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EFFECT OF SUBSTITUTING BARLEY WITH CORN OR SORGHUM ON RUMEN FERMENTATION AND POST-RUMINAL STARCH DIGESTION IN LAMBS

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By

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Chairperson: **Liang Juan Boo, PhD**

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Locally grown barley is the primary dietary energy source for ruminant production in Iran. However, its production in recent years has declined due to increasing shortage of water in the barley cropping regions. In addition, barley ferments rapidly in the rumen and can lead to metabolic disorders. This thesis, consisted of three experiments, examined the suitability of replacing barley with corn or sorghum for lamb production in Iran. The first experiment evaluated the effects of partial substitution of barley with corn or sorghum on *in situ* dry matter and starch degradability followed by an *in vivo* feeding trial to examine intake and performance in finishing Iranian Baluchi lambs. In the *in situ* experiment, individual grains include ground barley, corn (C) and sorghum (S) and their mixtures in various combinations; 70 barley: 30 corn (LC), 70 barley: 30 sorghum (LS), 30 barley: 70 corn (HC) or 70 sorghum (HS) were incubated in nylon bags in the of fistulated Holstein steers. Results of this experiment showed that ruminal degradability of barley was higher than corn and sorghum, and further suggested that in order to effectively decrease ruminal degradability of barley with corn or sorghum, the substitution rate

needs to be about 70%. In the follow-up in vivo trial, thirty Iranian Baluchi male lambs at approximately 65 days old (32 ± 3.2 Kg) were allocated into individual pens and fed five experimental diets. The control diet contained 56% ground barley (B) as source of energy in the concentrate, and in the treatment diets, barley was substituted by ground corn and sorghum in either 30% or 70% to give low corn (LC), high corn (HC), low sorghum (LS) and high sorghum (HS) diets, respectively. HC and HS diets significantly improved ruminal pH with lambs in HS and HC diets recorded 35% and 15% higher average daily gain (ADG), respectively, than lambs in the control diet. Results of this study indicated that in order to enhance animal performance, the substitution rate of barley by corn or sorghum should be about 70% and in addition, substituting barley with sorghum was better than with corn.

The second experiment (Chapter 4) was designed to quantify the rate of ruminal DM, starch and N outflows and their post-ruminal digestibility when barley in the concentrate was substituted at 50% or 100% with sorghum. Eighteen male lambs (65 days of age and 31±1.9 kg live weight) were randomly allocated into three dietary treatments. The diets were similar to those of the previous experiment which barley was the main energy source in the concentrate of control diet while the others were 50% barley: 50% sorghum (BS) and 100% sorghum (S). Lambs in high barley (B) diet had higher total volatile fatty acids (VFA) production, thus lowest ruminal pH (5.9). Majority of the post-ruminal DM, starch and N were digested in the distal-duodenum followed by the anterior jejunum. Although lambs fed high sorghum (S) diet recorded higher outflow rates (g/d) of starch into the small intestine, because of its low digestibility, the ruminal starch outflow was poorly digested, leaving significant quantity been fermented in the large intestine or as waste excreted in the faeces. On the other hand, ruminal fermentation of starch

and N in lambs fed barley-sorghum (BS) diet was well synchronized, leading to significant ($P<0.05$) improvement in growth rate of the lambs.

The final study (Chapter 5) was designed to examine whether extrusion treatment would enhance the digestibility of sorghum starch to allow for 100% substitution of barley by sorghum in lamb diet. Based on results of *in situ* degradation rate and post-ruminal digestion parameters, extrusion using 150°C and 55 bar pressure was found to be most effective for sorghum. In a follow-up experiment, eighteen male Iranian Baluchi lambs randomly allocated into three dietary treatments which include 100% barley (B) in the concentrate as control, 50% barley: 50% extruded sorghum (BS_E) and 100% extruded sorghum (S_E). Because of the lower apparent ruminal degradability of the starch, higher abomasal flow of starch and N was recorded for lambs in the 100% extruded sorghum (S_E) diet. In addition, higher starch and N was digested in the S_E compared to B and BS_E diets. The higher quantity of starch digested and absorbed mostly as glucose in the S_E diet group was reflected by the corresponding higher glucose concentration in portal vein of lambs fed S_E diet. Lambs in S_E diet also recorded higher microbial N supply, ADG and more efficient feed conversion ratio compared to lambs in the B or BS_E treatments.

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

KESAN PENGGANTIAN BARLI DENGAN JAGUNG ATAU SORGUM PADA CIRI FERMENTASI RUMEN DAN PENCERNAAN PASCA-RUMINAL KANZI PADA ANAK BIRI-BIRI

Oleh

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Barli tempatan adalah sumber tenaga utama dalam pemakanan untuk pengeluaran ruminan di Iran. Walau bagaimana pun, kadar pengeluaran sejak beberapa tahun ini telah menurun disebabkan oleh kekurangan bekalan air di kawasan penanaman barli. Di samping itu, barli menapai dengan cepat dalam rumen, dan ini akan mengakibatkan penyakit metabolik. Kajian ini, yang terdiri daripada tiga eksperimen, mengkaji kesesuaian menggantikan barli dengan jagung atau sorgum untuk pengeluaran biri-biri di Iran. Kajian pertama adalah untuk menilai kesan penggantian sebahagian daripada barli dengan jagung atau sorgum ke atas degradasi *in situ* bahan kering (DM) dan kanji dan di ikuti oleh satu kajian pemakanan *in vivo* untuk meneliti pengambilan dan prestasi finishing biri-biri Baluchi Iran. Dalam eksperimen *in situ*, bijirin barli kisar (B), jagung (C), sorgum (S) dan campuran pelbagai kombinasi; 70 barli: 30 jagung (LC), 70 barli: 30 sorgum (LS), 30 barli: 70 jagung (HC) atau 70 sorgum (HS) telah di

fermentasi dalam beg nilon dalam rumen lembu jantan Holstein berfistula. Keputusan eksperimen ini menunjukkan bahawa keupayaan degradasi ruminal barli adalah lebih tinggi daripada jagung dan sorgum, sekaligus mencadangkan untuk mengurangkan keupayaan degradasi barli dalam rumen dengan jagung atau sorgum secara berkesan, kadar penggantian perlu berada di tahap lebih kurang 70%. Dalam percubaan pemakanan *in vivo* susulan, tiga puluh biri-biri jantan Baluchi berusia lebih kurang 65 hari (32 ± 3.2 Kg) telah ditempatkan dalam kandang individu dan diberi makan lima diet eksperimen. Diet kawalan mengandungi barli kisar 56% (B) sebagai sumber tenaga dalam konsentrat, dan dalam diet rawatan, barli telah digantikan oleh jagung kisar dan sorgum, pada aras samada 30% atau 70% untuk memberi diet jagung rendah (LC), jagung tinggi (HC), sorgum rendah (LS) dan sorgum tinggi (HS) diet. Diet HC dan HS memperbaiki pH rumen biri-biri, dan peningkatan ketara masing masing 35% dan 15% purata penambahan berat badan (ADG), untuk diet HC dan HS, berbanding dengan biri-biri diet kawalan. Keputusan kajian ini menunjukkan bahawa untuk meningkatkan prestasi haiwan, kadar penggantian barli oleh jagung atau sorgum haruslah mestilah lebih kurang 70% dan di samping itu, menggantikan barli dengan sorgum adalah lebih baik berbanding dengan jagung.

Kajian kedua (Bab 4) telah direka untuk mengukur kadar aliran keluar bahan kering, kanji dan N dari rumen dan pencernaan pasca-rumen apabila barli dalam konsentrat digantikan pada aras 50% atau 100% dengan sorgum. Lapan belas biri-biri jantan Baluchi Iran (65 hari umur dan 31 ± 1,9 kg berat hidup) dibahagikan secara rawak kepada tiga rawatan pemakanan. Komposisi diet adalah sama dengan eksperimen yang sebelumnya di mana barli (B) telah digunakan sebagai sumber tenaga utama dalam konsentrat diet kawalan, manakala yang lain adalah barli 50%: sorgum 50% (BS) dan sorgum 100% (S). Anak biri-biri diberi diet barli yang tinggi (B) menghasilkan jumlah asid lemak meruap (VFA) yang lebih tinggi, dengan pH rumen (5.9) yang

terendah. Majoriti DM, kanji dan N pasca-rumen telah dicerna dalam duodenum distal dan anterior-jejunum. Walaupun biri-biri kumpulan diet sorgum tinggi (S) mencatatkan kadar aliran keluar kanji (g/d) yang lebih tinggi ke dalam usus kecil, disebabkan oleh kadar pencernaan yang rendah, aliran keluar kanji kurang dicerna, menyebabkan kuantiti kanji yang besar telah di fermentasi dalam usus besar atau dikumuhkan dalam najis. Sebaliknya, fermentasi kanji rumen dan N dalam biri-biri diberi makanan diet barli-sorgum (BS) adalah lebih sinkroni, menyebabkan peningkatan ketara ($p<0.05$) dalam kadar pertumbuhan.

Eksperimen terakhir (Bab 5) telah direka untuk memeriksa samada rawatan penyemperitan akan meningkatkan pencernaan kanji sorgum bagi membolehkan penggantian 100% barli oleh sorgum dalam diet biri-biri. Berdasarkan keputusan kadar degradasi *in situ* dan parameter pencernaan pasca-rumen, penyemperitan pada suhu 150°C dan tekanan 55 bar didapati paling berkesan untuk sorgum. Dalam eksperimen susulan, lapan belas biri-biri jantan Baluchi Iran dibahagi secara rawak kepada tiga rawatan diet yang merangkumi barli 100% (B) sebagai kawalan, barli 50%: 50% sorgum tersemperit (BS_E) dan 100% sorgum tersemperit (S_E). Disebabkan keupayaan degradasi rumen kanji yang lebih rendah, aliran kanji dan N dari abomasum dicatatkan lebih tinggi untuk biri-biri diberi diet 100% sorgum tersemperit tinggi (S_E). Selain itu, lebih banyak kanji and N dicernakan dalam diet S_E berbanding dengan diet B dan BS_E. Kuantiti kanji yang tinggi dicernakan dan diserap sebagai glukosa dalam kumpulan diet SE dicerminkan oleh kepekatan glukosa yang lebih tinggi dalam vena portal biri-biri yang diberi diet S_E. Biri-biri diberi diet S_E juga mencatatkan bekalan N mikrob dan ADG yang lebih tinggi, dan nisbah FCR lebih cekap berbanding dengan biri-biri dalam rawatan B atau BS_E.

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I certify that an Examination Committee met on date of viva voce to conduct the final examination of **Mohammad Yahaghi** on his doctor of philosophy thesis entitled "**Effect of substitution of barley with corn or sorghum on rumen fermentation and post-ruminal starch digestion in lambs**" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the relevant degree.

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

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DECLERATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently submitted for obtaining any other degree at Universiti Putra Malaysia or any other institution.

MOHAMMAD YAHAGHI

Date: 24 November 2011

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