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EFFECT OF CUTTING LENGTH OF WHOLE- CROP CORN SILAGE ON QUALITY AND RUMEN FERMENTATION IN GOATS

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By

KHIN THIDA KHAING

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

March 2015

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DEDICATION

This thesis is especially dedicated to:

My beloved parents**,**

U MYINT HLAING
and
DAW AYE YI

My beloved husband and daughter**,**

DR. TIN MAUNG SOE
EAINT HMUE MAY

Who always supported and encourage me to do the best.

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

EFFECT OF CUTTING LENGTH OF WHOLE- CROP CORN SILAGE ON NUTRITION QUALITY AND RUMEN FERMENTATION IN GOATS

By

KHIN THIDA KHAING

March, 2015

Chairman: Anjas Asmara @ Ab. Hadi Bin Samsudin (Ph.D)
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Shortage and fluctuating quality of forage in developing countries are the major constraints to the development of ruminant production sector including Malaysia. To overcome these problems, the feeding of ruminants with conserved forages is an important feeding strategy to ensure the success of ruminant production. The use of whole-crop corn as a silage has drawn much attention nowadays. Many factors including forage maturity, particle length, packing density and types of storage could affect the quality of silage. Among these factors, cutting length can be considered as an important element that contributes to the silage quality. Thus, the objectives of this study were to determine suitable cutting length of whole-crop corn for ensiling process and its aerobic stability, and to see if the inclusion of corn silage to Napier grass in ruminant diets at different level had given more nutrients utilization and rumen fermentation. The whole-crop of Suwan corn was harvested at the 1/3 milk line stage of maturity and was cut into different cutting length; 2 cm, 4 cm and 6 cm before inserted into the 1 L air tight glass containers. The bacterial densities consist of total viable bacteria (TVB) and lactic acid bacteria population (LAB), fermentation characteristics and chemical composition were observed weekly starting from week 1 until week 5 of ensiling period. Samples of corn silage at week 5 were used to observe *in vitro* gas production and *in situ* ruminal degradability.

The aerobic stability of the silage was determined immediately at day 0, day 1 and day 2 after 5 weeks of ensilaged samples were opened. The aerobic stability measuring parameters were microbial analyses that involved TVB, LAB, yeasts and moulds, fermentation characteristics, and chemical analysis. Based on the data reported in experiments 1 and 2, the 2 cm cutting length of whole-crop corn silage was used for the feeding trial that was conducted on 15 male Boer cross goats around six months old of approximately 18.54 ± 1.83 kg of body weights. The goats were assigned into five treatment groups consisted of different proportions of Napier grass (G) and whole plant corn silage (CS) – G/CS; T1:100/0; T2:75/25; T3:50/50; T4:25/75 and T5:0/100 respectively. The measurement parameters were feed intake, growth performance, digestibility, rumen fermentation characteristics and rumen microbial populations.

Results showed that the bacterial densities of TVB and LAB were significantly different ($P < 0.05$) among the treatment groups at the ensiling period of week 1 until week 3. The concentration of fermentation acids demonstrated high level of lactic and

low level of butyric acid in the 2 cm cutting length of corn silage. The *in vitro* gas production and the DM, OM and CP disappearance percentage of short cutting length were significantly higher ($P<0.05$) than long cutting lengths. The results of aerobic stability measurements showed that the changes in microbial populations observed during exposure to air, but no significant result was observed among the cutting lengths of whole-crop corn silage. The concentrations of fermentative acids and chemical composition of all cutting length were reduced throughout the period of aerobic exposure.

An increase of corn silage to Napier grass proportion resulted in an increase in feed intake and growth performance in goats. The highest nutrient digestibility was observed in T5 and T3 diets. The highest proportion of propionic and lowest proportion of acetic acid was observed in T5 diet. The numbers of total bacteria populations were not significantly different among the treatment diets. However, the lowest population of protozoa and methanogen were detected in the rumen of goats fed T5 diet. Based on the results obtained in this study, it can be concluded that short cutting length (2 cm) showed good fermentation characteristics than long cutting length of whole-crop corn silage. The cutting length had no effect on aerobic stability, and all of the treatments silages spoiled after 1 day of aerobic exposure. Apart from that, high proportion of corn silage to grass diets resulted in increase in feed intake and growth performance of goats. Rumen fermentation profiles were significantly different among the treatment groups. Although total bacteria populations were not significantly different among the treatment diets, the populations of methanogen and protozoa were lowest in goat fed with T5 diet.

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

KESAN POTONGAN PANJANG SILAJ KESELURUHAN POKOK JAGUNG TERHADAP KUALITI DAN FERMENTASI RUMEN KAMBING

Oleh

KHIN THIDA KHAING
March, 2015

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Kekurangan dan perubahan kualiti foraj merupakan satu kekangan besar terhadap pembangunan produksi ruminan di negara-negara menbangun termasuklah Malaysia. Bagi mengatasi masalah-masalah ini pemakanan menggunakan foraj terperam menjadi satu strategi pemakanan yang penting untuk memastikan kejayaan dalam produksi ruminan Penggunaan keseluruhan pokok jagung sebagai silaj kini berjaya menarik perhatian. Pelbagai faktor mempengaruhi kualiti silaj seperti kematangan foraj, panjang potongan, kepadatan simpanan dan cara simpanan. memberi kesan terhadap kualiti silaj. Diantara faktor-faktor tersebut panjang potongan pokok jagung merupakan satu elemen penting yang menentukan kualiti silaj. Oleh itu, objektif kajian ini adalah untuk menentukan panjang potongan pokok jagung yang sesuai untuk proses pemeraman dan kestabilan anaerobik, dan untuk menilai penggunaan silaj jagung dan rumput Napier oleh ruminan pada kadar yang berbeza yang mana memberi lebih banyak pengambilan nutrient dan fermentasi rumen. Keseluruhan pokok jagung Suwan dituai pada fasa kematangan 1/3 garis susu dan dipotong mengikut panjang yang berbeza pada 2 sm, 4 sm dan 6 sm sebelum dimasukkan ke dalam bekas kedap udara berukuran 1 L. Ketumpatan total bakteria (TVB) dan populasi bakteria asid laktik (LAB), ciri-ciri fermentasi dan komposisi kimia dipantau berkala secara mingguan mulai minggu pertama sehingga minggu kelima tempoh pemeraman. Sampel silaj jagung pada minggu kelima digunakan untuk melihat penghasilan gas *in vitro* dan pencernaan ruminal secara *in situ*.

Kestabilan anaerobik silaj dinilai segera pada hari 0, hari 1 dan hari 2 selepas 5 minggu sampel peram dibuka. Parameter kestabilan anaerobik yang diukur adalah analisa mikrob (yis, kulat, TVB dan LAB), ciri-ciri fermentasi dan analisa komposisi kimia. Berdasarkan data yang dilaporkan eksperimen sebelum ini, panjang potongan silaj keseluruhan pokok jagung sebanyak 2 sm telah digunakan untuk ujian pemakanan keatas 15 ekor kambing kacukan Boer yang berumur sekitar enam bulan dan mempunyai berat badan 18.54 ± 1.83 kg. Kambing-kambing itu telah dibahagikan kepada 5 kumpulan diet yang mengandungi kadar rumput Napier (G) dan silaj keseluruhan pokok jagung (CS) yang berbeza; G/CS; T1: 100/0; T2: 75/25; T3: 50/50; T4: 25/75 dan T5: 0/100. Ukuran parameter yang diambil adalah jumlah makanan yang diambil, prestasi tumbesaran, kadar pencernaan, ciri-ciri fermentasi rumen dan populasi mikrob rumen.

Hasil kajian menunjukkan ketumpatan bakteria pada tempoh minggu satu hingga tiga eraman untuk TVB dan LAB adalah paling berbeza secara signifikan ($P<0.05$) antara

kesemua kumpulan pelakuan. Kosentrasi asid fermentasi menunjukkan kadar laktik asid yang tinggi dan kadar asid butirik yang rendah oleh panjang potongan silaj jagung sebanyak 2 sm. Produksi gas *in vitro* dan peratus kehilangan DM, OM dan CP oleh potongan yang pendek adalah lebih tinggi ($p<0.05$) daripada potongan yang panjang. Hasil ukuran kestabilan anaerobik menunjukkan perubahan terhadap populasi mikrob dalam tempoh pendedahan tetapi tidak signifikan diantara panjang potongan yang berbeza silaj keseluruhan pokok jagung. Kadar kosentrasi asid fermentasi dan komposisi kimia oleh semua kumpulan berkurangan sepanjang pendedahan terhadap aerobik.

Pertambahan jumlah hasil silaj jagung berbanding rumput Napier dalam campuran pemakanan menunjukkan peningkatan kadar pengambilan makanan dan prestasi tumbesaran kambing. Kadar pencernaan nutrien adalah tertinggi untuk diet T5 dan T3. Kadar asid propionik yang tinggi dan asid asetik yang rendah dilihat dalam diet T5. Jumlah populasi bacteria total tidak berbeza secara dianatara kumpulan diet. Namun populasi protozoa dan metanogen yang paling rendah didapati dalam rumen kambing yang diberi diet T5. Berdasarkan dapatan kajian ini adalah dapat disimpulkan bahawa kadar silaj potongan pokok jagung yang yang pendek (2 sm) menunjukkan ciri-ciri fermentasi yang baik daripada kadar silaj potongan pokok jagung yang panjang. Kadar potongan pokok jagung tidak memberi kesan terhadap kestabilan aerobik dan kesemua silaj rosak selepas 1 hari pendedahan terhadap aerobik. Selain itu, kandungan silaj jagung yang tinggi dari rumput dalam diet meningkatkan kadar pengambilan makanan dan tumbesaran kambing. Fermentasi profil rumen adalah berbeza secara signifikan diantara kumpulan diet. Walaupun populasi bakteria total adalah tidak berbeza secara signifikan diantara kumpulan diet, populasi metanogen dan protozoa adalah terendah dalam rumen kambing yang diberi makan diet T5.

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I certify that a Thesis Examination Committee has met on (30 March 2015) to conduct the final examination of KHIN THIDA KHAING on her thesis titled "Effect of cutting length of whole-crop corn silage on quality and rumen fermentation in goats" in accordance with Universities and University College 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 Doctor of Philosophy (PhD).

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ADF	- acid detergent fibre
ADL	- acid detergent lignin
BCVFA	- branch chain volatile fatty acid
BW	- body weight
$BW^{0.75}$	- metabolic size of body weight
cfu	- colony forming unit
CH_4	- methane
cm	- centimeter
CO_2	- carbon dioxide
CP	- crude protein
CL	- cutting length
dl	- deciliter
DM	- dry matter
DMI	- dry matter intake
DNA	- deoxyribonucleric acid
FCR	- feed conversion ratio
FI	- feed intake
FM	- fresh matter
g	- gram
g/d	- gram per day
h	- hour
IVOMD	- *in vitro* organic matter digestibility
kg	- kilogram
kg/d	- kilogram per day
L	- liter
LAB	- lactic acid bacteria
ME	- metabolizable energy
mg	- milligram
min	- minute (s)
MJ	- mega joule
ml	- milliliter
mm	- millimeter
mM	- millimole
N	- nitrogen
NDF	- neutral detergent fibre
NRC	- Nutritional Research Council
OM	- organic matter
OMD	- organic matter digestibility
rRNA	- ribosomal ribonucleric acid
RT-PCR	- real time polymerase chain reaction
s	- second
TLC	- theoretical length of chop
TVB	- total viable bacteria
VFA	- volatile fatty acid
µg	- micro gram
µl	- micro liter
µm	- micro meter

CHAPTER 1

INTRODUCTION

A rapid increase of world human population particularly in the developing countries has increased the demand for food including from the livestock production sector. It is estimated that the total livestock production will have to double by the year 2020 in order to meet the growing human population (Reddy *et al*., 2003). In Malaysia, poultry farming is the most popular animal farming activity adopted by livestock farmers due to faster rate of return, lower risk and east of management using established and manageable technologies. On the other hand, the ruminant sector is still struggling due to insufficient agricultural land for ruminant and long return of investment plus unavailability of good quality feedstuff for those groups of animal. The ruminant production in Malaysia needs to be expanded and accelerated with much greater momentum.

An increased population of these animals would also increase demand for much greater supplies and availability of feeds particularly roughages and forages either in fresh or preserved for throughout the year. In addition, these forages must be of high nutritive values to provide the animals with nutrients required for their growth and reproductive performance. However, the fluctuating quantity and quality of forage is the primary constraint for the production of ruminant sector. Feeding of ruminants with conserved forages has become an important feeding strategy. Ensiled forages are essential sources of roughage that are fed throughout the year particularly during the periods of restricted seasonal availability of pastures for the grazing animal (Wilkinson and Davies, 2013). Almost any forage could be ensiled, but whole-crop corn is the most popular forage to be ensiled due to relatively high fermentable carbohydrate content that produces excellent quality of silage with palatable source of energy (Mohammed *et al*., 2003). In addition, the fermentation process occurs readily and does not usually need to use additives to improve the fermentation process. The used of whole- crop corn as a silage provides nutritious feed for ruminants due to its high protein efficiency, relatively high digestible energy and total digestible nutrients (Venkateswarlu *et al.,* 2012).

The fermentation quality and nutritional value of ensiling process is influenced by many factors. The particle length of ensiled forage has been considered as important criteria in determining the good quality silage. According to Mertens (2005), shorter particles pack better in silos, but long particles resist packing and may limit air exclusion from the silage. Short particles allowing it to be compressed vey well that will eliminate as much air as possible in order to obtain anaerobic condition to enhance fermentation process as well as to preserve the nutrients in the ensilaged mass (Johnson *et al.*, 2003a). However, Zebeli *et al. (*2009) reported that a fine particle leads to a loss of fibrous roughage properties which are necessary to maintain rumen function and may result in acidosis. Therefore, cutting length of forage should be considered as a critical role in order to attain not only good ensiling characteristic but also in the maintenance of normal rumen metabolism.

When silage is exposed to air during the time of feeding, aerobic deterioration occurs as a result of aerobic microorganisms proliferation such as yeasts, moulds and aerobic bacteria. There are changes in chemical composition of silage by utilizing fermentation

acid especially lactic acid and soluble nutrients as a substrate for their oxidation process. Besides the loss of nutrients, reduction in feed intake and animal production can be seen as a result of feeding spoiled silage to ruminants (Whitlock *et al*., 2000). Good quality silages are very susceptible to aerobic deterioration due to high level of lactic acid which was used by the yeasts as a source of energy. Thus, it is very important issue to evaluate the effect of cutting length on aerobic stability and deterioration process of ensilaged mass.

Efficient fermentation ensures more palatable and digestible feed, which optimize feed intake and lead to animal performance improvement. Moreover, starch in the kernels optimized the growth of rumen microbial population and influenced the rate of microbial protein synthesis, nitrogen utilization and production of volatile fatty acids (Jalč *et al*., 2009). In the past few years, Napier grass *(Pennisetum purpureum)* has become the most popular fodder grass among dairy and feedlot producers in Malaysia (Halim *et al.*, 2013). It has high potential DM yield, usually managed by grazing or cut-and-carry and the availability of the grass throughout the year (Bureenok *et al*., 2012) has made it the most preferred than other fodder grass. However, Widiawati and Thalib (2009) stated that cell wall content of Napier grass is slowly degraded in the rumen and more resistant to rumen microbial fermentation. Accordning to Mazzenga, (2009), the microbial fermentation of corn silage cell wall is relatively more degradable due to low content of structural carbohydrate and high content of soluble carbohydrate. Up to now, limited numbers of goat producers have used whole-crop corn silage as a ruminant feed in Malaysia. There is potential for inclusion of whole-crop corn silage to Napier grass to improve the efficiency of nutrient utilization and growth performance and rumen microbial fermentation in ruminants.

Based on the above mentioned consideration, a study was conducted with the following objectives:

(1) to determine the effect of cutting length on bacterial densities, fermentation characteristics and nutritive value of whole-crop corn silage
(2) to determine the effect of cutting length on aerobic stability of whole-crop corn silage
(3) to evaluate the dry matter intake, growth performance, digestibility, rumen fermentation characteristics and microbial population in goats fed different inclusion level of whole-crop corn silage to Napier grass based diets

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