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DEVELOPMENT OF CORN SILAGE TECHNOLOGY AND ITS FINANCIAL FEASIBILITY FOR BEEF CATTLE IN MALAYSIA

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By

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The Malaysian beef cattle industry has shown a sluggish rate of growth despite the need to reduce imports of over 70% and one of the major limiting factors is the lack of suitable and economic feed. Intensive beef production practised in Malaysia, such as in feedlots, generally rely on the use of available crop by-products such as palm kernel cake (PKC) and imported feed ingredient to complement fodder. An alternative feed that has not been exploited is corn silage, a high-quality feed that is widely used and researched worldwide. In this regard, a series of experiments were done to identify appropriate technologies of corn silage production for the beef cattle industry in Malaysia. The first three experiments were asscociated with the technical aspects of silage making while the fourth study evaluates the financial performance of the technology. In the first experiment, the objective was to determine the optimum harvest stage for making corn silage in terms of yield and quality. An additional objective was to evaluate differences among varieties of corn. Four varieties of corn were harvested at either the silking, milk, dough and dent stages. The results showed that grain corn varieties out performed Malaysia's widely planted sweet corn variety mainly due to the huge yield difference. Sweet corn dry matter (DM) yield at 15.3 t/ha was significantly lower ($P \leq 0.05$) than Suwan, which yielded 28.6 t/ha. Generally, the corn plant was best harvested at the dent stage as the yield was the highest while the quality improved with advanced cob development. Although the crude protein (CP) was the highest at the earlier silking stage (11.4%), the difference was low compared to the dent stage (10.2%). In the second experiment, five different types of silo: i) Mini Bunker, ii) Well, iii) Siloseal, iv) Plastic Drum and v) Plastic Bag were evaluated. All the silo types were successful in producing well fermented silage characterized by a low pH (<4.0). However, the silage quality deteriorated with time after opening with a faster rate of deterioration on the surface layers compared with those at lower depths ($P \leq 0.05$). The deterioration rate also varied with the silo type. Plastic Drum was selected as the best silo type based on its superior aerobic stability (more than 21 days), good pH (between 3.2 and 3.7), very low top spoilage rate (0.2 %) and low DM loss (10.8 %). Mini Bunker produced silage with poor aerobic stability and high temperature while Well, Siloseal and Plastic Bag showed some good potential. The third experiment's objective was to determine the potential of corn

silage-based feed in a feeding trial using a beef feedlot system. Comparisons were made among three groups of cattle which were fed respectively with i) corn silage, ii) 50% corn silage plus 50% rice straw or iii) rice straw only as the basal feeds. The feed value and the animal performance showed that corn silage-based diet could produce a good growth rate for beef cattle. The average daily gain (ADG) obtained of 808 g/day from corn silage diet was comparable to cattle fed on conventional PKC/napier grass ration obtained elsewhere. However, the ADG was below that obtained in some other countries signalling potential for improvement. Lastly, all three major components in the corn silage chain: corn plant, corn silage and beef production were tested for their financial feasibility. The analysis showed that both corn plant and corn silage production were financially feasible with net present values (NPV) of RM217,128 and RM373,088 respectively. The calculations were made based on the assumptions developed from the previous experiments and survey done earlier. Only the Plastic Drum was feasible among the silo type with positive NPV of RM373,088. However, the partial budgeting analysis showed that corn silage as feed for beef cattle was not as profitable as conventional feed of PKC with napier grass. The difference in the net benefit per cycle was about 23%. In conclusion, corn silage production was proven to be technically and financially feasible using the technologies developed in the research. Corn silage's lower profitability than grass/concentrates ration highlight the need for further research in reducing the production cost and determining the best ratio of corn silage to be used in the feed.

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

PENGHASILAN TEKNOLOGI DAN KAJIAN KEWANGAN SILAJ JAGUNG UNTUK TERNAKAN LEMBU PEDAGING DI MALAYSIA

Oleh

MUHAMAD HAZIM BIN NAZLI

Januari 2018

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Industri lembu pedaging Malaysia telah memperlihatkan kadar pertumbuhan yang perlahan walaupun terdapat keperluan untuk mengurangkan kadar import yang melebihi 70%. Salah satu faktor penghalang utama ialah kekurangan makanan haiwan yang sesuai dan ekonomik. Pengeluaran daging lembu secara intensif ada diamalkan di Malaysia terutama fidlot yang secara amnya bergantung pada penggunaan produk sampingan tanaman seperti hampas isirong sawit (PKC) dan bahan makanan haiwan yang diimport untuk melengkapi rumput foder. Satu makanan alternatif yang belum dieksploitasi adalah silaj jagung, satu makanan berkualiti tinggi yang banyak digunakan dan dikaji di seluruh dunia. Oleh itu, satu siri eksperimen telah diljalankan untuk mengenal pasti teknologi pengeluaran silaj jagung yang sesuai untuk industri lembu pedaging di Malaysia. Tiga eksperimen pertama melibatkan aspek teknikal pembuatan silaj sementara kajian keempat menilai prestasi kewangan teknologi tersebut. Objektif eksperimen yang pertama adalah untuk menentukan peringkat optimum untuk menuai jagung bagi membuat silaj melalui hasil dan kualiti. Satu objektif tambahan adalah untuk menilai perbezaan di antara beberapa varieti jagung. Empat varieti jagung tersebut telah dituai pada peringkat Sutera, Susu, Doh atau Gigi. Hasil kajian menunjukkan bahawa varieti jagung bijirin lebih bagus untuk pembuatan silaj mengatasi varieti jagung manis yang ditanam secara meluas di Malaysia. Hasil bahan kering varieti Jagung Manis sebanyak 15.3 t/ha adalah lebih rendah ($P \leq 0.05$) berbanding Suwan yang memberi hasil sebanyak 28.6 t/ha. Secara amnya, pokok jagung terbaik dituai pada peringkat Gigi kerana hasil pada peringkat ini adalah yang tertinggi manakala kualitinya meningkat oleh kerana pertumbuhan tongkol jagung yang lebih maju. Walaupun kandungan protein kasar adalah tertinggi pada peringkat Sutera (11.4%), perbezaanya adalah sangat rendah berbanding peringkat Gigi (10.2%). Dalam kajian kedua, lima jenis silo yang berbeza: i) Bunker Mini, ii) Telaga, iii) Siloseal, iv) Drum Plastik dan v) Beg Plastik telah dinilai. Semua jenis silo berjaya menghasilkan silaj yang diperam dengan baik dengan pH yang rendah (<4.0). Walau bagaimanapun, kualiti silaj setelah silo dibuka merosot merentasi masa dengan kadar kemerosotan yang lebih cepat pada lapisan permukaan berbanding silaj yang lebih dalam ($P \leq 0.05$). Kadar kemerosotan juga berbeza mengikut jenis silo. Drum Plastik dipilih sebagai jenis silo yang terbaik

berdasarkan tempoh kestabilan aerobik (melebihi 21 hari), pH (di antara 3.2 dan 3.7), kadar kerosakan atas yang sangat rendah (0.2 %) dan kadar kehilangan bahan kering yang rendah (10.8 %). Bunker Mini menghasilkan silaj yang mempunyai kestabilan aerobik yang lemah dan suhu yang tinggi sementara Telaga, Siloseal dan Beg Plastik menunjukkan potensi yang baik. Objektif eksperimen ketiga adalah untuk menentukan potensi makanan haiwan berasaskan silaj jagung dalam ujian pemakanan menggunakan sistem lembu pedaging fidlot. Perbandingan dibuat di antara tiga kumpulan lembu yang diberi makan dengan i) silaj jagung, ii) 50% silaj jagung dengan 50% jerami padi atau iii) jerami padi, sebagai makanan asas. Nilai pemakanan dan prestasi haiwan menunjukkan bahawa pemakanan berasaskan silaj jagung dapat menghasilkan kadar pertumbuhan yang baik untuk lembu pedaging. Purata kenaikan harian (ADG) yang diperoleh sebanyak 808 g/hari daripada pemakanan silaj jagung adalah setanding dengan lembu pedaging yang diberi makanan konvensional mengandungi campuran PKC dan rumput. Walau bagaimanapun, ADG tersebut adalah kurang berbanding sesetengah negara menandakan potensi untuk peningkatan. Akhirnya, ketiga-tiga komponen utama dalam rantaian silaj jagung; pengeluaran pokok jagung, silaj jagung dan daging lembu telah diuji untuk menentukan dayamaju kewangan. Analisis menunjukkan bahawa kedua-dua penghasilan pokok dan silaj jagung adalah berdayamaju dengan jumlah nilai kini sebanyak RM217,128 dan RM373,088. Namun, hanya Drum Plastik berdayamaju berbanding jenis silo yang lain dengan jumlah nilai kini positif sebanyak RM373,088. Manakala analisis belanjawan separa menunjukkan keuntungan penggunaan silaj jagung sebagai makanan ternakan lembu pedaging adalah kurang berbanding makanan konvensional PKC ditambah dengan rumput napier dengan perbezaan jumlah manfaat per kitaran sebanyak 23%. Kesimpulannya, pengeluaran silaj jagung telah terbukti secara teknikal dan kewangan berdasarkan teknologi yang telah dibangunkan dalam kajian ini. Keuntungan silaj jagung yang lebih rendah berbanding campuran rumput dan dedak menyerlahkan keperluan untuk penyelidikan yang lebih lanjut terutama dalam mengurangkan kos pengeluaran dan menentukan nisbah silaj jagung yang terbaik untuk digunakan dalam makanan ternakan.

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I certify that a Thesis Examination Committee has met on 23 January 2018 to conduct the final examination of Muhamad Hazim bin Nazli on his thesis entitled "Development of Corn Silage Technology and Its Financial Feasibility for Beef Cattle in Malaysia" 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 Doctor of Philosophy.

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LIST OF ABBREVIATIONS

AA	Amino Acid
ABI	Agro Biotechnology Institute
AD	Acid Detergent
ADF	Acid Detergent Fibre
ADG	Average Daily Gain
ANOVA	Analysis of Variance
AOAC	Association of Analytical Communities
AP	Agrofood Policy Malaysia 2011-2020
BC	Before Christ
BCR	Benefit Cost Ratio
BE	Breakeven
BTL	Breeding Test Line
BW	Body Weight
CIMMYT	The International Maize and Wheat Improvement Center
CP	Crude Protein
CS	Corn Silage
CWP	Cob to Whole Plant Ratio
DAE	Days After Emergence
DCF	Discounted Cash Flow
DDM	Digestible Dry Matter
DE	Digestible Energy
DM	Dry Matter
DMI	Dry Matter Intake
DVS	Department of Veterinary Services
ETP	Economic Transformation Programme
FAOSTAT	Food and Agriculture Organization Statistical Database
FCE	Feed Conversion Efficiency
FCR	Feed Conversion Ratio
GHG	Greenhouse Gas
HM	High Moisture
IRR	Internal Rate of Return
ITA	Institute of Tropical Agriculture
LAB	Lactic Acid Bacteria
LS	Leaves to Stem
LSD	Least Significance Difference
MARDI	Malaysia Agriculture Research and Development Institute
MB	Mini Bunker
ME	Metabolizable Energy
MOA	Ministry of Agriculture
MRR	Marginal Rate of Return
ND	Neutral Detergent
NDF	Neutral Detergent Fibre

NE_G	Net Energy for Gain
NE_M	Net Energy for Maintenance
NIRS	Near Infrared Spectrophotometer
NKEA	National Key Economic Area
NPV	Net Present Value
OM	Organic Matter
PB	Plastic Bag
PBP	Payback Period
PD	Plastic Drum
PE	Polyethylene
PI	Profitability Index
PKC	Palm Kernel Cake
PKE	Palm Kernel Expeller
PV	Present Value
PVC	Polyvinyl chloride
RCBD	Randomized Completely Block Design
ROI	Return of Investment
SEA	South East Asia
TDN	Total Digestible Nutrient
UPM	Universiti Putra Malaysia
VI	Voluntary Intake
WSC	Water Soluble Carbohydrate

CHAPTER 1

INTRODUCTION

Beef production in Malaysia was only 23.5% of the national requirement with per capita consumption at 7.05 kg/year in 2015 (DVS, 2016). Malaysian self-sufficiency level for beef is declining while the consumption is increasing causing heavy dependence on imported beef. This situation has worsened due to slow growth of the local beef cattle industry (Serin, Radam, Shamsudin, & Mohamed, 2008). As the industry has always been dominated by small and medium scale farmers with limited grazing land and resources, the industry is dependent on purchased concentrates derived from imported ingredient (Mohamed, 2007). With the feed prices increasing and the market continuously crowded with cheaper imported meat, the local beef producers need cheaper alternative feed as feed constitutes about 70% of the total production cost. This problem can be resolved by producing the feed locally as it can be cheaper while the quality and quantity can be also manipulated accordingly. An option is to adopt whole corn plant silage that are widely used all over the world. Corn is one of the major summer forage crops for silage making in various climates including tropical and sub-tropical countries (Weinberg, Khanal, Yildiz, Chen, & Arieli, 2011). Unfortunately, neither silage nor corn production hold any significance in generating the Malaysian economy, instead it becomes the nation's biggest import item in term of quantity in recent years. Even though most of the corn imports are for non-ruminant feed, the situation highlights the need for locally produced feed to reduce dependence on costly import and subsequently increase the nation's 'feed security'.

Silage is basically fermented feed for animals that can be made from forages, crop residue or industrial by-products. The fermentation relies on acidification process under anaerobic condition naturally by epiphytic bacteria or artificially using additives. This will preserve the silage over a long period of time with minimum nutritive losses. Basically, corn silage production can be divided into two main parts; crop production and silage production. The crop production involves land and corn cultivation including the harvesting process while the silage production relates to corn preparation for the ensilation until it becomes corn silage. Apart from the varying genetic makeup of different corn varieties, the harvest stage also heavily influences corn plant quantity and quality. In contrast to fodder grass, corn is usually harvested in a later reproductive stage, though the stage where the quality and yield of corn is optimum is still debatable. Extensive researches have been done in determining the optimum corn harvest stage but there is a scarcity of such studies in a tropical climate and almost none in Malaysia. The tropical climate can significantly affect corn production in many ways especially via the different temperature fluctuations and shorter day time compared to the summer days in temperate area. These differences can also significantly affect the second part of corn silage production, in which the silo is in play. Silo is an integral part of successful silage making as it provides protection against the external variable and most importantly it keeps the silage

in anaerobic condition over a long period. Like the corn plant, the tropical temperature can adversely affect the silo and the corn silage within. As there is very limited research on the silo types in Malaysia, the need for such study is certainly justified.

In addition to the lack of research in tropical corn silage production, studies on the feeding value of corn silage for tropical beef cattle is also lacking. As beef cattle performance is different in hot and humid tropical climate from the temperate area, the response towards corn silage inclusion as feed will also differ. Research is also needed in the inclusion of industrial by-products into the corn silage feed as an effort to improve feed efficiency. As Malaysia is abundant with industrial by-products especially from the oil palm and paddy sectors, the inclusion may provide a cost-effective solution. When incorporating research findings into commercial activities, farmers' main concerns are the cost and revenue of such input. Thus, it is important to determine corn silage financial feasibility to convince the farmers in their decision-making process. The study can also aid policy makers and fund providers in assessing the financial viability of businesses involving corn silage. A comprehensive study involving the technical and financial aspect of corn silage production in Malaysia is very much needed. The objectives of the study were:

1. To identify the optimum corn harvest stage for silage making.

2. To determine the most suitable silo type for silage making.

3. To determine the intake and growth performance of beef cattle when fed corn silage.

4. To determine the financial feasibility of using corn silage as basal feed in local beef cattle feedlot production.

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