangaraju *et al.* (2000) observed that the values for gas volume (ml/200 mg DM) by RIVIGP-24 (without and with PEG-6000) were

45.0±0.39 and 61.3±0.63, 13.7±0.18 and 13.6±0.20, and 27.3±0.45 and 27.3±0.40 for bengal gram husk, deoiled rice bran and finger millet straw, respectively.

Raghavendra Bhatta (1998) observed improvement in *in vitro* gas production of various feedstuffs with PEG were:

Substrate	24 hours gas production (ml/200 mg DM)	
	Without PEG	With PEG
Feedstuffs		
Gram husk	29.0	49.0
Salseed meal	42.7	49.2
Acacia pods	43.0	54.0
Spent tea waste	47.0	47.5
Samai husk	7.5	7.5
Maize grain	60.0	62.0
Molasses	58.0	58.0
Ragi straw	24.0	25.0
Wheat straw	24.5	24.0
Tree leaves		
Moringa leaves	43.5	43.5
Calliandra leaves	37.0	43.0
Subabul leaves	34.5	40.0
Sesbania leaves	44.2	44.3
Glirisidia leaves	39.0	41.0

2.5 Comparison of energy values obtained by Digestion trial, RIVIGP and SEDS.

Nataraja *et al.* (1998) obtained ME (MJ/kg DM) for six total diets comprised either finger millet straw (FMS) or chopped paddy hay (CPH) and compound feed mixture (CFM) at maintenance level fed to cows by digestion trial were 11.0, 9.2, 10.5, 10.1, 8.8

and 7.6, respectively. The corresponding estimates obtained from RIVIGP and SEDS were 10.2 and 10.2, 9.1 and 9.2, 9.5 and 10.7, 9.4 and 10.5, 8.3 and 7.1 and 6.6 and 6.9, respectively.

Krishnamoorthy *et al.* (1999) obtained ME (MJ/kg DM) for nine total diets comprised finger millet straw (FMS) and compound feed mixture (CFM) at maintenance level fed to cows from digestion trial and SEDS were 8.0 and 10.3, 11.0 and 10.2, 9.2 and 9.2, 10.5 and 10.7, 10.1 and 10.5, 7.5 and 8.4, 8.0 and 8.0, 9.9 and 9.2 and 8.9 and 8.9, respectively.

Kamalamma (1993) observed ME (MJ/kg DM) values of 10.5 ± 0.08 and 7.09 ± 0.29 and 8.95 and 7.98 for concentrate mixture and ragi straw by RIVIGP and SEDS, respectively.

Sreerangaraju (1998) observed ME (MJ/kg DM) of 8.60 and 8.10, 6.50 and 5.50 for bengal gram husk and finger millet straw by RIVIGP and SEDS, respectively.

2.6a *In vitro* gas production with concomitant microbial biomass measurement

Blummel (1994) reported that an inverse relationship exists between microbial biomass and the volume of gas produced per 100 mg TDOM. On an average $42.0 \text{ mg } (\pm 6.9)$ of cells and $24.4 \text{ ml } (\pm 2.5)$ of gas produced from 100 mg TDOM. There was a significant ($r=0.64$, $p<0.01$, $\text{sy.x} = 5.22$) negative correlation between substrate converted to microbial biomass and gas produced from a given unit of TDOM. Substrate incorporation into biomass ranged from 32.7 to 55.7 mg per 100 mg true fermented matter and was lowest with the nitrogen free substrate (cellulose).

Blummel *et al.* (1997a) have demonstrated how a combination of *in vitro* gas production measurement with a

concomitant quantification of truly degraded organic matter provides important information about partitioning of fermentation products (Fig. 2.1). The *in vitro* microbial biomass production can be calculated as,

$$\text{Microbial biomass} = \text{TDOM} - (\text{gas volume} \times \text{SF})$$

For roughage, the SF is 2.20 and for concentrates it is 2.34.

Another study by Blummel *et al.* (1998) examined the microbial growth kinetics for hays after 8, 12, 18 and 24h of incubation by the modified Hohenheim gas test and found maximum microbial mass recovery to approximately coincide with the incubation time at which half of the asymptotic gas volume was produced (Halftime, $t_{1/2}$).

In the 15 straws microbial biomass production estimated at $t_{1/2}$ (time at which half of gas is produced) by purine bases and microbial nitrogen analysis were reasonably well related to microbial mass estimated at $t_{1/2}$ as

MBP=TDOM - (gas volume X S.F), the R^2 for relationship being 0.65.

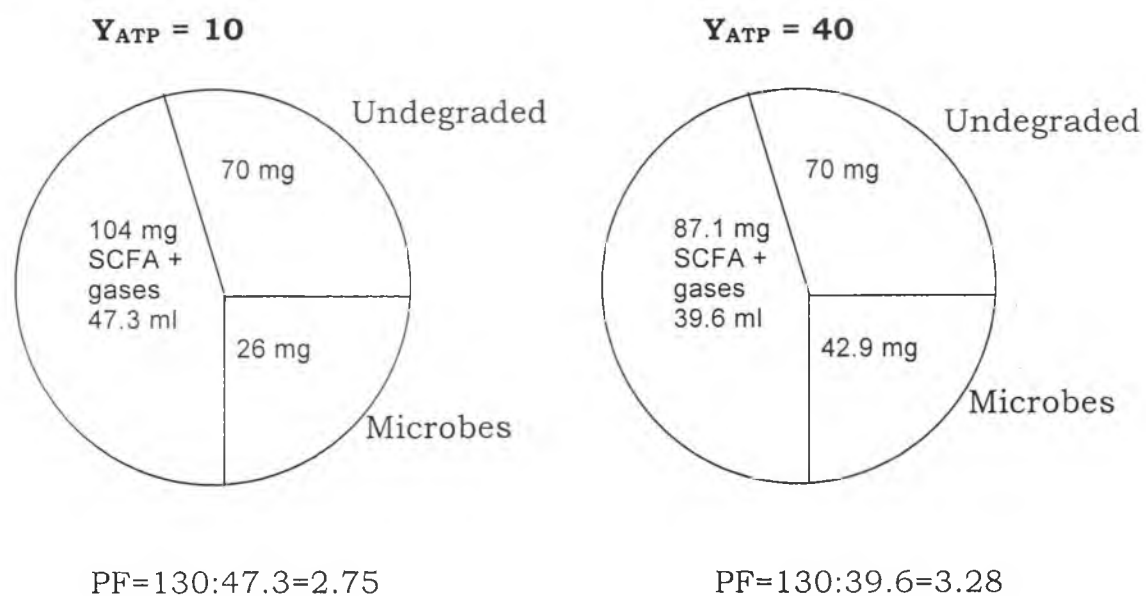
In contrast, gas volume measurement alone amounted for 39 per cent of variation in MBP (Blummel *et al.*, 1999).

The parameters in the equation; MBP=TDOM- (gas volume x SF) also allows to calculate partitioning factor (PF) for the feedstuffs.

2.6b Partitioning factor

Blummel *et al.* (1997b) found that selecting roughage by *in vitro* gas production may well be a selection against maximum microbial yield and a combination of *in vitro* gas volume

Fig. 2.1 Stoichiometrical relationship between Y_{ATP} yield, gas production and Partitioning factor (PF)



Modified Blummel *et al.* (1997a)

measurements with a complementary determination of substrate truly degraded is proposed to calculate PF reflecting the variations of short chain fatty acid (SCFA) production per unit substrate degraded. PF is defined as ratio of substrate truly degraded (mg) to the gas produced (ml) by it and it was regarded as the measure of the efficiency of microbial biomass synthesis.

Kiran (2004) observed mean PF (mg/ml) of 5.51 ± 1.07 , 3.91 ± 0.39 , 3.57 ± 0.65 and 3.65 ± 0.86 for protein supplements, energy supplements, other byproducts and roughage, respectively.

PF (mg/ml) for finger millet straw (FMS) sugarcane bagasses (SCB), tamarind seed hulls (TSH) and bengal gram husk (BGH) were 3.05, 2.79, 3.94 and 2.52, respectively (Krishnamoorthy *et al.*, 2005).

2.7 Critical remarks

The various methods to estimate energy value of feeds reviewed in this chapter were tried on temperate and tropical forages and feeds. Application of these methods and regression equation to evaluate unconventional feeds like pulse byproducts i.e., straws and chunnies containing soluble polyphenolic compounds like tannin has not been studied in detail.

Nataraja *et al.* (1998) evaluated some tropical feedstuffs for ME using RIVIGP, SEDS and digestion trial, but they were not having any soluble polyphenolic i.e., tannin compound. Tannins interfere with the gas production in RIVIGP, this suggested that carbohydrate could be the main substrate bound by tannin (Sreerangaraju *et al.*, 2000). RIVIGP is being used in some laboratories and the report indicate that this technique is as good as nylon bag technique to predict feed intake and apparent

digestibility and is simple, rapid, economic and considerably superior to chemical analysis and other *in vitro* techniques (Khazaal *et al.*, 1993). On the other hand, detergent system of feed analysis is widely used in many laboratories in India and adaptability of this technique in industrial laboratories is not too difficult.

Partitioning factor (PF) was regarded as a measure of efficiency of the microbial biomass synthesis (Blummel and Becker, 1997) and large number of feed samples can be evaluated for microbial biomass synthesis potential, which would add a new dimension to feed quality assessment. The PF of chunnies and straws selected for the study have not been studied. Therefore, this study was taken up to assess the potential of detergent system of feed analysis and RIVIGP to measure energy value and PF of straws and chunnies.

*MATERIALS
AND
METHODS*

III. MATERIALS AND METHODS

3.1 Location

The present study included *in vivo* feeding experiments, chemical analysis and *in vitro* studies. The feeding cum digestion trial was conducted at the Goat unit, Department of Livestock Production and Management, Veterinary college, KVAFSU, Bidar and the laboratory work at Department of Animal Nutrition, Veterinary College, KVAFSU, Bidar and Department of Livestock Production and Management, KVAFSU, Veterinary College, Bangalore.

3.2 Procurement of pulse byproducts

The chunnies and straws of BNG, BLG, GNG and RDG pulses used for feeding trial and laboratory studies were procured from Dal Mills and local farmers of Bidar district, respectively, as and when available and stored in feed room.

3.3 Total mixed ration (TMR) formulation

The TMR included straws and chunnies of BNG, BLG, GNG and RDG. The TMR contained 48% chunni and 50% straw, 1% mineral mixture, 0.5% salt and 0.5% lime powder. The ingredient compositions of four TMR are presented in Table 3.1.

3.4. Chemical Analysis

The samples of chunnies, straws and TMR were analysed for the proximate constituents (AOAC, 1995) except for CF, which was determined according to Bureau of Indian Standard (BIS) modified AOAC procedure (ISI, 1965) and acid detergent fibre (ADF), acid detergent lignin (ADL), biogenic silica (BS), sand silica (SS) and total silica (TS) according to Goering and Van Soest

Table 3.1 Ingredient composition (per cent as is) of total mixed rations used in different groups

Ingredient	TMR-BNG	TMR-BLG	TMR-GNG	TMR-RDG
<u>Chunnies</u>				
Bengal gram	48	-	-	-
Black gram	-	48	-	-
Green gram	-	-	48	-
Red gram	-	-	-	48
<u>Straws</u>				
Bengal gram	50	-	-	-
Black gram	-	50	-	-
Green gram	-	-	50	-
Red gram	-	-	-	50
Mineral mixture*	1	1	1	1
Common salt	0.5	0.5	0.5	0.5
Lime powder	0.5	0.5	0.5	0.5

*Commercial mineral mixture

Calcium-24%, phosphorus-9%, manganese-1.2%, iron-0.6%, copper-0.1%, cobalt-0.02%, sodium chloride-30%, iodine-0.1% and fluorine not exceeding 0.03%

(1970). The neutral detergent fibre (NDF) was estimated by the method of Robertson and Van Soest (1977) using amylase enzyme.

Using chemical composition data obtained from the detergent system of feed analysis, true digestible dry matter (TDDM) and apparent digestible dry matter (ADDM) were calculated by summative equations (Goering and Vansoest, 1970).

Roughages (Straws)

$$\text{TDDM} = (\text{NDS} \times 0.98) + [\text{NDF} \times ((147.3 - (78.9 \log_{10} ((L + \text{BS}) \times 100 / \text{ADF}))) / 100)] - (\text{SS} \times 1.4) \dots \text{i}$$

$$\text{ADDM} = \text{TDDM} - (365.7 - 0.275 \text{TDDM}) \dots \text{ii}$$

TDN was calculated from the equation of Van Soest (1971)

$$\text{TDN} = \text{ADDM} - (\text{TA} - \text{TS}) + 1.25 \text{EE} + 19 \dots \text{iii}$$

CFM (Chunnies): (Giger-Reverdin *et al.*, 1994)

$$\text{ME} = 13.38 + 0.0118 \text{EE} - 0.00547 \text{NDF} + 0.0065 \text{ADF} - 0.0378 \text{ADL} + 0.00291 \text{CP}$$

The TDN was converted to digestible energy (DE) by the factor: one kg TDN = 18.45 MJ DE (NRC, 1989), DE was converted to ME by the factor ME = 0.82DE (Gill *et al.*, 1976).

ME of the TMR was calculated by using both roughage and CFM formulae as per their proportion in the TMR.

3.5 Rumen fermentation characteristics

The samples of straws, chunnies and TMR were subjected to *in vitro* rumen incubation studies according to Menke *et al.* (1979) and Menke and Steingass (1988).

3.5.1 Donor cow and collection of rumen fluid

A lactating dairy cow weighing about 360 kg, producing 3.5 to 4.0 kg milk per day fitted with flexible rumen canula of large diameter (*Bar Diamond Inc.*, USA) served as the donor of the rumen inoculum. She was fed with a basal diet consisting of finger millet straw and compound feed mixture (CFM). The rumen fluid was collected between 9.00 and 9.30 am.

Composition of CFM offered to donor cow:

Ingredients	% Composition
Maize	75.5
GNC	10.0
Wheat bran	10.0
Salt	1.0
Urea	1.0
Mineral mixture	2.0
Sodium sulfate	0.5
Vit. A	0.034

3.5.2 Effect of PEG on gas production and Metabolizable energy content.

The feed samples were subjected to *in vitro* rumen incubation by incubating 200±05 mg air equilibrated feed samples with 30 ml buffered rumen fluid in 100 ml calibrated glass syringes. The samples were incubated in triplicates without and with PEG 6000 at a ratio of 1:2. Each time, the difference in the composition and activity of rumen fluid was controlled by parallel incubation of reference standard feedstuffs as suggested by Menke *et al.* (1979). Using chemical composition and net gas production (corrected for blank and reference standards) at 24 h

incubation, ME was calculated using the following equations proposed by Menke and Steingass (1988)

Roughages (Straws):

$$\text{ME} = 2.20 + 0.1357 \text{ GP} + 0.0057 \text{ CP} + 0.0002859 \text{ EE}^2$$

CFM (Chunnies):

$$\text{ME} = 1.06 + 0.157 \text{ GP} + 0.0084 \text{ CP} + 0.022 \text{ EE} - 0.0081 \text{ TA}$$

ME of the TMR was calculated by using both formulae as per their proportion in the TMR.

The incubation was repeated and a total of six replicates were used for calculating ME.

The interference of tannins in rumen fermentation and the recovery of tannin-bound substrate in faeces were assessed by using PEG in rumen incubations (Makkar *et al.*, 1995). The magnitude of increase in gas production upon PEG addition to the substrate at a ratio of 2:1 was taken as an index of tannins interference in rumen fermentation.

3.5.3 Kinetics of gas production

Air equilibrated feed samples (200±5 mg) were incubated in 100 ml calibrated glass syringes in triplicates, basically by the procedure of Menke *et al.* (1979) and Menke and Steingass (1988) with 30 ml buffered rumen fluid with three blank incubations. The rate and extent of gas production of feed samples used in this study were obtained during the 96 h incubation with gas volume recordings after 2, 4, 6, 8, 10, 12, 16, 20, 24, 30, 36, 48, 60, 72, 84 and 96 h of incubation. Rate and extent of gas production were calculated by non-linear regression using an exponential

model, $Y = D (1 - e^{-k(t-l)})$, where, Y is gas volume at time t, D potential gas production, k is rate at which D is produced per hour and l is the discrete lag time(Orskov and McDonald, 1979) . The half life ($t_{1/2}$) of gas production in the model $Y = D (1 - e^{-k(t-l)})$ was the time when half of the D was produced and calculated as $t_{1/2} = \ln 2 / K$ (Blummel, 2000).

The incubation was repeated and a total of 6 replicates were used for calculating kinetic parameters.

3.5.4 Partitioning factor (Efficiency of rumen microbial biomass synthesis)

The feed samples were incubated in 100 ml calibrated glass syringes commonly used for Hohenheim gas production test (Menke *et al.*, 1979; Menke and Steingass, 1988). Three replicates of 500 ± 5 mg of air equilibrated feed samples were weighed into the syringes with 40 ml buffered rumen fluid.

In vitro ADDM was determined after terminating the incubation at $t_{1/2}$ of the individual feed samples. The syringes were kept in ice water for 15 to 30 min for arresting microbial fermentation. The entire content of syringe was transferred into centrifuge tubes and centrifuged at $20,000 \times g$ for 30 min at 4°C . Supernatant was carefully removed with a Pasteur pipette. The syringes were washed thrice with distilled water and shaken each time to remove residual particles after which the contents were added to the respective centrifuge tube. After complete rinsing of the syringes, centrifugation was once again repeated and the supernatant was siphoned off and discarded. The residues were freeze dried for six hour and followed 24 h drying in the forced-air oven at 60°C .

In vitro ADDM was calculated as

$$t^{1/2} \text{ ADDM} = \text{mg(DM) of substrate incubated} - [\text{mg(DM) residue} - \text{mg (DM) blank}]$$

In vitro TDOM was determined after recording the gas production and terminating the incubation at half time ($t^{1/2}$) of gas production. The procedure of Goering and Van Soest (1970) for determination of true digestibility was then applied by refluxing the incubated residue for one hour and recovering the undigested matter on filter crucibles of porosity 2.

PF values were calculated as the ratio of mg of TDOM to the ml of gas produced at $t^{1/2}$. Microbial biomass production was calculated as $[t^{1/2} \text{ TDOM} - (\text{Gas volume at } t^{1/2} \times \text{stoichiometric factor})]$ where in SF is 2.2 for roughages and 2.34 for concentrates.

3.6 Feeding trial

3.6.1 Particulars of Animals

A total of sixteen adult Bidri goats were randomly distributed in to four groups based on their body weight. Each group consisted of four goats. The description of goats used in different groups and the type of TMR used are presented in Table 3.2. Before starting feeding trial, the goats were dewormed using fenbendazole.

3.6.2 Housing and feeding of goats

All the goats were housed individually in a galvanized cages (size – $3^l \times 4^l \times 4^l$) throughout the experimental period under well protected shed and were provided with similar managerial practices. Each cage was provided with feeding and watering troughs.

Table 3.2 Particulars of Bidri goats used in different groups

Goat no	Body wt	Diet
Group I		
21	29.42	TMR –I
19	32.54	
20	35.42	
15	27.14	
Group II		
6	27.98	TMR –II
2	29.30	
10	32.10	
1	25.50	
Group III		
9	27.54	TMR- III
7	28.36	
5	23.05	
8	23.30	
Group IV		
12	31.65	TMR – IV
13	21.37	
14	29.82	
16	34.36	

The goats were offered *ad-libitum* TMR in the morning at 9.00 am and in the evening around 4.00 pm. The leftover feeds were weighed on the next day morning to estimate DMI. All the goats were provided with wholesome drinking water.

3.6.3 Weighing

The goats were weighed on a platform electronic balance once a week in the morning before having access to feed and water.

3.6.4 Sampling of TMR

The representative samples of TMR offered and residue left over were collected twice a week to estimate the dry matter intake.

3.7 Digestion trial

3.7.1 Collection and sampling

The goats were adapted to the TMR for a period of three weeks. The digestion trials lasted for five days, during which daily intake of TMR and out put of dung was recorded. Samples of TMR offered and residuals were collected everyday for dry matter estimation.

The dung from each goat was collected manually as and when voided in the cage and stored in polythene bags. The quantity of dung voided was weighed every day at 9.00 am. The total dung voided from each goat was mixed thoroughly and sample was collected for analysis. Sampling for dry matter and nitrogen estimation were done separately. For dry matter estimation 1/100th of the dung voided was weighed and dried at

100°C for overnight. Dried dung samples obtained for five days from each animal were pooled, ground through one mm sieve and preserved for analysis of proximate constituents except for nitrogen. For nitrogen estimation 1/200th of the daily dung voided was transferred in a previously weighed wide mouth bottle (200ml) daily and preserved with 40% (w/v) sulfuric acid.

The samples of dung were analyzed for proximate constituents (AOAC, 1995) except for crude fibre, which was determined according to Bureau of Indian Standards (BIS) modified AOAC procedure (ISI, 1965).

The digestibility of nutrients was calculated as the difference in the nutrient intake and nutrient outgo as a proportion of the intake.

$$\text{Apparent digestion Coefficient (ADC)} = \frac{\text{Quantity of nutrient intake (g/d)} - \text{Quantity of nutrient outgo in dung (g/d)}}{\text{Nutrient intake (g/d)}}$$

A total digestible nutrient (TDN) of the TMR was calculated by adding digestible nutrients.

$$\text{TDN\%} = (\text{CP\%} \times \text{ADC}) + (\text{CF\%} \times \text{ADC}) + (\text{NFE\%} \times \text{ADC}) + (\text{EE\%} \times \text{ADC} \times 2.25)$$

The TDN was converted to DE (MJ) by using the factor 18.45 (NRC, 1989) and DE was converted to ME by a factor of 0.82 (Gill *et al.*, 1976). Thus, 1 kg TDN=15.15 MJ of ME.

3.8 Comparison of energy values obtained by different methods

The energy values obtained by digestion trial were compare with those estimated by RIVIGP and SEDS .

3.9 Statistical Analysis

Data obtained during the experimental period has been subjected to the statistical analysis (Snedecor and Cochran, 1989).

RESULTS

IV. RESULTS

4.1 Chemical composition

The proximate composition (per cent of dry matter) of chunnies, straws and TMR prepared from the byproducts of the corresponding pulse crops are presented in Table 4.1. The chunnies and straws used in different groups differed in their chemical composition. CP content was the lowest for BNG chunni (7.81%) and BNG straw (3.54%). The CF content varied from 17.20 per cent in BLG chunni to 41.25 per cent in BNG chunni. It further varied from 32.06 per cent in RDG to 44.20 per cent in BLG straws.

The TMR prepared out of BNG, BLG, GNG and RDG had CP content of 6.35, 13.66, 14.08 and 10.35 per cent and the CF content of 42.22, 28.12, 26.08 and 29.19 per cent respectively.

The chemical constituents obtained by detergent system of analysis and ME predicted from summative equation are presented in Table 4.2.

The NDF and ADF content of BNG, BLG, GNG and RDG chunnies were 59.09 and 61.45, 40.50 and 37.46, 37.94 and 34.07, and 42.54 and 43.72 per cent, respectively. The lignin content in BLG chunni was highest (6.37%) while lowest (3.57%) was observed in BNG chunni.

The NDF and ADF content of BNG, BLG, GNG and RDG straws were 63.07 and 50.42, 69.83 and 63.37, 64.44 and 58.20, and 60.71 and 46.10 per cent, respectively. However, the lignin content of straws varied from 11.28 to 15.93 per cent.

Table 4.1 Proximate composition (per cent DM) of chunnies, straws and total mixed rations used during experimental period

Feed stuffs	TA	OM	CP	EE	CF	NFE
Chunnies						
Bengal gram	3.79	96.21	7.81	1.81	41.25	47.28
Black gram	15.74	84.26	16.06	1.31	17.20	53.11
Green gram	13.98	86.01	16.18	2.03	17.75	53.42
Red gram	7.66	92.33	13.47	4.29	24.92	52.95
Mean	10.29	89.70	13.38	2.36	25.28	51.69
Straws						
Bengal gram	6.60	93.40	3.54	1.18	39.20	49.55
Black gram	7.96	92.04	8.42	2.10	44.20	40.02
Green gram	9.08	90.92	8.91	1.47	38.33	45.00
Red gram	4.52	95.48	7.72	2.39	32.06	54.19
Mean	7.04	92.96	7.15	1.78	38.45	47.19
Total mixed ration						
Bengal gram	6.93	93.07	6.35	2.17	42.22	43.25
Black gram	11.27	88.72	13.66	2.18	28.12	46.15
Green gram	11.63	88.37	14.08	2.43	26.08	47.78
Red gram	7.50	92.50	10.35	4.07	29.19	50.67
Mean	9.33	90.66	11.11	2.71	31.40	46.96

Table. 4.2 Chemical composition and the Metabolizable energy (ME) calculated from summative equation for chunnies, straws and total mixed rations.

Feed Stuffs	Per cent Dry matter (DM)							ME (MJ/kg DM)
	NDF	NDS	ADF	ADL	SS	TS	BS	
Chunnies								
Bengal gram	59.09	40.30	61.45	3.57	0.61	0.21	0.40	13.23
Black gram	40.50	57.05	37.46	6.37	2.90	5.65	2.75	11.84
Green gram	37.94	59.02	34.07	4.75	3.04	4.14	1.10	12.43
Red gram	42.54	56.03	43.72	5.85	1.43	1.69	0.26	12.58
Mean	44.90	53.10	44.17	5.13	1.99	2.92	1.13	12.52
±SE	±5.56	±4.97	±7.04	±0.71	±0.67	±1.40	±0.65	±0.33
Straws								
Bengal gram	63.07	36.32	50.42	11.30	0.61	2.06	1.45	5.45
Black gram	69.83	29.12	63.37	15.93	1.05	1.23	0.18	4.27
Green gram	64.44	34.19	58.20	14.24	1.37	1.14	0.23	4.55
Red gram	60.71	38.70	46.10	11.28	0.59	0.32	0.27	6.06
Mean	64.51	34.58	54.52	13.19	0.90	1.19	0.53	5.08
±SE	±2.23	±2.35	±4.46	±1.32	±0.21	±0.41	±0.35	±0.47
Total mixed ration								
Bengal gram	59.74	39.67	54.43	7.59	0.59	0.66	0.07	9.26
Black gram	55.05	43.15	46.44	10.87	1.80	2.91	1.11	7.98
Green gram	48.67	39.25	44.80	9.54	2.08	2.53	0.45	8.41
Red gram	52.08	46.92	43.79	7.72	1.00	0.97	0.03	9.25
Mean	53.88	44.75	47.36	8.93	1.37	1.77	0.41	8.72
±SE	±2.71	±2.44	±2.79	± 0.90	± 0.40	± 0.64	± 0.29	±0.37

$$\text{ME of TMR (MJ/kg DM)} = [(\text{ME of chunni}) \times \text{proportion of chunni in TMR} + (\text{ME of straw}) \times \text{proportion of straw in TMR}]$$

The ME (MJ/kg DM) of the TMR calculated by using the roughage formula and CFM formula as per their proportion in the TMR and it was observed to be 9.26, 7.98, 8.41 and 9.25 for BNG, BLG, GNG and RDG, respectively.

4.2 Rumen fermentation characteristics

4.2.1 Effect of PEG on gas production and metabolizable energy content

The gas produced (ml/200 mg DM) by the RIVIGP-24 (ml/200 mg DM) from chunnies, straws and TMR without and with PEG is presented in Table 4.3.

Addition of PEG resulted in higher cumulative gas production in BLG (63.12%) as compared to RDG (27.60%) among the chunnies. Among straws RDG produced more gas (17.41%) as compared to other straws (0.98 to 5.18%). Further addition of PEG resulted in a significant ($P \leq 0.01$) increase in cumulative gas production to the extent of 26.80, 23.15, 17.91 and 24.70 per cent for TMR-BNG, TMR-BLG, TMR-GNG and TMR-RDG, respectively.

ME content (without and with PEG addition) predicted from rumen *in vitro* gas production test and from chemical composition for these feedstuffs are presented in Table 4.3.

The ME (MJ/kg DM) content by using roughage formula and CFM formula as per their proportion in the TMR without and with PEG were 8.19 and 9.89, 6.37 and 7.99, 7.25 and 8.76, and 9.29 and 10.86 for BNG, BLG, GNG and RDG, respectively.

4.2.2 Kinetics of gas production

The cumulative gas production at different time intervals of incubation (2, 4, 6, 8, 10, 12, 16, 20, 24, 30, 36, 48, 60, 72, 84

Table 4.3 Gas production and metabolizable energy content from chunnies, straws and total mixed rations on incubation with rumen inoculum without and with polyethylene glycol (PEG)

Feed stuffs	Gas (ml/200 mg DM)		ME (MJ/kg DM)		Significance	
	With out PEG	With PEG	With out PEG	With PEG	Gas	ME
Chunnies						
Bengal gram	46.71	68.39	9.14	12.54	**	**
Black gram	32.78	53.47	6.57	9.81	**	**
Green gram	40.05	58.37	8.02	10.90	**	**
Red gram	51.92	66.25	10.67	12.94	**	**
Mean	42.86	61.62	8.60	11.55		
±SE	±4.78	±4.00	±1.00	±0.84		
Straws						
Bengal gram	35.79	36.14	7.28	7.35	NS	NS
Black gram	24.84	25.33	6.18	6.24	NS	NS
Green gram	27.59	29.02	6.51	6.71	**	**
Red gram	38.02	44.64	7.96	8.86	**	**
Mean	31.56	36.28	6.98	7.29		
±SE	±3.66	±4.68	± 0.46	±0.66		
Total mixed rations						
Bengal gram	41.38	52.47	8.19	9.89	**	**
Black gram	30.49	37.55	6.37	7.99	**	**
Green gram	36.68	43.25	7.25	8.76	**	**
Red gram	44.73	55.78	9.29	10.86	**	**
Mean	38.32	47.26	7.77	9.37		
±SE	± 3.56	± 4.83	± 0.72	±0.73		

Note :-

- 1) NS - Non significant
- 2) ** - $P \leq 0.01$

ME of TMR (MJ/kg DM)=

$$[(\text{ME of chunni}) \times \text{proportion of chunni in TMR} + (\text{ME of straw}) \times \text{proportion of straw in TMR}]$$

and 96 h) for chunnies, straws and TMR are presented in Appendix Table 1, 2 and 3, and are graphically represented in Fig. 4.1, 4.2 and 4.3, respectively.

The parameter estimates of gas production kinetics (potential gas production, D; rate of gas production, k; half time, $t_{1/2}$ and lag time, l) for chunnies, straws and TMR are presented in Table 4.4. The mean potential gas production without and with lag time for chunnies, straws and TMR were 74.44 & 74.83, 43.81 & 43.53 and 57.55 & 57.62 respectively. The mean rate of gas production (k) without and with lag time for chunnies, straws and TMR were 0.0369 & 0.0356, 0.0543 & 0.0573 and 0.0479 & 0.0473, respectively.

Similarly the mean half time (h) ($t_{1/2}$) without and with lag time for chunnies, straws and TMR were 19.15 & 20.04, 13.23 & 12.32 and 14.55 & 14.66, respectively.

The chunnies and straws chosen for the present study largely showed positive lag time except for the BLG (-3.396 h) and GNG (-1.338 h) among the chunnies and BNG (-0.471 h) among the straws, which showed negative lag time. TMR showed negative lag time except for the RDG (0.844 h).

4.2.3 Partitioning factor (Efficiency of Rumen Microbial Biomass synthesis)

The substrate degradation, gas production, partitioning factor and efficiency of microbial biomass synthesis at the time of half asymptotic gas production ($t_{1/2}$) for the feedstuffs studied are presented in Table 4.5.

In chunnies the $t_{1/2}$ -ADDM was 163.12 mg and $t_{1/2}$ -TDOM was 257.72 mg representing 32.62 and 51.54 per cent of the total

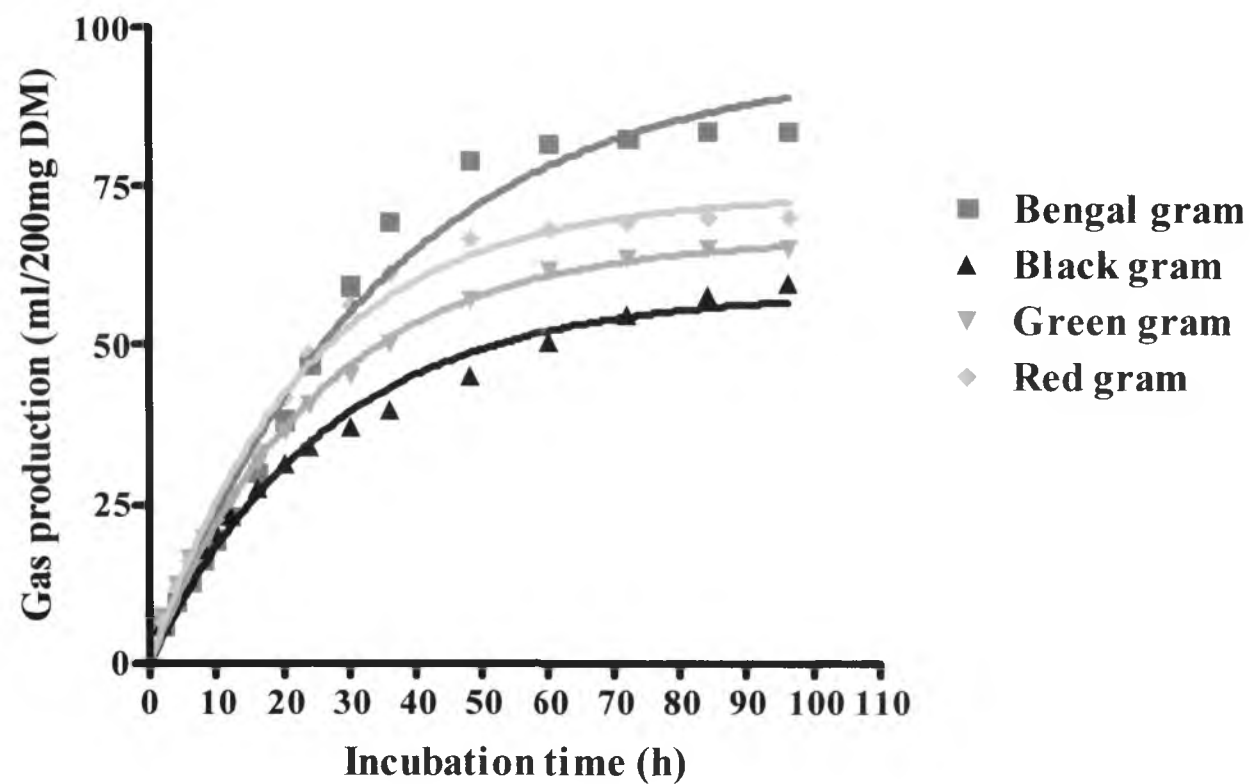


Fig. 4.1. In vitro cumulative gas production for pulse Chunnies fitted with exponential model.

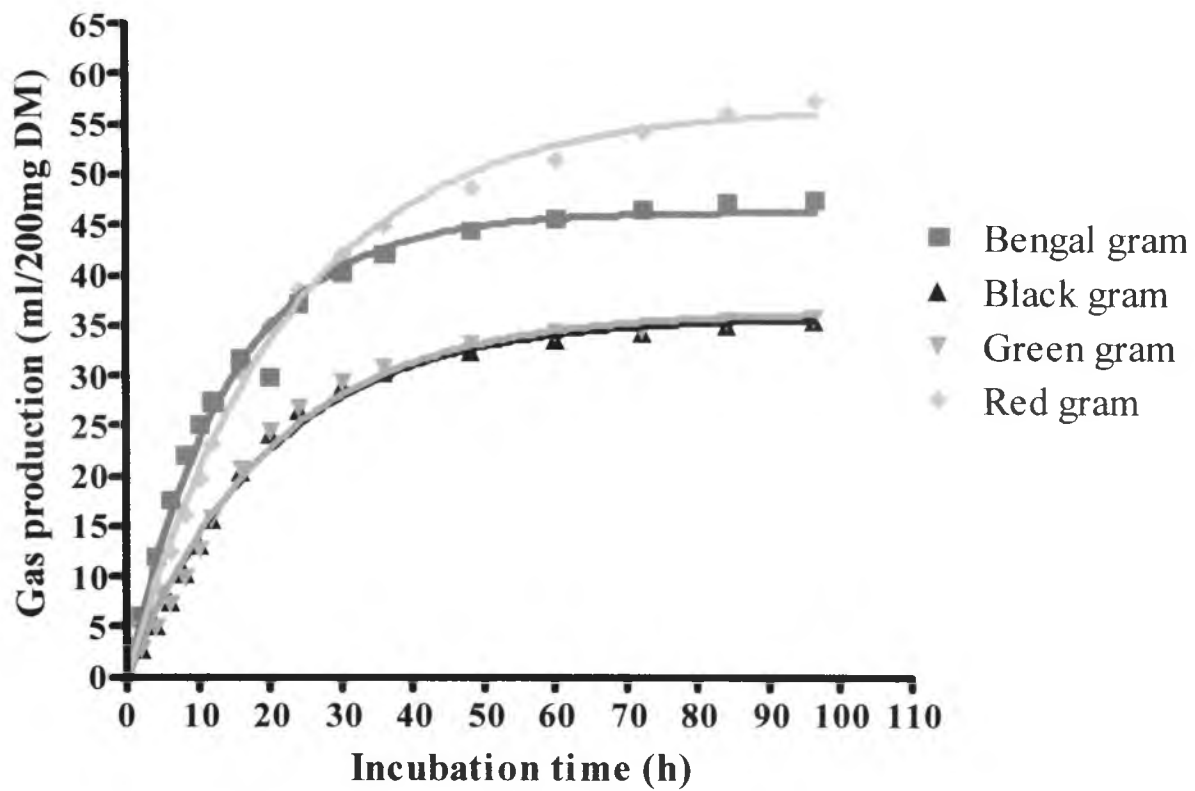


Fig. 4.2. In vitro cumulative gas production for pulse straws fitted with exponential model.

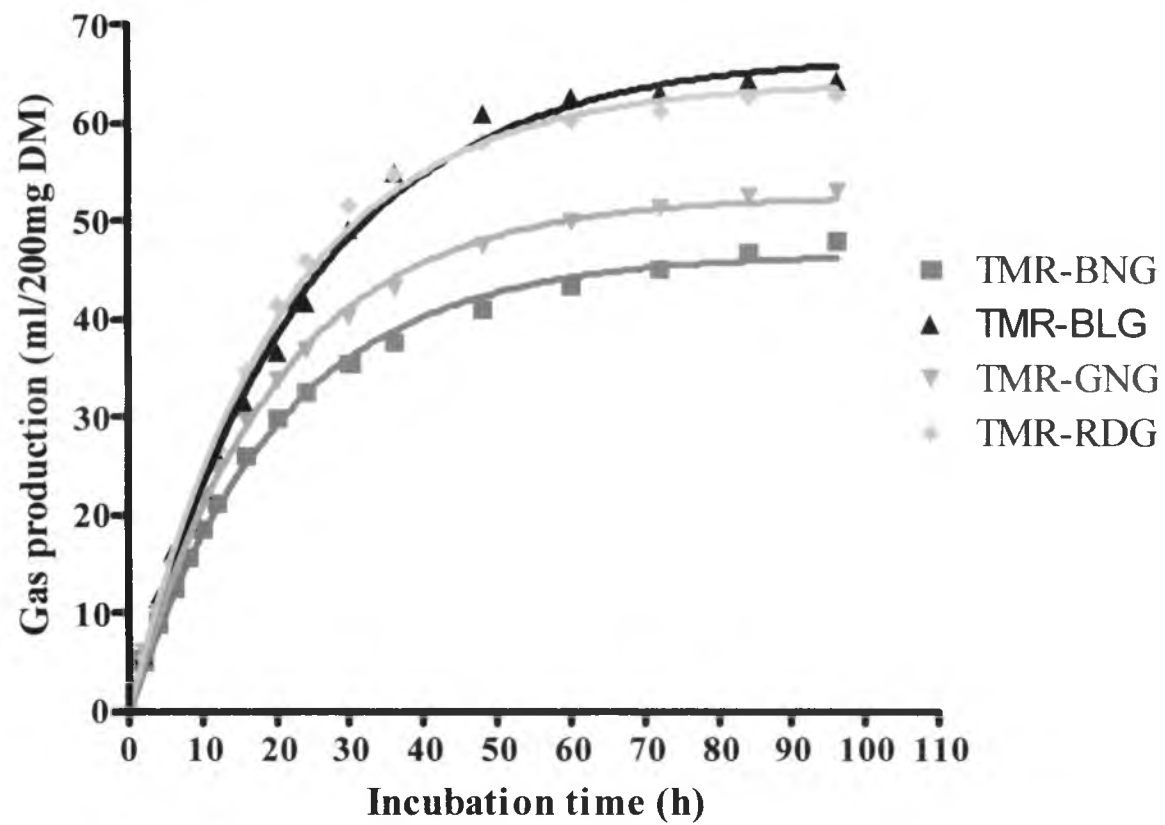


Fig. 4.3. In vitro cumulative gas production for total mixed rations (TMR) fitted with exponential model.

Table. 4.4 Parameter estimates for chunnies, straws and total mixed rations obtained from nonlinear regression computations without and with lag time

Feedstuffs	Without lag			With lag			
	D	k	t $\frac{1}{2}$	D	k	l	t $\frac{1}{2}$
Chunnies							
Bengal gram	94.81	0.0290	23.89	91.60	0.0339	1.801	20.33
Black gram	58.33	0.0376	18.42	62.51	0.0277	-3.396	24.87
Green gram	69.06	0.0386	17.96	70.62	0.0343	-1.338	20.12
Red gram	75.56	0.0425	16.32	74.60	0.0465	0.984	14.85
Mean	74.44	0.0369	19.15	74.83	0.0356	-0.4872	20.04
±SD	15.33	0.0057	3.29	12.26	0.0079	2.351	4.10
CV	20.59	15.42	17.17	16.38	22.19	-48.25	20.44
Straws							
Bengal gram	46.24	0.0734	9.44	46.49	0.0694	-0.471	9.94
Black gram	35.90	0.0501	13.85	35.32	0.0574	1.321	12.02
Green gram	36.37	0.0491	14.12	35.72	0.0570	1.455	12.11
Red gram	56.74	0.0446	15.53	56.60	0.0454	0.167	15.21
Mean	43.81	0.0543	13.23	43.53	0.0573	0.618	12.32
±SD	9.85	0.0129	2.63	10.13	0.098	0.9281	2.17
CV	22.48	23.86	19.92	23.28	17.10	150.18	17.63
Total mixed rations							
Bengal gram	67.05	0.0424	16.35	67.07	0.0423	-0.022	16.31
Black gram	46.57	0.0495	14.01	47.05	0.0461	-0.713	14.96
Green gram	52.50	0.0510	13.59	52.92	0.0481	-0.587	14.34
Red gram	64.10	0.0487	14.24	63.43	0.0529	0.844	13.04
Mean	57.55	0.0479	14.55	57.62	0.0473	-0.1195	14.66
±SE	9.65	0.0038	1.23	9.25	0.0044	0.7091	1.36
CV	16.76	7.93	8.46	16.06	9.33	-593.39	9.27

= Gas asymptote (ml); k = Rate of gas production (h); t $\frac{1}{2}$ = Time of half asymptotic gas production; l = discrete lag time

Table. 4.5 Gas production, substrate degradation, partitioning factor (PF) and efficiency of rumen microbial biomass synthesis of feedstuffs measured at time of half asymptotic gas production ($t_{1/2}$) from 500 mg substrate incubation

Feedstuffs	Variables							
	$t_{1/2}$	Gas at $t_{1/2}$ (ml)	$t_{1/2}$ -ADDM (mg)	$t_{1/2}$ -TDDM (mg)	$t_{1/2}$ -TDOM (mg)	PF (mg/ml)	MBP	ERMBS
Chunnies								
Bengal gram	23.89	100.81	190.0	281.3	269.1	2.67	33.20	12.34
Black gram	18.42	72.07	142.0	282.7	232.6	3.23	63.96	27.50
Green gram	17.96	80.57	171.7	300.7	255.1	3.17	66.57	26.09
Red gram	16.32	72.25	148.8	298.0	274.1	3.80	105.03	38.32
Mean	19.15	81.42	163.12	290.67	257.72	3.22	67.19	26.06
SD	3.29	13.52	21.96	10.09	18.58	0.46	29.43	10.65
CV	17.17	16.60	13.46	3.47	7.21	14.36	43.80	40.89
Straws								
Bengal gram	9.44	54.47	131.4	206.0	180.4	3.31	60.57	33.57
Black gram	13.85	41.85	117.4	188.3	156.6	3.74	64.53	41.21
Green gram	14.12	47.85	121.4	202.3	167.4	3.49	62.13	37.11
Red gram	15.53	68.36	137.0	200.8	188.0	2.75	37.61	20.00
Mean	13.23	53.13	126.80	199.35	173.10	3.32	56.21	32.97
SD	2.63	11.38	8.99	7.68	13.90	0.42	12.51	9.19
CV	19.91	21.43	7.09	3.85	8.03	12.66	22.25	27.89
Total mixed ration								
Bengal gram	16.35	75.70	148.6	230.6	206.2	2.72	29.06	14.09
Black gram	14.01	55.67	134.6	223.9	192.6	3.55	62.33	32.36
Green gram	13.59	63.15	155.2	268.6	226.9	3.59	79.13	34.87
Red gram	14.24	71.26	140.7	249.4	223.5	3.14	56.75	25.39
Mean	14.55	66.44	144.77	243.12	212.3	3.25	56.82	26.68
SD	1.23	8.86	9.01	20.12	15.96	0.41	20.81	9.30
CV	8.46	13.34	6.22	8.28	7.52	12.54	36.62	34.86

MBP=TDOM-(gas at $t_{1/2}$ x stoichiometric factor*); PF = TDOM÷gas at $t_{1/2}$; ERMBS = MBP/TDOM X 100

* Stoichiometric factor is 2.20 for straws and 2.34 for chunnies and TMR

dry matter, respectively. The PF (mean) was 3.22 which ranged from 2.67 in BNG to 3.80 in RDG

In straws the $t_{1/2}$ -ADDM was 126.8 mg and $t_{1/2}$ -TDOM was 173.1 mg representing 25.36 and 34.62 per cent of the total dry matter, respectively. The PF (mean) was 3.32 which ranged from 2.75 in RDG to 3.74 in BLG

In TMR the $t_{1/2}$ -ADDM was 144.77 mg and $t_{1/2}$ -TDOM was 212.3 mg representing 28.95 and 42.46 per cent of the total dry matter, respectively. The PF (mean) was 3.25 which ranged from 2.72 in BNG to 3.59 in GNG TMR.

4.3 *In vivo* studies

4.3.1 Nutrient intake and digestibility

The intake, outgo and digestibility of various chemical components of experimental TMR fed to different groups of animals are presented in Appendix tables 4 to 7.

The mean dry matter and nutrient intake from TMR in different groups are presented in Table 4.6. The total DMI in different groups varied from 3.96 to 5.48 per cent of the body weight.

The RIVIGP-24 (ml/200 mg DM) from faeces for individual goats are presented in Appendix Table 8. The mean cumulative gas productions from faeces for four groups are presented in Table 4.7. The mean cumulative gas production (ml/200 mg DM) from faeces over 24 hours (without PEG) were 15.20, 2.54, 4.98 and 7.24 for Group I, II, III and IV, respectively. The addition of PEG resulted in mean cumulative gas production of 15.31, 3.07, 5.80 and 8.65 for the corresponding four groups. Thus, the PEG addition resulted an increase in cumulative gas production by

Table 4.6 Intake (Mean $\pm$ SE) of dry matter (DM) and nutrient during digestion trial in different groups

Group	Body wt	DMI		Total nutrient intake				
		g/day	% body wt	OM	CP	EE	CF	NFE
Group-I	32.95	1315.78	3.96 ^b	1224.60	83.551 ^c	28.55 ^b	555.52	569.07
	± 2.71	± 165.69	± 0.21	± 154.20	± 10.52	± 3.60	± 69.95	± 71.66
Group-II	30.48	1477.59	4.85 ^{ab}	1310.92	201.84 ^{ab}	32.21 ^b	415.50	681.91
	± 1.57	± 129.29	± 0.36	± 114.70	± 17.66	± 2.82	± 36.36	± 59.67
Group- III	28.39	1540.06	5.48 ^a	1360.95	216.84 ^a	37.42 ^b	401.64	735.84
	± 1.96	± 33.34	± 0.39	± 29.46	± 4.69	± 0.81	± 8.70	± 15.93
Group-IV	31.59	1439.33	4.59 ^{ab}	1331.38	148.97 ^b	58.68 ^a	420.14	729.28
	± 2.44	± 209.38	± 0.40	± 193.68	± 21.67	± 8.52	± 61.12	± 106.13
Significance		NS	*	NS	**	**	NS	NS

Note: Mean $\pm$ SE values bearing different superscript in a column differ significantly (* $P \leq 0.05$, ** $P \leq 0.01$)

Table 4.7 Gas production from faeces on incubation with rumen inoculum without and with polyethylene glycol-(PEG)

Group	Gas (ml/200 mg DM)		Signifi -cance	Percent increases
	With out PEG	With PEG		
GP -I	15.20±0.98 ^a	15.31±0.56 ^a	**	1.32±5.05
GP -II	2.54±0.20 ^d	3.07±0.44 ^d	**	19.68±10.31
GP -III	4.98±0.80 ^c	5.80±0.52 ^c	**	20.09±13.16
GP -IV	7.24±1.17 ^b	8.65±1.72 ^b	**	19.39±11.64

Note: - Different superscripts differ significantly at $P \leq 0.01$ level.

1.32, 19.68, 20.09 and 19.39 per cent for Group I, II, III and IV, respectively.

Correlation between CP content of TMR with RIVIGP-24 (without PEG) was -0.96 and with RIVIGP-24 (with PEG) was -0.97 ($P=0.005$).

The mean digestibility of proximate components, TDN and ME content for the four TMR used in digestion trial are presented in Table 4.8. The TDN content of the TMR in different groups varied from 54.63 per cent in BNG to 62.61 per cent in RDG. The CP digestibility among different treatment groups varied significantly ($P\leq 0.01$), the lowest being 46.47 per cent in Group I and the highest being 58.24 per cent in Group II. The digestibility of EE varied from 76.04 per cent in Group III to 90.75 per cent in Group IV. Similarly CF digestibility ranged from 59.53 per cent in Group I to 65.58 per cent in Group II.

The ME content (MJ/kg DM) of TMR used was 8.27, 8.62, 8.40 and 9.48 in Group I, II, III and IV, respectively.

4.4 Comparison of energy content of TMR obtained by digestion trial, RIVIGP and SEDS

The ME content of the TMR consumed by individual animals as derived by taking into account the DMI from TMR and ME values obtained from digestion trial, RIVIGP and SEDS are in Appendix Table 9. The ME obtained by RIVIGP and SEDS for the four TMR are compared with ME obtained by digestion trials (Table 4.9) and presented graphically in Fig. 4.4.

The *in vivo* estimates of energy corrected for maintenance level of intake (NRC, 1981) varied from 8.57 to 9.97 MJ/kg DM.

Table. 4.8 Mean per cent digestibility of proximate principles, TDN and ME content of different total mixed rations used during digestion trial.

Total mixed ration	Per cent digestibility						DOMD	TDN	ME (MJ/kg DM)
	DM	OM	CP	EE	CF	NFE			
Bengal gram	54.00 ±1.12	55.10 ^b ±0.92	46.47 ^c ±1.27	89.50 ^a ±1.31	59.53 ±2.23	51.28 ^b ±1.25	51.28 ^b ±0.85	54.63 ^b ±0.88	8.27 ^b ±0.13
Black gram	56.11 ±1.25	60.42 ^a ±1.36	58.24 ^a ±1.54	82.45 ^b ±1.38	65.58 ±2.47	58.08 ^a ±1.07	53.72 ^{ab} ±1.31	56.92 ^{ab} ±1.46	8.62 ^{ab} ±0.22
Green gram	54.09 ±0.92	58.15 ^{ab} ±0.93	55.34 ^{ab} ±1.28	76.04 ^c ±1.82	62.98 ±1.59	57.18 ^a ±1.28	51.27 ^b ±0.80	55.43 ^b ±1.09	8.40 ^b ±0.16
Red gram	58.03 ±1.54	60.78 ^b ±1.64	52.73 ^b ±1.25	90.75 ^a ±0.30	64.35 ±2.38	59.34 ^a ±1.59	56.22 ^a ±1.52	62.61 ^a ±1.52	9.48 ^a ±0.23
Significance	NS	*	**	**	NS	**	*	**	**

Note: Mean ± SE values bearing different superscript in a column differ significantly (*P≤0.05, **P≤0.01)

Table. 4.9 Metabolizable energy (ME) content (MJ/kg DM) of total mixed rations obtained from digestion trial, RIVIGP and SEDS

Total mixed ration	Digestion trial			RIVIGP		SEDS
	ME observed (MEp)	Level of energy intake (multiples of maintenance (Mx))	ME corrected for maintenance level of intake (ME _m)	With out PEG	With PEG	
Bengal gram	8.27	1.49	8.57 ^{efg}	8.19 ^{gh}	9.89 ^b	9.26 ^c
Black gram	8.62	1.64	9.01 ^{cd}	6.37 ^j	7.99 ^h	7.98 ^h
Green gram	8.40	1.73	8.83 ^{de}	7.25 ⁱ	8.76 ^{def}	8.41 ^{gh}
Red gram	9.48	1.80	9.97 ^b	9.29 ^c	10.86 ^a	9.25 ^c
Mean ±SE	8.69 ± 0.31	1.66 ± 0.08	9.09² ± 0.35	7.77⁴ ± 0.72	9.37¹ ± 0.73	8.72³ ± 0.37

Note:-

Mx = multiple of maintenance

ME_m = (ME observed + (Mx-1) 0.6)

a, b, ... i; Different superscripts differ significantly at P≤0.01 level.

1,2,3 & 4; Different superscript in a row differ significantly at P≤0.01 level.

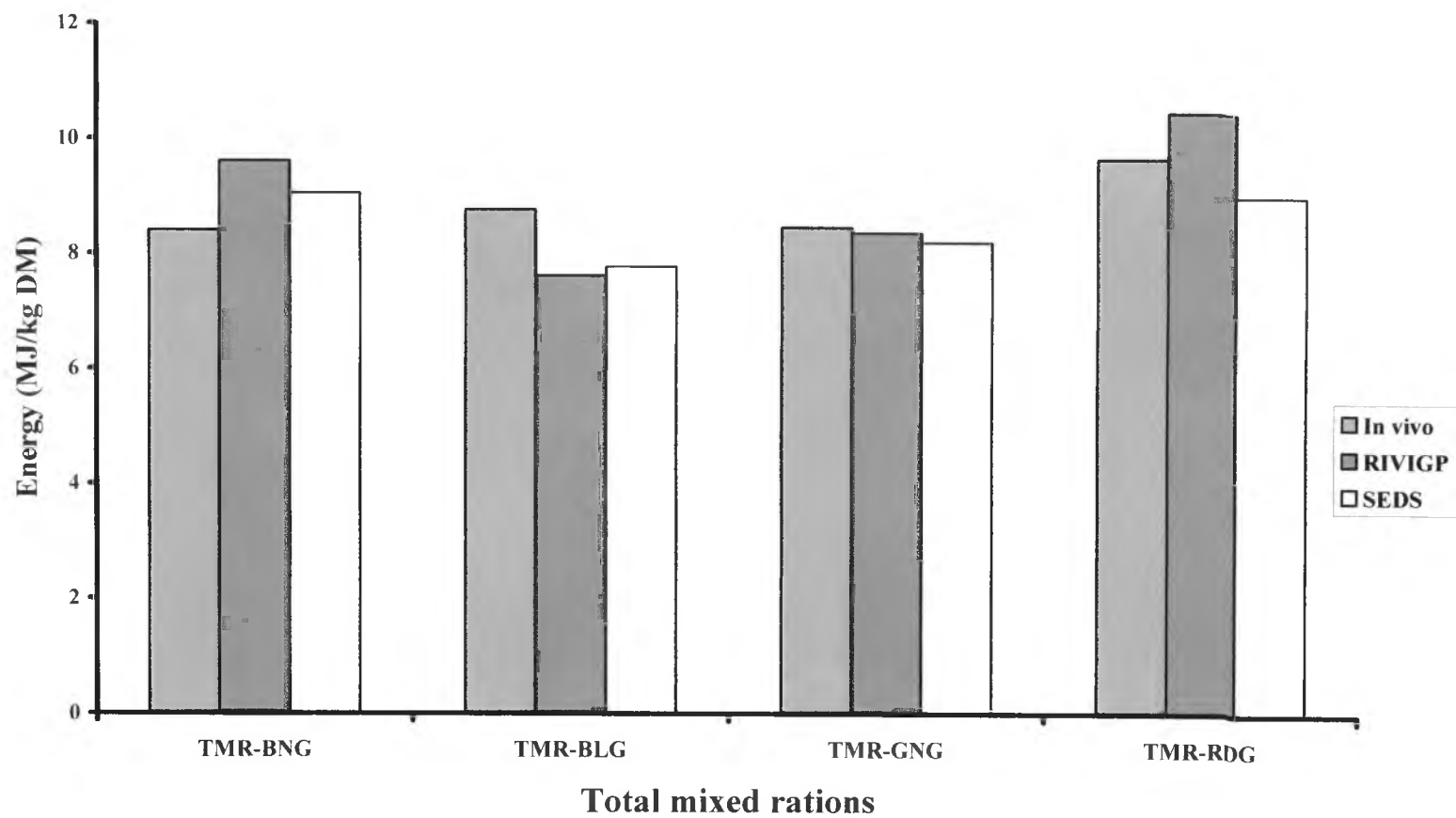


Fig. 4.4. Comparison of energy values obtained by different methods

A significant ($P \leq 0.01$) variation was observed between the mean ME estimated by RIVIGP (without and with PEG) and SEDS with MEm.

DISCUSSION

V. DISCUSSION

5.1 Chemical composition

Chemical composition of different feedstuffs revealed that BNG chunni appeared to be of lower quality as indicated by higher CF, lower CP (Table 4.1) and higher fibre fractions (NDF and ADF) (Table 4.2). However, the ADL content and ME predicted from RIVIGP and SEDS did not support this observation. GNG chunni appeared to be of higher quality as indicated by lower CF, higher CP (Table 4.1), lower fibre fractions (NDF and ADF) and lower ADL content in it (Table 4.2). The values observed in the present experiment are lower than the values reported by Annonymus (2003). This variation in the chemical composition observed may be attributed to the variance in the proportion of chunni and husk in the samples.

Among the straws BLG showed a higher CF content (Table 4.1), higher fibre fractions (NDF and ADF) and higher lignin (Table 4.2) as well as low ME (Table 4.2 and 4.3). Further RDG straw showed a lower CF, higher CP (Table 4.1), lower fibre fraction (NDF and ADF), lower lignin and higher ME (Table 4.2 and 4.3) than other straws. The values observed in the present experiment are lower than those observed by Bhadane *et al.* (2004) and Rekhate *et al.* (2004).

TMR, prepared by using BNG straw and chunni showed higher CF, lower CP (Table 4.1) and higher fibre fractions (NDF and ADF) (Table 4.2). The TMR prepared by using RDG chunni and straw showed a lower fibre fractions (NDF and ADF), lower ADL and higher ME (Table 4.2 and 4.3). The variations in TMR composition reported by Rekhate *et al.* (2004) and Bhadane *et al.* (2004), may be due to the variations in the composition of TMR.

The lignin content in chunnies was higher, compared to conventionally used feed ingredients, the protein content in the range of 13 to 16 per cent, with the exception of BNG indicating the potential of these byproducts to be used as a source of supplementary protein under conditions of feed scarcity. The NDF content ranging from 38 to 59 per cent with a CP content of 13 to 16 per cent perhaps also asserts their suitability as a complete feed by itself.

The differences between the chunnies and straws are evident in chemical composition (Table 4.2). A high ME content of BNG chunni as compared to other chunnies was due to lignin being smaller proportion of ADF (Table 4.2), confirming the observation i.e. the lignin and silica all of which have a negative effect on digestibility (Van Soest, 1982). In general, the SEDS predicted lower ME as compared to RIVIGP (Nataraj, 1995). In the present experiment that SEDS predicted higher energy than RIVIGP for chunnies but not in straws. High tannin content (Sreerangaraju *et al.*, 2000) of chunnies might have been a contributing factor because the ME content (with PEG) of RIVIGP-24 was predicted higher energy (Table 4.3). Since, different methods give different energy values, their validity can be tested only by comparing with *in vivo* estimates of energy values.

5.2 Rumen fermentation characteristics

5.2.1 Effect of PEG on gas production and metabolizable energy content

The RIVIGP-24 and ME content of straws, chunnies and TMR used in this experiment differed significantly ($P \leq 0.01$) (Table 4.3). The straws and chunnies contained tannin as indicated by increase in gas production on addition of PEG. Addition of

tannin binders such as PVP and PEG (Makkar *et al.*, 1995) are known to inactivate tannins, their use in rumen incubation studies are recommended to assess the potential interference of such tannins in nutrient availability from tannin contained feedstuffs (Makkar *et al.*, 1995).

Addition of PEG to chunnies, straws and TMR resulted in an increase in gas production from 42.86 to 61.62 ml, 31.56 to 36.28 ml and 38.32 to 47.26 ml per 200 mg DM, respectively (Table 4.3). This confirms that the tannins present in pulse byproducts interferes in rumen digestion (Sreerangaraju *et al.*, 2000).

Faecal samples of the four groups incubated with PEG resulted in an increase in gas production by 0.11, 0.53, 0.82 and 1.41 ml for Group I, II, III and IV, respectively (Table 4.7). This increase in gas production was negligible, indicating that the tannin bound substrate had completely dissociated in the post rumen digestive tract and undergone digestion (Sreerangaraju *et al.*, 2000).

5.2.2 Kinetics of gas production

The microbial N synthesis was more efficient when dietary energy and N supply in the rumen were synchronised (Sinclair *et al.*, 1995). Efficient use of feed carbon can be achieved by maximizing the efficiency of rumen microbial growth, which maximizes conversion of feed N into microbial biomass (Blummel *et al.*, 2001).

The potential gas production (D) represents the total fermentable organic matter. Therefore, this was regarded as an indirect estimate of energy content of feedstuffs (Menke *et al.*, 1979) and of microbial protein synthesis (Krishnamoorthy *et al.*,

1991). Blummel (1994) reported that the kinetic parameters obtained from gas test or Dacron bag techniques are useful in predicting intake of poor quality roughages. The k , $t_{1/2}$ and l represent gas production characteristics.

Since, $t_{1/2}$ is derived from k (Table 4.4) and lag time is part of the $t_{1/2}$ (which gets separated during the curve fitting in the nonlinear regression model), the discussion will be restricted to only k .

The mean values of the k for chunnies, straws and TMR were 0.0369, 0.0543 and 0.0479 respectively (Table 4.4). The k value obtained for BLG straw in the present experiment is not in agreement to that reported for BLG straw (Krishnamoorthy *et al.*, 1995). Further, one cannot expect the same rate for a particular feed ingredient unless the same feed ingredient is tested with the same rumen inoculum.

5.2.3 Partitioning factor (efficiency of rumen microbial biomass synthesis)

Blummel (1994) reported that an inverse relationship exists between microbial biomass synthesis and the volume of gas produced when both were expressed per 100 mg degraded organic matter. Therefore, selecting roughages by *in vitro* total gas production may well be a selection against maximum microbial yield and a combination of *in vitro* gas volume measurements with a complementary determination of substrate truly degraded was proposed. The ratio of true degraded organic matter (mg) to the gas produced (ml) defined as the partitioning factor was regarded as the measure of efficiency of microbial biomass synthesis.

The pulse byproducts in general are known to contain polyphenolic substances such as tannins in addition to lignin. The PF values higher than 4.41 have been reported for feedstuffs containing tannins and this was believed to be an artifact associated with the analytical system (Makkar, 2000) that contribute erroneously to microbial biomass.

The mean values of the PF of chunnies, straws and TMR were 3.22, 3.32 and 3.25 respectively (Table 4.5). The PF in the range of 2.75 to 4.41 was reported to be meaningful and acceptable (Blummel *et al.*, 1997b). The PF values for chunnies, straws and TMR fall within the theoretical range of 2.75 to 4.41 except for the BNG chunni and TMR-BNG. These lower PF observed may be due to the low rate of gas production (higher $t_{1/2}$) or due to the lower protein content. Blummel *et al.* (2003) observed that the feeds containing higher CP content could contribute to higher PF values under *in vitro* systems where no absorption and passage of NH_3 occurs, than in *in vivo*.

5.3. In Vivo studies

5.3.1 Nutrient intake and digestibility

No significant ($P \leq 0.01$) difference in DMI between the groups was observed, however the marginal difference in dry matter intake among the groups observed (Table 4.6) may be due to the difference in the chemical composition (Table 4.1 and 4.2) and also may be due to variation in body weight of experimental animals (Bhadane *et al.*, 2004, Ram *et al.*, 1990; Ramaprasad *et al.*, 1999). The DMI from TMR-GNG (5.48% of body weight) was more than the other TMR (3.96 to 4.85% of body weight) ($P \leq 0.05$). The higher CP content in TMR-GNG might have been a contributing factor as reported by Van Soest (1982) who reported

that CP content have a higher positive correlation with forage intake.

A low digestibility of CP observed in Group I (Table 4.8) may be due to low level of CP in the TMR-BNG resulting in lower daily intake (Bhuyan *et al.*, 1997 and Chander Datt and Singh, 1996).

A high correlation ($r=0.98$) between DOMD and TDN indicates the usefulness of DOMD as a measure of TDN as suggested by Alderman (1979). Difference in TDN among the TMR observed, may be due to the difference in ingredients and chemical composition of the TMR (Table 3.1 and 4.2).

5.4 Comparison of energy content of total mixed ration obtained by digestion trial, RIVIGP and SEDS

The ME estimates by RIVIGP were in good agreement with the *in vivo* estimates of ME (Table 4.9). Krishnamoorthy *et al.* (1995a) reported that the energy content of a variety of conventional Indian feedstuffs obtained by RIVIGP-24 were within ± 15 per cent of the values reported in the literature. These findings indicate that RIVIGP, although standardized to evaluate feedstuffs of temperate origin (Menke *et al.*, 1979; Menke and Steingass, 1988) may also have the potential to evaluate tropical feedstuffs for energy content. However, Krishna and Gunther (1987) and Khazaal *et al.* (1993) reported that the RIVIGP may not be the appropriate method to evaluate feedstuffs that are rich in polyphenolic and related anti-nutritional factors.

In this experiment, the energy content of unconventional feedstuffs (chunnies and straws) obtained by RIVIGP-24 (without and with PEG) were within the range observed by Krishnamoorthy *et al.* (1995a) for conventional feedstuffs.

Therefore, RIVIGP (with PEG) can also be used for energy evaluation of unconventional feedstuffs i.e. pulse byproducts.

The ME estimates by SEDS were in good agreement with the *in vivo* estimates of ME (Table 4.9). Therefore, energy estimation by SEDS has the advantage of easy adaptability of detergent system of feed analysis without maintaining a rumen fistulated animal (Krishnamoorthy *et al.*, 1999).

SUMMARY

VI. SUMMARY

A study was conducted to assess the potential of RIVIGP and SEDS for pulse byproducts (chunnies and straws) to obtain estimates of energy values comparable to those determined by digestion trial and also to evaluate the pulse byproducts for the efficiency of rumen microbial biomass synthesis (PF). The nutritive value of chunnies and straws from pulse crop were assessed by chemical analysis, *in vitro* and *in vivo* methods.

Four types of chunnies and straws i.e., BNG, BLG, GNG and RDG were selected for the study. By using these chunnies and straws four types of TMR were formulated and used for the study. The samples of chunnies, straws and TMR were subjected to proximate and detergent system of analysis. The ME (MJ/kg DM) content of the TMR obtained from SEDS were 9.26, 7.98, 8.41 and 9.25 for BNG, BLG, GNG and RDG, respectively.

The gas production (ml/200 mg DM) by RIVIGP-24 method for different chunnies, straws and TMR without and with PEG were analysed. The ME (MJ/kg DM) estimates obtained from RIVIGP of TMR without and with PEG were 8.19 and 9.89, 6.37 and 7.99, 7.25 and 8.76, and 9.29 and 10.86 for BNG, BLG, GNG and RDG, respectively.

The cumulative gas productions at different time intervals (2, 4, 6, 8, 10, 12, 16, 20, 24, 30, 36, 48, 60, 72, 84 and 96 h) were studied. The chunnies and straws largely showed a positive lag time except for the BLG (-3.396 h) and GNG (-1.338 h) chunnies and for BNG (-0.471 h) straw, which showed negative lag time. TMR showed a negative lag time except for the RDG (0.844 h). The PF values for chunnies, straws and TMR fall

within the theoretical range of 2.75 to 4.41 except for the BNG chunni and TMR-BNG.

Animal feeding experiment was conducted using four different TMR with four groups of goats. Each group consisted of four goats. All the animals were subjected to the experimental feeding for a period of three weeks followed by a collection period of five days. During the experimental period the record of daily feed intake, residue leftover and weekly body weight were recorded.

All the four TMR used during experimental period differed in their chemicals composition. The CP content of 6.35, 13.66, 14.08 and 10.35 per cent, and the CF content of 42.22, 28.12, 26.08 and 29.19 per cent for the four TMR such as BNG, BLG, GNG & RDG groups respectively was observed.

The DMI of four groups i.e., BNG, BLG, GNG & RDG was 3.96, 4.85, 5.48 and 4.59 per cent body weight, respectively. Further the TDN content observed to be 54.63, 56.92, 55.43 and 62.61 per cent, respectively.

The ME content of the TMR (corrected for maintenance level of intake) obtained by digestion trial for BNG, BLG, GNG and RDG were 8.57, 9.01, 8.83 and 9.97 MJ/kg DM, respectively. Corresponding estimates obtained by RIVIGP and SEDS were 9.89 and 9.26, 7.99 and 7.98, 8.76 and 8.41, and 10.86 and 9.25, respectively.

CONCLUSION

Based on the observations made during this study it is concluded that the ME estimated by RIVIGP with PEG will be in agreement with *in vivo* estimates of ME for legume byproducts. Further, ME estimated by SEDS were also in agreement with *in vivo* estimates of ME and as well as RIVIGP method. The estimation of energy content of pulse byproducts by SEDS has the advantage over RIVIGP and in terms of easy adaptability of detergent system of feed analysis.

It is also concluded that the byproducts of pulses such as BNG, BLG, GNG & RDG chunnies, straws and the TMR prepared can be effectively used in small ruminant feeding as a source of supplementary protein.

REFERENCES

VII. REFERENCES

- ALDERMAN, 1979, Application of practical ration systems. In: *Standardization of Analytical Methodology for Feeds*. Eds. W.J. Pigden, C.C. Balch and Michael Graham, Ottawa, Canada, pp. 29-35.
- ANNONYMUS, 2003, Technical report on *in vitro* evaluation of various feed pellets and their production potential in lactating Indian goats. National Agricultural Technology project.
- AOAC, 1995, Official methods of analysis. *Association of Official Analytical Chemists*, 15th Edition, Washington, D. C, USA.
- ARMSTRONG, D.G., 1964b, The evaluation of dried grasses as sources of energy for ruminant livestock. *Agricultural Programme*, England, **39**: 1-14.
- BHADANE, K. P., REKHATE, D. H. AND DHOK, A. P., 2004, Nutrient utilization in goats fed Arhar straw (*Cajanus cajan*) based pelleted complete feed. *Indian Journal of Animal Nutrition*, **21** :127 – 129.
- BHUYAN, R., BARUAH, K. K., BORA, M. C. AND DAS, P.C., 1997, Effect of dietary protein and energy levels on growth, nutrient utilization and feed efficiency in Beetal x Assam local goats. *Indian Journal of Animal Nutrition*. **14** : 20 – 24.
- BLUMMEL, M., 1994, Relationship between kinetics of stover fermentation as described by the Hohenheim *in vitro* gas production test and voluntary feed intake of 54 cereal stovers. Ph.D. thesis, University of Hohenheim Stuttgart, Germany.

- BLUMMEL, M. AND BECKER, K., 1997, The degradability characteristics of fifty-four roughage and roughage neutral detergent fibre as described by *in vitro* gas production and their relationship to voluntary feed intake. *British Journal of Nutrition*, **77**: 757-786.
- BLUMMEL, M., MAKKAR, H.P.S. AND BECKER, K., 1997a, *In vitro* gas production – a technique revisited. *Journal of Animal Physiology and Animal Nutrition*, **77**: 24-34.
- BLUMMEL, M., STEINGASS, H. AND BECKER, K., 1997b, The relationship between *in vitro* gas production, *in vitro* microbial biomass yield and ^{15}N incorporation and its implication for prediction of voluntary feed intake. *British Journal of Nutrition*, **77**: 911-921.
- BLUMMEL, M., MAKKAR, H.P.S. AND BECKER, K., 1998, The *in vitro* gas production characteristics of whole roughage versus extracted neutral detergent fibre and their implications for analyzing the fermentation of cell solubles by a differential approach. In: *In vitro Techniques for Measuring Nutrient Supply to Ruminants* Eds. Deaville, E.R., Owen, E., Adesogan, A.T., Rymer, C., Huntigton, J.A. and Lawrence, T.L.J., BSAS No.22, Edinburgh, pp. 85-88.
- BLUMMEL, M., AIPLE, K.H., STEINGAS, H. AND BECKER, K., 1999, A note on stoichiometrical relationship of short chain fatty acid production and gas production in feedstuffs of widely differing quality. *Journal of Animal Physiology and Animal Nutrition*, **81**: 157-167.
- BLUMMEL, M., 2000, Predicting the partitioning of fermentation products by combined *in vitro* gas volumes and true substrate degradability measurements : opportunities and limitations. Invited paper for the EAAP satellite symposium – gas production : fermentation kinetics for feed evaluation and to assess microbial activity, Wageningen, Netherlands.

- BLUMMEL, M., KRISHNA, N. AND ØRSKOV, E.R., 2001, Supplementation strategies for optimizing ruminal carbon and nitrogen utilisation: concepts and approaches. In review papers: 10th *Animal Nutrition* Conference, Karnal, India, Nov. 9-10th, pp. 10-23.
- BLUMMEL, M., KARSLI, A. AND RUSSEL, J.R., 2003, Influence of diet on growth yields of rumen microorganisms *in vitro* and *in vivo*: Influence on growth yield of variable carbon fluxes to fermentation products. *British Journal of Nutrition*, **90**: 1-11.
- CHANDER DATT AND SINGH, G P., 1996, Effect of supplementation of protein to untreated and urea treated wheat straw on intake and nutrient utilization in crossbred cattle. *Indian Journal of Animal Nutrition*, **13** : 137 – 141.
- CONRAD, H.R., WEIS, W.P., ODWONGO, W.O. AND SHOCKEY, W.L., 1984, Estimating net energy lactation from components of cell solubles and cell walls. *Journal of Dairy Science*, **67**: 427-436.
- GIGER REVERDIN, S., JOCELYNE AUFRERE, SAUVANT, D., DEMARQUILLY, C. AND VERMOREL, M., 1994, Prediction of the energy values of compound feeds for ruminants. *Animal Feed Science and Technology*, **48**: 73-98.
- GILL, R.S., CHAUHAN, T.R. AND ICHHPONANI, J.S., 1976, Metabolisable energy content of rations containing varying proportions of berseem, concentration mixture and wheat straw when fed to buffaloes. *Indian Journal of Animal Science*, **46**: 327-332.
- GIRARD, V. AND DUPUIS, G., 1988, Effect of structural and chemical factors of forages on potentially digestible fibre, intake and true digestibility by ruminants. *Canadian Journal of Animal Science*, **68**: 787-799.

- GOERING, H.K. AND VAN SOEST, P.J., 1970, Forage fibre analyses. Agriculture Research Service, USDA, Agriculture Handbook No. 379, Washington, DC, UAS.
- GRAHAM, N., 1967, The net energy of three subtropical forages. *Australian Journal of Agricultural Research*, **18**: 137-147.
- ISI, 1965, Indian standards specifications for cattle feed IS: 3198-1965. Indian Standards Institute, Manak Bhavan, New Delhi.
- KAMALAMMA, 1993, Effect of feeding yeast culture on dry matter intake, milk yield and milk composition in crossbred dairy cows. M.V.Sc. Thesis, University of Agricultural Sciences, Bangalore.
- KHAN, M.Y., 1991, Energy measurement of feeds for ruminants. *Proceeding of I. International Animal Nutrition Workers Conference for Asia and Pacific*, Bangalore, India, Compendium I. pp. 46-50.
- KHAZAAL, K., DENTINHO, M.T., RIBEIRO, R. AND ORSKOV, E.R., 1993, A comparison of gas production during incubation with rumen contents *in vitro* and nylon bag degradability as predictors of the apparent digestibility *in vitro* and the voluntary intake of hays. *Animal Production*, **57**: 105-112.
- KIRAN, D., 2004, Evaluation of ruminant feedstuffs for efficiency of rumen microbial biomass synthesis (Partitioning factor). M.V.Sc. Thesis, University of Agricultural Sciences, Bangalore.
- KRISHNA, G. AND GUNTHER, K.D., 1987, Comparative performance of existing *in vitro* methods for testing the nutritional value of agro-industrial byproducts and wastes. *Journal of Animal Physiology and Animal Nutrition*, **58**: 108-115.

- KRISHNAMOORTHY, U., 1992, A report of the utility of equipment donated by the Alexander von Humboldt Foundation, Germany. Department of Dairy Production, Dairy Science College, University of Agricultural Sciences, Bangalore.
- KRISHNAMOORTHY, U., STEINGASS, H. AND MENKE, K.H., 1991, Preliminary observations on the relationship between gas production and microbial protein synthesis *in vitro*. *Archive Animal Nutrition*, **41**: 521-526.
- KRISHNAMOORTHY, U., SOLLER, H., STEINGASS, H. AND MENKE, K.H., 1995a, Energy and protein evaluation of tropical feedstuffs for whole tract and ruminal digestion by chemical analyses and rumen inoculum studies *in vitro*. *Animal Feed Science and Technology*, **52**: 177-188.
- KRISHNAMOORTHY, U., KAILAS, M.M. AND HEGDE, B.P., 1995b, Application of detergent system of feed analysis in quality assessment for energy content and ration formulation for ruminants. *Proceeding VII. Animal Nutrition Research Workers Conference*, Bombay, Compendium II, pp. 101.
- KRISHNAMOORTHY, U., KAILAS, M.M. AND HEGDE, B.P., 1999, Prediction of ME contents in compound feeds and finger millet straw by the summative equations of detergent system and their potential in diet formulation for dairy cattle. *Indian Journal of Animal Nutrition*, **16**: 94-102.
- KRISHNAMOORTHY, U., CHANDRAPAL SINGH, K. AND KAILAS, M.M., 2005, Evaluation of roughages for rumen microbial biomass synthesis. *Indian Veterinary Journal*, **82**: 453-454.
- MAKKAR, H.P.S., 2000, Some recent developments in evaluation and utilisation of unconventional feed resources. In: *Proceeding of the 3rd Asian Buffalo Congress*, Kandy, Sri Lanka, March 27th to 31st, 2000, pp. 167-181.
- MAKKAR, H.P.S., BLUMMEL, M. AND BECKER, K., 1995, Formulation of complexes between polyvinyl pyrrolidones or polyethylene glycols and tannins and their implication in gas production and true digestibility in *in vitro* techniques. *British Journal of Nutrition*, **73**: 897-913.

- MARTEN, G.C. AND BARNES, R.F., 1979, Prediction of energy digestibility of forage with *in vitro* rumen fermentation and fungal enzyme systems. In *Standardization of Analytical Methodology of Feeds*. Eds. W.J. Pigden, C.C. Balch and Michael Graham, Ottawa, Canada, pp. 61-71.
- MENKE, K.H. AND STEINGASS, H., 1988, Estimation of the energetic feed value obtained from chemical analysis and *in vitro* gas production using rumen fluid. *Animal Research and Development*, **28**: 7-55.
- MENKE, K.H., RAAB, L., SALEWSKI, A., STEINGASS, H., FRITZ, D. AND SCHNEIDER, W., 1979, The estimation of digestibility and metabolisable energy content of ruminant feeding stuffs from the gas production when they are incubated with rumen liquor *in vitro*. *Journal of Agricultural Science, Cambridge*, **93**: 217-222.
- MINSON, D.J., 1979, Relationships of conventional and preferred fractions to determined energy values. In: *Standardization of Analytical Methodology of Feeds*. Eds. W.J. Pigden, C.C. Balch and Michael Graham, Ottawa, Canada, pp. 72-78.
- MINSON, D.J., 1982, Effect of chemical composition on feed digestibility and metabolisable energy. *Nutrition Abstract Review*, **52**: 591-614.
- MORGAN, D.E., 1974, Development of laboratory methods of estimating the digestibility and energy value of forages. *Annual Report, Agricultural Development and Advisory Services* (Science Ann), 1972, pp. 94-103.

- NAGABHUSHANA, V., SHARMA, K., PATTANAIK, A.K. AND NARAYANA DUTTA, 2005, *In vitro* evaluation of critical supplementation of wheat straw with graded levels of various source of cobalt. *Animal Nutrition and Feed Technology*, **5**: 85-98.
- NATARAJ, M.B., 1995, Evaluation of ruminant feedstuffs for energy content by digestion trial, rumen *in vitro* incubation (gas production) and chemical analysis. M.V.Sc. Thesis, University of Agricultural Sciences, Bangalore.
- NATARAJ, M.B., KRISHNAMOORTHY, U. AND KRISHNAPPA, P., 1998, Assessment of rumen *in vitro* incubation (gas production) technique and chemical analyses by detergent system to predict metabolisable energy content in mixed diets of lactating cows. *Animal Feed Science and Technology*, **74**: 169-177.
- NRC, 1981, Nutrient requirements of goats: Angora, dairy and meat goats. Indian, temperate and tropical countries. National Research Council, National Academic Press, Washington, DC.
- NRC, 1989, Nutrient requirements of dairy cattle. National Research Council, 6th Revised Edition, National Academic Press, Washington, DC.
- ØRSKOV, E. R. AND McDONALD, I., 1979, The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. *Journal of Agricultural Science*, **92** : 499 – 503.
- PIGDEN, W.J., BALCH, C.C. AND MICHAEL GRAHAM, 1979, *Standardization of Analytical Methodology of Feeds*. Ottawa, Canada, pp. 8.
- RAGHAVENDRA BHATTA, 1998, Effect of feeding tamarind (*Tamarindus indica*) seed husk as a source of tannin on rumen fermentation *in vitro* and performance of crossbred dairy cows in mid lactation. Ph.D. Thesis, University of Agricultural Sciences, Bangalore.

- RAM, A. K., MEHRA, U. R. AND CHALLA, J., 1990, Preparation and evaluation of complete feed mix blocks for goats. *Indian Journal of Dairy science*, **43** : 458 – 461.
- RAMACHANDRA, B. AND KRISHNAMOORTHY, U., 2000, Evaluation of some feeds by *in vitro* gas production. *Indian Veterinary Journal*, **77**: 976-978.
- RAMAPRASAD, J., PRABHAKAR RAO, L. AND SRINIVASA, RAO, D., 1999, Evaluation of leguminous hay based complete rations in sheep. *Indian Journal of Animal nutrition*, **16** : 48 – 52.
- RANJHAN, S.K., 1993, Modern approaches of feed evaluation and their application in India. In: *Feeding of Ruminants on Fibrous Crop Residues*. Ed. K. Singh, Karnal, Haryana, pp. 131-140.
- REKHATE, D. H., MADAVI, V. B., DHOK, A. P. AND PATIL, J. M., 2004, Evaluation of Arhar and gram straw based pelleted complete feed in goats. *Indian Journal of Animal Nutrition*, **21** : 257 – 260.
- ROBERTSON, J.B. AND VAN SOEST, P.J., 1977, Dietary fibre estimation in concentrate feedstuffs. *Journal of Animal Science*, **45**: 254.
- SEN, K.C., RAY, S.N. AND RANJHAN, S.K., 1978, *Nutritive Value of Indian Cattle Feeds and Feeding of Animals*. ICAR Publication, New Delhi.
- SINCLAIR, L.A., GARNSWORTHY, P.C., NEWBOLD, J.R. AND BUTTERY, P.J., 1995, Effect of synchronizing the rate of dietary energy and nitrogen in the diets with similar carbohydrate composition on rumen fermentation and microbial protein synthesis in sheep. *Journal of Agricultural Sciences*, **124**: 463-472.
- SNEDECOR, G.W. AND COCHRAN, W.G., 1989, *Statistical Methods*. Iowa State University Press, Ames, Iowa, USA.

- SREERANGARAJU, G., 1998, Effect of feeding bengalgram (*Cicer arietinum*) husk (as a source of tannin) on dry matter intake, growth rate and nutrient digestibility in stall-fed lambs. M.V.Sc. Thesis, University Agricultural Sciences, Bangalore.
- SREERANGARAJU, G., KRISHNAMOORTHY, U. AND KAILAS, M.M., 2000, Evaluation of Bengal gram (*Cicer arietinum*) husk as a source of tannin and its interference in rumen and post-rumen nutrient digestion in sheep. *Animal Feed Science and Technology*, **18**: 131-138.
- TILLEY, J.M.A. AND TERRY, R.A., 1963, A two stage technique for the *in vitro* digestion of forage crops. *Journal of British Grassland Society*, **18**: 104-111.
- VAN Es, A.J.H., 1978, Feed evaluation of ruminants. 1. The system in use from May 1977 onwards in the Netherlands. *Livestock Production Science*, Netherlands, **5**: 331-345.
- VAN SOEST, P.J. and ROBERTSON, J.B., 1979, Systems of analysis for evaluating fibrous feeds. In: *Standardisation of analytical Methodology for Feeds*. Eds: W.J. Pigden, C.C. Balch and Michael Graham. Ottawa, Canada, pp. 49-60.
- VAN SOEST, P.J., 1967, Development of a comprehensive system of feed analysis and its application to forages. *Journal of Animal Science*, **26**: 119.
- VAN SOEST, P.J., 1971, Estimation of nutritive value from laboratory analyses. *Proceeding Cornell Nutrition Conference for the Feed Manufacturers*, New York, USA, pp. 106-117.
- VAN SOEST, P.J., 1982, *Nutritional Ecology of the Ruminant*. O&B Books, Corvallis, OR USA.

APPENDIX

Appendix Table 1

Net gas production (ml/200mg DM) at different intervals of time for chunnies

Time interval (h)	2	4	6	8	10	12	16	20	24	30	36	48	60	72	84	96
Bengal gram	5.46	10.04	13.39	16.12	19.56	23.26	30.66	39.55	48.89	61.05	70.91	81.57	83.34	84.39	84.66	84.92
	5.44	10.00	13.34	16.06	19.48	23.16	30.53	38.87	47.64	60.28	70.63	80.20	83.00	84.06	84.32	84.58
	4.87	8.87	11.13	14.87	18.26	22.44	29.22	38.00	46.70	60.79	71.05	81.57	81.22	82.27	82.53	82.79
	5.91	9.82	12.52	15.73	18.51	22.34	28.08	35.46	43.63	55.28	65.28	74.84	77.88	78.92	80.31	79.97
	5.95	9.37	13.14	16.38	19.18	22.50	29.34	37.83	46.06	57.79	67.34	77.50	81.61	81.61	84.06	84.24
	5.96	8.85	12.62	16.91	20.76	23.04	30.40	38.90	47.13	59.93	71.05	78.59	82.70	83.76	85.16	85.33
Mean	5.60	9.49	12.69	16.01	19.29	22.79	29.70	38.10	46.68	59.19	69.38	79.04	81.63	82.50	83.51	83.64
Black gram	5.44	10.01	13.87	17.12	19.49	22.65	26.86	30.99	33.45	36.61	39.59	44.95	50.92	55.66	58.56	60.40
	5.39	9.91	12.69	15.91	18.25	20.86	25.55	29.64	32.07	35.20	38.16	43.46	48.85	53.54	55.89	58.24
	5.93	10.46	14.82	17.52	20.40	23.54	28.25	32.34	35.83	38.45	41.41	47.25	52.66	57.36	61.29	63.12
	6.41	11.35	16.12	18.81	21.58	24.35	27.99	31.20	33.63	36.40	39.09	43.94	49.05	53.21	56.16	57.89
	6.39	11.31	15.55	19.26	21.50	23.75	28.41	31.61	34.03	36.79	39.99	44.31	49.40	53.03	55.96	57.69
	6.38	11.30	15.53	18.21	21.48	23.73	28.39	32.10	34.51	38.31	41.50	46.33	51.94	56.08	60.05	61.78
Mean	5.99	10.72	14.76	17.80	20.45	23.15	27.58	31.31	33.92	36.96	39.96	45.04	50.47	54.81	57.98	59.85
Green gram	6.40	11.42	15.74	18.94	21.79	25.43	30.61	35.20	39.70	44.88	49.38	58.29	62.09	64.17	65.47	65.21
	6.43	11.46	15.80	19.01	21.36	25.01	30.22	35.86	39.85	41.94	45.93	46.54	51.92	52.96	54.27	55.05
	5.86	10.85	15.16	18.87	21.71	24.29	30.49	36.09	40.06	45.22	49.70	57.54	62.37	64.43	66.24	65.98
	8.45	13.36	18.10	21.29	24.56	27.32	33.53	38.27	42.23	47.06	51.80	59.73	63.78	66.36	67.74	67.91
	7.92	12.82	17.04	20.22	23.49	26.25	31.93	36.66	40.62	45.95	51.72	60.67	65.75	67.81	69.19	68.85
	7.51	13.01	16.24	18.42	22.26	25.58	31.34	36.67	40.68	46.10	51.42	59.98	64.60	66.70	68.10	67.75
Mean	7.09	12.15	16.35	19.46	22.53	25.65	31.35	36.46	40.52	45.19	49.99	57.12	61.75	63.74	65.17	65.12
Red gram	6.23	11.24	15.57	18.94	21.62	24.91	30.44	35.72	39.87	44.02	48.34	54.12	58.79	60.52	61.99	62.08
	5.94	11.54	16.43	19.14	23.08	27.27	35.14	44.49	51.66	60.05	64.60	72.03	71.15	72.72	72.99	73.25
	5.97	10.54	14.40	18.70	21.07	25.29	33.19	41.53	49.26	58.21	63.30	68.66	69.89	70.94	71.73	71.47
	6.95	11.91	16.17	19.91	23.21	27.56	35.38	44.34	51.47	59.99	64.77	69.11	71.11	71.11	72.50	72.16
	6.97	12.45	17.24	20.46	23.77	27.08	34.39	42.84	49.45	57.46	62.77	68.17	69.65	70.70	71.04	70.70
	6.96	11.92	16.18	19.92	23.22	26.53	33.83	42.27	49.40	57.93	63.23	67.58	69.58	70.10	70.97	70.63
Mean	6.50	11.60	16.00	19.51	22.66	26.44	33.73	41.86	48.52	56.28	61.17	66.61	68.36	69.35	70.21	70.05

Appendix Table 2

Net gas production (ml/200mg DM) at different intervals of time for straws

Time interval (h)	2	4	6	8	10	12	16	20	24	30	36	48	60	72	84	96
Bengal gram	6.83	13.24	18.45	23.14	25.87	27.58	32.19	36.38	37.74	40.99	42.10	44.83	45.26	46.28	46.63	47.31
	6.79	13.16	18.34	23.02	25.73	27.94	32.02	35.67	38.56	40.77	42.89	45.10	45.52	46.54	47.39	47.05
	6.31	12.19	18.41	23.10	25.82	27.53	32.13	35.79	38.69	41.42	43.55	45.25	46.19	47.22	48.07	48.24
	5.26	11.19	17.46	21.61	24.41	26.95	31.02	33.48	35.85	38.40	40.77	43.40	44.58	46.11	46.87	47.13
	5.25	11.18	16.43	21.08	24.39	27.44	31.50	3.98	36.83	39.88	41.75	44.37	46.06	47.08	47.84	48.10
	5.26	11.19	16.44	20.60	23.90	26.45	30.51	32.97	35.35	38.91	40.77	43.40	45.09	45.60	46.36	46.62
Mean	5.95	12.02	17.59	22.09	25.02	27.31	31.56	29.71	37.17	40.06	41.97	44.39	45.45	46.47	47.19	47.41
Black gram	3.24	6.06	8.19	10.83	14.07	16.80	21.41	24.05	26.95	28.66	30.28	32.49	33.43	33.94	34.28	34.97
	3.24	5.55	7.68	10.33	13.57	15.79	21.43	24.59	27.49	29.71	31.33	33.04	33.98	35.00	35.34	36.03
	3.26	5.07	7.21	10.39	12.62	15.89	20.01	24.22	26.11	28.86	29.46	31.69	32.63	33.15	34.01	34.18
	2.74	5.14	7.88	11.05	13.88	16.45	21.07	25.10	27.50	30.07	31.44	33.58	34.78	36.32	36.58	36.84
	2.22	4.11	6.84	9.49	12.32	14.88	19.50	22.50	24.38	26.94	28.83	30.97	32.16	32.68	33.96	34.22
	2.21	4.08	6.28	8.92	11.72	14.26	19.36	23.86	26.75	29.29	30.65	32.77	34.47	34.47	35.75	36.00
Mean	2.82	5.00	7.35	10.17	13.03	15.68	20.46	24.05	26.53	28.92	30.33	32.42	33.58	34.26	34.99	35.37
Green gram	3.89	6.28	8.49	11.76	14.58	17.94	22.72	26.52	28.99	31.29	32.97	34.74	35.71	36.24	37.13	37.30
	2.80	5.15	7.86	11.62	14.94	17.73	22.45	26.20	28.13	30.92	31.53	33.80	34.77	34.77	35.64	35.81
	3.36	5.22	7.43	10.17	13.00	16.36	20.61	23.88	25.82	28.12	29.27	31.04	32.01	32.01	33.43	33.08
	2.27	4.20	6.47	8.66	11.55	14.17	19.95	23.53	25.98	29.13	30.53	32.72	34.47	34.99	35.78	36.04
	1.76	3.70	6.00	7.67	10.58	13.23	18.52	23.19	25.66	28.30	30.24	32.45	33.68	34.21	35.53	35.80
	2.82	4.76	7.05	8.20	11.63	14.81	19.04	22.65	26.17	28.29	30.23	32.96	34.19	34.72	35.52	35.78
Mean	2.82	4.88	7.22	9.68	12.71	15.71	20.54	24.33	26.79	29.34	30.80	32.95	34.14	34.49	35.50	35.64
Red gram	6.94	10.32	14.05	17.78	21.60	24.89	32.18	36.95	40.42	43.71	46.40	50.22	52.73	55.33	57.24	58.97
	5.91	9.82	13.56	17.30	21.13	24.43	31.73	35.99	39.47	42.78	45.47	49.30	51.82	53.90	55.82	57.03
	4.90	8.31	12.08	15.84	19.69	23.01	30.89	35.70	38.68	42.00	44.71	48.56	51.10	54.25	55.65	56.88
	4.90	8.93	12.26	16.02	19.44	23.11	29.94	34.58	38.61	41.76	44.74	48.50	51.30	54.45	56.29	57.60
	4.36	7.86	11.17	14.93	18.33	21.47	28.80	33.43	36.40	40.59	43.56	47.31	51.15	53.77	55.60	56.39
	4.40	8.45	11.27	14.53	18.49	21.67	28.53	33.73	37.25	40.95	43.42	47.73	50.55	53.72	55.57	56.36
Mean	5.24	8.95	12.40	16.07	19.78	23.10	30.35	35.06	38.47	41.96	44.72	48.60	51.44	54.24	56.03	57.21

Appendix Table 3

Net gas production (ml/200mg DM) at different intervals of time for total mixed rations

Time interval (h)	2	4	6	8	10	12	16	20	24	30	36	48	60	72	84	96
IR-BNG	5.83	9.18	12.35	15.53	18.78	21.02	25.65	29.85	32.25	35.00	36.63	39.89	41.86	43.92	45.29	46.49
	5.84	9.71	13.40	16.58	19.84	22.08	27.23	31.44	33.85	36.59	38.74	42.01	43.98	46.04	47.42	48.62
	6.42	10.33	14.06	17.79	20.05	23.35	27.51	31.24	33.67	36.45	38.62	41.40	43.92	45.48	46.87	48.08
	4.37	8.39	11.72	14.95	17.84	20.46	25.71	29.29	32.26	34.89	37.33	41.09	43.89	45.47	47.30	49.14
	3.83	7.31	10.62	13.32	16.19	19.32	24.02	28.12	31.08	34.21	36.65	40.39	43.17	44.74	47.09	48.40
	4.38	8.94	12.27	15.51	17.87	20.50	25.76	29.35	31.80	34.43	36.88	40.65	42.93	44.50	45.82	47.13
Mean	5.11	8.98	12.40	15.61	18.43	21.12	25.98	29.88	32.49	35.26	37.48	40.90	43.29	45.02	46.63	47.98
IR-BLG	6.47	11.45	16.78	19.49	22.29	26.13	30.33	36.18	39.68	47.72	53.05	58.47	60.48	61.00	62.40	62.05
	6.49	12.53	16.83	19.55	23.40	25.68	31.47	35.76	41.37	47.86	54.26	59.17	61.18	61.71	62.58	62.23
	6.39	11.83	16.06	19.77	22.53	25.81	30.99	35.74	41.26	48.17	53.95	59.82	61.29	61.81	63.19	63.36
	4.91	10.51	15.42	19.19	22.60	26.28	31.01	36.71	42.32	50.20	56.33	62.73	65.01	65.53	66.85	66.58
	4.38	11.55	16.45	20.22	22.58	26.26	31.51	37.72	42.27	50.68	55.75	62.67	63.37	64.42	65.73	65.99
	5.41	10.99	14.83	18.05	21.98	25.64	30.88	36.55	42.13	49.98	55.66	62.45	63.67	64.19	65.50	65.24
Mean	5.67	11.48	16.06	19.38	22.56	25.97	31.03	36.44	41.51	49.10	54.83	60.88	62.50	63.11	64.38	64.24
IR-GNG	6.51	10.99	14.77	18.55	22.42	25.76	29.98	33.76	36.75	40.62	43.34	47.74	50.29	51.34	52.75	52.92
	6.02	10.53	14.87	19.20	22.56	25.93	30.70	33.98	38.05	40.88	43.62	48.58	50.08	51.67	52.56	53.27
	7.48	10.87	15.65	19.39	22.18	25.48	30.70	34.96	37.39	40.70	43.92	47.74	49.74	51.31	52.70	52.87
	5.41	9.94	14.30	18.05	20.93	24.60	30.35	34.97	37.94	41.60	44.57	49.37	51.63	53.20	55.03	54.77
	4.42	9.54	13.43	16.70	20.14	23.32	28.63	33.31	36.31	39.49	43.03	46.83	49.65	50.71	52.57	52.83
	5.46	8.99	13.40	15.60	19.56	22.74	27.50	31.11	34.11	37.81	39.75	44.59	46.89	49.00	49.79	50.59
Mean	5.88	10.14	14.40	17.92	21.30	24.64	29.64	33.68	36.76	40.18	43.04	47.47	49.71	51.21	52.57	52.88
IR-RDG	6.91	10.80	15.56	19.27	22.56	27.40	36.21	42.00	47.53	52.89	56.09	58.85	61.88	61.88	63.78	63.95
	5.99	11.01	16.38	19.64	22.98	27.39	35.31	40.68	45.79	50.72	54.51	57.33	59.35	60.41	61.82	62.00
	5.96	11.49	17.37	19.56	23.95	27.80	35.17	42.10	45.61	51.57	54.82	58.68	60.17	61.22	62.63	62.80
	3.86	8.95	14.39	18.69	22.11	25.80	34.22	42.03	45.54	51.34	54.32	58.09	59.85	61.43	62.74	63.01
	5.39	9.92	14.79	18.53	22.44	26.61	34.96	41.14	46.71	52.45	54.88	59.14	61.40	62.45	63.23	63.49
	4.87	8.87	12.18	16.96	20.35	24.53	32.35	39.57	44.10	49.31	52.79	56.53	58.80	59.84	61.14	61.40
Mean	5.50	10.17	15.11	18.77	22.40	26.59	34.71	41.26	45.88	51.38	54.57	58.11	60.24	61.20	62.56	62.78

APPENDIX TABLE 4

Daily intake (g/day) of dry matter and nutrients from total mixed ration for individual goats in different groups during digestion trial

Goat No.	DM	OM	CP	EE	CF	NFE	Body wt	%DMI
Group I								
21	1129.58	1051.30	71.73	24.51	476.91	488.54	31.59	3.57
19	1599.48	1488.64	101.57	34.71	675.30	691.77	36.14	4.42
20	1519.18	1413.90	96.47	32.97	641.40	657.04	37.16	4.09
15	1014.90	944.57	64.45	22.02	428.94	438.94	26.90	3.77
Mean	1315.78	1224.60	83.55	28.55	555.52	569.07	32.95	3.96
±SE	±165.69	±154.20	±10.52	±3.60	±69.95	±71.66	±2.71	±0.21
Group II								
6	1779.68	1578.93	243.10	38.79	500.45	821.32	30.95	5.75
2	1411.00	1251.84	192.74	30.76	396.77	651.17	29.66	4.76
10	1476.07	1309.57	201.63	32.18	415.07	681.21	33.93	4.35
1	1243.63	1103.35	169.88	27.11	349.71	573.93	27.40	4.54
Mean	1477.59	1310.92	201.84	32.21	415.5	681.91	30.48	4.85
±SE	±129.29	±114.71	±17.66	±2.82	±36.36	±59.67	±1.57	±0.36
Group III								
9	1575.44	1392.22	221.82	38.28	410.87	752.74	30.62	5.14
7	1516.55	1340.17	213.53	36.85	395.51	724.61	31.96	4.74
5	1470.38	1299.37	207.03	35.73	383.47	702.55	25.61	5.74
8	1597.88	1412.05	224.98	38.83	416.73	763.47	25.36	6.30
Mean	1540.06	1360.95	216.84	37.42	401.64	735.84	28.39	5.48
±SE	±33.34	±29.46	±4.69	±0.81	±8.70	±15.93	±1.96	±0.39
Group IV								
12	1308.36	1210.23	135.41	53.25	381.91	662.95	32.78	3.99
13	986.63	912.63	102.12	40.15	288.00	499.79	24.52	4.02
14	1698.69	1571.29	175.81	69.14	495.85	860.73	31.73	5.35
16	1763.65	1631.37	182.54	71.78	514.81	893.64	35.29	5.00
Mean	1439.33	1331.38	148.97	58.58	420.14	729.28	31.59	4.59
±SE	±209.38	±193.68	±21.67	±8.52	±61.12	±106.13	±2.44	±0.40

APPENDIX TABLE 5

Quantity of faeces voided (g/day) and its proximate composition (%DM) for individual goats in different digestibility groups

Goat No.	Wet	Dry	TA	OM	CP	EE	CF	NFE
Group I								
21	983.00	496.91	8.60	91.40	7.49	0.38	33.75	49.78
19	1933.00	776.87	10.00	90.00	6.91	0.58	38.48	44.03
20	1767.00	701.67	9.12	90.88	7.23	0.54	37.02	46.09
15	1042.00	459.21	8.85	91.15	7.97	0.47	39.12	43.59
Mean	1431.25	608.66	9.14	90.86	7.40	0.49	37.09	45.87
±SE	±282.25	±89.30	±0.35	±0.35	±0.26	±0.05	±1.38	±1.63
Group II								
6	1702.00	774.58	21.30	78.70	12.74	1.05	21.81	43.10
2	1446.00	578.11	20.45	79.55	13.92	0.92	19.65	45.06
10	1440.00	671.04	19.89	80.11	11.79	0.79	23.47	44.06
1	1198.00	567.01	18.46	81.54	13.62	0.74	23.04	44.14
Mean	1446.5	647.68	20.02	79.97	13.02	0.87	21.99	44.09
±SE	±118.83	±55.77	±0.69	±0.69	±0.55	±0.08	±0.99	±0.46
Group III								
9	1724	693.39	19.63	80.37	13.56	1.52	21.67	43.62
7	1834	726.63	19.12	80.88	14.00	1.30	20.36	45.22
5	1954	677.45	20.80	79.20	13.68	1.10	19.08	45.34
8	1836	729.63	18.29	81.71	13.52	1.16	23.07	43.96
Mean	1837	706.77	19.46	80.54	13.69	1.27	21.04	44.53
±SE	±54.23	±14.74	±0.61	±0.61	±0.12	±0.11	±0.99	±0.50
Group IV								
12	1350	534.33	13.87	86.13	12.63	0.96	24.36	48.18
13	865	384.23	14.54	85.46	12.03	0.89	23.35	49.19
14	2239	765.96	12.68	87.32	11.08	0.87	26.50	48.87
16	2097	758.27	13.30	86.70	11.00	0.87	24.73	50.10
Mean	1637.75	610.70	13.60	86.40	11.68	0.90	24.73	49.08
±SE	±373.04	±106.98	±0.46	±0.46	±0.45	±0.02	±0.76	±0.46

APPENDIX TABLE 6

Outgo of dry matter and nutrients (g/day) in faeces for individual goats in different digestibility groups

Goat No.	DM	TA	OM	CP	EE	CF	NFE
Group I							
21	496.91	42.73	454.17	37.22	1.89	167.71	247.36
19	776.87	77.69	699.18	53.68	4.50	298.94	342.05
20	701.67	63.99	637.68	50.73	3.79	259.76	323.40
15	459.21	40.64	418.57	36.60	2.16	179.64	200.17
Mean	608.66	56.26	552.4	44.56	3.08	226.51	278.24
±SE	±89.30	±10.25	±79.15	±5.15	±0.73	±36.52	±38.24
Group II							
6	774.58	164.98	609.59	98.68	8.13	168.93	333.84
2	578.11	118.22	459.89	80.47	5.32	113.60	260.50
10	671.04	133.47	537.57	79.11	5.30	157.49	295.66
1	567.01	104.67	462.34	77.23	4.19	130.64	250.28
Mean	647.68	130.33	517.35	83.87	5.73	142.66	285.07
±SE	±55.77	±14.96	±41.16	±5.75	±0.97	±14.52	±21.87
Group III							
9	693.39	136.11	557.28	94.02	10.54	150.26	302.46
7	726.63	138.93	587.70	101.73	9.54	147.94	328.58
5	677.45	140.91	536.54	92.67	7.45	129.26	307.15
8	729.63	133.45	596.18	98.64	8.46	168.32	320.74
Mean	706.77	137.35	569.42	96.76	8.97	148.94	314.73
±SE	14.74	±1.88	±15.91	±2.41	±0.76	±9.22	±6.96
Group IV							
12	534.33	74.11	460.22	67.48	5.13	130.16	257.44
13	384.23	55.87	328.36	46.22	3.42	89.72	189.00
14	765.96	97.12	668.84	84.87	6.66	202.98	374.32
16	758.27	100.85	657.42	83.41	6.60	187.52	379.89
Mean	610.70	81.99	528.71	70.49	5.45	152.59	300.16
±SE	106.98	±12.15	±94.89	±10.39	±0.88	±30.21	±53.79

APPENDIX TABLE 7

Nutrient digestibility in individual goats in different digestibility groups

Goat No.	DM	OM	CP	EE	CF	NFE	TDN
Group I							
21	56.01	56.80	48.11	92.29	64.83	49.37	55.35
19	51.43	53.03	47.15	87.03	55.73	50.59	51.73
20	53.81	54.90	46.41	88.50	59.50	50.78	53.49
15	54.75	55.68	43.21	90.19	58.07	54.40	54.27
Mean	54.00	55.10	46.47	89.50	59.53	51.28	53.71
±SE	±1.12	±0.92	±1.27	±1.31	±1.25	±1.25	±0.88
Group II							
6	56.48	61.39	59.41	79.04	66.24	59.35	56.63
2	59.03	63.29	58.25	82.70	71.37	60.00	58.40
10	54.54	58.95	60.76	83.53	62.06	56.60	54.59
1	54.41	58.10	54.54	84.54	62.64	56.39	52.54
Mean	56.11	60.42	58.24	82.45	65.68	58.08	55.54
±SE	±1.25	±1.36	±1.54	±1.38	±2.47	±1.07	±1.46
Group III							
9	55.99	59.97	57.61	72.47	63.43	59.82	55.19
7	52.09	56.15	52.36	74.35	62.59	54.65	50.79
5	53.93	58.17	55.24	79.15	66.29	56.28	54.29
8	54.34	57.78	56.16	78.21	59.61	57.99	53.45
Mean	54.09	58.15	55.34	76.04	62.98	57.18	53.43
±SE	±0.92	±0.93	±1.28	±1.82	±1.59	±1.28	±1.09
Group IV							
12	59.16	61.97	50.17	90.37	65.92	61.17	61.91
13	61.05	64.02	54.73	91.48	68.84	62.18	63.85
14	54.91	57.43	51.73	90.37	59.06	56.51	57.72
16	57.00	59.70	54.30	90.80	63.57	57.49	59.84
Mean	58.03	60.78	52.73	90.75	64.35	59.34	60.83
±SE	±1.54	±1.64	±1.25	±0.30	±2.38	±1.59	±1.52

APPENDIX TABLE 8

Cumulative gas production values from faeces over 24 hours
for individual goats

Goat No.	Gas (ml/200 mg DM)	
	Without PEG	With PEG
Group I		
21	13.99	13.97
19	14.75	16.17
20	17.72	15.89
15	14.33	15.21
Mean	15.20	15.31
±SE	±0.98	±0.56
Group II		
6	2.88	3.66
2	2.61	2.88
10	2.06	2.07
1	2.62	3.69
Mean	2.54	3.07
±SE	±0.20	±0.44
Group III		
9	4.52	4.77
7	4.76	6.41
5	3.71	5.34
8	6.95	6.69
Mean	4.98	5.80
±SE	±0.80	±0.52
Group IV		
12	4.98	6.86
13	6.14	5.87
14	9.35	12.57
16	8.50	9.33
Mean	7.24	8.65
±SE	±1.17	±1.72

APPENDIX TABLE 9

Metabolizable energy content of the total mixed ration used in digestion trial, as obtained by *in vivo* digestion trial, RIVIGP and SEDS

Goat No.	DMI (g/day) TMR	ME (MJ/kg DM)						
		In vivo	RIVIGP			SEDS		
			TMR	Straw	Chunni	TMR	Straw	Chunni
Group I								
21	1129.58	8.52	7.35	12.54	9.89	5.45	13.23	9.26
19	1599.48	7.98	7.35	12.54	9.89	5.45	13.23	9.26
20	1519.18	8.24	7.35	12.54	9.89	5.45	13.23	9.26
15	1014.90	8.36	7.35	12.54	9.89	5.45	13.23	9.26
Mean ±SE	1315.78 ±165.69	8.27 ±0.13	7.35	12.54	9.89	5.45	13.23	9.26
Group II								
6	1779.68	8.79	6.24	9.81	7.99	4.27	11.84	7.98
2	1411.00	9.06	6.24	9.81	7.99	4.27	11.84	7.98
10	1476.07	8.48	6.24	9.81	7.99	4.27	11.84	7.98
1	1243.63	8.17	6.24	9.81	7.99	4.27	11.84	7.98
Mean ±SE	1477.59 ±129.29	8.62 ±0.22	6.24	9.81	7.99	4.27	11.84	7.98
Group III								
9	1575.44	8.66	6.71	10.90	8.76	4.55	12.43	8.41
7	1516.55	8.00	6.71	10.90	8.76	4.55	12.43	8.41
5	1470.38	8.53	6.71	10.90	8.76	4.55	12.43	8.41
8	1597.88	8.4	6.71	10.90	8.76	4.55	12.43	8.41
Mean ±SE	1540.06 ±33.34	8.40 ±0.16	6.71	10.90	8.76	4.55	12.43	8.41
Group IV								
12	1308.36	9.65	8.86	12.94	10.86	6.06	12.58	9.25
13	986.63	9.94	8.86	12.94	10.86	6.06	12.58	9.25
14	1698.69	9.01	8.86	12.94	10.86	6.06	12.58	9.25
16	1763.65	9.33	8.86	12.94	10.86	6.06	12.58	9.25
Mean ±SE	1439.33 ±209.38	9.48 ±0.23	8.86	12.94	10.86	6.06	12.58	9.25

APPENDIX TABLE 10

Weekly average dry matter intake (g/day) from total mixed rations for individual goats in different groups during feeding trial

Goat No.	Week				Mean
	1	2	3	4	
Group I					
21	1175.69	1284.42	1273.76	1129.58	1215.86
19	1397.25	1470.86	1682.40	1599.48	1537.50
20	1441.66	1733.14	1517.88	1519.18	1552.96
15	1282.05	972.85	1094.84	1014.90	1091.16
Mean	1324.16	1365.32	1392.22	1315.78	1349.37
±SE	±69.09	±184.70	±149.99	±165.69	±133.89
Group II					
6	1303.02	1610.30	1689.82	1779.68	1595.70
2	926.93	1068.78	1336.40	1411.00	1185.78
10	1194.04	1474.62	1608.46	1476.07	1438.30
1	1003.59	1101.84	1165.66	1243.63	1128.68
Mean	1106.89	1313.88	1450.08	1477.59	1337.11
±SE	±99.51	±155.90	±139.99	±129.29	±126.25
Group III					
9	1421.36	1695.86	1690.11	1575.44	1595.69
7	1484.17	1627.80	1575.40	1516.55	1550.98
5	1075.37	1419.73	1601.30	1470.38	1391.69
8	1341.55	1575.53	1728.56	1597.88	1560.88
Mean	1330.60	1579.73	1648.84	1540.06	1524.81
±SE	±103.86	±67.84	±41.78	±33.34	±52.42
Group IV					
12	1329.47	1226.17	1244.56	1308.36	1277.14
13	1106.46	1188.23	1085.96	986.63	1091.82
14	1676.37	1690.93	1750.49	1698.69	1704.12
16	1746.04	1671.10	1728.45	1763.65	1727.31
Mean	1464.58	1444.11	1452.36	1439.33	1450.10
±SE	±173.39	±158.26	±195.09	±209.38	±182.47

APPENDIX TABLE 11

Weekly body weight (kg) of goats in different groups

Goat No.	Week					Mean
	1	2	3	4	5	
Group I						
21	29.42	31.02	31.74	33.69	32.06	31.59
19	32.54	34.32	37.48	38.02	38.33	36.14
20	35.42	36.42	37.20	38.52	38.25	37.16
15	27.14	26.63	26.84	27.13	26.74	26.90
Mean	31.13	32.10	33.31	34.34	33.84	32.95
±SE	±2.09	±2.46	±2.92	±3.04	±3.22	±2.71
Group II						
6	27.98	30.04	31.24	31.15	34.36	30.95
2	29.30	27.70	28.80	30.84	31.65	29.66
10	32.10	33.36	34.16	34.63	35.42	33.93
1	25.50	26.27	27.66	28.13	29.42	27.40
Mean	28.72	29.34	30.46	31.19	32.71	30.48
±SE	±1.59	±1.79	±1.66	±1.54	±1.56	±1.57
Group III						
9	27.54	29.52	31.90	31.62	32.54	30.62
7	28.36	30.93	33.56	32.54	34.40	31.96
5	23.05	24.26	26.74	26.86	27.14	25.61
8	23.30	25.82	26.04	26.12	25.52	25.36
Mean	25.56	27.63	29.56	29.28	29.90	28.39
±SE	±1.60	±1.80	±2.15	±1.88	±2.45	±1.96
Group IV						
12	31.65	32.33	32.22	33.43	34.28	32.78
13	21.37	25.26	25.32	25.40	25.23	24.52
14	29.82	31.26	32.66	32.80	32.12	31.73
16	34.36	34.04	36.02	36.26	35.76	35.29
Mean	29.30	30.72	31.55	31.97	31.85	31.59
±SE	±3.24	±2.20	±2.60	±2.67	±2.49	±2.44

EVALUATION OF MAJOR PULSE BYPRODUCTS OF NORTH KARNATAKA BY IN VITRO AND IN VIVO METHODS

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AUGUST 2005

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ABSTRACT

A study was conducted to assess the potential of RIVIGP-24 & SEDS to obtain estimates of energy values, PF and feeding potential of pulse byproducts namely chunnies and corresponding straws of bengal gram, black gram, green gram and red gram in goats. Sixteen adult Bidri goats of similar body weights were randomly divided into four equal groups. The goats in each group were offered *ad-libitum* TMR, which consisted of 48 parts chunnies, 50 parts of corresponding straws, 1 part mineral mixture, 0.5 part salt and 0.5 part lime powder. The ME (MJ/kg DM) content of TMR at maintenance level of intake (ME_m) was 8.57, 9.01, 8.83 & 9.97 in group I, II, III & IV, respectively. The corresponding estimates obtained from RIVIGP (with PEG-6000) & SEDS were 9.89 and 9.26, 7.99 and 7.98, 8.76 and 8.41 and 10.86 and 9.25, respectively. The PF (mg/ml) at the time of half asymptotic gas production ($t_{1/2}$) for four TMR was 2.72, 3.55, 3.59 and 3.14, respectively. The result of digestibility trial revealed significantly ($P \leq 0.05$) higher DMI in group – III. The DMI varied from 3.96 to 5.48 percent of body weight. The CP digestibility was significantly ($P \leq 0.01$) higher in group-II.

It was concluded that the TMR prepared from pulse chunnies and straws will meet the ME requirement (8.57 to 9.97 MJ/Kg DM) of goats, which will be equivalent to 1.50 to 1.80 times of the maintenance requirement.