UNIVERSITI PUTRA MALAYSIA

NUTRITIONAL EVALUATION OF Moringa oleifera LAM. AS A SUBSTITUTE FOR CONCENTRATE FEED FOR BENGAL GOAT

NASRIN SULTANA

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By

NASRIN SULTANA

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

December 2014

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DEDICATION

TO THE SOUL OF MY MOTHER WITH

SUPPLICATION FOR FORGIVENESS

AND

TO MY FATHER, WITH LOVE

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

NUTRITIONAL EVALUATION OF *Moringa oleifera* LAM. AS A SUBSTITUTE FOR CONCENTRATE FEED FOR BENGAL GOAT

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December 2014

Chairman: Professor Abdul Razak Bin Alimon, PhD

Faculty: Agriculture

Insufficient quality feed is a major limiting factor for goat production in many developing countries including Bangladesh. To overcome this problem, maximizing the use of locally available feed resources and locally grown forages is an alternative option. *Moringa oleifera* tree is a small tree cultivated in many regions in the south Asian countries and is not fully utilized as ruminant feed. Moringa foliage has not been extensively evaluated in terms of nutritional characterization at different cutting intervals and its partial or whole replacement of concentrate in the diets of goats. It contain polyunsaturated fatty acid and has antioxidant activity, however studies on its effects on goat meat quality in Bangladesh have not been done yet. Therefore, the current study was undertaken with the objectives to (i) evaluate the nutritional characteristics of different plant fractions of *Moringa oleifera* tree harvested at different cutting intervals and (ii) evaluate the growth performance and carcass and meat quality of Black Bengal goats fed diets supplemented with moringa foliage. To achieve these objectives three experiments were conducted

In the first experiment, an existing moringa plot at BLRI with 180 trees, of area 201.86 m^2 was used. The plot was divided into 12 blocks which size was 16 m^2 having 15 plants and the plots were subjected to three regimes of 4, 6 or 8 weeks cutting intervals. The experimental design was a randomized complete block design (RCBD) consisting of three treatments (4, 6 and 8 weeks cutting interval) with four replications. The highest dry matter (DM) content of total foliage (2247.05; 242.83g kg^{-1}), leaf (261.26; 247.30g kg^{-1}) and stem (204.10; 197.65g kg^{-1}) were found at the 6 and 8 weeks cutting intervals than 4 weeks cutting interval. The CP content of total foliage (214.80 to 216.20g kg^{-1}DM), leaf (256.65 to 261.33g kg^{-1}DM) or stem (81.30 to 88.44 g kg^{-1}DM) did not differ significantly (P>0.05) among the cutting intervals. The ADF (268.30; 268.46 g kg^{-1}DM), NDF (347.11; 369.51g kg^{-1}DM), and ADL (99.89; 109.00 g kg^{-1}DM) content of total foliage was significantly ($P< 0.01$) lower in 4 and 6 weeks interval respectively than 8 weeks (310.29, 381.77 and 120.36g kg^{-1}DM, respectively) whereas the fiber content in the leaf was similar among the cutting intervals. IVDMD and IVOMD of total foliage were significantly

(P<0.05) higher (801.63; 781.05 g kg^{-1} and 798.07; 785.06g kg^{-1}DM, respectively) in 4 and 6 weeks interval than 8 weeks interval (772.10 and 761.35g kg^{-1}DM, respectively).Data from the present study suggests that moringa foliage and leaf were better quality in terms of nutrient composition, IVDMD and IVOMD at 4 to 6 weeks cutting interval compare to 8 week.

In the second experiment, moringa foliage samples were taken according to experiment-1. Samples from four blocks in each treatment were pooled and taken sample for analysis of the experiment. This experiment was arranged in complete randomized design (CRD) to determine the effect of cutting interval on ant-nutritional compound, anti-oxidant activity and fatty acid profile of moringa foliage. Total phenols (51.86; 43.89 mg tannic acid equivalent g^{-1}DW), tannin (34.90; 43.89 mg tannic acid equivalent g^{-1}DW), and condense tannin (0.23; 0.17 mg catechin equivalent g^{-1} DW) content of moringa foliage were significantly (P<0.01) higher at 4 and 6 weeks cutting interval than at 8 weeks (29.00, 16.66 and 0.14respectively). Subsequently, the DPPH radical scavenging activity of moringa foliage was significantly (P<0.05) higher (60.06 %) at 4 wks cutting interval than 6 and 8 wks (55.96 and 53.97 % respectively).From the results obtained in the second experiment exposed that moringa foliage was possess higher antioxidant activity at 4 week cutting interval than 6 and 8 week.

In the third experiment, a total of thirty growing Black Bengal goats were allocated into five groups with six goats per treatment. The design of the experiment was a completely randomized design (CRD). The rice straw was used as a basal diet at the rate 30% of total feed. Concentrate mixture feed was substituted with moringa foliage at 25, 50, 75 and 100 among remaining 70% diet. The five dietary treatments consisted of varying proportion of moringa foliage (MF) and concentrate (C), T_1 (100MF); T_2 (75MF:25C); T3 (50MF:50C); T4 (25MF: 75C) and T5 (100C).The duration of feeding and growth trial was 105 days. After completing the feeding trial, digestibility trial was carried out. Then, four animals from each treatment were randomly selected for slaughter to evaluate the carcass and meat quality. The CP and energy content in moringa foliage and concentrate mixture were 19.95 and 20.04 percent and 11.36 and 11.31 MJ kg^{-1} DM respectively. Average daily live weight gain (67.83, 79.33, 74.33, 71.33 and 67.33 g d^{-1} respectively for 100M, 75M: 25C, 50C:50C, 25M: 75C and 100C diet) FCR (6.38, 6.30, 6.28, 6.46 and 6.80 respectively for 100M, 75M: 25C, 50C:50C, 25M: 75C and 100C diet), nutrient intake and utilization were not significantly (P>0.05) different among treatments group except ADF intake and digestibility. Carcass weight and dressing percentage was not (P>0.05) influenced by different dietary treatment. Percentage of lean meat as percent of cold carcass weight was significantly (P<0.05) higher in 75M:25C (73.72%) and 100M (72.18%) diet compare to 50M:50C (69.60%), 25M:75C (69.05%) and 100C (69.30%) diets. Similarly, lean:fat was also significantly (P<0.05) higher in 75M:25C (15.01%) and 50M:50C (11.77%) than that of 50M:50C (69.60%), 25M:75C (69.05%) and 100C (69.30%) diets. Lean**:** fat was increased upto 75% inclusion level of moringa foliage. Intramuscular fat was also increased with increasing level of concentrate feed in diets. Drip loss of *longissimus dorsi* (LD) muscle and cooking loss of *semitendinosus* (ST) muscle was found lower (17.32%; 38.98%, respectively) (P<0.05) value in 100M diet and increased with

increasing concentrate feed proportion (17.48, 20.22, 20.37 and 20.62% and 40.85, 41.61, 45.59 and 45.38% ,respectively for drip loss and cooking loss followed by 75M:25C, 50M:50C, 25M:75C and 100M diet). Conversely, shear-force (kg) of both muscles was significantly ($P<0.05$) increased with increasing concentrate feed in diet. Color characteristics in terms of lightness (L*), redness (a*) and hue angle (H°) of *longissimus dorsi* (LD) muscle was higher (46.29, 12.55 and 44.89, respectively) in 100M diet compare to other diets. Similar trend was observed in *semitendinosus* (ST) muscle. Moringa foliage was increased the UFA and PUFA in *longissimus dorsi* (LD) and *semitendinosus* (ST) muscles compared to that of a complete concentrate diet. Additionally, proportion of polyunsaturated fatty acid and saturated fatty acid increased with increasing level of moringa foliage and proportion omega-6 and omega-3 fatty acid was reduced with increasing level of moringa foliage in the diets. Moringa foliage, which is affluent in the 18:3*n*-3, is an important device to generate *n*-3 PUFA in the meat. Malondialdehyde (MDA), a major lipid oxidation substrate in both *longissimus dorsi* (LD) and *semitendinosus* (ST) muscles was reduced with increasing supplementation of moringa foliage. The decreasing in lipid peroxidation level in both muscles indicates the role of moringa foliage as an antioxidant that can protect oxidized lipid in muscle

The present study reveals goats fed moringa foliage supplemented diets achieved a favorable growth performance and more desirable leaner carcass with higher proportion of meat and lower weight of subcutaneous fat to improve carcass characteristics. Increasing moringa foliage in diet tended to improve meat quality in terms of water holding capacity and color characteristics. Substitution of concentrate with moringa foliage in diet could also decrease the total SFA and increase polyunsaturated fatty acids in chevon would be favorable in improving health and well-being and reducing degenerative diseases in human being. Moreover, moringa foliage has the significant antioxidant potential, therefore, supplemented of moringa foliage in diets to goats could protect products from oxidative deterioration during the postmortem period. The protective effect of moringa foliage may elucidate its extensive use in shelf life of meat. Thus, moringa foliage could be used as a substitute of expensive concentrate feed for goat.

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

PENILAIAN DALAM PEMAKANAN *Moringa oleifera* LAM. SEBAGAI GANTIAN BAGI MAKANAN KONSENTRAT UNTUK BENGAL KAMBING

Oleh

NASRIN SULTANA

Disember 2014

Pengerusi: Profesor Abdul Razak Bin Alimon, PhD

Fakulti: Pertanian

Makanan berkualiti yang tidak mencukupi adalah faktor utama untuk menghadkan pengeluaran kambing di negara-negara membangun termasuk Bangladesh. Untuk mengatasi masalah ini, memaksimumkan penggunaan sumber makanan tempatan yang sedia ada dan foraj tempatan yang berkembang adalah pilihan alternatif. *Moringa oleifera* adalah pokok kecil yang ditanam di kebanyakan rantau di negara-negara Asia selatan dan tidak digunakan sepenuhnya sebagai makanan ruminan. Daun Moringa belum dinilai secara meluas dari segi pencirian pemakanan pada jangka masa yang berbeza pemotongan dan penggantian sebahagian atau keseluruhan konsentrat dalam diet kambing. Ia mengandungi asid lemak tak tepu dan mempunyai aktiviti antioksidan, bagaimanapun kajian mengenai kesannya terhadap kualiti daging kambing di Bangladesh telah tidak dilakukan lagi. Oleh itu, kajian semasa telah dijalankan dengan objektif untuk (i) menilai ciri-ciri pemakanan bahagian tumbuhan yang berbeza pokok *Moringa oleifera* yang dituai pada selang pemotongan yang berbeza dan (ii) menilai prestasi pertumbuhan, karkas dan kualiti daging kambing Black Bengal yang diberi makan diet tambahan dengan daun moringa. Untuk mencapai objektif ini tiga eksperimen telah dijalankan. Dalam uji kaji yang pertama, satu plot moringa sedia ada di BLRI dengan 180 pokok, dengan keluasan 201.86 m2 adalah digunakan. Plot telah dibahagikan kepada 12 pokok yang saiz adalah 16 m2 dan mempunyai 15 pokok, dan plot tertakluk kepada tiga bahagian 4, 6 atau 8 minggu selang masa pemotongan. Reka bentuk eksperimen adalah rekabentuk rawak lengkap blok (RCBD) yang terdiri daripada tiga rawatan (4, 6 dan 8 minggu selang masa pemotongan) dengan empat replikasi. Peratus berat kering tertinggi (DM) daripada jumlah foraj (2247.05; 242.83g kg-1), daun (261.26; 247.30g kg-1) dan batang (204.10; 197.65g kg-1) telah didapati pada 6 dan 8 minggu masa pemotongan berbanding pada 4 minggu jangkamasa pemotongan. Kandungan CP daripada jumlah dedaunan (214.80 untuk 216.20g kg-1DM), daun (256.65 untuk 261.33g kg-1DM) atau batang (81.30-88.44 g kg-1DM) tidak berbeza secara signifikan ($P>0.05$) antara jangkamasa pemotongan. ADF (268.30; 268.46 g kg-1DM), NDF (347.11; 369.51g kg-1DM), dan ADL (99.89; 109.00 g kg-1DM) kandungan daripada jumlah dedaun adalah ketara ($P<0.01$) yang lebih rendah pada 4

dan 6 minggu jangkamasa pemotongan berbanding daripada 8 minggu (310.29, 381.77 dan 120.36g kg-1DM) manakala kandungan serabut dalam daun adalah sama antara jangkamasa pemotongan. IVDMD dan IVOMD nyata jumlah foraj ($P<0.05$) lebih tinggi (801.63; 781.05 g kg-1 dan 798.07; 785.06g kg-1DM, masing-masing) dalam tempoh 4 dan 6 minggu daripada tempoh 8 minggu (772,10 dan 761.35g kg-1DM, masing-masing). Data dari kajian ini menunjukkan bahawa daun moringa adalah lebih berkualiti dari segi kandungan nutrien, IVDMD dan IVOMD pada 4 hingga 6 minggu masa pemotongan berbanding 8 minggu.

Dalam eksperimen kedua, sampel forage moringa diambil mengikut eksperimen 1. Sampel dari empat blok di setiap rawatan telah dikumpulkan dan diambil sampel untuk analisis eksperimen. Eksperimen ini telah disusun dalam rekabentuk rawak lengkap (CRD) untuk menentukan kesan jangkamasa pemotongan pada faktor anti-pemakanan, aktiviti anti-oksidan dan profil asid lemak forage moringa. Jumlah fenol (51.86; 43.89 mg asid tannic bersamaan g-1DW), tanin (34.90; 43.89 mg asid tannic bersamaan g-1DW), dan kondensasi tanin (0.23; 0.17 mg bersamaan catechin g-1 DW) kandungan forage moringa nyata ($P<0.01$) lebih tinggi pada jangkamasa pemotongan 4 dan 6 minggu berbanding pada 8 minggu (masing-masing 29.00, 16.66 dan 0.14). Selepas itu, aktiviti radikal DPPH daripada daun moringa bererti ($P<0.05$) lebih tinggi (60.06%) pada 4 minggu waktu pemotongan berbanding minggu 6 dan 8 (masing-masing 55.96 dan 53.97%). Keputusan yang diperolehi dalam eksperimen kedua mendedahkan dedaunan moringa adalah mempunyai aktiviti antioksidan yang lebih tinggi pada 4 minggu masa pemotongan berbanding 6 dan 8 minggu.

Percubaan ketiga, sejumlah 30 ekor kambing Black Bengal telah diperuntukkan kepada lima kumpulan dengan enam kambing setiap rawatan. Reka bentuk eksperimen adalah reka bentuk yang sama sekali rawak (CRD). Jerami padi digunakan sebagai diet yang basal pada kadar 30% daripada jumlah makanan. Makanan campuran konsentrat diganti dengan daun moringa pada 25, 50, 75 dan 100 di kalangan baki 70% diet. Lima rawatan diet terdiri daripada perkadaran yang berbeza-beza foraj moringa (MF) dan konsentrat (C), T1 (100MF); T2 (75MF: 25C); T3 (50MF: 50C); T4 (25MF: 75C) dan T5 (100C). Tempoh penyusuan dan percubaan pertumbuhan adalah 105 hari. Selepas menamatkan ujian pemberian, percubaan penghadaman dilakukan, empat haiwan dari setiap rawatan telah dipilih secara rawak untuk disembelih untuk menilai kualiti karkas dan daging. CP dan tenaga kandungan dalam daun moringa dan konsentrat campuran ialah 19.95 dan 20.04 peratus dan 11.31 11.36 dan MJ masing-masing kg-1 DM. Purata pertambahan berat badan harian hidup (67.83, 79.33, 74.33, 71.33 dan 67.33 g masing-masing d-1 untuk 100M, 75M: 25C, 50C: 50C, 25M: 75C dan diet 100C) FCR (6.38,6.30, 6.28, 6.46 dan 6.80 masing-masing untuk 100M, 75M: 25C, 50C: 50C, 25M: 75C dan diet 100C), pengambilan nutrien dan penggunaan tidak bererti ($P> 0.05$) yang berbeza antara kumpulan rawatan kecuali pengambilan ADF dan penghadaman. Berat karkas dan peratus karkas tidak ($P> 0.05$) dipengaruhi oleh rawatan diet yang berbeza. Peratusan daging tanpa lemak sebagai peratus daripada berat karkas sejuk nyata ($P<0.05$) lebih tinggi di 75M: 25C (73.72%) dan 100M (72.18%) diet ke 50M: 50C (69.60%), 25M: 75C (69.05%) dan 100C (69.30%) diet. Begitu juga, tanpa lemak: lemak adalah juga ketara ($P<0.05$) lebih tinggi di 75M: 25C (15.01%) dan 50M: 50C

(11.77%) berbanding dengan 50M: 50C (69.60%), 25M: 75C (69.05%) dan 100C (69.30%) diet. Lemak telah meningkat hampir tahap kemasukan 75% daripada daun moringa. Lemak intramuskular telah juga meningkat dengan peningkatan tahap makanan konsentrat dalam diet.

Lemak intramuskular telah juga meningkat dengan peningkatan tahap makanan konsentrat dalam diet. Drip loss daripada longissimus dorsi (LD) otot dan kehilangan semitendinosus (ST) otot didapati lebih rendah (17.32%; 38.98%, masing-masing) ($P<0.05$) nilai dalam 100M diet dan meningkat dengan peningkatan nisbah makanan konsentrat (17.48, 20.22, 20.37 dan 20.62% dan 40.85, 41.61, 45.59 dan 45.38%, masing-masing) bagi drip loss dan cooking loss seperti berikut, 75M: 25C, 50M: 50C, 25M: 75C dan 100M diet). Sebaliknya, ricih-daya (kg) bagi kedua-dua otot nyata ($P<0.05$) meningkat dengan peningkatan makanan konsentrat dalam diet. Ciri-ciri warna dari segi ringan (L *), kemerahan (* a) dan sudut warna (H °) longissimus dorsi (LD) otot adalah lebih tinggi (46.29, 12.55 dan 44.89, masing-masing) dalam 100M diet ke diet lain. Aliran yang sama ditunjukkan dalam semitendinosus (ST) otot. Daun Moringa telah meningkatkan UFA dan PUFA dalam *longissimus dorsi* (LD) dan semitendinosus (ST) otot berbanding dengan diet konsentrat yang lengkap. Selain itu, nisbah asid lemak tak tepu dan asid lemak tepu meningkat dengan tahap foraj moringa dan bahagian omega-6 dan omega-3 asid lemak yang semakin meningkat telah dikurangkan dengan meningkatkan tahap diet foraj moringa. Moringa, yang mempengaruhi dalam 18 : 3n-3, adalah satu peranti yang penting untuk menjana n-3 PUFA dalam daging. Malondialdehyde (MDA), yang utama substrat pengoksidaan lipid dalam kedua longissimus dorsi (LD) dan semitendinosus (ST) otot berkurangan dengan peningkatan suplemen foraj moringa. Yang semakin berkurangan di peringkat peroksidaan lipid dalam kedua-dua otot menunjukkan peranan daun moringa sebagai antioksidan yang boleh melindungi lipid teroksida dalam otot.

Kajian ini mendedahkan kambing yang ditambah diet daun moringa mencapai prestasi pertumbuhan yang menggalakkan dan karkas lebih wajar lebih ramping dengan kandungan daging yang berat daripada daging dan rendah lemak subkutaneus memperbaiki ciri-ciri karkas. Peningkatan diet dedaun moringa cenderung untuk meningkatkan kualiti daging dari segi keupayaan pegangan air dan ciri-ciri warna. Penggantian konsentrat dengan dedaun moringa dalam diet juga boleh mengurangkan jumlah SFA dan meningkatkan asid lemak politaktepu dalam chevon memberi faedah dalam meningkatkan kesihatan dan kesejahteraan dan mengurangkan penyakit degeneratif bagi manusia. Selain itu, daun moringa mempunyai potensi antioksidan yang penting, oleh itu, ditambah dedaunan moringa dalam diet untuk kambing boleh melindungi produk daripada kemerosotan oksidatif dalam tempoh bedah siasat. Kesan foraj moringa boleh menjelaskan perlindungan penggunaan yang lama dalam penggunaan daging. Oleh itu, dedaun moringa boleh digunakan sebagai pengganti makanan konsentrat mahal untuk kambing.

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I certify that a Thesis Examination Committee has met on 4 December 2014 to conduct the final examination of Nasrin Sultana on his thesis entitled "Nutritional Evaluation of *Moringa oleifera* Lam. As a Substitute for Concentrate Feed for Bengal Goat" 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.

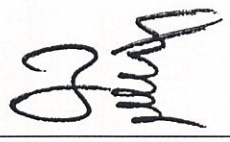
Members of the Thesis Examination Committee were as follows:

Jothi Malar a/p P.V. Panandam, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

Dahlan bin Ismail, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Mohd Ridzwan bin Abd Halim, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Internal Examiner)

Hassan Fazaeli Mahmoud, PhD
Professor
Animal Science Research Institute
Iran
(External Examiner)



ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 23 January 2015

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

Abdul Razak Bin Alimon, PhD
Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

HalimatunYaakub, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Awis Qurni Bin Sazili, PhD
Senior Lecturer
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

Khan Shahidul Huque, PhD
Chief Scientific Officer
Animal Production Research Division
Bangladesh Livestock Research Institute
(Member)

_____
BUJANG BIN KIM HUAT, PhD.
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Declaration by graduate student

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Name and Matric No: Nasrin Sultana (GS28483)

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision
- Supervision responsibilities as stated in Rule 41 in Rules 2003 (Revision 2012- 2013) were adhered to.

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Name of Chairman of Supervisory Committee

PROF. DR. ABDUL RAZAK ALIMON
Pensyarah
Jabatan Sains Haiwan
Fakulti Pertanian
Universiti Putra Malaysia

Abd. Razak Bin Alimon, PhD

Signature ----------

DR. HALIMATUN YAAKUB
Associate Professor
Department of Animal Science
Universiti Putra Malaysia

Name Of Member Of Supervisory Committee

Halimatun Yaakub, PhD

Signature ----------

Name Of Member Of Supervisory Committee

Awis Qurni Bin Sazili, PhD

DR. AWIS QURNI SAZILI
Pensyarah Kanan
Jabatan Sains Haiwan
Fakulti Pertanian
Universiti Putra Malaysia

Signature.....

for

Name Of Member Of Supervisory Committee

Khan Shahidul Huque, PhD

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ADF	acid detergent fiber
ADG	average daily gain
ADL	acid detergent lignin
ANOVA	analysis of variance
BG	Bengal goat
BHT	butylated hydroxyl toluene
BLRI	Bangladesh Livestock Research Institute
BW	body weight
CETAB	cetyl trimethylammonium bromide
°C	degrees centigrade
CLA	conjugated lenoleic acid
CP	crude protein
d	day
DCP	dicalcium phosphate
DM	dry matter
DMD	dry matter digestibility
DMI	dry matter intake
DPPH	2, 2-diphenyl-1-picryhydrazyl
DW	dry weight
DSW	dry sample weight
EE	ether extract
FA	fatty acid
FAO	food and agriculture organization
FCR	feed conversion ratio

FID	flame ionized detector
FMAE	fatty acid methyl esters
g	gram
GE	Gross energy
h	hour
ha	hectare
IVDM	*in-vitro* dry matter
IVOM	*in-vitro* organic matter
IVDMD	*in-vitro* dry matter digestibility
IVOMD	*in-vitro* organic matter digestibility
KCl	potassium chloride
l	litre
kg	kilo calories
LD	*longissimus dorsi*
MDA	malondialdehyde
ME	metabolizable energy
MF	moringa foliage
m	metre
ml	milliliter
mm	millimeter
mg	milligram
MOL	*Moringa oleifera* leaf
MUFA	mono unsaturated fatty acids
n-3:n-6 ratio	total n-3 PUFA to total n-6 PUFA ratio
NDF	neutral detergent fiber

NDS	neutral detergent solution
NRC	Nutritional Research Council
OM	organic matter
OMD	organic matter digestibility
PUFA	polyunsaturated fatty acid
PUFA: SFA ratio	total PUFA to total SFA ratio
SE	standard error
SFA	saturated fatty acid
ST	*semitendinosus*
t	ton
TBARS	thiobarbituric acid reactive substances
TFC	total flavonoid compounds
TPC	total phenol compounds
TNCF	total non-carcass fat
UNO	United Nation Organization
USFA	unsaturated fatty acid
VSF	Volodkevitch shear force
W	weight
WAD	West African Dwarf goats
WBSF	Warner-Bratzler shear force
WHO	World Health organization
y	year

CHAPTER 1

INTRODUCTION

Feed unavailability is a most important constraint to the development of ruminant production in the developing countries in Asia and in many parts of the world, where the ruminant animals are usually raised on natural pastures, crop residues, agro-industrial by-products and non-conventional feed resources; mainly of local fodder, shrubs or tree leaves which are usually deficient in nutrient contents. These feeds are generally low in quality and imbalanced in terms of mineral and vitamin contents. They are deficient in protein, energy, minerals and vitamins. Animals fed on these feeds fail to get adequate nutrients for their maintenance and production, and show poor productive and reproductive performances. These low quality roughages require supplementation with concentrates as sources of protein, energy and macro and micro minerals to support improved their performance. However, concentrates are expensive and may not be accessible to small holder farmers.

There is a general shortage of concentrate feed in the Asian countries which is partially meet by importation. Imported feed ingredients lead to a higher production cost of livestock products. Therefore, strategies need to be developed through enhancing the production of indigenous feed resources and their efficient utilization for ruminants (Makkar, 2012).

Forage from fodder trees and shrubs may be contributed for increasing the supply of quality feed and availability of feed to resource-limited livestock farmers (Moyo *et al*., 2012a). The most of fodder tree and shrub forages are cultivated easily with minimum cost and without using any modern technology (Mendieta-Araica *et al*., 2011b). The tree fodders provide a cheap source of protein and micronutrients. Now a days, scientists has been shown increasing research interests on searching alternative protein sources for goats from forage trees and shrubs (Sanon *et al*., 2008;Yayneshet *et al*., 2008; Marume, 2010 and Oni *et al*., 2010).

Moringa oleifera Lamarck is a small non-leguminous multipurpose native tree to Bangladesh, India, Pakistan, and Afganistan (Sreelatha and Padma, 2009). It grows fast, is rich in protein and contains negligible amounts of anti-nutritive compounds (Nouala *et al*., 2006; Ogbe and affiku, 2011; Aye and Adegum, 2013, Mendieta-Araica *et al*., 2011b). A major fraction of the protein of moringa leaves is true protein (Makkar, 2012) including a rich source of carotenoids, vitamin C and antioxidants (Yang *et al*., 2006; Sreelatha and Padma, 2009) makes moringa leaves more nutritionous feed for goats (Sarwatt *et al*., 2002; Asaolu *et al.*, 2010, 2011 and 2012; Moyo *et al*., 2012a and) and other ruminant animals (Murro *et al*., 2003; Sarwatt, *et al*., 2004; Mendieta-Araica *et al*., 2011b; Gerbregiorgis *et al*., 2012 and Sánchez *et al*., 2006a).

The goat population in Bangladesh is 27.1 million (FAOSTAT, 2008). Most of the goats possess Black Bengal which is about 90% of the total goats (DLS, 2010). The characteristics of Black Bengal goats are small in size having live weight 16-18 kg for a mature female and 24-26 kg for adult males, highly prolific, good meat and skin quality and survive to harse environment (Chowdhury and Faruque, 2004; Khan and Khatun, 2013). The goat stands second position in terms of meat, milk and skin production, in placed of about 38.0, 23.0 and 28.0%, respectively to the total contribution of livestock in Bangladesh (FAO, 1997). The goats are mostly raised by small, marginal and landless farmers under scavenging system. Now a days, established Govermment farms including some private organization are keeping goat unde semi-scavanging system (DLS, 2010). Goat are usually graze on fallow land, embankment of river, road side and in the cultivable land between cropping interval about eight hours.The goats are also grazing about eight hours in the pasture lands and they are also provided some concentrate mixed (maize grain, wheat bran, kheshari bran and soybean meal) under semi scavenging system. Goats have been recently documented as a tool of poverty alleviation by the Government of Bangladesh (DLS, 2010).

Meat production is the most important function of goats in the tropics (Devendra, 1991). The Bengal Goat (BG) of Bangladesh is kept mainly for meat production, and their carcass quality was found to be low under traditional poor feeding system (Chowdhury and Faruque, 2004). These animals are mainly raised under scavenging and browsing system. However, raising them under a semi-intensive system with supplementation of quality feeds resulted in a higher average daily gain and improved dressing percentage and carcass quality (Chowdhury and Faruque, 2004). Most of the goats in the South East Asia are reared by small holder farmers, rarely getting concentrate feeds due to high feed cost and capital constraint. Moringa trees are available and grow abundantly at farm levels, and it's foliages may support better growth, and carcass yield and meat quality.

1.1. Research Problem

The world consumption of animal products might be double in a future period of four decades than that of the reporting year, and a large part of the increase would be in the Asia (FAO, 2011). The average per capita meat consumption in the Asia is lower than the world average (Makkar, 2012). The demand of animal protein has been increasing with the rise of population, urbanization, and income and dietary shift to high quality food in the most parts of the Asia. However, availability of feeds both in terms of quality and quantity is considered to be the most limiting factor for goat production in Bangladesh, and efficient utilization of locally available feed resources may increase feed availability cost effectively at farm levels.To increase goat production, maximum utilization of indigenous feed resources could be an alternative to expensive concentrate feed.

1.2. Research hypothesis

Bangladesh has available *Moringa oleifera* tree, but still are not utilized as ruminant feed. Moringa foliage has not been evaluated in terms of nutritional characterization at different cutting interval and the effect of partial or whole substitution of concentrate feed on goat performances and the effect of polyunsaturated fatty acid and antioxidant activity in moringa foliage on goat meat quality in Bangladesh. An optimum level of moringa foliage inclusion in diets replacing concentrate feeds with an enhanced growth performance and meat quality of Bengal goats (BG) was determined through conducting feeding trials. Hence, the research hypotheses are:

i) The nutrient composition and digestibility of moringa foliage is sufficiently high and can be used as feed for ruminants
ii) Moringa foliage can replace partially or wholly the concentrate component in Bengal goat diet.
iii) The carcass composition and quality of goats fed diets supplemented with moringa foliage is superior to that of goats receiving diet of straw and concentrate only.

1.3. Research Objectives

The general objective of this study was to evaluate the nutritional characterization of different plant fractions of *Moringa oleifera* tree harvested at different cutting intervals, and to evaluate the growth performance and carcass and meat quality of Black Bengal goats fed diets supplemented with moringa foliage.The specific objectives were as follows:

1. To determine nutrient composition of different plant fractions of *Moringa oleifera* harvested at different cutting intervals.
2. To determine anti-nutritional compounds, anti-oxidant activity and fatty acid composition of moringa foliages at different cutting interval.
3. To evaluate the effects of partial and whole replacement of concentrate feed by moringa foliage on the growth, carcass composition and meat quality of Bengal goats fed on a paddy straw based diet.

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