UNIVERSITI PUTRA MALAYSIA

UTILISATION OF TREATED STRAW FROM NEWLY-DEVELOPED PadiU PUTRA-1 RICE VARIETY AS FEED SUPPLEMENT FOR SUSTAINABLE GOAT PRODUCTION

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IPTSM 2022 5

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By

AHMED MUIDEEN ADEWALE

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

February 2022

DEDICATIONS

This Thesis Is Dedicated to My Father, Mother and My Siblings with Love, Humility and Respect

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

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February 2022

Chairman : Professor Awis Qurni bin Sazili, PhD
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The persistent challenges of meeting the global population's demand for animal protein in the ruminant industry, centred on feed to boost production. To bridge the niche areas for the realisation of food security, the availability of feed that is cheap, noncompetitive, qualitative, and sustainable is required. Agricultural waste, such as rice straw that is illicitly disposed of, causing health impairment and global environmental nuisance through burning could be improved by biological additive and used as ruminant feed. However, biological additives have been reported to improve straw quality through ensiling and possibly animal performance. As a result, the objective of the study refers to the use of enriched straw from a newly developed rice variety as a feed supplement for a sustainable goat production. This thesis comprised of three research chapters.

The aim of the first experiment was to examine the efficacy of biological additives on nutrient profiles, ensile quality, *in vitro* rumen fermentation in different varieties of treated rice straw; ML4, ML10, ML21, ML24, MR219 and PadiU Putra-1 were ensiled with water (Control), enzyme (E) and combination of bacteria and enzyme (BE) in a complete randomise design (CRD) experiment. The rice straw varieties, obtained from the paddy research farm were chopped to about 2-3 cm, treated according to the above treatments to attain 70% moisture content, compressed in a 1 L jar and ensiled for 30 days. Results showed that treatment with the combination of bacteria and enzyme had lower neutral detergent fiber (42.31%) and lower acid detergent fiber (21.08%) for PadiU Putra-1 than other treatments (enzyme and control) and varieties. For the ensiled extract, the lowest pH, NH_3, butyric acid and propionic acid were obtained in BE treatment in most of the rice straw varieties. In addition, straw treated with BE had significantly higher lactic acid content, *in vitro* gas production kinetics, digestibility, and rumen fermentation compared to the enzyme and control. This study revealed that a combination of bacterial and enzyme treatment effectively improved the quality of treated rice straw, with the PadiU Putra-1 variety being the most outstanding. Selection

of the appropriate biological treatment and variety of rice straw is important to improve straw quality. However, the treated rice straw needs further evaluation for its *in vivo* efficacy.

The second experiment investigated the effects of PadiU Putra-1 treated rice straw with biological additives on growth performance, nutrient digestibility, rumen fermentation, microbial population, and relative expressions of ruminal MCT1 and growth hormone genes in goats. Twenty-four male crossbred Boer goats were randomly assigned to the following diets: (i) Control (untreated straw); (ii) Enzyme treated straw; and (iii) BE, enzyme plus lactic acid bacteria treated straw. Each diet, in the form of total mixed ration consisted of 50% treated rice straw and 50% concentrate was fed at 3.5% DM body weight of the experimental animals for 14 weeks. The results showed that average daily gain (ADG) of goats was 13% and 26%, respectively, higher in enzyme and BE treatment than the control ($P<0.01$). Feed efficiency (gain:feed) was also enhanced by 8% and 23% in Enzyme and BE treatment diets relative to control. Goats fed treated straws had higher nutrient digestibility leading to higher digestible nutrient intake ($P<0.001$). Dietary treatments had no effect on rumen fermentation except propionate concentrations which were higher in the treated rice straw groups leading to lower acetate to propionate ratio ($P<0.01$). Goats fed treated rice straw had higher cellulolytic bacteria but lower protozoa and methanogens which resulted in lower methane concentration; greater expression of ruminal MCT1 and hepatic GHR, IGF-1 genes ($P<0.01$) indicating better rumen absorption, growth process and nutrient metabolism.
The third research chapter examines the influence of biologically treated rice straw on blood profiles (haematology and biochemistry), non-carcass, carcass characteristics and meat quality in goats. The blood samples from each animal were taken from the jugular vein using vacuum EDTA and serum tube for haematological and biochemical blood profile analysis ascertain the non-detrimental effect of the diet while the meat quality analysis was performed after the slaughtering and the ageing days. The blood profile results indicated dietary treatment had no detrimental effect on the haematological and biochemical profiles, but the days of sampling had significant effect. On the carcass trait, enzyme treatment increased slaughter weight, hot carcass, and cold carcass by 4%, 6%, and 6%, respectively, compared to the control, whereas BE treatment increased the above parameters by 9%, 13%, and 15%, respectively ($P<0.05$). In addition, the dietary treatment improved the chilling loss and dressing percentages, but had no effect on the non-carcass and primal cuts. Dietary treatment influenced the cooking loss percentage and shear force, whereas other physicochemical meat qualities were unaffected but had a post-mortem ageing effect.

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

PENGGUNAAN JERAMI YANG DIRAWAT DARIPADA PadiU PUTRA-1 YANG BAHARU DIHASILKAN SEBAGAI TAMBAHAN MAKANAN UNTUK PENGELUARAN KAMBING LESTARI

Oleh

AHMED MUIDEEN ADEWALE

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Cabaran berterusan untuk memenuhi permintaan populasi global untuk protein hewani dalam industri ruminan, tertumpu kepada makanan untuk meningkatkan produksi. Untuk menghubungkan kawasan khusus untuk mewujudkan keselamatan makanan, ketersediaan makanan yang murah, tidak kompetitif, kualitatif, dan lestari diperlukan. Sisa pertanian, seperti jerami padi yang dibuang secara haram menyebabkan gangguan kesihatan dan gangguan persekitaran global melalui pembakaran dapat dielakkan dengan bahan tambahan biologi dan digunakan sebagai makanan ruminan. Walau bagaimanapun, bahan tambahan biologi telah dilaporkan dapat meningkatkan kualiti jerami melalui pengawetan hijau dan kemungkinan meningkatkan prestasi haiwan. Hasilnya, objektif kajian merujuk kepada penggunaan jerami yang diperkaya dari varietas padi yang baru dihasilkan sebagai makanan tambahan untuk pengeluaran kambing yang lestari. Tesis ini terdiri daripada tiga bab penyelidikan.

Tujuan bab penyelidikan pertama adalah untuk mengkaji keberkesanan bahan tambahan biologi terhadap profil nutrien, kualiti silase, fermentasi rumen secare in vitro dalam pelbagai jenis silase jerami padi; ML4, ML10, ML21, ML24, MR219 dan PadiU Putra-1 diawetkan dengan air (Kawalan), enzim (E) dan kombinasi bakteria dan enzim (BE) dalam eksperimen reka bentuk rawak (CRD) lengkap. Varieti jerami padi yang diperoleh dari ladang penyelidikan padi dipotong menjadi kira-kira 2-3 cm, dirawat mengikut rawatan seperti di atas untuk mencapai kandungan kelembapan 70%, dimampatkan dalam balang 1 L dan diawet selama 30 hari. Hasil kajian menunjukkan bahawa protein mentah dalam silase jerami padi yang dirawat lebih tinggi daripada kawalan. Rawatan dengan kombinasi bakteria dan enzim mempunyai serat pencuci neutral yang lebih rendah (42,31%) dan serat pencuci asid yang lebih rendah (21,08%) untuk PadiU Putra-1 daripada rawatan (enzim dan kawalan) dan varieti lain. Untuk ekstrak silase, pH terendah, NH_3, asid butirat dan asid propionik diperoleh dalam rawatan BE pada kebanyakan varietas jerami padi. Jerami yang dirawat dengan BE memiliki kandungan asid laktat tertinggi, kinetik pengeluaran gas in vitro, pencernaan,

dan fermentasi rumen dibandingkan dengan enzim dan kawalan. Kajian ini mendedahkan bahawa gabungan rawatan bakteria dan enzim berkesan meningkatkan kualiti jerami padi yang dirawat, dengan varieti PadiU Putra-1 adalah yang paling menonjol. Pemilihan rawatan biologi dan varieti jerami padi adalah penting untuk meningkatkan kualiti jerami. Namun, jerami padi yang dirawat memerlukan penilaian lebih lanjut untuk keberkesanan in vivonya.

Bab penyelidikan kedua menyelidiki kesan PadiU Putra-1 jerami padi yang dirawat dengan bahan tambahan biologi terhadap prestasi pertumbuhan, pencernaan nutrien, fermentasi rumen, populasi mikrob, dan ekspresi relatif MCT1 secara rumin dan gen hormon pertumbuhan pada kambing. Dua puluh empat ekor kambing Boer jantan dipilih secara rawak dan diberikan diet berikut: (i) Kawal (jerami yang tidak dirawat); (ii) Jerami yang dirawat dengan enzim; dan (iii) BE, enzim ditambah jerami yang dirawat bakteria asid laktik. Setiap diet dalam bentuk jumlah catuan campuran terdiri dari 50% silase jerami padi dan 50% diberi makan dengan berat badan DM sebanyak 3.5% untuk haiwan percubaan selama 14 minggu. Hasil kajian menunjukkan bahawa purata penambahan berat harian kambing adalah masing-masing 13% dan 26%, lebih tinggi enzim dan silage BE daripada kawalan (P <0.01). Nisbah penukaran makanan juga ditingkatkan sebanyak 11% dan 19% dalam diet silase enzyme dan BE berbanding kawalan. Kambing yang diberi makan jerami yang diperlakukan mempunyai kecernaan nutrien yang lebih tinggi yang menyebabkan penyerapan nutrien yang dicerna lebih tinggi (P <0,001). Rawatan makanan tidak dipengaruhi fermentasi rumen kecuali kepekatan propionat yang lebih tinggi pada kumpulan silase yang dirawat menyebabkan nisbah asetat ke propionat lebih rendah (P <0,01). Kambing yang diberi makan silase mempunyai bakteria selulolitik yang lebih tinggi tetapi kandungan protozoa dan metanogen lebih rendah yang mengakibatkan kepekatan metana lebih rendah; ungkapan MCT1 rumin dan GHR hepatik, gen IGF-1 yang lebih besar (P <0.01) menunjukkan penyerapan rumin yang lebih baik dan penggunaan nutrien untuk pengeluaran.

Bab penyelidikan ketiga meneliti pengaruh silase jerami padi yang dirawat secara biologi terhadap profil darah (hematologi dan biokimia), bahagian bukan bangkai, ciri bangkai dan kualiti daging pada kambing. Sampel darah dari setiap haiwan diambil dari urat jugular dengan menggunakan vakum EDTA dan tiub serum untuk analisis profil darah hematologi dan biokimia sementara analisis kualiti daging dilakukan setelah penyembelihan dan hari penuaan. Hasil profil darah menunjukkan rawatan diet tidak memberi kesan buruk pada profil hematologi dan biokimia, tetapi hari-hari pengambilan sampel mempunyai pengaruh yang ketara. Pada sifat bangkai, rawatan enzim meningkatkan berat penyembelihan, bangkai panas, dan bangkai sejuk masing-masing sebanyak 4%, 6%, dan 6%, berbanding dengan rawatan kawalan, sedangkan rawatan BE meningkatkan parameter di atas sebanyak 9%, 13%, dan 15%, masing-masing (P <0.05). Di samping itu, rawatan diet meningkatkan peratusan kehilangan penyejukbekuan dan produksi bangkai, tetapi tidak berpengaruh pada bukan bangkai dan potongan primal. Rawatan makanan mempengaruhi peratusan kehilangan ketika memasak dan daya ricih, manakala kualiti fizikokimia daging yang lain tidak terjejas tetapi mempunyai kesan penuaan selepas kematian.

ACKNOWLEDGEMENTS

First of all, I want to thank Allah (S.W.T) to whom all adoration and praises is due for the successful completion of this work.

My utmost gratitude goes to my supervisor, chairman of my supervisory Committee, Prof. Dr. Awis Qurni Sazili for his patience, understanding, guidance and encouragement throughout the duration of this work in spite of his engagements. I wish to extend my special gratitude to my co-supervisor Dr. Liang Juan Boo, Prof. Dr. Mohd Rafii Yusop and Assoc. Prof. Dr. Nur Ain Izzati Mohd Zainudin for their magnanimous support, suggestion, good advice and germane criticism, may God reward you abundantly.

My special thanks to all members of my family for their love, motivation, encouragement and prayers. My surpassed parents, I remain deeply grateful for giving me the financial support and freedom to pursue my academic dream. I am exceedingly thankful for discomforting yourself to offer me the best. May Allah in His Infinite Mercy bestow on you long life in good health and happiness to reap from the fruit of your labor (AMIN). You are indeed my all in all. Also my appreciation goes to my siblings (Haleemat, Morufat, Rashidat, my niece and my nephew) and Jaleelah for their persistence patience, prayers and encouragement. I am grateful for your awesome love, concern and encouragement throughout the study period.

I want to sincerely appreciate my colleagues and friends (Dr. Yusuf Oladosu, Dr. Atiq, Dr. Leela Lyana, Dr. Kifah, Dr. Idayu, Mrs. Batool, Dr. Anwar, Dr Suganya, Nadirah, Dr. Osama, Dr. Abubakar Ahmed, Renuh, Stephini, Abubakar, Liyana, Dr. Candy, Nizam, Zaihan, Mr. Muhammed, Wan Rasidah, Dr Pavan Kumar, and Dr. Ismaila Muhammad. Special thanks to the Department of Animal Science in Faculty of Agriculture, Universiti Putra Malaysia, specifically (*In vitro*, Meat Science and Nutrition Laboratory) where most of my research analysis were carried out. To all staff of Institute of Tropical Agriculture and Food Security, UPM thank you very much for making my life as a post graduate student a delightful experience. In addition, huge thanks to all the staff of Animal Research Centre (ITAFoS), Mr Eddy Shahriza, Mr Fazmen Lee, Mr Farhan and Mr Ahmad Zahidi and Mr Faizol from Animal Production Laboratory (ITAFoS) and Mr Khairul from Vaccine and Immunotherapeutics Laboratory (IBS) for their support during my farm work. To all those I couldn’t mention who contributed to the success of this study in one way or the other, I say a big thanks to all.

Lastly, special thanks to all those who have contributed to the success of this research directly or indirect. May Almighty God bless you abundantly.

I certify that a Thesis Examination Committee has met on (date of viva voce) to conduct the final examination of Ahmed Muideen Adewale on his thesis entitled "Utilisationof enriched straw from newly developed rice variety as feed supplement for a sustainable goat production" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Doctor of Philosophy**.**

Members of the Thesis Examination Committee were as follows:

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This thesis was submitted to the Senate of the 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 were as follows:

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Date: 10 November 2022

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

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LIST OF ABBREVIATIONS

ADF	Acid detergent fibre
ADL	Acid detergent lignin
NH_3	Ammonia
ANOVA	Analysis of variance
CO_2	Carbon dioxide
Cm	Centimeter
CTAB	Cetyltrimethylammonium bromide
Cfu	colony forming units
CF	Crude fiber
CP	Crude protein
D	Day
ºC	degree Celsius
DNA	deoxyribonucleic acid
Na_2HPO_4	disodium phosphate
DH_2O	distilled water
DM	Dry matter
EDTA	ethylene diamine tetraacetic acid
FAO	Food and Agricultural Organization
G	gram
H	hour
IVDMD	*In vitro* dry matter digestibility
Kg	kilogram
L	liter

MJ/Kg	megajoules per kilogram
ME	Metabolisable energy
CH_4	Methane
µg	micro gram
µl	micro liter
µl	microliter
µm	micrometer
µM	micromole
µmol	Micromole
Ml	milliliter
mM	Millimolar
Mmol	Millimole
Min	minute
M	Mole
KH_2PO_4	monopotassium phosphate
Nm	Nanometer
NDF	Neutral detergent fiber
Ppm	Part per million
%	percent
PVPP	Polyvinyl polyprolidone
KCl	potassium chloride
Rpm	Revolutions per minute
S	second
NaCl	sodium chloride

SEM	Standard error of mean
H_2SO4	Tetraoxosulphate (vi) acid
TVFA	Total volatile fatty acid
pH_u	ultimate pH
USDA	United States Department of Agriculture
UPM	Universiti Putra Malaysia
v/v	volume per volume
$CaCl_2•2H_2O$	calcium chloride dehydrate
$MgCl_2•6H_2O$	magnesium chloride hexahydrate

CHAPTER 1

INTRODUCTION

The demand for animal protein products (meat and milk) has been estimated to skyrocket by 70% by 2050, solely because of the increase in the global population of more than 9 billion people with concurrent globalisation which influence the consumer taste as well as their perception (Ahmed *et al.,* 2018).

Ruminant in general are very essential and they play a crucial role in the enhancement of livestock sustainability in every country due to their special feed utilization which differs from other animal groups as well as it general acceptance by all religion and races especially for goat (Wanapat *et al.,* 2008). In addition, they make use of agricultural by products which are not consumed by human into high quality resources for body metabolism through the conversion of plant protein mostly less quality protein as well as non-protein nitrogen into high-quality animal proteins as meat or milk (Xu *et al.,* 2019).

However, the quest for commercial animal production scale to meet up the challenges of demand for animal protein through proper feeding without impairment to the environment is of major interests among researchers to explore (Silva *et al.,* 2015). The utilisation of agricultural by products which are ubiquitous in a value-added mechanism through the use of biological additive to enhance the nutrient composition is an accepted innovation. The agricultural by product that is easy to get in proximity as well as cheap if not free in most places due to the fact that the farmers mostly dispose it off the farm by burning which causes environmental pollution or left on farm and flooded with water which triggers the increase in acidity present in the soil. However, there is no skepticism about forage quality been dependent on structural pattern, compositional ratio, age, plant part, soil fertility and these have made the nutritional composition to differ and unpredictable except post evaluation through *in vitro* techniques and *in vivo* trials (Reis *et al.,* 2016; Ahmed *et al.,* 2017).

Biological additive are mechanism of agricultural by product enhancement through microbes to improve the quality of the feed. Most frequently used microbes are lactic acid bacterial (improve silage fermentation and prevent spoilage) and fibrolytic enzyme from fungi. Individual microbes or combined has been employed for the treatment of straw for better acceptance and utilisation by the animals (Thomas *et al.,* 2013).

According to Kung and Charley (2010), biological treated rice straw has been demonstrated to improve the nutrient content relatively to the control through aerobic stability enhancement as well as inhibition of the aerobic pathogen which could have subjected the silage to deterioration. Elwakeel *et al.,* (2007) showed an increase in the *in vitro* dry matter digestibility of different four diary feedstuff when fibrolytic enzyme was applied. Thomas *et al.,* (2013) reported that differences among the varieties with reference to the treatment application was observed coupled with improvement in the nutrient composition and treated rice straw fermentation parameters, increase in the true *in vitro* digestibility of the biological treatment relatively to the control and enhancement in the *in situ* disappearance was noted in the biological additive treatments in a findings where sorghum silage varieties (DBMR, PS 747, S700D and MMR) were treated by fibrolytic enzyme and inoculant.

Moreover, Elkholy *et al.,* (2009) demonstrated the impact of ensiled corn crop in sheep and the author discovered that the fiber crude fractions of the ensiled treatment were reduced, the ammonia as well as the pH of the ensiled treatment were lower compared with the control. In addition, the digestibility coefficient value of organic matter, crude protein and ether extract were all higher in sheep fed treated corn silage product relatively to the sheep in the control groups. The ruminal volatile fatty acid was enhanced couple with the rumen ammonia. Also, the blood parameters (total protein, blood urea nitrogen (due to high absorption of ammonia from the rumen to the blood), albumin and blood glucose) in sheep fed treated corn products were increased.

Furthermore, cattle fed grass treated with LAB, the influence of biological additives on silage quality manifested among the treatments with increase in voluntary intake as well as digestibility in the nutrient has evidenced by (Ando *et al.,* 2006). Most of the finding employed corn silage or whole corn silage and few on wheat silage for animal trial. In the few of the trial carried out on animal trial mostly in cattle, some positive result has been reported while some reported no difference in the performances (Zhang *et al.,* 2019).

The utilisation of ensiled straw has been tremendous especially in the area of ensile quality but more is yet to be executed on animal trial, even though the biological application cannot be exhausted on animal performance especially with the use of rice straw which are ubiquitous and causing environmental impairment due to burning disposal management. To the best of my knowledge, the treatment of rice straw (PadiU Putra-1) known for its blast resistance and high yielding properties has not been examined and this brings forth the objectives of the present study which is the utilisation of enriched straw from newly developed rice variety as feed supplement for a sustainable goat production.

Hypothesis statements:

The biological enrichment of PadiU Putra-1 rice straw will improve ensiled and nutritional qualities. It can also enhance the rumen fermentation profile, microbial population and performance of goat fed with biological treated rice straw.

Problem statement

1. The burning of different varieties of straw causes health and environmental impairment. Usually, the quality of straw variety is low, but information on its biological amelioration and how it impacts *in vitro* gas production techniques is yet to be understood.

2. In terms of animal performance, the understanding of PadiU Putra1 rice straw, which is known for blast resistance and high yield potential, remains unexplored.

3. The knowledge of how biological treated PadiU Putra 1 rice straw influences meat quality and blood profile is yet to be studied.

General objective

Utilisation of treated straw from newly developed padiu putra-1 rice variety as feed supplement for a sustainable goat production

Specific objectives

1. To evaluate the effects of biological additive treatments on nutrient profiles, fermentation qualities, and *in vitro* gas production kinetics, digestibility and rumen fermentation in different varieties of rice straw (ML4, ML10, ML21, ML24, MR219 and PadiU Putra-1).

2. To determine the influence of biological additive treated rice straw on growth performance, rumen fermentation, microbial population, digestible nutrient intake, and gene expression in Boer crossed bred goat.

3. To examine the impact of biological additive treated rice straw on blood profile (hematology and biochemistry), carcass characteristics and meat quality in goats.

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