

**NUTRITIVE VALUE IMPROVEMENT AND UTILIZATION OF RICE
STRAW IN A TOTAL MIXED RATION FOR LAMBS**

By

MD. MAINUL HASAN

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

May 2006

DEDICATION

This thesis is dedicated to my parents, beloved family members, and friends for their continuous encouragement and inspiration.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

NUTRITIVE VALUE IMPROVEMENT AND UTILIZATION OF RICE STRAW IN A TOTAL MIXED RATION FOR LAMBS

By

MD. MAINUL HASAN

May 2006

Chairman: Associate Professor Mohd Ridzwan Abd. Halim, PhD

Faculty: Agriculture

In the nutritional assessment study - two popular rice varieties in Malaysia namely, MR 185 and MR 219 were examined. Significant variations in straw nutritional composition were observed between plant fractions of rice varieties. Variations were also observed between the cut and stubble fraction of rice plants. The leaves of cut fraction for MR 185 straw variety showed higher nutritive quality, in terms of crude protein concentration (6.8%), fiber (ADF 46.8% and NDF 69.5%), total digestible nutrients (50.4%) and digestible energy (2.2 MJ/kg) compared to the stubble and un-cut plant parts. Therefore, cut fraction of straw was recommended to be collected for ruminant feed and the stubble could be incorporated into the soil to maintain land productivity for the next crop or other purpose.

In another experiment, changes of protein and fiber concentration of rice straw were observed over time. Rice straw was exposed to open weather in the field for 30 days. Nutritive values of rice straw were found to be relatively stable when they were

exposed to the weather. There was no significant reduction of CP concentration but fiber concentration increased with delaying straw collection from the field. Therefore, farmers could delay straw collection from the field but earlier collection of straw was suggested for feeding ruminants.

In the nutritive value improvement study - two straw treatment (urea and steam) methods of rice straw were evaluated. Urea increased CP concentration of treated rice straw by 47% compared to untreated rice straw. *In vitro* DM and OM digestibility of urea treated rice straw was increased by 29.3% and 35.9%, respectively compared to the untreated rice straw. This was confirmed by the *in vitro* gas production at a sequential incubation with buffered rumen fluid. Potential gas volume was higher in urea treated rice straw (52.2 ml/200mg) than untreated rice straw (41.9 ml/200mg) and steam treated rice straw (50.9 ml/200mg). Steam treatment caused a significant decrease in lignin (ADL) concentration (30.3%) compared to urea treated rice straw (34.1%) and untreated rice straw (35.0%) due to the effect of high pressure and rapid decompression to weaken the cell wall structure and the release of fermentable sugar from the depolymerized lignin and cell wall matrix. The disruptions and the physical changes in rice straw cell wall structure due to steam treatment enable microbes to penetrate to the cell wall matrix resulting in improved digestibility.

In the feed evaluation study – iso-nitrogenous and iso-caloric various formulation of total mixed ration was examined. Three straw treatments (untreated, urea and steam treated) and three levels (40, 55 and 70%) of straw inclusion were used together with other ingredients to make total mixed ration.

In a feeding trial, dry matter intake of the ration and average daily gain of the Malin local-bred lambs was examined. The ration comprising 40% steam treated straw showed highest intake ($126.5 \text{ g kg}^{-1} \text{W}^{0.75}$) and gave highest daily gain (176.8 g d^{-1}). Untreated straw with 70% inclusion showed lowest intake ($71.7 \text{ g kg}^{-1} \text{W}^{0.75}$) and gave the lowest weight gain (50.0 g d^{-1}). Steam treated ration increased intake by 27.4% and urea treated ration by 21.5%; average daily gain of the lambs increased by 73.5% in steam and 65.0% in urea treated ration compared to untreated ration. Increasing level of straw inclusion from 40 to 70% reduced intake by 21.1% and weight gain by 38.8%.

In the digestibility study, there were no significant differences ($P>0.05$) in nutritional quality among the rations. No significant differences were also obtained in rate of particulate particle constant, mean retention time and solid flow rate. However, increasing level of straw inclusion tended to increase retention time due to the slower passage rate. Therefore, this study concluded that the rice straw has a potential to be utilized in ruminant feeding system by using straw treatment and improving its nutritive value with the addition of other ingredients. Hence, production of TMR is worth trying and this could conceivably be practiced by large farms for intensive ruminant production.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PEMBAIKAN NILAI PEMAKANAN DAN KEGUNAAN JERAMI PADI
DALAM RANGSUM CAMPURAN LENGKAP UNTUK KAMBING BIRI-
BIRI**

Oleh

MD. MAINUL HASAN

Mei 2006

Pengerusi: Profesor Madya Mohd Ridzwan Abd. Halim, PhD

Fakulti: Pertanian

Di dalam kajian nilai pemakanan – dua varieti padi yang popular di Malaysia iaitu, MR 185 dan MR 219 diuji. Variasi yang bererti di dalam kandungan nilai pemakanan telah diperhatikan diantara pecahan bahagian-bahagian tumbuhan kedua-dua varieti padi. Variasi juga diperhatikan antara bahagian tanaman padi lain yang dipotong dan bahagian batang padi. Bahagian daun yang dipotong bagi jerami padi varieti MR 185 menunjukkan kualiti pemakanan yang paling tinggi iaitu, kepekatan protein kasar (6.8%), serat (ADF 46.8% dan NDF 69.5%), jumlah nutrien boleh-hadam (50.4%) dan tenaga boleh-hadam (2.2 MJ/kg) berbanding batang padi dan bahagian tanaman yang tidak dipotong. Oleh itu, jerami padi daripada bahagian tanaman yang dipotong adalah disyorkan untuk dijadikan makanan haiwan ruminan dan bahagian batang padi pula boleh dicampur/digaul ke dalam tanah untuk mengekalkan produktiviti bagi tanaman selepasnya atau bagi tujuan lain.

Di dalam eksperimen yang lain pula perubahan kepekatan protein dan serat bagi jerami padi ini diperhatikan dari masa ke semasa. Jerami padi didedahkan kepada cuaca di padang selama 30 hari. Kualiti pemakanan jerami padi ini didapati agak stabil apabila ia didedahkan kepada cuaca. Langsung tiada kemerosotan CP kasar yang jelas berlaku tetapi kepekatan serat bertambah seiring dengan masa atau berkadar terus dengan masa. Dengan ini, petani boleh melewati pengumpulan / kutipan jerami daripada ladang tersebut tetapi pengumpulan yang lebih awal disyorkan jika jerami tersebut digunakan untuk makanan ruminan.

Di dalam kajian lanjutan nilai pemakanan – dua rawatan jerami iaitu kaedah urea dan stim telah dijalankan dan dinilai. Urea meningkatkan kepekatan CP jerami padi sebanyak 47% dibandingkan dengan jerami padi yang tidak dirawat. *In vitro* bagi bahan kering (DM) dan bahan organik (OM) boleh hadam bagi jerami padi yang dirawat oleh urea meningkat sebanyak 29.3% dan 35.9%, masing-masing berbanding jerami padi yang tidak dirawat. Ini dibuktikan oleh pengeluaran gas *in vitro* pada turutan inkubasi/pengeraman dengan penampunan cecair rumen. Keupayaan pengeluaran isipadu gas paling tinggi diperolehi daripada jerami padi yang dirawat dengan urea (52.2 ml/200mg) berbanding jerami yang tidak dirawat (41.9 ml/200mg) dan jerami yang dirawat dengan stim (50.9 ml/200mg) disebabkan oleh kadar malar bererti yang lebih tinggi untuk pengeluaran gas telah diperolehi dengan jerami yang diberi rawatan berbanding dengan tanpa rawatan dan rawatan stim. Rawatan stim menyebabkan peningkatan yang bererti di dalam kepekatan lignin (ADL) (30.3%) berbanding jerami yang dirawat dengan urea (34.1%) dan jerami tanpa rawatan (35.0%) disebabkan oleh kesan daripada tekanan yang tinggi dan pemampatan yang cepat untuk melemahkan struktur dinding sel dan membebaskan gula fermentasi

daripada lignin depolimerisasi dan dinding sel matriks. Gangguan dan penukaran fizikal pada dinding struktur sel jerami padi disebabkan oleh rawatan stim yang membolehkan mikrob menembusi dinding sel matriks dan menghasilkan peningkatan terhadap keboleh-hadaman. Oleh itu, jerami yang dirawat dengan stim juga berkesan dalam meningkatkan kualiti jerami padi tetapi keperluan tenaga dan kos menghadkan penggunaannya oleh petani-petani yang kekurangan sumber.

Di dalam kajian menilai pemakanan - variasi formulasi iso-nitrogenous dan iso-caloric bagi rangsum campuran lengkap telah diuji. Tiga jenis rawatan (tanpa rawatan, urea dan stim) dan tiga paras (40, 55 and 70%) jerami dengan penyertaan bahan lain digunakan untuk menyediakan rangsum campuran lengkap. Dalam percubaan pemberian makanan, pengambilan bahan kering rangsum ini dan hasil purata harian bagi baka kambing tempatan Malin telah diuji. Rangsum terdiri daripada 40% jerami yang distim menunjukkan pengambilan yang paling tinggi ($126.5 \text{ g kg}^{-1} \text{W}^{0.75}$) dan memberi hasil harian yang paling tinggi (176.8 g d^{-1}). Jerami dengan penyertaan 70% bahan lain tanpa rawatan menunjukkan pengambilan yang paling rendah ($71.7 \text{ g kg}^{-1} \text{W}^{0.75}$) dan memberi hasil yang paling rendah (50.0 g d^{-1}). Rangsum yang dirawat dengan stim menunjukkan pengambilan yang meningkat 27.4% dan rangsum yang dirawat urea sebanyak 21.5%; hasil purata harian kambing meningkat sebanyak 73.5% bagi rangsum dengan rawatan stim dan 65.0% bagi rangsum dengan rawatan urea berbanding tanpa rawatan. Paras peningkatan bagi jerami yang dicampur dengan 40 to 70% bahan lain menurun pengambilannya sebanyak 21.1% dan hasil berat yang diperolehi ialah 38.8%.

Untuk kajian boleh-hadam tiada terdapat perbezaan yang bererti ($P>0.05$) dalam kualiti pemakanannya diantara rangsum. Tiada perbezaan bererti juga diperoleh pada kadar particulate partikel tetap, min masa penahanan dan kadar aliran pejal. Walau bagaimanapun, paras peningkatan jerami campuran cenderung kepada penambahan masa penahanan disebabkan oleh kadar laluan yang perlahan. Kesimpulannya jerami padi mempunyai potensi untuk digunakan sebagai sistem pemberian makanan untuk ruminan melalui penekanan terhadap rawatan jerami dan memperbaiki nilai pemakanannya dengan penggunaan teknologi untuk meningkatkan nilai tambahnya. Lagi pula, pengeluaran TMR adalah berbaloi untuk dicuba, di mana ia mungkin boleh diamalkan oleh ladang-ladang besar untuk pengeluaran ruminan yang intensif.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to the chairman of my supervisory committee, Associate Professor Dr. Mohd Ridzwan Abd. Halim, Department of Crop Science, Faculty of Agriculture, Universiti Putra Malaysia, for his guidance, suggestions and encouragements. My gratitude also extended to the other members of the supervisory committee, Associate Professor Dr. Liang Juan Boo and Professor Dr. Abdul Razak Alimon, at Department of Animal Science, Faculty of Agriculture, Universiti Putra Malaysia, for their invaluable guidance, comments and suggestions on my research and manuscript of dissertation.

My sincere thanks expressed to all of my friends who have helped me in many ways in conducting the experiment. I would like to thanks to the entire staff of the Faculty of Agriculture, Universiti Putra Malaysia, for their kind cooperation in providing facilities and assistance during my study. Thanks to the staff of MARDI, Serdang to allow me to use their instrumental facilities for pelletizing the experimental ration. I am also indebted to the National Council for Scientific Research and Development, Ministry of Science and Technology, Malaysia for funding this project.

Finally, my sincere appreciation goes to my parents and beloved family members for their understanding, patience and moral support throughout my study. Thanks for sacrifice to my wife, Mamotaj Dilruba and my daughter, Maheen Mamota Hasan.

I certify that an Examination Committee has met on 9th May 2006 to conduct the final examination of Md. Mainul Hasan on his Doctor of Philosophy thesis entitled “Nutritive Value Improvement and Utilization of Rice Straw in a Total Mixed Ration for Lambs” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

Idris Abdol, PhD

Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Halimatun Yaakub, PhD

Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Zainal Aznam Mohd Jelani, PhD

Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Metha Wanapat, PhD

Professor
Faculty of Agriculture
Khon Kaen University
(External Examiner)

HASANAH MOHD. GHAZALI, PhD

Professor/Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

Mohd Ridzwan Abd. Halim, PhD

Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Abdul Razak Alimon, PhD

Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Liang Juan Boo, PhD

Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

AINI IDERIS, PhD

Professor/Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MD. MAINUL HASAN

Date:

TABLE OF CONTENTS

	Page
DEDICATION	ii
ABSTRACT	iii
ABSTRAK	vi
ACKNOWLEDGMENTS	x
APPROVAL	xi
DECLARATION	xiii
LIST OF TABLES	xvii
LIST OF FIGURES	xviii
LIST OF PLATES	xix
LIST OF ABBREVIATIONS	xx
CHAPTER	
I INTRODUCTION	1
II LITERATURE REVIEW	6
Characteristic features of rice straw	6
Feeding value of rice straw	9
Challenges in feeding rice straw	11
Variability in rice straw quality	13
Morphological and varietal characters	14
Cultural and management practices	16
Impact of time of harvest and time to baling of rice straw	17
Fibrous residues and their characters	20
Problems of feeding fibrous residues	21
Need for improvement of rice straw	23
Practical aspects of treating fibrous residues	24
Current utilization of fibrous residues	25
Effect of grinding and pelleting on feed processing	27
Treatments of rice straw	29
Physical methods	30
Chemical methods	31
Supplementation of low quality fibrous residues	33
Formulation of straw-base ration for ruminants	35
Economic evaluation of rice straw-based feed	37
Fiber digestion in ruminant animals	39
Evaluation of feed through digestibility	40
Techniques for measuring digestibility	40
Factors affecting feed intake	41
Factors affecting digestibility	43
Plant factor	43
Rumen microbial factor	44
Passage rate of rumen digesta	45
Flow dynamics	46

	Potentials of rice straw-based feed	47
	Development of various livestock feeds from oil palm by-products	48
	OPF based total mixed ration for ruminants	52
III	VARIABILITY OF NUTRIENT COMPOSITION IN FRACTIONS OF RICE PLANT AND CHANGES OF THEIR PROPERTIES OVER TIME	54
	Introduction	54
	Materials and methods	57
	Sample collection	57
	Sample management	58
	Sample preparation and treatments	59
	Chemical analysis	60
	Statistical analysis	60
	Results	61
	Nutritive values of rice straw	61
	Changes of CP and ADF concentration over time	63
	Discussion	65
	Nutritive values of rice straw	65
	Changes of CP and ADF concentration over time	68
	Conclusion	69
IV	EVALUATION OF STEAM AND UREA TREATMENT FOR IMPROVING THE NUTRITIVE VALUE AND DIGESTIBILITY OF RICE STRAW	70
	Introduction	70
	Materials and methods	73
	Collection of rice straw sample	73
	Sample preparation and treatments	73
	Urea treatment of rice straw	74
	Steam treatment of rice straw	75
	<i>In vitro</i> techniques	75
	Chemical analysis	78
	Statistical analysis	78
	Results	79
	Effect of treatment on nutritive values of rice straw	79
	<i>In vitro</i> gas production	80
	<i>In vitro</i> digestibility	81
	Discussion	82
	Effect of treatments on nutritive values of rice straw	82
	<i>In vitro</i> digestibility and gas production	85
	Conclusion	87
V	FORMULATION AND EVALUATION OF TOTAL MIXED RATION OF RICE STRAW FOR FEEDING LAMBS	88
	Introduction	88
	Materials and methods	91
	Experimental site and duration of study	91
	Dietary treatments and preparation of TMR	91
	Production process of TMR	93

Animal, management and experimental design	96
Measurements and sample collection	96
Feeding trial	96
Feed intake and weight gain	96
Digestibility trial	97
Faecal collection	97
Passage rate	97
Cr-detection from faecal grab	98
Chemical analysis and calculation	99
Statistical analysis	99
Results	100
Compositions of dietary treatments	100
Feed intake and weight gain	101
Nutrient digestibility of dietary rations	103
Out flow rate of particulate particles and mean retention time	104
Optimum formulation of total mixed ration of rice straw	105
Discussion	106
Nutritional facts of the dietary treatments	106
Feed intake and weight gain	106
Nutrient digestibility	107
Out flow rate and mean retention time	110
Conclusion	112
VI GENERAL DISCUSSION AND CONCLUSIONS	114
REFERENCES	121
APPENDICES	141
BIODATA OF THE AUTHOR	155