UNIVERSITI PUTRA MALAYSIA

NUTRITIVE VALUE OF BARLEY FODDER GROWN IN A HYDROPONICS SYSTEM

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: Associate Professor Dr. Zainal Aznam Mohd Jelan

Faculty: Agriculture

A series of experiments were conducted to evaluate barley fodder (BF) as a feed for ruminants. Barley seeds were grown in a specially designed and controlled environment cabin at 15 – 18°C. The first experiment was conducted to germinate barley seeds from day 0 (d0) to day 10 (d10, n=11) and samples were collected daily for chemical composition analysis. In the second experiment, the rumen simulation technique (RUSITEC) was used to measure the *in vitro* dry matter (DM) and crude protein (CP) digestibility and the volatile fatty acids (VFA) produced by BF at different times. The nylon bag technique was also used to measure the DM degradability of BF in the rumen of cattle at 2, 4, 8, 12, 24 and 48 hours.

The third experiment on the intake and digestibility of eight-day old BF was measured by an *in vivo* technique, using four bucks. The fourth experiment involved the measurement of rumen fluid parameters (pH, ammonia and VFA) in three rumen fistulated bucks that were fed on eight-day old BF *ad libitum*.

The CP, organic matter (OM), ether extract (EE), neutral detergent fibre (NDF), acid detergent fibre (ADF) and crude fibre (CF) contents of BF from d1 to d10 increased, but the DM content decreased with the age of BF. DM content at d7 and d8 were 16 and 18% while CP content were 12 and 13% respectively. The amount of calcium (Ca), phosphorus (P) and Nitrate (NO_3^-) did not change significantly throughout sprouting time. The *in vivo, in vitro* and *in sacco* DM degradability studies showed that 80 to 100% DM loss for BF harvested on d7 to d10.

DM intake was lower in the third experiment although digestion coefficient (DC) of BF was very high (98%). This condition was probably due to the abnormal growth of BF during the experimental period. Rumen fluid pH was 5.9-6.0 and ammonia-N (NH_3-N) content was 7.0 to 8.8 mg/mL. Total fatty acids production was 70 to 100 mmol/L between two and eight hour of collection. The acetic:propionic:butyric ratios were 58:36:1.3, 68:25:2, 61:35:1.2, 64:33:0.7 and 65:32:1 at 0, 2, 4, 6 and 8 hours, respectively.

Overall results showed that VFA and ammonia-nitrogen (NH_3-N) were produced at a minimum level when BF was given *ad libitum* although the digestibility was higher in both *in sacco* and *in vitro* studies. BF should be given at different levels in order to get optimum pH, VFA and NH_3-N production.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

NILAI PEMAKANAN FODER BARLI YANG DITANAM DI DALAM SISTEM HIDROPONIK

Oleh

AZILA ABDULLAH

September 2001

Pengerusi: **Profesor Madya Dr. Zainal Aznam Mohd Jelan**

Fakulti: **Pertanian**

Beberapa siri eksperimen telah dijalankan bagi menilai rumput barli (BF) sebagai makanan ruminan. Pertumbuhan rumput barli dilakukan di dalam persekitaran kabin khas yang bersuhu di antara 15-18°C. Eksperimen pertama ialah dengan melakukan pertumbuhan dan persampelan BF dari umur 0 (d0) hingga umur 10 hari (d10, n=11) untuk dianalisa kandungan bahan kimianya. Eksperimen kedua ialah dengan menggunakan teknik simulasi rumen (RUSITEC) untuk mengukur penghadaman bahan kering (BK), protin kasar (CP) dan pengeluaran asid lemak meruap (VFA) pada masa-masa yang berlainan. Teknik nilon beg digunakan untuk mengukur penghadaman BK di dalam rumen lembu untuk tempoh 2, 4, 8, 12, 24 dan 48 jam.

Eksperimen ketiga ialah mengukur pengambilan makanan dan penghadaman BF pada umur lapan hari secara *in vivo* ke atas empat ekor kambing jantan. Eksperimen keempat melibatkan pengukuran parameter cecair rumen (pH, ammonia dan VFA) di dalam tiga ekor kambing berfistula yang diberi BF berumur lapan hari secara *ad libitum.*

Kandungan CP, bahan organic (OM), ekstrak eter (EE), serat asid detergent (ADF) dan serat kasar (CF) dalam BF semasa d1 hingga d10 meningkat tetapi kandungan BK menurun. Kandungan BK pada d7 dan d8 masing-masing adalah 16 dan 18% manakala kandungan CP pula ialah masing-masing 12 dan 13%. Jumlah kandungan kalsium (Ca), fosforus (P) dan nitrat (NO_3^-) tidak menunjukkan sebarang perubahan yang ketara di sepanjang tempoh pertumbuhan. Kajian *in vivo, in vitro* dan *in sacco* menunjukkan bahawa terdapat kehilangan BK sehingga 80% hingga100% pada BF yang dituai semasa d7 dan d10.

Pengambilan BK adalah rendah di dalam kajian ketiga walaupun pekali penghadaman (DC) adalah tinggi ((98%). Keadaan ini mungkin disebabkan oleh pertumbuhan BF yang tidak normal semasa kajian dijalankan. PH cecair rumen ialah diantara 5.9-6.0 dan kandungan ammonia nitrogen (NH_3-N) ialah 7.0 hingga 8.8 mg/mL. Jumlah pengeluaran VFA ialah 70-100 mmol/L semasa pengutipan sampel dilakukan pada dua dan lapan jam. Nisbah acetic:propionic:butyric masing-masing ialah 58:36:1.3, 68:25:2, 61:35:1.2, 64:33:0.7 dan 65:32:1 semasa 0, 2, 4, 6 dan 8 jam pengutipan sampel.

Keseluruhan keputusan menunjukkan bahawa pengeluaran VFA dan NH_3-N adalah pada kadar yang minima apabila BF diberi secara *ad libitum*, walaupun penghadaman adalah tiggi di dalam kajian secara *in sacco* dan *in vitro*. BF seharusnya diberi pada tahap-tahap yang berbeza untuk mendapatkan pH yang optimum dan pengeluaran VFA dan NH_3-N yang optimum.

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science.

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LIST OF ABBREVIATIONS

ADF	-	Acid detergent fiber
BF	-	Barley fodder
Ca	-	Calcium
CaCl anhydrous	-	Dehydrated calcium chloride
CF	-	Crude fiber
CO_2	-	Carbon dioxide
CP	-	Crude protein
Cu	-	Copper
DC	-	Digestibility coefficient
DM	-	Dry matter
EE	-	Ether extract
H_2SO_4	-	Sulphuric acid
KCl	-	Potassium chloride
ME	-	Metabolise energy
MgCl anhydrous	-	Dehydrated magnesium chloride
Mn	-	Manganese
NaCl	-	Sodium chloride
$NaHCO_3$	-	Sodium bicarbonate
$NaHPO_412H_2O$	-	Sodium hydrogen phosphate
NDF	-	Neutral detergent fiber
NH_3-N	-	Ammonia nitrogen
NO_2^-	-	Nitrite
NO_3^-	-	Nitrate
OM	-	Organic matter
OPF	-	Oil palm fronds
P	-	Phosphorus
RUSITEC	-	Rumen simulation technique
VFA	-	Volatile fatty acid
Zn	-	Zinc

CHAPTER 1

INTRODUCTION

Fodder is an important component in ruminant diet. Many types of fodder had been used in ruminant particularly grass and legume species. *Leucaena leucocephala, Gliricidia sepium* and guinea grass (*Panicum maximum*) are among the fodder shrubs and grasses, respectively that are currently being utilized as ruminant feeds (Halim, 1993; Wong and Annuar, 1999; Khamseekhew *et al.*, 1999 & 2000). Their growth and performances depend on the soil type and weather condition with intensive labor work and management. Varieties of them are of low nutritive value due to the faster rate of maturity. Minson (1990) reported that the average crude protein (CP) was the lowest for tropical grasses when compared to temperate grasses because of their rapid growth. Other grasses such as *Axonopus compresses*, *Paspalum conjugatum* and *Imperata cylindrica* are characteristically low in dry matter production and CP (4-15 t/hectare/year and 4-9%, respectively, Halim, 1993).

Beside fodders and grasses, the ruminant can also consume agricultural by-products like oil palm fronds (OPF), pineapple waste and rice straw either in fresh or treated form. These materials are known to have low nutritive value due to its high crude fiber (CF) content. OPF for example have been reported to have high CF content of more than 400g/kg DM (Islam *et al.*, 1998). Rice straw and pineapple waste have only 4 and 6% CP and about 30 and 13% of CF, respectively (Alimon, 1993).

In Malaysia, large pasturelands are limited when compared to the high ruminant population. Malaysia has more than 83000 buffaloes, 680000 cattle and 500000 sheep and goats (NAP 3). Most farmers prefer the cash and profitable crops such as oil palm, rubber, cocoa or rice instead of fodder plantations. Nevertheless, several commercial ruminant farms have opened improved pastures and fodder crops, but land space is a constraint. Furthermore, mass production of fodder requires proper maintenance and good management.

Due to all these limitations, steps must be taken to diversify the fodder availability through the introduction of exotic species that have been identified to contain high quality nutritive value to be grown under similar agro-climatic condition. The automated and mechanized intensive production systems under controlled environment such as hydroponics can be used. Hydroponics system is the soiless culture of vegetables commonly used for human consumption. One unit of the system was brought to Universiti Putra Malaysia (UPM) in 1996 to produce feed for horses and ruminants that require high energy feed. The system can increase the production of fodder with the utilization of limited land and labor.

The main objective of this study was to investigate the potential use of barley fodder (BF) as ruminant feed produced by this hydroponics system.

The specific objectives are:

1. to determine the chemical composition of barley fodder at various stages of growth.
2. to determine the nutritive value of barley fodder for the best age of harvest.
3. to determine the intake and digestibility of barley fodder in goats fed *ad libitum*.
4. to determine the digestibility of barley fodder by *in vitro* (RUSITEC) and *in situ* (nylon bag) methods.
5. to determine the rumen fermentation pattern in goats fed barley fodder.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Growing of plants in water or nutrient solutions, referred as hydroponics, has been practiced for centuries. The term hydroponics was given by Dr. W.F Gericke in 1936 who did several studies on planting vegetables using water. This system was used to grow vegetables on a commercial scale to supply fresh food products for human. Vegetables grown by this method were claimed to be fresh and tasty. No pesticide were added and thus considered good for health.

The introduction of sprouted fodder for animals using hydroponics had been recognised as early as 1930 by Spangenberg (Leitch, 1939). The equipment consisted of cabinets with uniform unit sections, shallow tank shelves and removable perforated trays. A daily yield was 273 kg fodder for 10 days rotation. The most modern system consists of a cabin with controlled environment for germination and growth of barley as animal feed. The cabin is continuously lighted by fluorescent light and air-conditioned at a temperature of 18°C.

BF is used to feed high valued animals like racehorses, dairy goats and cattle. The internal environment of the cabin needs to be controlled. There is no adverse effect of temperature and nutrient solutions or lighting on the seeds or growing fodder. One unit of this system could produce one tonne of fodder per day.

Compared with the traditional crop grown on land, it needs about four hectares of land to grow grass that is equivalent to the amount produced by the system.

2.2 Methods of Growing Fodder

The current method to grow fodder is almost similar to the system used earlier. In a 'cabinet culture' by Spangenberg, 1930 (as cited by Leitch, 1939), 2.7 kg of seed per tray was soaked for 24 hours and then removed to another shelf, irrigated by turning on the tap water for three minutes daily. The germinating capacity for seed maize was about 96% (Leitch, 1939), and was about 60 to 65% in barley (Peer and Leeson, 1985a). Trubey (1969) had pre-germinated the seeds by plugging the water outlets of the culture and adding water until the seeds submerged. Four hours later, the water was drained and the process was repeated after 20 hours. The author reported that the seeds began to sprout at the end of 48 hours. The method was also used by Hillier and Perry (1969) to grow oats for six days. Water absorption by the seed caused rupture of the seed coat and started the germination process. Some proteolytic and lipolytic enzymes together with the secretion from the scutellum that surrounded the embryo prepared the stored material to be transported to and from the growing embryo. Carbohydrates and fats will be used for energy required by the growing embryo.

With modern technology, the cabinet was modified. A big container, which is highly insulated, thermostatically controlled and electrically powered was used. The germinating capacity increased up to 90%. The seeds still need to be soaked, but only for about 2 to 3 hours and spread evenly on white plastic trays instead of using baskets (Trubey, 1969). The germinating time till the time the fodder can be fed was seven days with minimum labour.

2.3 Types of Fodder

Seeds grown in the hydroponics system have been recognised previously as artificially grown fodder (BFGA) by Maity *et al*., 1996, oat grass (Hillier and Perry, 1969), oats seedlings (Trubey *et al*., 1969) or sprouted seed (Falen and Petersen, 1969). As far as the thesis is concerned, the seed produced in this system will be identified as barley fodder (BF).

Many types of seed can be grown as fodder. Among the usual types of seed used are maize/corn (Rule *et al*., 1986), barley and soybeans (Peer and Leeson, 1985a,b & c; Maity *et al*., 1996; Ong *et al*., 1997), oats (Trubey *et al*., 1969; Hillier and Perry, 1969) and wheat (Farlin *et al*., 1971). Because of the environmentally-controlled system, temperate seeds can be fully adapted to the suitable environment.

Peer and Leeson (1985b) fed 4-day old BF to young growing pigs and found that the digestibilities of dry matter (DDM), digestible protein (DP) and digestible energy (DE) were low. The use of BF in dairy cattle did not improve milk production and milk composition (Maity *et al*., 1996). Feeding BF at different levels to sows also did not have any effect on the litter size performance although they provided an addition of 4.7 MJ of ME when given to the sows (Ong *et al*., 1997).

2.4 Nutritive Value of Fodder

Feed contains many types of organic and inorganic materials such as carbohydrate, protein, fibre, minerals and also vitamins. These nutrients determine the nutritive values of the feed. Nutritive value is a role of the feed intake and the efficiency of nutrients extracted from the feed during digestion (Norton, 2000). Animals provided with high nutritive values feed produce high levels of growth and productivity.

Researchers have reported different result on the nutritive value of fodder. Trubey *et al.*, (1969) compared the nutrient composition of oat seedlings grown under light or dark conditions and the influence of culture solution at three and six days of sprouting. They found that six-day old seedlings had a higher fresh weight, CP, ash and soluble carbohydrate (CHO) content. However the dry matter (DM) was higher in three-day old seedlings. There was no significant effect of light on the fresh weight, CP and water-soluble carbohydrate of the oats.

Hillier and Perry (1969) stated that the CP and CF contents of oat sprout based on DM basis was about 20.7 and 21.1%, respectively as compared to the oat grain itself. However the DM content was much lower. Peer and Leeson (1985a & b) carried out two subsequent analyses on the composition and nutritive value of BF. They also found that the younger the age of the sprout, the higher the DM content. CP did not significantly increase throughout the sprouting period. During growth, there was a linear increase in concentration of aspartic acid, alanine, lysine, threonine, glycine and gamma amino butyric acid, but proline and glutamic acid decreased.

FOMETA, the pioneer of the BF technology published a reference called *'Test and Testimonials on Fometa Mechanical Fodder Production System'*. The fodder produced by this unit increased animal productivity such as milk yield, growth and improved animal health. BF has high CP content (Table 2.1) and high digestibility (80 - 85%). It also contains a high content of carotene (Vitamin A), which is not found in other types of feed materials.

Table 2.1: Nutritive value of barley fodder

Crude protein %	19.7	ME %	12.6	Ca %	0.104
Digest. Protein %	16.8	Carotene	25 IU/kg/DM	P %	0.470
Crude fibre %	13.2	Vit. E	26.1 IU/kg/DM	Mg %	0.140
DM %	18.6	Zn	34 ppm	K %	3
Fat %	4.4	Mn	29990 ppm		
Digestibility	80 - 85	Cu	8 ppm		

Digestibility, carbohydrate and energy contents decreased with sprouting time but fibre content increased. DM digestibility, digestible protein and energy were lower compared to ground barley, but superior to whole barley (Peer and Leeson, 1985a). Digestion trials showed that the digestible energy of BF was 12.5 MJ/kg compared to ground barley which was 15.9 MJ/kg. The DM content was low as the fodder was grown under a wet condition (hydroponics).