

**GROWTH AND NUTRIENT UTILISATION WITH
SUPPLEMENTATION OF GROWTH
PROMOTANT IN MURRAH BUFFALO HEIFERS**

By
RAMESH

Thesis submitted to the Chaudhary Charan Singh Haryana
Agricultural University in partial fulfillment of the
requirements for the degree of:

MASTER OF VETERINARY SCIENCE

in

ANIMAL NUTRITION



**College of Animal Sciences
Chaudhary Charan Singh
HARYANA AGRICULTURAL UNIVERSITY,
Hisar
2000**

636.2085
R1459

T

Initial

Nov

Nehru Library, HAU, HISAR
Acc. No. 233809, Dr. 8.5.2000
Source: *Donor P-4*
Letter No. & Date: *8722-26*
Price: *28.75*
Deptt. *Humanities*

636.2085 R145C



233809

**DEDICATED
TO MY
LATE FATHER**

CERTIFICATE – I

This is to certify that this thesis entitled, "GROWTH AND NUTRIENT UTILISATION WITH SUPPLEMENTATION OF GROWTH PROMOTANT IN MURRAH BUFFALO HEIFERS", submitted for the degree of Master of Veterinary Science in the subject of ANIMAL NUTRITION of Chaudhary Charan Singh Haryana Agricultural University, Hisar is a bonafide research work carried out by Dr. Ramesh under my supervision and that no part of this thesis has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

M.A. Akbar

(M.A. Akbar)

Major Advisor

Assistant Research Scientist (Sr. Scale)

Department of Animal Nutrition

CCS Haryana Agricultural University,

Hisar – 125 004

Naresh Kumar

(Naresh Kumar)

Co-Major Advisor,

Senior District Extension Specialist,

(Animal Science),

Krishi Gyan Kendra, Gurgaon (Haryana)

CERTIFICATE – II

This is to certify that this thesis entitled, "GROWTH AND NUTRIENT UTILISATION WITH SUPPLEMENTATION OF GROWTH PROMOTANT IN MURRAH BUFFALO HEIFERS", submitted by Dr. Ramesh to the Chaudhary Charan Singh Haryana Agricultural University, Hisar, in partial fulfilment of the requirements for the degree of Master of Veterinary Science in the subject of ANIMAL NUTRITION has been approved by the Student's Advisory Committee after an oral examination on the same.

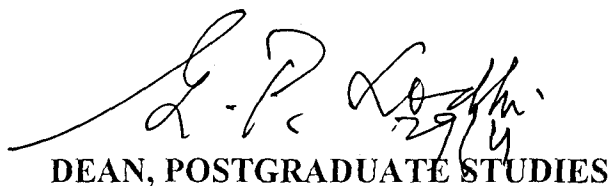


MAJOR ADVISOR

Namash Kumar
12/4/2020
CO-MAJOR ADVISOR



HEAD OF THE DEPARTMENT



DEAN, POSTGRADUATE STUDIES

ACKNOWLEDGEMENTS

It gives me immense pleasure to express profound gratitude to my Major Advisor, Dr. M.A. Akbar, Assistant Research Scientist (Senior Scale), Department of Animal Nutrition, CCS Haryana Agricultural University, Hisar for his affectionate, cooperative guidance and help rendered to me throughout my Master's programme. His friendly and optimistic behaviour inspired me throughout my study period to achieve the fruitful results.

I would like to render my great thanks to the worthy members of my Advisory Committee, Dr. Naresh Kumar Yadav, Co-Major Advisor, Senior DES, Department of Animal Nutrition; Dr. J.P. Puri, Associate Professor, Department of Veterinary Physiology; Dr. Narinder Singh, Professor and Head, Department of Livestock Production and Management; Dr. S.S. Khirwar, Professor and Head, Department of Animal Nutrition and Dr. Narendra Singh, Dean, College of Animal Sciences, CCS Haryana Agricultural University, Hisar for their worthy advice and help rendered during the course of investigation, valuable suggestions and going through the manuscript despite their busy schedule.

I am greatly indebted to Dr. S.S. Khirwar, Professor and Head, Department of Animal Nutrition for his persuasion, help and guidance rendered and also providing facilities for my experiment.

I wish to accord my sincere thanks to Dr. S.C. Chopra, Department of Animal Breeding and Dr. M.L. Kakar, Senior Endocrinologist, Department of Animal Production Physiology for rendering necessary guidance and providing facilities for the research work and keen interest shown for this investigation.

I would like to pay my thanks to all the Faculty Members as well as secretarial and laboratory staff of the Department of Animal Nutrition for their ever-willing assistance and kind cooperation particularly Dr. D.C. Sangwan and

Mr. S.C. Goyal. I extend my sincere thanks to my all friends and well wishers for their encouragement and sweet associations.

I am particularly grateful to my life partner Smt. D.B. Sharma for her inspirations and patience during my study period. I took this opportunity to express my affection to my sons Master Punit and Master Nitin.

Finally I thank authorities of CCS Haryana Agricultural University and the Directorate of Animal Husbandry, Government of Haryana for providing necessary facilities and grant of study leave.



(Ramesh Sharma)

CONTENTS

CHAPTER NO.	TITLE	PAGE NO.
I	INTRODUCTION	1-3
II.	REVIEW OF LITERATURE	4-50
III.	MATERIALS AND METHODS	51-63
IV.	RESULTS AND DISCUSSION	64-82
V.	SUMMARY AND CONCLUSIONS	83-87
VI.	LITERATURE CITED	i-xxiv
VII.	APPENDICES	I-IV

LIST OF TABLES

Table No.	Title	Page No.
1.	Distribution of experimental animals under different dietary treatments	52
2.	Chemical composition of feeds and fodders offered to experimental animals	53
3.	Body weight changes and average dry matter intake of animals under different dietary treatments during experimental period	65
4.	Nutrient intake per kg gain in body weight and gain per Kg nutrient intake under different dietary treatments	67
5.	Average daily increase in body measurements (cm) of animals under different dietary treatments during experimental period	69
6.	Nutrient intake of experimental animals during the digestion trial under different dietary treatments	71
7.	Nutrient digestibility and nutritive value of rations under different dietary treatments	73
8.	Mean values of rumen pH and volatile fatty acids under different dietary treatments	75
9.	Mean haematological values during experimental period under different dietary treatments	78
10.	Mean values of certain biochemical parameters during experimental period under different dietary treatments	79
11.	Economics of feeding monensin during experimental period	81

LIST OF FIGURES AND ILLUSTRATIONS

FIGURE NO.	BETWEEN PAGES
1.	65-66
2, 3 & 4	69-70

INTRODUCTION

Buffalo is an important domestic ruminant species which contributes substantially to our national economy. India has 78.83 million buffaloes out of 198.80 million of the world population (FAO, 1994). It is a principal dairy animal of our country and contributes 55 per cent of the total milk production (Anon., 1999). Buffalo rearing in India is mainly preferred to cattle as it is better convertor of feed and produces milk with high fat percentage. In addition, it provides meat, hides, offals, draught power, manure besides fuel for the Indian ruralities. This species is reared mainly by landless, small and marginal farmers. In spite of the above all contributing aspects, there are some constraints for buffalo rearing to exploit full genetic potential for better growth and production. The productivity of ruminants in tropical countries like India is low due to the non-availability of quality feed or imbalanced feeding and unfavourable climatic conditions. Feed alone contributes 70 per cent of the total cost of animal raising, out of which major portion is shared by concentrate feeding. In our country, major constraint is non-availability of quality feed, and feeding is largely based on post-harvest agricultural residues, some grains, agro-industrial by-products and weeds harvested from crop fields. Although efforts are being made to increase green fodder availability but requirements are hardly met due to a wide gap between demand and supply.

Furthermore, poor growth rate in young buffaloes is one of the important factors for poor performance. Generally, in villages young buffaloes are neglected in terms of feeding during the period in which growth potential exists. They are fed either poor quality roughages or kept on grazing with small amount of concentrate. The poor growth rate maybe due to inadequate nutrition associated with poor feeding by farmers. One more aspect related to ruminant species to be stressed is loss of energy and proteins as gas production in rumen. Major loss is through methane and ammonia production in rumen.

Hence, due to the handicap of non-availability of quality feed, poor growth rate, loss of energy and proteins through rumen metabolism; growth, production and feed utilisation can be improved either by feed processing technology or by using certain feed additives and growth promotants along with feed. Many researchers have improved performance of animal by using different feed additives and growth promotants like ionophores antibiotics, probiotics, hormones, certain chemicals etc. Ionophore-antibiotics like monensin (Richardson *et al.*, 1976), Lasalocid (Herod *et al.*, 1979), Salinomycin (McClure *et al.*, 1980) and Narasin (Potter *et al.*, 1979) have been widely used in developed countries to improve growth and feed utilisation. Out of these monensin is mainly and preferably used in these countries.

Monensin is a polyether ionophore, antibiotic in nature, produced by *Streptomyces cinnamonensis* (Haney and Heohn, 1967). Action of this biological

compound affects microbial activity in rumen changing composition of microbiota. This, in turn, results systemic action in body like depression in feed intake when fed with high level of fermentable carbohydrates (Raun *et al.*, 1976), decreased acetate to propionate ratio (Richardson *et al.*, 1976), improved nutrients digestibility (Wedegaerther and Johnson, 1983) and feed efficiency (Potter *et al.*, 1979), depression of methanogenesis (Chalupa *et al.*, 1980), sparing of proteins (Dart *et al.*, 1978) and modified roughage intake (Pond and Ellis, 1981). However, most of the reports available in literature are based on research done on cattle in temperate climate and there is paucity of information on supplementation of monensin in tropical countries specially on buffaloes. Keeping in view the above facts, the present study was undertaken to evaluate the extent of positive changes which ultimately were expected to be reflected in growth and feed utilisation in Murrah buffalo heifers with the following broad objectives:

1. To elucidate the effect of growth promotant on growth and nutrient utilisation.
2. To study the effect of supplementation of growth promotant on certain blood constituents.
3. To study the economics of using growth promotant.

2. REVIEW OF LITERATURE

Monensin, a growth promotant, has an influence on animal performance which is well established. This feed supplement is widely used to improve feed efficiency in exotic cattle. However, use of monensin as feed supplement is not yet tested in a systematic manner in buffaloes. Although, scanty and scattered informations are available on the exotic cattle and other species which are described in the paragraphs that follows :

Effect of monensin on feed/nutrient intake

The influence of monensin on feed intake is well established. In feedlot cattle trials several workers showed lower feed intake but unchanged gain (Embry and Swan, 1974; Hale *et al.*, 1975; Raun *et al.*, 1976). While others reported lower feed intake and increased in gain (Bolsen *et al.*, 1975; Sherod *et al.*, 1975; Utley *et al.*, 1975). The depression in feed intake may be explained due to more energetic efficiency with increased molar proportion of propionate in rumen with monensin treated feed (Richardson *et al.*, 1976; Raun *et al.*, 1974).

In a study, Davis and Erhart (1976) reported that when urea was added to rations containing monensin (9.5% CP-DM basis), CP increased to 11.5 per cent (DM basis) and rate of gain increased as length of time urea was fed increased. Steers fed rations containing monensin consumed less feed and, therefore, less crude protein than those that received no monensin. Since, additional crude protein equivalent, fed as urea, resulted in improved gains; apparently, crude protein consumption was below optimum for steers

that received rations containing monensin without additional urea. Potter *et al.* (1976) observed that when monensin dosages of 200 mg/head/day or below were fed, with pasture or green chop feeding; it had no effect on dry matter consumption, while at 300 mg and 400 mg/head/day the intake was decreased 5 per cent below control. This effect of monensin on feed consumption is different when cattle were fed high grain rations (Raun *et al.*, 1976). They observed decreased feed consumption at 750 mg level of monensin intake. This suggests monensin increased gain by providing the animal with more net energy per unit of feed consumed.

Further, Raun *et al.* (1976) observed reduced feed intake of 5 to 13 per cent by monensin at 11 and 33 ppm levels feeding and feed utilisation was improved. Perry *et al.* (1975) reported in his experiment on beef steers fed monensin required 10 per cent less dry matter per kg gain (Brown *et al.*, 1974; Embry and Ewan, 1974; Farlin *et al.*, 1975; Raun *et al.*, 1974). It indicates that the feed efficiency was improved. Perry *et al.* (1975) was of the opinion that the observed effect of monensin on VFA production is in agreement with research reports from Lilly Research Laboratories (Brown *et al.*, 1974; Potter *et al.*, 1974; Raun *et al.*, 1974). Brown *et al.* (1974) reported highly significant, but much smaller increases in propionate (43.3 to 44.7 vs 38.1%) due to added levels of from 5.5 to 44 ppm of monensin. Potter *et al.* (1974) reported three pasture trials in which levels of from 50 to 400 mg of monensin per head daily were compared to 0 level. In one experiment, no effect on VFA levels was obtained, whereas in a second

experiment significant decreases in acetate and butyrate and increases in propionate were obtained. Similar effects were obtained in the third experiment. Raun *et al.* (1974⁶) added 0, 2.7, 5.5, 11, 22, 44 and 88 ppm of monensin to cattle finishing diets and obtained significant increases in propionate, valerate and isovalerate, and decreases in butyrate from such treatments.

Mooseley *et al.* (1977) reported less feed intake in monensin fed heifers which required 10 per cent less dry matter intake per kg gain in body weight. In an another experiment effects of monensin on forage intake and lactation of cows grazing low quality dry winter range grass were examined in two trials by Mooseley *et al.* (1978). In trial 1, cows were fed a 30 per cent protein soybean meal supplement with 0, 50 or 200 mg of monensin per cow per day; and in trial 2, cows were fed the same supplement with 0 or 200 mg of monensin. Cow weight change during the winter was unchanged by adding 200 mg of monensin to the supplement in both trials. Relative forage intake (trial 1) was reduced 13.6 per cent ($P < .05$) and 19.6 per cent ($P < .05$) when 50 and 200 mg of monensin were fed, respectively. Grazing time in trial 2 was reduced 14.6 per cent when monensin was fed at 200 mg. Moreover, Lemenager *et al.* (1978) reported that forage intake was depressed ($P < .05$) from 9.61 kg on the control to 8.30 kg and 7.73 kg for the 50 and 200 mg treatments, respectively.

Mac Cartar *et al.* (1979) explained in their study on Brangus heifers supplemented with monensin @ 200 mg/animal with either 50 per cent

roughage and 50 per cent concentrate or 80 per cent roughage and 20 per cent concentrate diet that monensin reduced feed intake per kg gain @ 7.7 and 18.8 per cent, respectively when compared to control group. They reported similar dietary intake of M.E. and CP for all diets and found equivalent rates of daily gain (0.60 kg per head/day).

Wahle *et al.* (1985) explained the effects of monensin supplementation, 33 mg/kg of barley or dried grass diets of sheep. Monensin supplementation had no significant effect on the estimated ME intake or live weight gain but increased proportion of propionate in rumen volatile fatty acids. Fontenot *et al.* (1993) conducted 3 trials in each of 3 trials 15 pens of 8 steers were fed on high maize-silage diets. In trials 1 and 2, three pens of 8 steers each were fed on high-maize-silage diets. In trials 1 and 2 three pens of 8 steers each were fed no additive, sorbitol 35 g, monensin 350 mg, sorbitol 30 g plus monensin 350 mg daily. In trial 1 pens were fed sorbitol 200 g per animal every 6 days, and in trial 2, 3 pens were fed sorbitol 60 g/day plus monensin 350 mg/day. In trial 3, 3 pens were fed sorbitol 0, 20, 40 or 80 g/day per animal and 3 pens were fed 40 g/day after 56 days. All steers were fed monensin 350 mg/day. In trial 1, sorbitol had no effect on daily gain, and monensin increased ($P < 0.05$) daily gain. Intake of DM was lower ($P < 0.05$) for steers fed sorbitol (35 g/day). DM intake/gain was improved by feeding monensin ($P < 0.05$) or sorbitol 35 g/day ($P < 0.07$). The improvement amounted to 18 per cent when the additives were used in combination. In trial 2, daily gains were similar for the cattle fed all diets. DM intake was lower ($P < 0.05$)

for steers fed monensin or sorbitol 60 g/day and was lower ($P < 0.12$) for the cattle fed sorbitol 35 g/day. DM intake/gain was lower for cattle fed monensin and sorbitol, especially when fed in combination. In trial 3, daily gain was not consistently affected by feeding different levels of sorbitol. Improvement in feed efficiency was 12 per cent when sorbitol 20 g/day was fed, and 9 and 6 per cent, respectively, with 40 and 80 g (quadratic response, $P < 0.06$). Rate of passage was measured in 6 steers fed on a basal diet alone or plus sorbitol 35 g daily. Rumen ingesta, collected from these steers, were used to determine in vitro DM disappearance (IVDMD). Sorbitol did not influence the rate of passage or IVDMD. Supplementing sorbitol shows potential for increasing feed efficiency in finishing steers, especially in combination with monensin.

Wyatt *et al.* (1989) studied the interactive effects of ammonia treatment of Bermuda grass hay and supplementary monensin (200 mg/head daily) in heifers. Each heifer was given 2.27 kg concentrate per day. They found that acetate : propionate ratio was decreased in rumen fluid 4 h after monensin supplementation.

Stock *et al.* (1995) found reduced dry matter intake ($P < 0.01$) and improved average daily gain, and feed conversion efficiency ($P < 0.01$) when high grain (80%) diets were supplemented with either monensin 22 mg and tylosin 11 mg/kg or monensin 33 and tylosin 11 mg/kg.

In a factorial design experiment 35 $\frac{3}{4}$ Brazilian Gir-Holstein yearling bulls and steers were given to appetite diets of 58 per cent Napier grass

(*Purpureum purpureum*) silage and 42 per cent concentrates without or with monensin 200 mg daily. The adaptation period was 60 days starting from 10 days after castration of steers. Monensin had no effect on weight gain, total feed intake or feed efficiency. Mean daily gain was significantly greater and feed efficiency better in bulls than in steers (1.03 and 0.76 g and 8.47 and 10.51 kg/kg gain, respectively). Intake of DM per unit metabolic weight was greater in bulls (Morais *et al.*, 1993).

In a trial, Garza *et al.* (1990) fed to Angus X Hereford heifers 80 per cent concentrate diet without (control) or with monensin 30 mg/day or lasalocid 220 mg/day, twice daily at 1.6 per cent body weight. The ionophores were hand mixed with the diet and offered daily in the morning. Water was allowed freely and the intake measured daily. Water intake was similar for the 3 groups, 5.9 gal/day. Ruminal evasion of drinking water was higher, 5.9 gal/day. Rumen volume and rate of fluid passage were not altered by monensin or lasalocid compared with the control. DM in the rumen was 22 per cent higher with monensin. The increased residence time of DM in the rumen with monensin may partly explain why it often reduces feed intake. Similarly, Lemenager *et al.* (1978) reported that intake of range grass was 16 per cent lower ($P < 0.01$) when 200 mg monensin was added daily.

Horn *et al.* (1977) studied that forage intake was increased 13.1 per cent when 200 mg of monensin was fed; however, Pond and Ellis (1981) suggested that this amount of monensin may depress intake of poor quality forage and grazing cattle fed monensin may be consuming upto 15 per cent

more forage to achieve the higher gains under pasture conditions, however, the increased forage intake response may be related to the forage digestibility.

Cross *et al.* (1994) conducted a digestion and nitrogen balance study with sheep using drought-stressed (DS) and normal (C) maize silage. Steers were given DS or C maize silage and monensin sodium (MS) 0 and 200 mg each daily. Diets were balanced to meet requirements for CP, calcium and phosphorus. Drought-stressed silage had higher DM, DPE and $\text{NH}_3\text{-N}$ content than C silage and steers given C silage required cotton seed oilmeal supplementation to meet requirements. Steers given DS silage had higher ($P < 0.01$) silage DM intakes than those given C silage. There were no interactions between silage and MS and no differences among treatments of gain and feed efficiency. Steers given DS silage had higher ($P < 0.05$) blood methaemoglobin and lower rumen acetate and a higher percentage of butyrate. Steers given MS had higher rumen propionate and a lower percentage of acetate.

Thonney *et al.* (1981) showed that cattle fed monensin ate less ($P < 0.01$) and gained more comparative to control. This result was possibly caused by the steers aversion to monensin supplementation which in turn decreased dry matter intake too drastically for them to maintain adequate energy intake above maintenance for efficient growth. Similar results were also reported by different workers (Richardson *et al.*, 1976; Utley *et al.*, 1975; Sherrod *et al.*, 1975).

Lemenager *et al.* (1978) reported less feed intake with monensin supplementation of 200 mg daily on forage intake. While, Potter *et al.* (1976);

Cross *et al.* (1994) and Mooseley *et al.* (1978) reported no change in feed intake when monensin was given 200 mg daily with pasture or green chop feeding. Similarly, Cross *et al.* (1994) and Morais *et al.* (1994) reported no effect on feed intake, weight gain and feed efficiency on monensin supplementation.

In another study, when monensin at a level of 0, 11, 22 mg per kg DM was supplemented to Holstein steers fed 90 per cent concentrate either with soybean meal or urea addition, there was a decrease in DM intake but feed and nitrogen utilisation was improved (Lana *et al.*, 1997).

Krishan (1998) reported in milch buffaloes higher daily intake of DM ($P < 0.01$) and TDN ($P < 0.05$) while DCP intake was only apparently higher in monensin treated group than control group.

Many researchers have reported decreased feed or dry matter intake when animals fed on pastures or roughages with monensin supplementation (Perry *et al.*, 1975; Perry *et al.*, 1976; Mooseley *et al.*, 1978; Wahle *et al.*, 1985; Fontenot *et al.*, 1993).

Effect of monensin on feed efficiency and body weight changes

Maximum feed efficiency has been reported with monensin fed at 30 g/t (33 ppm) of air-dry ration (Brown *et al.*, 1974; Raun *et al.*, 1974). However, at that level a decrease in rate of gain has been observed by some workers (Davis and Erhart, 1975; Farlin *et al.*, 1975; Wilson *et al.*, 1975). Others have shown no effect (Brown *et al.*, 1974; Embry and Swan, 1974; Sherrod *et al.*, 1975). The reduction in feed intake produced by the 30 g/t level of

monensin is more prevalent early in the treatment period. It is possible that adapting cattle to a lower level of monensin such as 10 g/t prior to feeding the optimum level (30 g/t) may increase overall intake and improve performance.

Davis and Erhart (1976) reported that 5 per cent urea treated air dried ration with monensin fed at 10 g/t ration for 7 or 21 days increased rate of gain 4.6 and 6 per cent, respectively, compared with rations containing no monensin. Monensin fed at 30 g/t ration throughout the feeding period produced gains below ($P < .05$) those fed monensin at 10 g/t for 21 days, which might be due to lesser feed intake. Monensin intake increased feed efficiency with slight variation among treatments.

Gill *et al.* (1976) reported that when steers were fed corn silage with dry matter 14, 30, 75 per cent, respectively without and with monensin 300 mg per day then monensin improved feed efficiency 6.0 per cent across all roughage levels ($P < 0.01$) but had no effect on gain. These results were similar to those reported by Embry *et al.* (1974), Farlin *et al.* (1975) and less than those reported by Davis (1975) and Raun (1974, 1975).

Raun *et al.* (1976) observed a 17 per cent improvement in feed efficiency when cattle were fed high concentrate rations containing 33 ppm monensin. Utley *et al.* (1976) reported that heifers fed 200 mg of monensin per day during the growing trial gained 0.76 kg/day compared with 0.68 kg/day ($P < .05$) for heifers fed the control diet. Average daily feed intakes and feed required per unit of gain were 6.8 and 5.8 kg for heifers fed monensin compared with 7.8 and 6.9 kg for controls.

Perry *et al.* (1976) explained that beef steers fed 33 ppm monensin for 232 days gained at an identical rate (0.89 kg per day) with cattle receiving no monensin and is in agreement with the reports of Brown *et al.* (1974); Embry and Swan (1974) and Raun *et al.* (1974). Although, Potter *et al.* (1974) and Oliver *et al.* (1975) reported significant increases in the daily gain of cattle grazing pastures. Mooseley *et al.* (1977) showed that monensin supplemented heifers required 10.9 per cent less DM intake per kg body weight gain.

Two cattle growth trials were conducted by Tom *et al.* (1979) to evaluate the performance response to monensin when supplementing diets with various sources and levels of protein. Growth trial I determined performance of growing steers fed two sources of supplemental protein [brewers dried grains (BDG) vs. urea two levels of diet crude protein (CP) (10.5% vs 12.5%) and two levels of monensin (0 vs 200 mg/head/day]. Their results indicated appreciable monensin response in feed/gain when fed in combination with BDG and amounted to a 16.3 per cent improvement on the 10.5 per cent protein treatment and an 8.7 per cent improvement for the 12.5 per cent protein treatment. Monensin addition with either level of urea supplementation had a tendency to decrease rate of gain and feed efficiency. This may indicate microbial protein synthesis is inhibited by the addition of monensin. Monensin was effective in altering volatile fatty acid (VFA) concentrations in favour of propionate ($P < .05$) on both BDG and urea supplemented diets. Rumen $\text{NH}_3\text{-N}$ concentrations were reduced by monensin. Steer growth trial 11

involved two protein levels, supplied by soybean meal (SBM), (either 11.1 or 13.1%) and two levels of monensin (0 or 30 g/908 kg of feed). Monensin addition supported an 8.1 per cent improvement in feed/gain on the 11.1 per cent CP rations, whereas only a 3.2 per cent improvement occurred on the 13.1 per cent protein diets. The largest response in feed/gain occurred on the lower protein diets (10.5% CP trial I and 11.5% CP trial II). Monensin additions did not appear to increase the protein requirement (as a percentage of the diet) for growing steers.

Baile *et al.* (1982) conducted a trial on 60 Holstein-Friesian heifers, initially weighing 196 kg. The animals were fed to gain 0.68 kg/day until calving on a ration without monensin, or were given the same ration with monensin at 200 or 600 mg daily. For heifers on the control and 2 monensin treatments, respectively daily gain averaged 0.60, 0.69 and 0.69 kg, feed intake 7.47, 7.46 and 7.43 kg and feed/gain 12.41, 10.85 and 10.75.

Coastal Bermuda grass forage was treated with sodium hydroxide or monensin, or both, processed into pellets and fed to growing calves. Calves fed on pellets that contained monensin gained 12.7 per cent faster ($P < 0.05$), consumed 1.6 per cent less feed per day ($P > 0.05$) and required 12.3 per cent less feed per unit of gain ($P < 0.05$) than did control animals (Utley *et al.*, 1982).

Ben *et al.* (1982) reported that when 28 suckling male dairy calves on a commercial farm were given monensin supplements (from 750 mg g/kg live weight to 35 mg/kg depending on age) from the age of 1 wk, and were

compared with those in a similar group not given monensin. During a 52-day suckling period, the supplemented calves gained 12 per cent faster than the non-supplemented calves, with little difference in the conversion ratio of metabolisable energy into live weight. During the subsequent 42 days, there was no difference between groups in daily gain, but the supplemented calves were 64 per cent more efficient than the non-supplemented calves in the conversion of metabolisable energy into live weight.

Two growth trials conducted by Lana *et al.* (1997) to evaluate the effects of monensin on amino acid sparing. When Holstein steers were fed a 90 per cent concentrate diet supplemented with soyabean meal (13.5% CP), DM intake, average daily gain (ADG) and efficiencies of feed and nitrogen utilization were greater than with urea ($P < 0.10$). Monensin improved ADG with both nitrogen supplements ($P < 0.01$), but the positive effects of monensin on efficiencies of feed ($P = 0.12$) and nitrogen ($P = 0.26$) utilization were greater for soybean meal than for urea. Increasing amounts of monensin (0, 11 or 22 mg/kg of DM) caused a linear increase in DM intake with urea. Diets with soyabean had greater intakes than diets with urea ($P < 0.01$); the greatest intake was of a soyabean diet with monensin at 11 mg/kg of DM. Holstein steers fed soyabean meal at 13.5 per cent CP had lower DM intake and greater efficiencies of feed and nitrogen utilization than steers fed 16.7 per cent CP ($P < 0.10$). CP level had no effect on ADG. Monensin always increased the efficiencies of feed and nitrogen utilization ($P < 0.05$), but these trends were greater for diets with 16.7 than for those with 13.5 per cent CP. Overall,

monensin decreased DM intake ($P < 0.01$), but this effect was greater for 16.7 per cent than for 13.5 per cent CP. Because the positive effects of monensin on net energy for gain ($P = 0.16$) and efficiency of nitrogen utilization ($P = 0.26$) were greater for soyabean meal than for urea, it seemed that monensin was sparing amino acids.

Ak *et al.* (1995) reported that when five groups of lambs were fed from 1 to 29 days of age on a diet supplemented with monensin 0, 10, 15, 20 or 25 mg/kg. Average daily body weight gain was 349.8, 374.5, 369.8, 393.2 and 368.7 g, respectively. Feed conversion ratio was 4.81, 4.47, 4.06, 4.30 and 4.30 kg feed/kg gain, respectively.

Patil *et al.* (1996) conducted a trial with 12, 4-month-old Malpura lambs which were divided into 3 groups of 2 males and 2 females each, individually fed on monensin 0 (M0), 11 (M11) and 22 (M22) mg/kg concentrate mixture (600 g daily) and allowed to graze on pasture. Average daily gain in body weight was 82.65, 106.12 and 123.46 g (males) and 70.4, 93.87 and 104.08 (females) in M0, M11 and M22 treatments, respectively. It is suggested that monensin had a significant effect on intake of concentrate mixture and liveweight gain.

Cross *et al.* (1994) and Morais *et al.* (1993) reported no effect on weight gain and feed efficiency with supplementation of monensin. Thonney *et al.* (1994); Stock *et al.* (1995); Wyatt *et al.* (1989) have confirmed earlier reports that monensin depressed feed intake and increased weight gain and feed efficiency.

Effect of monensin on digestibility, utilisation and nutritive value of ration

Dinius *et al.* (1976) reported that when monensin was blended with a forage diet at levels of 0, 11, 22, 33 ppm and fed to determine its effect on cotton fibre, no difference in cellular digestibility from cotton fibre in response to monensin level were observed. Similarly, DM digestibility was not affected when cotton fabric strips placed *in vivo* for 72 hours. *In vivo* DM, CP, cellulose and hemicellulose digestibility was not affected.

Lemenager *et al.* (1978) showed that IVDMD results of esophageal samples taken during the intake trials were used to calculate forage intakes. Dinius *et al.* (1976) reported no change in *in vivo* digestibilities of dry matter, crude protein, hemicellulose and cellulose of orchardgrass hay when monensin was added. The estimated forage digestibilities based upon IVDMD techniques were 41.7, 38.2 and 39.8 per cent for December, February and March intake trials, respectively. Estimated forage composition was 50.42 per cent acid detergent fiber, 7.51 per cent lignin, 38.49 per cent cellulose and 3.53 per cent protein. Based upon lignin content of forage and feces, total tract digestibilities for the 0, 50 and 200 mg monensin treatments were (%); dry matter, 48.0, 48.5, 47.8; acid detergent fiber, 52.5, 52.1, 52.1; and cellulose, 67.4, 67.6, 68.1, respectively.

Poos *et al.* (1979) reported that lambs fed either brewer's dried gain (BDG) or urea supplemented diets without monensin retained more nitrogen than lambs fed 30 mg of monensin per day ($P < .05$). This decrease in nitrogen retention was the result of a significantly greater urinary nitrogen loss.

Nitrogen digestibilities were not influenced by addition of monensin. Between sources of supplemental nitrogen, however, lambs fed urea apparently had more nitrogen digested ($P < .05$).

DM digestibilities were reduced by monensin ($P < .05$). This decrease amounted to 5.5 percentage units and 2.8 percentage units for BDG and urea diets, respectively. This decrease in DM digestion may be a reflection of a decreased fiber digestibility observed by others (Simpson *et al.*, 1976; Simpson, 1978) *in vitro* when rumen inoculum was obtained from animals not previously exposed to monensin. *In vivo* studies by Dinius *et al.* (1976) indicated no effect on DM or fiber digestibility when steers had been fed monensin 21 days prior to initiation of the trial. These results may indicate a possible adaptation to monensin and could explain the decrease in DM digestion observed in this trial, as lambs were pre-fed for only 10 days prior to collection of data. Dinius *et al.* (1976) found no reduction in cellulose digestibility when animals had been adapted to monensin for a 21-day period. Russel *et al.* (1980) reported that monensin was fed at levels of 0 and 33 ppm in a series of digestion and metabolism trials to determine its effect on utilization of high grain diets and on ruminal parameters in yearling steers. Monensin had no effect ($P > .05$) on apparent digestibility of dry matter, gross energy or starch when fed with a 90 per cent corn diet (10.5% crude protein, dry matter basis). Monensin in this corn based diet tended to increase crude protein digestibility (63.4 vs 61.3%) and decrease ruminal ammonia concentration (2.5 vs 6.5 mg/100 ml) measured 3 hr post-prandially ($> .05$).

In metabolism trials with a 76 per cent sorghum grain diet (11.7% crude protein, dry matter basis), monensin improved apparent digestibility of crude protein ($P < .05$) but not dry matter or gross energy ($P < .05$). Retention of nitrogen, expressed as a percentage of nitrogen intake, tended to improve (24 vs 20%) in response to monensin addition to the sorghum grain-based diet ($P > .05$); a similar trend was observed ($P > .05$) for nitrogen retention expressed as a percentage of nitrogen absorbed (41 vs 36%). Total ruminal volatile fatty acid (VFA) concentrations measured 3 hr post-prandially were not altered by monensin fed with either diet. The proportion of acetic acid decreased ($P < .05$) and that of propionic acid increased ($P < .05$) in response to monensin fed with the corn-based diet. Monensin did not appreciably alter proportions of VFA when fed with the sorghum grain-based diet. Results suggest that a possible improvement in N utilization may account for some of the benefits of feeding monensin with high grain diets.

Rogers *et al.* (1982) explained that when four rumen fistulated steers were fed a diet (50% concentrate mixture and 50% corn silage) *ad libitum* with 33 ppm monensin supplementation then DM and DM digestibility was improved apparently over without monensin supplementation. EE and ADF digestibility increased non-significantly. Starch digestibility increased significantly ($P < 0.10$) and crude protein digestibility was enhanced with a significant improvement ($P < 0.05$). Increase in CP digestibility may be explained in past by the decrease in feed intake. However, others observed similar trends for increasing CP digestibility with monensin even when feed intakes were equalized.

Ricke *et al.* (1984) conducted two experiments to evaluate metabolism and rumen fermentation responses of lambs fed monensin or lasalocid 33 ppm kg/DM in alfalfa-corn diet. Experiment I was a lamb metabolism trial. In experiment 2 ruminally cannulated sheep were used and cotton thread cellulose and soybean nitrogen disappearance were measured by the in situ dacron bag technique. In experiment one, DM and fibre (ADF, NDF, hemicellulose) digestibilities were not influenced by monensin treatment. Absorbed nitrogen was not increased by monensin. In experiment 2 cellulose disappearance was not affected by monensin indicating that there was no adaptive response by rumen cellulolytic bacteria. VFA pattern was affected in rumen as reported earlier by Richardson *et al.* (1976).

Wedegaertner *et al.* (1983) reported that six 300 kg steers were each fed a 70 per cent cracked corn plus corn silage diet at two levels of intake above maintenance with and without 3 mg monensin/kg^{0.75} body weight (W^{0.75}). A changeover design was used. Dietary energy and nitrogen were partitioned by duplicate, 22 h indirect respiration calorimetry measurements of heat and methane production on each animal concurrent with 7-d total feces and urine collection trials. Feed and feces were analysed for energy, N, starch and neutral detergent fiber (NDF). The partial efficiency and(or) heat increment of metabolizable energy (ME) used for gain and maintenance was partitioned by regression of energy storage vs intake. At equalized gross energy intakes (adjustments made by covariance), monensin improved (P<.01) the apparent digestibilities of energy, from 71.8 to 74.8 per cent; NDF, from 50.5 to 57.5

per cent, and crude protein from 61.6 to 65.8 per cent. Methane production averaged 5.7 per cent of the control gross energy (GE), but was reduced by 26 per cent ($P < .01$) by monensin additions. Metabolizable energy was increased ($P < .01$) from 63.3 to 66.8 per cent of gross energy intake by monensin, resulting in an increase ($P < .01$) in retained energy (64.7 to 72.3 kcal/W^{.75}). Heat production was increased ($P < .05$) by monensin, but only in proportion to the increased ME. Daily energy retentions adjusted to equal ME intake were similar with or without monensin (69.9 vs. 67.1 kcal/W^{.75}). No significant effects of monensin on the heat increment of ME use for maintenance or gain were observed. Both NE_m and NE_g were improved by approximately, seven per cent by monensin.

Tharnton *et al.* (1981) conducted an experiment on growing steers with low, medium, high roughage diets supplemented with or without 200 mg monensin. Dry matter digestibility and N retention were not statistically altered, both tended to increase with monensin.

Faulkner *et al.* (1985) reported that when the influence of monensin 0, 6.1, 12.2, 18.3 or 36.6 mg/kg on diet fibre digestibility, microbial protein synthesis and ruminal escape of dietary protein was evaluated in 2 steer metabolism trials. A growth trial was made to study possible interactions of forage quality and monensin level. In metabolism trial 1, four steers with rumen cannula were assigned to 4 monensin levels in a 4 x 4 Latin square design to measure fibre digestibility, rate of passage and protein metabolism. In metabolism trial 2, five steers with duodenal cannula were assigned to 5

monensin levels in a 5 x 5 Latin square design to measure fibre digestibility, bacterial N flow and plant N flow. In the 2 metabolism trials, the level of monensin influenced organic matter (OM) digestibility, neutral detergent fibre (NDF) digestibility and ruminal NDF digestibility quadratically, with the intermediate levels of monensin being superior to the high level of monensin or no monensin. A quadratic increase in particulate disappearance rate ($P=0.09$) and no effect ($P=0.95$) on liquid disappearance were also observed in trial 1. In trial 1, monensin level quadratically decreased ($P=0.10$) the bacterial protein concentration and increased ($P=0.02$) the ratio of total N:diaminopimelic acid in whole rumen contents. In trial 2, no overall difference in duodenal N flow ($P=0.64$) or flow of individual amino acids ($P=0.46$) was observed. In the growth trial, no interaction of maize stalk quality and monensin was observed ($P<0.38$). Monensin linearly decreased feed intake ($P=0.09$) and quadratically affected daily gain ($P=0.03$) and feed/gain ($P=0.07$). The 100 mg level, which corresponds to the 18.3 mg/kg level in the metabolism trials, was superior to the 0- or 200-mg level in this trial ($P=0.07$).

Cottyn *et al.* (1983) showed the effects of monensin 24 and 29 and of avoparcin 24 to 31 and 61 to 64 mg/kg DM on digestibility and rumen volatile fatty acids were investigated with wethers. Diets consisted of 85 per cent maize silage and 15 per cent concentrate. Monensin resulted in significantly depressed digestibility of DM and crude fibre. The effect on the digestion of ether extract and N-free extract was variable while organic matter and crude

protein digestibility were not significantly affected. Avoparcin about 30 mg/kg had no effect on organic matter, crude protein and N-free extract digestibility. DM, ether extract and crude fibre digestion was variable. Higher concentrations of avoparcin depressed digestion of DM, crude fibre and N-free extract compared with control, monensin and avoparcin about 30 mg/kg. The effect on organic matter and crude protein differed between the trials. Monensin and avoparcin decreased acetic acid concentration and increased the amount of propionic acid, although this effect was observed only in one of the two trials with avoparcin about 30 mg/kg. Avoparcin gave the lowest acetate:propionate ratio compared with control and monensin.

Ricke *et al.* (1984) conducted an experiment on lambs which were given a diet based on lucerne and maize without or with monensin or lasalocid 33 mg/kg. Digestibility of DM and fibre was not influenced by monensin or lasalocid. Absorbed nitrogen was increased with lasalocid but not with monensin. No direct or adaptive rumen effects on cellulose or nitrogen disappropionate concentration and lowered the acetate:propionate ratio; only monensin decreased rumen ammonia. There was no difference in concentration of ammonia or volatile fatty acids (VFA) 2 and 4 h after feeding. When pool size was considered, sheep given monensin had lower total quantities of rumen ammonia at 8 and 12 h after feeding. Both additives decreased acetate:propionate ratios at 6 and 12 h. Lasalocid increased acetate, propionate and total VFA pool size at 12 h.

Beede *et al.* (1986) conducted digestion and metabolism experiments to estimate effects of monensin in low-protein diets. Monensin supplementation

(27 mg/kg diet DM) of steers (303 kg) given 8.7 per cent crude protein increased ($P < 0.01$) apparent N digestibility and N retention and decreased ($P < 0.01$) percentage of N apparently absorbed lost in urine. Apparent digestibilities of DM, gross energy and acid detergent lignin were increased ($P < 0.05$). Digestibilities of neutral detergent and acid detergent fibre were not affected by monensin. In growing wether goats (15 kg) given 8.5 per cent crude protein, monensin (23 mg/kg diet DM) improved ($P < 0.01$) apparent N digestibility and apparent N absorption. Urinary N excretion also increased ($P < 0.05$), resulting in no difference in N retention. Monensin did not affect digestibilities of DM or gross energy. Efficiency of feed conversion and average daily gain were improved with monensin supplementation of growing goats fed on a low-protein, high-roughage diet. Monensin resulted in typical shift of acetate-to-propionate ratio in both experiments. Results suggest that improved N utilization may account for some benefits of feeding monensin.

Lebzien *et al.* (1986) reported that when during two 4-week periods 4 low-yielding Black Pied cows with rumen fistula and duodenal cannula had a diet of maize silage 62 and concentrate, including minerals, 38 per cent. Mean daily intake of DM was 9.1 kg. Diet was supplied alone or with monensin @ 33 mg/kg DM. With monensin apparent digestibility of crude protein increased significantly, but that of other nutrients was unreduced significantly during 3 h after the morning feed and propionic acid increased from 17 to 35 per cent of total fatty acids, with corresponding reduction in molar proportions of acetic and butyric acids. Amount of organic matter

fermented in the rumen and break-down of dietary protein were not affected by monensin. Utilization of degradable dietary protein for microbial protein synthesis decreased with monensin from 81 to 61 per cent and urinary N excretion increased significantly. Net synthesis of thiamin was reduced significantly, but thiamin requirement was met with both treatments.

Pomar *et al.* (1989) showed in two trials, 36 Holstein calves 19 to 20 weeks old and 48 rams were used in a 2 x 3 x 2 factorial designed study with 2 ground roughages (lucerne or timothy grass) in pelleted diets (20, 40 or 60%) and addition of monensin 0 or 33 mg/kg to investigate diet digestibility. Calves and rams were fed on the test diets ad libitum for a period of 8 and 5 weeks, respectively, before the digestibility trial. DM digestibility in both species and energy digestibility in calves were significantly higher for lucerne diets than for timothy diets; however, digestibility of crude protein (CP) in both animal species and of cell walls (neutral detergent fibre; NDF) in calves was lower in lucerne diets. Digestibility of acid detergent fibre (ADF) and NDF fractions increased but DM digestibility decreased when roughage content in the diets increased; the reduction in DM digestibility was greater with timothy than with lucerne. Addition of monensin did not affect digestion coefficients of DM, ADF and NDF in calves and rams. However, a monensin x roughage level interaction indicated a decrease of ADF and NDF digestibility in calves fed on 20 per cent roughage and an increase of ADF and NDF digestibility in calves fed on 60 per cent roughage.

Morounek *et al.* (1989) conducted trial on six calves, initially 3 weeks old, kept in metabolism crates and fed on milk with free access to starter and

meadow hay, were weaned at 8 weeks old. Monensin 0.5 mg/kg 0.75 was given or not given until 10 weeks old. Monensin decreased rumen volatile fatty acid concentration, acetate/propionate ratio, butyrate and increased propionate. Digestibility of DM, organic matter, crude protein, nitrogen free extract and crude ash was not different between groups, but digestibility of lipids significantly increased in monensin-fed calves. Serum cholesterol, calcium and leukocyte count increased in the monensin-fed calves.

Lee *et al.* (1990) reported that when 12 entire male Korean native goats were given diets at 80 per cent of ad libitum intake containing 80 per cent concentrate, 20 per cent ground orchard grass hay and monensin 0, 22 or 33 mg/kg. Monensin decreased DM intake (Ps 0.05) and increased digestibility of DM, crude fibre, neutral detergent fibre and energy (Ps 0.05); changes was greater for monensin 22 than for 33 mg/kg. Monensin did not affect nitrogen retention. As monensin increased, rumen propionic acid concentration increased (Ps 0.05), and butyric acid content and acetic acid to propionic acid ratio decreased (Ps 0.05). With monensin, rumen pH and microbial protein concentration increased (Ps 0.05), but there was no change in rumen viscosity and ammonia-nitrogen concentration, or plasma $\text{NH}_3\text{-N}$ and urea-N concentration.

Sun *et al.* (1991) conducted a 4x4 Latin square design experiment, 4 steers 228 kg BW, were fed on Bermudagrass or orchard grass hay ad libitum with 0.5 per cent BW of ground maize and monensin 0 or 200 mg. Neither intake nor digestibility were significantly affected by monensin but monensin tended to reduce intake and digestibility with Bermudagrass.

Araujo *et al.* (1991) conducted a trial on 16 Holstein-X Brahman steers, were given diets of maize silage, hay and concentrate with 2.6 per cent fibre (groups 1 and 2) or diets of maize silage and concentrate with 15 per cent fibre (groups 3 and 4) without (groups 1 and 3) or with (groups 2 and 4) monensin 120 mg/kg. Mean intake of DM was 9.47, 8.43, 6.75 and 5.02 kg/day in the 4 groups, respectively. Digestibility of DM was 48.82, 51.95, 49.49 and 75.85 per cent, protein 60.22, 61.82, 59.12 and 78.38 per cent and fibre 38.25, 52.74, 27.20 and 53.04 per cent. Results indicate that inclusion of monensin in the diet increases DM digestibility. Its use in high-fibre diets is recommended.

Fredrickson *et al.* (1993) conducted a trial on 8 ruminally cannulated cross-bred steers grazing native Blue groma range land to evaluate effects of monensin ruminal delivery device (MR DD) and forage ruminal digestion. Three periods were assessed, mid-August, early October and mid-November. Release of monensin was 68 mg/day. Intake, DM digestibility, ruminal passage rates, retention time, pH and ammonia were not affected by (M RDD). *In situ* NDF disappearance at 96 hours was decreased by MRDP (68 vs 65% for control and MRDD respectively). As grazing season progressed, intake declined. At 98 hour *in situ* NDF was greatest in August and least in November.

Fahmy *et al.* (1993) reported that ground maize stalks containing 60 per cent moisture were treated with various chemical reagents to study their effects on *in vivo* digestibility or organic matter (OM), neutral detergent fibre

(NDF), hemicellulose (HMI), acid detergent fibre (ADF) and cellulose (CELL) in 24 mature wethers. Effect of monensin addition 0 or 10 mg/kg DM feed was studied. The crude protein content of maize stalks was increased by 8.19 and 11.88 per cent on treatment with urea or urea plus sulphur dioxide, and S concentration was increased by 1.35 and 3.1 per cent by SO₂ or urea plus SO₂ treatment. As wethers refused to eat these high S diets, they were diluted with the control diet. Digestibility of OM, NDF, HMI, ADF and CELL was significantly improved when urea-treated maize stalks or urea plus SO₂ treated maize stalks were fed, compared with control maize stalks. SO₂ pre-treatment significantly increased OM and NDF digestibility of maize stalks.

Zinn and Borques (1993) showed in 2, 2 x 2 factorial design trials, 100 crossbred cattle and 96 Holstein steers were given diets with net energy for maintenance 2.27 and net energy for gain 1.57 Mcal/kg containing 75 per cent steam-flaked maize, 4 per cent yellow grease and 12 per cent forage and monensin 0 or 33 mg/kg and 0 or 0.75 per cent sodium bicarbonate. There were no interactions between supplemental NaHCO₃ and monensin on growth or rumen and total tract digestion. There were no treatment effects on average daily gain, DM intake, feed efficiency or net energy value of the diet. NaHCO₃ did not influence rumen or total tract digestion of organic matter (OM), starch, and nitrogen, rumen pH, or rumen volatile fatty acids molar proportions. Monensin decreased (6.6%, P<0.10) rumen OM digestion. However, differences in ruminal digestion were compensated for by increased (3.2%, P<0.05) postrumen OM digestion. Effects of monensin on total tract digestion of OM, ADF, N, starch and gross energy were small.

Gallaway *et al.* (1993) reported in 3 Latin square experiments Holstein steer calves were fed on late vegetative Bermudagrass (*Cynodon dactylon*) or mature Bromegrass (*Bromus inermis*) free choice, protein supplement, maize 0 or 7.2 g/kg body weight and lasalocid or monensin 0, 0.5 or 1.0 mg/kg body weight. In experiment 1, neither lasalocid nor monensin 0.5 mg affected intake or digestion with either forage source. In experiment 2, neutral detergent fibre digestibility was not reduced by ionophores and was slightly greater ($P < 0.05$) for ionophores at 1.0 than at 0.5 mg. Digestible organic matter intake with bermudagrass was slightly greater with ionophores 1.0 than 0.5 mg, but an opposite difference between ionophore levels occurred with bromegrass (ionophore level x forage source interaction, $P < 0.07$). The concentration of total volatile fatty acids in rumen fluid at 4 h post-feeding was lower ($P < 0.05$) for monensin than for lasalocid; the acetate to propionate ratio was decreased by ionophores.

Su *et al.* (1993) reported that when in an experiment, 24 Nubian x Taiwan goats were fed on a diet supplemented with monensin 0, 15 and 30 mg/kg. Feed intake was similar for all 3 diets. Compared with the unsupplemented control diet, monensin 15 mg/kg increased weight gain by 3.6 per cent and feed conversion efficiency by 8.2 per cent. However, the higher level of monensin reduced performance to below that of controls. Digestibility coefficients determined *in vivo* and *in vitro* were higher for the diet with monensin 15 mg/kg than for the other 2 diets. For the 3 diets, the percentage of propionate generated in a continuous fermentation system was 18.2, 32.7 and 32.0, respectively ($P < 0.05$).

Patil *et al.* (1996) reported that grazing Malpura lambs were supplemented with concentrate mixtures containing monensin 0, 11 and 22 mg/kg, respectively. Daily concentrate intake decreased linearly ($P < 0.01$) with increasing monensin, while roughage DM intake was significantly higher in monensin groups. Nutrient digestibility was comparable among groups except for DM which was significantly higher in monensin groups. Nitrogen retention was highest in group 3, followed by groups 2 and 1.

A feedlot and a metabolism trial were conducted by Zinn *et al.* (1994) to evaluate the interaction of forage (lucerne hay 2.5 vs 5%; sudangrass hay 7.5 vs 15%) level (10 vs 20%) and monensin (0 vs 28 mg/kg, air-dry basis) on utilization of a steam-flaked maize-based finishing diet. Treatment did not affect growth or site and extent of digestion of organic matter (OM), ADF, nitrogen and starch. Monensin intake did not influence average daily gain (ADG), DM intake, feed conversion efficiency, estimated net energy (NE) value of the diet or ruminal and total tract digestibility of OM, ADF and starch. Monensin decreased (14.5%, $P < 0.10$) passage of microbial N to the small intestine and rumen digestion of feed N (10.4%, $P < 0.05$). Rumen digestibility of ADF, OM and starch were not affected by forage intake. However, rumen digestibility of feed N was 20 per cent greater ($P < 0.05$) with the high-forage diet. High forage intake decreased total tract digestion of OM (2.4%, $P < 0.05$), DE (2.7%, $P < 0.05$) and ME (4.8%, $P < 0.01$). It is concluded that failure of monensin to elicit a growth response in feedlot steers given a steam-flaked maize-based finishing diet is not due to differences in dietary forage level.

Duff *et al.* (1995) reported in an experiment conducted on castrated beef steers fed ad libitum on 90 per cent concentrate diet without or with monensin 200 mg/day. The *in vitro* dry matter digestibility of concentrate diet was significantly higher than the controls.

Haimoud *et al.* (1996) reported when three non-lactating cows with rumen, duodenal, and ileal cannulae were used in a 3 x 3 Latin square design to evaluate the effect of oral avoparcin and monensin on fibre, starch and nitrogen digestion. Cows were fed on 3 high-forage (48% maize silage, 35% Italian ryegrass hay) diets; the control diet had no additive, and the others contained avoparcin or monensin 33 mg/kg DM. Neither additive affected apparent total tract digestibilities of organic matter, fibre, starch or N. Avoparcin and monensin reduced rumen breakdown of fibre, starch and dietary N. Efficiency of bacterial N synthesis was unchanged, and passage of bacterial N to the small intestine was not modified. Compared with the control, additives caused a greater proportion of feed starch, N, and total amino acids to be digested in the small intestine than in the rumen. Diets containing avoparcin or monensin increased availability of total essential amino acids in the small intestine compared with control diets. Post-rumen digestion of fibre was greater for diets supplemented with antibiotics, because cows compensated digestion in the lower forestomach.

Gado (1997) conducted an experiment on twenty four male Baladi goats at 10 months of age with an average weight 13.1 kg were randomly assigned to three treatments for 90 days. Goats were given concentrate mixture feed

(CM) to cover the maintenance requirements of TDN and CP while berseem hay (BH) was given ad libitum. Rations were supplemented with monensin 0, 20 and 40 mg/head daily. Monensin levels improved ($P < 0.05$) nutritive value as % total digestible nutrients (TDN). Feed conversion (kg/kg) also improved ($P < 0.05$) and the apparent nitrogen retention decreased in the monensin supplemented groups.

Su *et al.* (1997) did a trial when a total of 48 Nubian Taiwan native crossbred goats were randomly allotted to 6 groups and individually fed one of 6 rations (A, B, C, D, E, F) which contained monensin 0 (A, B, C) or 15 mg/kg (D, E, F), 0 (A, D), 0.5 (D, E) or 1 per cent urea (C, F). Results showed that there was no difference in daily intake and daily weight gain of goats among treatments. There was no difference in feed conversion efficiency of goats except for goats given diets E and F. Goats fed on diets A and D had better digestibility of organic matter, nitrogen, NDF and ADF than those fed on diets E and F.

Earlier reports have shown no effect on DM digestibility of animals fed with monensin (Dinius *et al.*, 1976; Lenenger *et al.*, 1978). Similar were the findings of Ricke *et al.* (1984), Morounek *et al.* (1989), Zinn *et al.* (1998), Lebzein *et al.* (1986). Russel *et al.* (1980) reported no change of DM digestibility with grain diets at 33 ppm level of monensin fed to steers. Improved OM digestibility have been reported by Wedegaertner *et al.* (1983) at a significant level (Faulkner *et al.*, 1985; Beede *et al.*, 1986; Fahmy *et al.*, 1993, Zinn and Borques, 1993). DM digestibility have been reported increased

significantly (Lee *et al.*, 1990; Araujo *et al.*, 1991; Patil *et al.*, 1996) while non-significant improvement have been reported by Rogers *et al.* (1982) and Su *et al.* (1993). Depressed digestibility of DM is reported by Sun *et al.* (1991) which was non-significant. Poos *et al.* (1979) and Cottyn *et al.* (1983) explained a significant decrease in DM digestibility when wethers supplemented with monensin.

Fibre digestibility was reported to be increased by Pomar *et al.* (1989) when monensin was given 33 mg/kg with 60 per cent roughages to calves.

Thornton *et al.* (19) reported significant ($P < 0.01$) increase in ADF digestibility with roughage diet plus 200 mg monensin. While Rogers *et al.* (1982) were of the opinion of non-significant increase. Gado *et al.* (1997) reported increased fibre digestibility. Pomar *et al.* (1989) reported decreased fibre digestibility at 20 per cent roughage level in calves when fed 33 mg monensin, while no effect on digestibility when calves and rams were offered roughage less than 10 per cent with 33 mg monensin.

Sun *et al.* (1991) reported that fibre digestibility decreased at a non significant level, but Patil *et al.* (1996) and Zinn *et al.* (1994) reported no effect on fibre digestibility as well as ether extract when animals supplemented with monensin. CP digestibility reported by Araujo *et al.* (1991) was significant, while Zinn and Barques (1993) reported apparent increase in CP digestibility with monensin treatment.

Patil *et al.* (1996) reported no effect on CP digestibility in goats with 11, 22 mg monensin feeding while Cottyn *et al.* (1983) reported non-significant decrease of CP digestibility in wethers.

Effect of monensin on body measurements

Mooseley *et al.* (1977) reported significant change in heart girth of beef heifers fed with monensin but no change in body length and height over control group on grazing while in another experiment with high energy ration observed significant increase of body height and length but girth was not affected with monensin treatment.

Patil *et al.* (1996) explained when three groups of 4 lambs, 4 months old, were allowed 8 h grazing supplemented with concentrate 8.6 kg/day plus monensin sodium 0, 11 or 22 mg/kg concentrate. Increasing monensin resulted in increased body length, body height at withers, pelvis girth and heart girth. Generally, the increases in body measurements were more pronounced in male lambs.

Effect of monensin on blood parameters

Glucose has been long regarded to be involved in control of feed intake in monogastric animals, but does not seem to be involved in regulation of meal size in ruminants (Baile and Della-Fera, 1981). In spite of the low absorption of glucose, ruminants seems to utilize almost as much glucose on a body weight basis as other animals when compared at the basal state (Ballard *et al.*, 1969). Blood glucose concentration in ruminants are known to be little affected by the level of feeding (Rook and Line, 1961; Malik *et al.*, 1974). The normal level of blood glucose in large ruminants including buffaloes has been reported to vary between 30-60 mg/100 ml under standard feeding and management (Satchidonandam and Venkatayam, 1962; Koneko and Cornelius, 1970 and Malik *et al.*, 1974).

The important role of plasma protein in animal body under thermal stress conditions is due to its high water holding capacity and maintaining the viscosity of blood (Abou-Akkadda *et al.*, 1973). Pandey and Roy (1968) also reported that since serum protein influences the water retaining capacity of animal, the high concentration in buffaloes would favour heat regulation under hot conditions. The normal level of plasma protein in buffalo calves has been reported to vary between 6-9 g/100 ml (Raghavan and Mullick, 1962; Malik *et al.*, 1974 and Hussain *et al.*, 1975). Effect of the plane of nutrition on the plasma protein profile in cattle and buffalo are conflicting (Bhatia *et al.*, 1972; Ducker *et al.*, 1985; Tsankova *et al.*, 1985). Tsankova *et al.* (1984) found that variation in protein content with energy constant in diet of lactating buffaloes resulted in differences in protein content of blood. It was noted that total protein in blood was greater in buffaloes given more protein in the diet.

Lindsay (1970) demonstrated that blood glucose concentration increased slightly at the lower dosage. The small increases observed in glucose may be due to an increased conversion of propionic acid to glucose. Raun *et al.* (1976) observed that blood glucose level and urea nitrogen tended to increase with the feeding of monensin at levels below 44 parts per million. Puri *et al.* (1994) studied that values of blood glucose increased significantly ($P < 0.01$) in monensin fed animals which may be due to the increased ruminal propionic acid, a glucose precursor. These findings corroborate the observations of Potter *et al.* (1976) and Grings and Males (1988). Ali Haimoud *et al.* (1995)

reported that monensin sodium 33 mg/kg increased the plasma glucose levels in lactating cows (3.6 vs 3.1 mM) than control cows. Cows treated with sodium monensin had significantly higher plasma glucose concentrations than untreated cows, however, treatment did not significantly influence plasma urea nitrogen or cholesterol concentrations (Abe *et al.*, 1994).

Maanen *et al.* (1978) investigated that blood glucose pool size was not changed significantly by addition of 150 mg monensin daily in Holstein bullocks. Horton *et al.* (1980) conducted a study in bullocks which were given diets without or with monensin 33 mg/kg and barley was 30, 50, 70 and 90 per cent and found that plasma glucose was not affected by amount of barley or monensin, whereas plasma urea nitrogen increased with larger amounts of barley. Walker *et al.* (1980) demonstrated that in the last third of pregnancy, 100 Hereford cows were allocated to 4 treatments; 100 per cent of their feed requirements without monensin, 95 per cent of full feed + 50 mg monensin daily, or 90 per cent of full feed with monensin 200 or 300 mg per day and found no effect on serum proteins, urea nitrogen and glucose. Badawy *et al.* (1996) reported that 100 mg monensin per head daily did not alter plasma glucose level, urea concentration, total protein and cholesterol in prepubertal buffalo heifers aged 10-14 months. No significant differences in plasma concentration of glucose and urea was observed between monensin treated and control multiparous Holstein cows post partum (Stephenson *et al.*, 1997).

Lober *et al.* (1986) indicated that blood glucose concentration decreased when 1000 mg monensin daily was given in fattening bulls. Serum urea tended

to decrease in primiparous Holstein cows when monensin 300 mg per day per cow was added to the high forage diet but did not change when it was added to the low forage diet (Ramanzin *et al.*, 1997).

Abe *et al.* (1992) reported that monensin, salinomycin and lasalocid were injected into jugular veins of Holstein steers, weighing about 266 kg, 1 h after morning feed. Jugular blood samples were taken from -15 to 240 min after administration. Monensin caused a rapid increase in plasma glucose.

Puri *et al.* (1994) showed when four rumen-fistulated buffaloes, were fed on a mixture of wheat straw plus concentrate without or with monensin 150 mg/day. After 25 days of feeding, rumen fluid and blood was sampled before feeding, and 3 and 6 h later. In rumen fluid, the molar percentage of propionic acid was increased and that of acetate was decreased by monensin. Monensin also increased blood glucose concentration.

Ale *et al.* (1994) explained when a randomised trial was conducted to determine the effects of sodium monensin on plasma metabolite concentrations. Cows treated with sodium monensin in a controlled-release capsule had significantly lower plasma beta-hydroxybutyrate (BHB) concentrations and tended to have significantly higher plasma glucose concentrations than untreated cows. Treatment did not significantly influence plasma free fatty acid, urea nitrogen or cholesterol concentrations. Despite higher plasma glucose concentrations and lower plasma BHB concentrations.

Duff *et al.* (1994) reported that beef steers treated with monensin had no differences in serum cholesterol level over untreated steers.

McMillan *et al.* (1995) reported that pregnant cows given a rumensin capsule at 66 days before calving or left untreated. Rumensin treatment had no effect on glucose concentration in plasma.

Cinar *et al.* (1995) reported that 29 Holstein calves in 4 groups were given a commercial diet providing daily monensin 0, 50, 100 or 500 mg/head. Average liveweight at the start of feeding was 74.8, 73.8, 75.7 and 72.4 kg; and at the end 93.1, 97.8, 183.3 and 104.5 kg, respectively. There were no significant differences between groups in average concentrations of thyrokin and triiodothyronine in blood serum estimated weekly. However, values significantly differed for serum glucose, 60.00, 64.37, 74.12 and 73.75 mg/100 ml, and for insulin, 35.63, 37.16, 40.68 and 42.76 fU/ml.

Yalcin *et al.* (1995) explained when monensin 7 or 14 mg/kg diet was given to 30 weaned female Merino sheep, 1.5 to 2.0 months old, for 6 weeks. There was no significant effect of monensin on pH and concentrations of urea-nitrogen and ammonia-N in rumen fluid, and on concentrations of ketone bodies, glucose, total lipids, total cholesterol, calcium, inorganic phosphorus, copper and zinc in blood serum.

Stephenson *et al.* (1997) reported that when fed 32 g ruminal bulls to holstein cows 50 days before predicted calving. Treated cows had lower plasma concentrations of glucose, free fatty acid (FFA) and beta-hydroxy butyrate than control cows prepartum, indicating that monensin influenced energy metabolism. There were no significant differences in plasma glucose concentrations, FFA and BHBA over control group post-partum. Urca

concentration increased significantly in all cows pre-partum but no significant change in plasma urea concentration were found with monensin supplementation.

Duffield *et al.* (1998) reported that in Holstein milch cows and heifers monensin treatment significantly reduced serum beta-hydroxybutyrate concentrations at weeks 1, 2 and 3 after calving and significantly increased blood sugar concentrations during weeks 1 and 2 of lactation. In addition, monensin treatment significantly reduced the loss of body condition score and decreased serum activity of aspartate aminotransferase during the postpartum period. Concentrations of serum urea were significantly higher during weeks 2 and 3 after calving for cows that were treated with monensin. Monensin treatment had no effect on the concentrations of calcium, phosphorus, or total protein.

Hegazy (1997) reported that when for 70 days before calving and 120 days after it, 7 buffalo cows were given 150 and 200 mg/kg monensin per head daily in the feed respectively. Seven pregnant buffalo cows were not given monensin (controls). The feeding of monensin significantly improved calf body weight at 120 days of age and the body condition score of cows at calving and the next conception. The cows given monensin had significantly higher plasma propionate and insulin concentrations, and significantly lower plasma acetate and urea concentrations, than controls.

Krishan *et al.* (1998) conducted a trial on murrh milch buffalo which were supplemented with 100 mg monensin per animal per day. He reported a

significant increase in blood glucose and total protein while significant decrease in blood urea and cholesterol levels.

Moronek *et al.* (1989) reported in calves fed with milk and calf starters plus monensin 0.5 mg/kg W^{0.75} increased level of serum cholesterol.

Badaway *et al.* (1996) reported in monensin treated cows plasma, neutrophil migration towards a chemoattractant was significantly greater than treated cows. It was hypothesised lower neutrophil chemotaxis with lower glucose concentrations.

Stephenson *et al.* (1996) investigated in buffalo heifers (10-14 months) treated with and without 100 mg monensin/day. Blood samples collected monthly tested for Haemoglobin (Hb) and packed cell volume (PCV). These values were not affected significantly with monensin supplementation.

Moronek *et al.* (1989) reported when calves fed with milk and calf starter, showed leucocyte count increased.

Effect of monensin on rumen pH and VFA concentration

Research has shown that feeding monensin to cattle and sheep decreases the molar percentage of acetic acid and increases propionic acid in the rumen. It has been suggested that increased propionate production is energetically more efficient (Raun *et al.*, 1976; Richardson *et al.*, 1976; Hungate, 1966; Wolin *et al.*, 1960). Recent *in vitro* work (Chalupa *et al.*, 1978) showed that monensin significantly increased the efficiency with which digestible carbohydrate was converted to volatile fatty acid (VFA). Ruman fluid taken from steers fed monensin contained more ($P < .05$) propionate and less ($P < .05$)

butyrate than that from steers fed no monensin. Since propionate is more efficiently produced by ruminants than either acetate or butyrate (Hungate, 1966), improved feed efficiency with monensin apparently resulted from the steers recovering a greater amount of useable energy from the ration which produced a decrease in feed consumption with no significant change in rate of gain. Gill *et al.* (1976) reported depressed acetate to propionate ratio when corn silage (75% DM) was fed with monensin.

The efficiency of ruminal fermentation may be limited by the relative inefficiency of the acetic acid and butyric acid fermentations (Shaw *et al.*, 1960). The propionic acid fermentation is more energetically efficient and theoretically reduces the large loss of methane associated with the production of acetic and butyric acids (Wolin, 1960; Hungate, 1966). Apart from the energy savings associated with the fermentation which yields propionic acid, the efficiency of utilization of propionic acid in the ruminant tissues may be higher than that of acetic acid (Blaxter, 1962). Smith (1971) has reviewed this subject and concluded that additional research was needed to define the heat increment of the individual volatile fatty acids when they are utilized by ruminants. In addition, Eskeland *et al.* (1974) reported that propionic acid increased nitrogen retention in ruminants more than either acetic acid or butyric acid. Such a response to propionic acid may be mediated through a sparing of protein from gluconogenesis, as both are precursors of glucose or propionic acid may be superior to acetic or butyric acids when serving as the energy source for protein synthesis. Monensin was tested in three *in vitro*

ruminal fermentation systems. Monensin caused a shift in the proportions of fermentation end product acids with very little effect on total acid production. At 1 ppm in the concentrate substrate system, monensin increased propionic acid 50 per cent and decreased both acetic and butyric acids. Similar changes were observed when monensin was tested *in vivo* in concentrate and pasture-fed fistulated cattle. In a subsequent non-fistulated cattle feeding experiment, 100 and 500 mg monensin/head/day increased the molar proportion of ruminal propionic acid from 31.9 to 41.0 and 43.5 per cent, respectively, while the molar proportions of acetic acid and butyric acid were each decreased. Total ruminal volatile acid concentration was unchanged by monensin. Monensin maintained this effect on the ruminal acids throughout the 148-day experiment.

Potter *et al.* (1976) reported that when animals kept on pasture or green feeding with monensin supplementation, the molar proportions of ruminal acetic and butyric acids were each decreased and propionic acid increased from 19.2 per cent in control group to 26.9 per cent in the 400 mg monensin fed group. Hence decreased energy losses improved daily gain, efficiency of feed utilisation.

Danius *et al.* (1976) reported decreased acetate molar concentration and increased propionate concentration in steers fed forage with 11, 22 and 33 ppm respectively. Total VFA concentration remained unchanged.

Perry *et al.* (1976) showed in an experiment that rumen fluid from heifers fed monensin contained less ($P < 0.05$) acetic acid, more ($P < 0.05$) propionic acid and less ($P < 0.05$) butyric acid than did rumen fluid from control animals.

Mooseley *et al.* (1977) showed similar pattern of change in VFA concentration as Potter *et al.* (1974) and Richardson *et al.* (1976). Lemenager *et al.* (1978) reported that ruminal acetate and butyrate were consistently decreased and propionate was increased when 200 mg of monensin was fed in lactating cows (Lemenager *et al.*, 1978).

Lemenager *et al.* (1978b) reported in steers fed on winter range grass with monensin, was a decrease in acetate, increase in propionate but unaffected butyrate concentration.

Volatile fatty acid analysis of rumen samples obtained 5 hr post-feeding support the propionate enhancer effects of monensin as reported *in vitro* and *in vivo* (Richardson *et al.*, 1974; Potter *et al.*, 1974). Monensin decreased acetate/propionate ratios while total VFA concentration tended to be increased for these treatments. The decreased acetate/propionate ratio on urea diets with monensin did not support an improvement in feed efficiency. This contradicts studies involving urea-monensin combinations in finishing trials reported by Davis and Erhart (1975, 1976) and Martin *et al.* (1976). However, the diets used in their trials did contain substantial quantities of plant protein, supplied as corn, with supplemental urea additions amounting to less than 1 per cent of ration dry matter. The trial reported herein contained 1.3 or 2.1 per cent urea.

Rumen $\text{NH}_3\text{-N}$ levels were lower for rations containing monensin vs their respective controls lowering of $\text{NH}_3\text{-N}$ levels have been reported *in vivo* by Dinius *et al.* (1976) which may be due to monensin effect on urease activity, absorption, proteolysis and protein synthesis (Tom *et al.*, 1979).

Whitestone *et al.* (1981) in his studies observed linear decrease in acetate production while propionate production did not change but molar concentration increased in ruminal fluid of steers fed. Hay and concentrate diet (60:40) with 4 mg monensin per kg diet.

McCarter *et al.* (1979) explained in his study on pure bred brangus heifers that when monensin 200 mg per animal was fed with either roughage : concentrate (50:50) or (80:20) levels in both condition propionate proportion increased and acetate and butyrate decreased.

Shell *et al.* (1983) showed with a study on four rumen-fistulated steers, averaging 315 kg during two experimental periods were used in a replicated 2 x 2 Latin square study designed to determine the effects of monensin supplementation on rumen volatile fatty acid (VFA) production, pH and liquid volume. A 72 per cent steam-flaked, sorghum grain diet was fed twice daily at 0700 and 1700 h at 2.0 per cent of live body weight. Production rates were determined at 11 times during a 24-h feeding cycle by short-term *in vitro* incubations of whole rumen contents. Monensin increased moles/100 mol ($P < .05$) and production rate ($\mu\text{moles liter}^{-1}, \text{min}^{-1}$; $P > .01$) of propionate and depressed moles/100 mol ($< .01$) and production rate ($P < .05$) of butyrate. Moles of acetate/100 mol were not affected ($P > .05$) by monensin. Daily propionate production (moles) as increased ($P < .01$) by 37 per cent by monensin. Monensin increased total production of acetate (11%) and total VFA production (16%), both nonsignificantly. Both rumen pH and liquid volumes were increased nonsignificantly by monensin.

Fuller *et al.* (1981) determined efficiency of fermentation of high grain and roughage substrate with and without monensin 33 or 44 ppm. Individual VFA production generally shifted without affecting total VFA production. High concentration diet demonstrated depression of butyric and isovaleric acid production. However, no effects of ionophore upon total VFA, acetic or valeric production. While others (Richardson *et al.*, 1976; Raun *et al.*, 1974) reported increased propionic acid molar concentration. Monensin addition to roughage substrate showed a less consistent effect on VFA pattern than did to high grain substrates. Ionophore reduced methane losses with both grain and roughage diets.

Rogers *et al.* (1982) explained that when four rumen fistulated steers were fed a diet (50% concentrate mixture and 50% corn silage) *ad libitum* with 33 ppm monensin supplementation, it decreased molar proportion of acetate and increased that of propionate. Monensin increased production of both acetate and propionate. However, large increase in production of propionate production appears to account for more of the increased propionate molar concentration. Increased total volatile fatty acids production per kg DM intake with monensin supplementation results from decreased feed intake thereby increasing ruminal retention time of DM and potentially extent of digestion. Efficiency of nitrogen utilisation was not altered. Further they observed no effect on ruminal pH with monensin supplementation.

Rogers and Davis (1982) reported that the effects of feeding dietary supplements of monensin and sodium bicarbonate singly or in combination

on production of rumen volatile fatty acids, nitrogen balance, and rumen water kinetics were studied. Four rumen fistulated steers were given to appetite a diet of concentrate mix 50 per cent and maize 50 per cent in a 4 x 4 Latin square design with a 2 x 2 factorial arrangement of treatments. Sodium bicarbonate increased feed intake, water intake, rumen pH, fluid dilution rate, and decreased both molar proportion and production rate of propionate in the rumen. In contrast, monensin did not change significantly rumen fluid dilution rate or ruminal pH but did decrease the molar proportion of acetate and increase that of propionate. Monensin increased production of both acetate and propionate in the rumen; however, the large increase in propionate production seemed to account for more of the increase in molar proportion of propionate in the rumen. Increase in total volatile fatty acid production/kg DM eaten with monensin seemed to result from decrease in feed intake, thereby increasing ruminal retention time of DM and potentially the extent of digestion. Efficiency of nitrogen utilization was not altered by either sodium bicarbonate or monensin.

O'Kelly *et al.* (1988) explained in their findings when 6 Hereford steers with rumen cannulae were given 1 feed of lucerne hay 5 kg daily then for 30 days (days 1 to 30) steers were not given or given monensin 33 mg/kg feed (as 1 dose). During days 31 to 33 lucerne hay was given in 4 equal feeds and during days 34 to 40 lucerne hay was given by automatic feeder in equal feeds at 1-h intervals in metabolism cages. Compared with untreated steers

those given monensin had reduced ammonia concentrations, protozoa species concentrations (except *Dasytricha*) and molar concentrations of iso-butyric and n-butyric acids in the rumen, and increased molar concentrations of propionic acid.

Zorilla *et al.* (1991) conducted a trial for 2 weeks with 11 mature rumen-cannulated cattle which were fed on 80 per cent concentrate basal diet followed by 5 weeks on diets containing no ionophores (control), monensin-tylosin 300 mg/day continuously, lasalocid 300 mg/day continuously or daily rotation of monensin-tylosin and lasalocid followed by a 3-week withdrawal period. Samples of rumen contents were taken weekly 2 h after the morning feed. Monensin plus tylosin tended to be more effective than other treatments at depressing total gas and methane production. *In vitro* ammonia concentration and rumen pH were not altered by diet. No synergistic effects on rumen microbial fermentation activity were apparent from the daily rotational ionophore programme compared with the mean of monensin-tylosin or lasalocid fed individually. It was suggested that *in vitro* batch culture procedures can rapidly screen ionophore feeding programmes.

Clary *et al.* (1993) explained in a factorial design 192 feedlot steers which were fed for 116 days on maize-based finishing diets containing 0 or 4 per cent tallow without (control) or with lasalocid (L) 31, monensin 25 plus tylosin 10 mg/kg (MT), or daily rotation of L and MT (LMT). Fat and ionophore interacted for DM intake ($P < 0.10$), average daily gain ($P < 0.01$)

and gain:feed (G/F) ($P < 0.05$). Compared with 0% fat, 4% fat decreased ($P < 0.005$) DM intake by steers given MT by 8.9%. In 0% - fat diets, MT increased ($P < 0.05$) average daily gain and G/F compared with control or L; however, this increase was negated or reversed in 4%-fat diets. Fat and ionophore interacted ($P < 0.16$) on dietary net energy (NE) concentration. In the 0%-fat diet, MT increased NE for maintenance and NE for gain by 5.1 and 7.0%, respectively, but MT had no effect on NE concentration of the 4%-fat diet. Alternate feeding of L and MT did not increase performance above that of separate, continuous feeding. In a metabolism study 6 rumen fistulated steers were fed on the same diets except that the LMT treatment was not included. Rumen digesta kinetics were not altered by addition of fat or ionophores to the diet. Fat and ionophore interacted ($P < 0.05$) for molar proportions of rumen acetate and propionate. Acetate was decreased ($P < 0.05$) and propionate was increased ($P < 0.05$) by ionophore addition to the 0%-fat diets; however, when 4% fat was fed, neither L nor MT affected acetate or propionate. Results suggest that the response of finishing cattle to ionophores may be altered by fat supplementation.

Vagnoni *et al.* (1995) reported in a growth trial using crossbred beef steers and a metabolism trial using Holstein steers (trials 1 and 2), were conducted to evaluate the effects of ammonia treatment (3% of hay DM, added as anhydrous NH_3) compared with urea, supplementation with or without monensin supplementation of mature 'Alicia' bermuda-grass hay-based diets for steers. Supplementation with monensin or urea decreased

rumen total volatile fatty acid (VFA) concentrations. Monensin also decreased the rumen acetate:propionate ratio ($P < 0.001$) and increased rumen pH ($P < 0.05$). Decreased concentrations of VFA and lower forage digestibilities observed with monensin supplementation in experiment 2 may explain the failure of monensin to affect ADG in experiment 1.

Duff *et al.* (1995) reported in an experiment conducted on castrated beef steers fed *ad libitum* on 90 per cent concentrate diet without or with monensin 200 mg/day. At 24 and 48 hours of incubation, monensin had lower acetate and higher propionate proportions in the rumen contents.

Dinius *et al.* (1976) observed when monensin was blended with forage diet at levels of 0, 11, 22 and 33 ppm and fed to steers had not affected ruminal pH.

Pretreatment rumen pH values were similar for control and monensin treatment group (Utley *et al.*, 1976).

Lambs fed with either urea or Brewer's dried grain (BDG) with monensin showed no ruminal pH change. Similarly, no effect of monensin 22 or 38 ppm/kg diet was observed on ruminal pH in lambs in another experiment (Poos *et al.*, 1979).

Perry *et al.* (1975) showed decreased molar proportions of acetate, butyrate, valerate while increased molar proportions of propionate. Maruenek *et al.* (1989) reported decreased total VFA molar proportions and decreased acetate to propionate ratio in calves supplied with monensin 0.5 mg/kg W^{0.75}.

Economics of feeding with monensin

Davis and Erhart (1975) reported that cost per kg gain in monensin supplemented steers was lower than unsupplemented steers, when animals were fed with air dry ration treated with 5 per cent urea.

Krishan (1998) reported in milch buffaloes the cost of feeding per buffalo per day and cost per kg milk production did not differ significantly from control group.

MATERIALS AND METHODS

The experiment was conducted at the Animal Farm of the Department of Animal Nutrition, CCS Haryana Agricultural University, Hisar.

Experimental Animals

Twelve Murrah buffalo heifers ranging between age group of 16 to 26 months were taken from Buffalo Research Centre of the Department of Livestock Production and Management, CCS HAU, Hisar. The heifers were divided into two groups of six each on the basis of nearness in their body weight and age. (Table 1).

Treatment and Feeding

The heifers were allowed 15 days adjustment period prior to start of the experiment and experiment was conducted for 120 days. Ration was computed at the level of 110 per cent as per ICAR (1998). The heifers were offered concentrate, green sorghum and wheat straw for feeding during the experimental period. The concentrate mixture, offered, was prepared using barley grains 16 parts, wheat broken 16 parts, deoiled rice-polish 32 parts, cotton seed cake 16 parts, mustard cake (expeller) 16 parts besides mineral mixture 2 parts, common salt 2 parts, having 19.33 per cent CP (Table 2). The details of experimental animals allocated to different treatments are:

Table 1. Distribution of experimental animals under different dietary treatments

Treatment	S. No.	Heifer No.	Initial body weight (Kg)
T₁ (Control)	1.	1241	116
	2.	1226	120
	3.	1210	186
	4.	1204	206
	5.	1188	208
	6.	1194	215
	Average		175.16±16.95
T₂ (Treatment)	1.	1247	120
	2.	1227	138
	3.	1192	172
	4.	1201	200
	5.	1196	204
	6.	1207	216
	Average		175.00±14.53

Table 2. Chemical composition of feeds and fodders offered to experimental animals

Feed	Dry matter (%)	On dry matter basis (%)				
		CP	EE	CF	NFE	Ash
Concentrate mixture	89.6	19.33	5.36	9.53	54.28	11.50
Green jowar	25.09	5.78	2.25	24.63	56.34	11.00
Wheat straw	87.29	3.12	1.59	33.87	50.92	10.50

T₁ – In this group, the heifers were offered weighed quantity of concentrate mixture at a fix rate of two kg per animal/day. In addition, green sorghum, wheat straw were offered to meet the daily requirements. This served as a control group.

T₂ – In this group, the heifers were fed as in T₁. In addition, monensin was fed @ 50 mg/day/animal for first seven days and thereafter @ 100 mg/animal/day, mixing thoroughly in concentrate mixture. Ration was computed fortnightly according to body weight changes to meet the daily requirements. All feeds and fodders were offered once during 24 hours at fix time in the morning hours. Chemical composition of feed and fodder is presented in Table 2.

Housing of animals: Heifers were kept in loose houses and were allowed to move freely except at the time of feeding. Clean and fresh drinking water was made available *ad libitum* for 24 hours in the sheds. All heifers were kept under similar *managerial conditions*.

Observations and Sample Collections

Body weight: Heifers were weighed before feeding and watering in the morning time fortnightly for two consecutive days throughout the experimental period and their weights were recorded.

Feed intake: The feed intake was determined on the basis of weighed quantity offered of concentrate mixture, green sorghum and wheat straw and then weighing refusals for two consecutive days at fortnightly intervals. Dry matter intake was assessed for each animal of different treatment groups. Representative samples of

concentrate mixture, green sorghum, wheat straw were drawn. The samples were weighed for dry matter. Similarly samples of refusals were also taken. These dried samples were analysed for proximate principles (AOAC, 1995).

Body measurements: Following measurements were recorded at fortnightly intervals during the experimental period.

1. **Body length:** It was measured from point of shoulder to pin bone. Each animal was kept straight and squared on four-legs on even floor and measured the length.
2. **Height:** It was measured from the floor to the highest point at the wither of animal.
3. **Chest girth:** The circumference of body over the chest of the animal just behind the point of elbow was measured for this purpose.

Digestibility and digestion trial: At the end of experimental period, a digestion trial of seven days was conducted for the estimation of digestibility of nutrients. During this period daily record of feed and fodder offered, refusals and faeces voided were maintained. The faeces of previous 24 h were collected manually in galvanised iron buckets covered with lids to avoid loss of moisture.

The samples of feeds, refusals and faeces were analysed for proximate principles (AOAC, 1995) and digestibility of nutrients was estimated. The DE and

ME values of feed were calculated according to Rostock equations published by Schiemann *et al.* (1971).

The sampling of feeds: The samples of feeds and feed refusals were collected daily during digestion trial. About 100 g of fresh sample of each feed offered was collected and weighed for dry matter. Similarly samples from refusals also taken. These weighed samples were kept in an oven at $100\pm 5^{\circ}\text{C}$ for 24 h and then weighed to find out dry matter. These dried samples were grinded by Wiley mill and preserved for further analysis and analysed for proximate principles (AOAC, 1995). Nitrogen was estimated by Macro-Kjeldahl's Method.

Sampling of faeces: Faeces voided daily during previous 24 hours by the individual animals were weighed. After thorough mixing of the faeces, representative sample was taken for determination of dry matter and nitrogen. For dry matter determination, $1/50^{\text{th}}$ part of total faeces was spread in weighed Enamel trays and dried in oven at $100\pm 5^{\circ}\text{C}$ for 24 hours. The dry weight was recorded and samples were preserved for further analysis after grinding. Samples were analysed for proximate principles (AOAC, 1995).

For nitrogen determination, $1/100^{\text{th}}$ part of total faeces was weighed and preserved in measured quantity of 40 per cent sulphuric acid (w/v) in wide mouth plastic bottles. Nitrogen was estimated by Macro-Kjeldahl's Method.

Blood samples: Blood samples were collected from each animal before feeding in the morning time at fortnightly intervals. Samples for haematological values

estimation were collected using anticoagulant EDTA (Ethylene diamine-tetra acetate) disodium salt, in 5 ml glass vials. Quantity of EDTA used was 1 mg/ml of blood collected in vials. Blood samples for biochemical tests were collected in test tubes using heparin anticoagulant. Heparin concentration was 400 IU/ml and quantity used was 10 mg per ml of the blood.

Blood samples collected in EDTA anticoagulant were analysed immediately for estimation of haematological values and samples collected in heparin anticoagulant were centrifuged @ 3000 rpm for 30 minutes for separation of plasma. Plasma was separated from each sample separately, collected in capped plastic vials and stored in refrigerator at 4°C for further analysis.

Sampling of rumen liquor

Rumen liquor samples were collected with the help of stomach tube using negative suction. Samples were collected once at 0 hour (before feeding) and at 4 hour (post-feeding) at a gap of 5 days toward the end of experimental period. The samples collected were strained through 4 layer muslin cloth and immediately their pH was recorded with digital pH meter (NIC, 333). Strained rumen liquor was mixed with formic acid 50 per cent (v/v) in the ratio of 9:1 and centrifuged at 3600 rpm for 10 minutes. The supernatants then were stored in small capped plastic vials at 4°C in a refrigerator for subsequent fractionation of volatile fatty acids by Gas-liquid Chromatography (GLC).

Analytical Techniques

The various analytical methods were employed for the analysis of samples of feeds, refusals, faeces, blood and rumen liquor.

Proximate Principles Analysis

Samples of feeds, refusals and faeces were analysed for proximate principles using AOAC (1995) methods. Samples were analysed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) and mineral matter (Total ash).

Digestible and Metabolizable Energy

The digestible energy (DE) and metabolizable energy (ME) content of the experimental rations were calculated by Rostock equations based on digestible coefficients of proximate nutrients, published by Schiemann *et al.* (1971) which are as under:

$$DE \text{ (mcal/kg DM)} = 5.72 \times CP + 9.05 \times EE + 4.38 \times CF + 4.06 \times NFE$$

$$ME \text{ (mcal/kg/DM)} = 4.49 \times CP + 9.05 \times EE + 3.61 \times CF + 3.66 \times NFE$$

Blood Analytical Techniques

Haemological Techniques

Haemoglobin: Haemoglobin (Hb) was estimated by Hellige Sahli's haemoglobinometer method. Five drops of N/10 hydrochloric acid were taken in measuring tube. Blood (0.02 ml) was drawn with the help of haemoglobinometer

pipette from a vial corresponding the animal number. Blood from external surface of pipette was wiped out with the help of finger. Then it was transferred in measuring tube containing N/10 hydrochloric acid. The pipette was rinsed well by repeatedly drawing and expelling the acid from it and the tube was shaken well to mix the contents. It was allowed to stand for five minutes and N/10 hydrochloric acid was added drop by drop in it and contents were mixed with the help of a glass on each addition until the colour matched with standard. The level of fluid (lower meniscus in measuring tube) was the reading of haemoglobin, expressed in g/dl of blood.

Estimation of Total Erythrocytic Count

Total Erythrocytic Count (TEC) was estimated using Neubauer's counting chamber. The red blood cells (RBC) diluting pipette was filled with blood upto the mark 0.5 from the vial corresponding to animal number, the outer surface of it was wiped of blood and then it was filled with RBC diluting fluid upto the mark, 101. This made its dilution 200 times. The contents then mixed properly and charged in the counting chamber. After waiting two minutes Erythrocytes were counted into five squares of the chamber under high power of microscope. The calculations were made by multiplying the total cells in 5 squares with 10,000 and TEC values were expressed in millions/cmm.

Total Leucocytic Count

Total Leucocytic Count (TLC) was estimated using Neubauer's counting chamber. The white blood cells (WBC) diluting pipette was filled with blood upto the mark 0.5 from a vial corresponding to animal number. Outer surface of it was wiped out and then it was filled with Gower's WBC diluting fluid upto the mark, II. This made its dilution 20 times. The contents then were mixed properly and charged in counting chamber. The leucocytes were counted into four squares of the chamber. The calculations were made by multiplying the total cells in four squares with 50 and TLC values were expressed in thousands/cmm.

Haematocrit value (Packed cell volume)

Packed cell volume (PCV) was estimated using Microhaematocrit method. Disposable capillary tubes were filled 2/3 with blood from vials corresponding to animal numbers. Capillaries were filled up 2/3 by capillary attraction and surface tension. The end, free of blood, was sealed with plasticine. These were placed in the grooves of the microhaematocrit centrifuge opposing one another with sealed ends away from the centre. The centrifuge was covered and tightened. Samples were centrifuged at 15,000 rpm for two minutes. The haematocrit values were read using microhaematocrit reader. The PCV values were expressed as percentage.

Estimation of differential leucocytic count

Blood smear was prepared using fresh blood from each animal and fixed by putting methanol on it for three minutes. The smears were flooded with one part of Giemsa's stain and ten parts of distilled water. After 40 minutes, it was washed with distilled water for 30 seconds, dried in the air and examined under oil immersion of microscope. A total of 100 leucocytes in each slide were identified and differentially counted.

Absolute values of erythrocytes

These values were calculated from PCV, Hb and TEC as follows:

Mean corpuscular volume:

Mean corpuscular volume (MCV) calculated as

$$= \frac{\text{PCV}}{\text{RBCs in millions}} \times 10 \text{ cubic micron (fl)}$$

Mean corpuscular haemoglobin calculated as:

Mean corpuscular haemoglobin (MCH)

$$= \frac{\text{Hb in g/100 ml}}{\text{RBCs in millions}} \times 10 \text{ micro microgm (pg)}$$

Mean corpuscular haemoglobin concentration calculated as :

Mean corpuscular haemoglobin concentration (MCHC)

$$= \frac{\text{Hb in g/100 ml}}{\text{PCV}} \times 100 \text{ per cent}$$

Biochemical techniques

Plasma glucose, total protein, urea and cholesterol were estimated as per methods detailed in operating manual of Auto-Blood chemistry Analyser (BTR-810, see Appendices I, II, III, IV respectively).

Volatile Fatty Acids (VFA) in Strained Rumen Liquor (SRL)

Individual volatile fatty acids were fractionated by the method proposed by James and Martin (1954) and developed by Annison (1954) and Bernard and Boucque (1968) using (GLC) gas-liquid chromatograph (Hewlett Packard Model 5890A), attached with an integrator. Chromosorb-101 packed in steel and stainless column served as stationary phase. The flow rate of nitrogen gas, used as mobile phase was 60 ul/min while the pressure of fuel viz. Hydrogen gas used for flame ionization detector was 10 pound per inch. The temperature of injector, column, flame ionisation detector was set at 200, 170 and 210°C, respectively. One ul of sample was injected into column to obtain peaks. One ul of a standard mixture, containing 50, 20, 5, 20, 5 meq/l of acetic, propionic, butyric, n-butyric and isovaleric acid respectively, was injected before and after every 4 samples as reference.

The concentration of VFAs in the liquor was calculated as :

VFA in test sample (meq/l):

$$\frac{\text{Peak area of unknown}}{\text{Peak area of standard}} \times \text{Concentration of VFA in standard}$$

Economics of supplementation with growth promotant

To calculate the economics of feeding with growth promotant, quantity of feed and fodder required were maintained during the experiment. The cost of compounded ingredients used for experimental ration viz., barley grain, wheat grain, deoiled rice polish, mustard cake, cotton seed cake were Rs. 538, 550, 211, 533, 750 per quintal. Common salt Rs. 78/40 kg and mineral mixture Rs. 40/kg.

Cost of green jowar was Rs. 53.00 per quintal and wheat straw Rs. 130.00 per quintal.

Statistical Analysis

The results obtained with regard to various parameters were statistically analysed as per the methods detailed in Snedecar and Cochran (1989).



RESULTS AND DISCUSSION

Voluntary Feed Intake

Dry matter intake

Average daily dry matter intake during the experimental period under treatments is presented in Table 3. Dry matter consumption expressed either in absolute amount (Kg/day) as per 100 Kg body weight or per Kg metabolic body size was statistically similar in both the treatments. This was in agreement with the observations of Potter *et al.* (1976), Cross *et al.* (1994) and Morais *et al.* (1993). However, apparently lower intake was observed in monensin supplemented group which might be due to improved energetic efficiency with increased molar proportion of propionate in the rumen with monensin supplementation (Richardson *et al.*, 1976; Raun *et al.*, 1974). The lower dry matter intake was reflected by more gain in body weight (Table 3) in monensin supplemented group (T₂). This was reflected by a relative lower dry matter intake (McCartar *et al.*, 1979; Wahle *et al.*, 1995). The trend of low dry matter intake in earlier reports were observed by Davis and Erhart (1976), Raun *et al.* (1976), Mooseley *et al.* (1977, 1978), Wyatt *et al.* (1989) and Stock *et al.* (1995).

Feed intake is influenced by several factors like quality and palatability of feed, age of animals, environmental temperature and feeding management including feeding frequency.

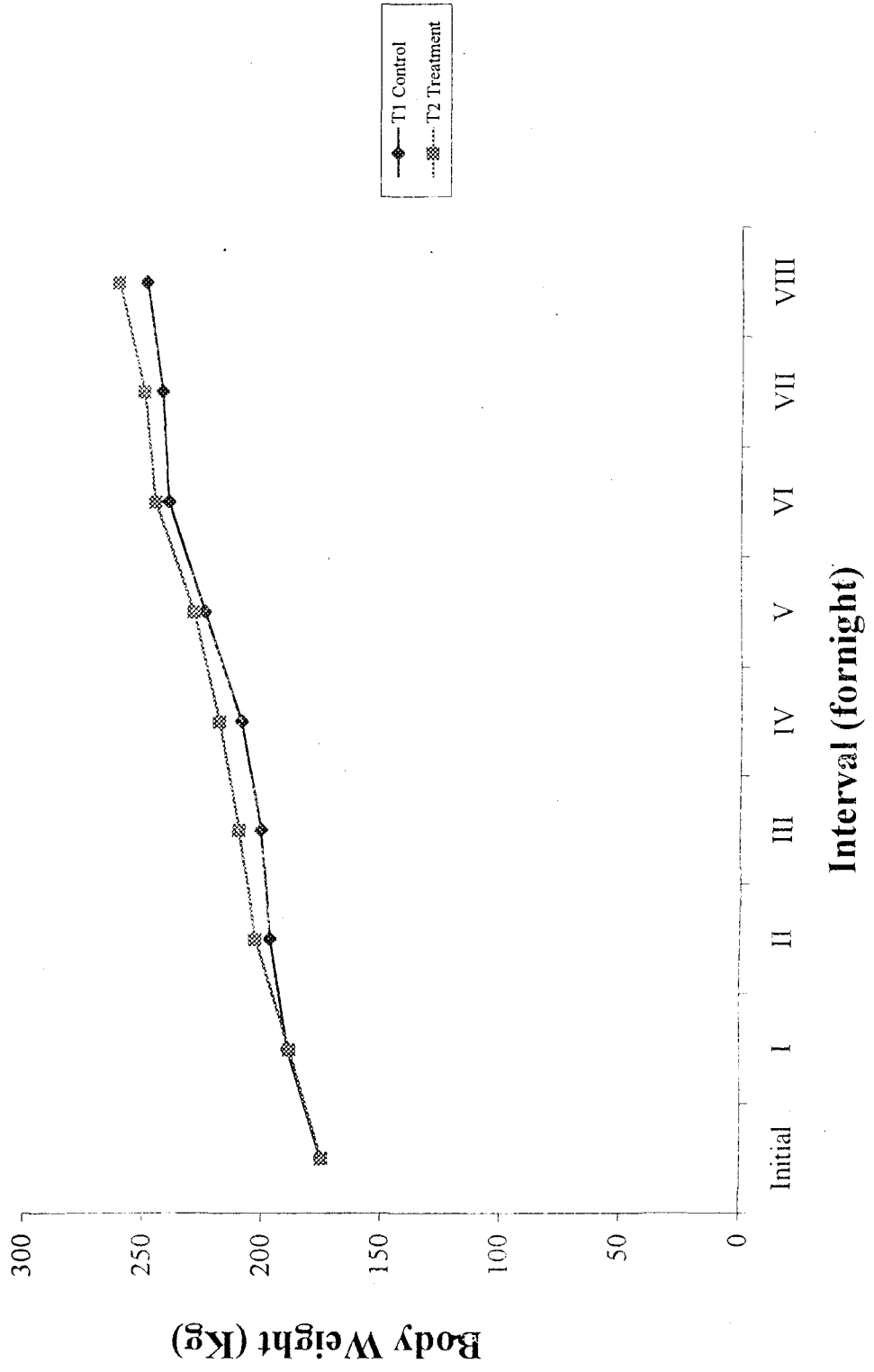
Table 3. Body weight changes and average dry matter intake of animals under different dietary treatments during experimental period

Attribute	Treatments	
	T ₁	T ₂
Initial body weight (Kg)	175.10 ±16.95	175.00 ±14.53
Final body weight (Kg)	249.20 ±16.98	261.00 ±15.69
Total body weight gain (Kg)	74.10 ±5.08	86.00** ±2.92
Average daily gain (Kg)	0.616 ±0.042	0.716** ±0.024
DM intake (Kg/day)	4.96 ±0.10	4.88 ±0.09
DM intake/100 Kg b.w. (Kg)	2.40 ±0.05	2.29 ±0.06
DM intake/ W ^{0.75} Kg (g)	90.28 ±1.30	87.06 ±1.91

Each figure is an average of six observations.

** P < 0.01.

Fig. 1. Average body weight (Kg) of heifers at fortnightly intervals during experimental period



Body Weight Changes and Feed Efficiency

Body weight changes

The total body weight gain and average daily gain of heifers during the 120 days experimental period have been presented in Table 3. The body weight changes recorded at fortnightly intervals have been presented in Fig. I. Total body weight gain was statistically significant ($P < 0.01$) in monensin supplement group (T_2). The average daily body weight gain increased significantly ($P < 0.01$) in T_2 group. The present findings corroborate with Davis and Erhart (1976), Raun *et al.* (1976), Wyatt *et al.* (1989), Stock *et al.* (1995), Thonney *et al.* (1981). The increase in body weight in T_2 was due to increased efficiency of feed and nitrogen utilisation (Lana *et al.*, 1997). Monensin supplementation has a protein sparing effect (Dart *et al.*, 1978). Because monensin increased molar proportion of propionate in rumen which is a precursor of glucose (Richardson *et al.*, 1976). Due to sufficient availability of glucose in the body, amino acids are not utilised by gluconeogenesis and hence growth is promoted by more protein deposition. So, in this study body weight gain was achieved significantly higher due to more feed utilisation efficiency, increased molar proportions of propionate and more protein utilisation post ruminally in monensin supplemented group (T_2).

Feed efficiency

The dry matter (DM), digestible crude protein (DCP), crude protein (CP) and TDN intake per Kg body gain have been shown in Table 4. The intake of DM,

Table 4. Nutrient intake per kg gain in body weight and gain per kg nutrient intake under different dietary treatments

Attribute	Treatments	
	T ₁	T ₂
Nutrient intake per Kg gain:		
DM intake (Kg)	9.26 ±0.13	7.71** ±0.27
CP intake (g)	884.83 ±73.66	750.83** ±23.96
DCP intake (g)	528.50 ±12.69	469.33** ±10.90
TDN intake (Kg)	4.73 ±0.38	4.28** ±0.17
Gain per Kg nutrient intake		
Gain/Kg DM intake (g)	111.00 ±7.52	130.00** ±4.43
Gain/Kg CP intake (Kg)	1.16 ±0.08	1.33* ±0.04
Gain/Kg DCP intake (g)	1.85 ±0.12	2.13* ±0.05
Gain/Kg TDN intake (g)	217.66 ±15.40	235.33* ±9.11

Each figure is an average of six observations.

** P < 0.01; * P < 0.05

CP, DCP and TDN was statistically significant ($P < 0.01$) in monensin supplemented group (T_2). DM intake per Kg gain was decreased significantly ($P < 0.01$). This observation is in accordance with Fontenot *et al.* (1993) and McCartar (1979). The increased feed efficiency with monensin supplementation was also observed by Lernerager *et al.* (1978), Davis and Erhart (1976), Raun *et al.* (1976), Potter *et al.* (1976), Utley *et al.* (1976) and Richardson *et al.* (1976). However, Cross *et al.* (1994) in sheep and Morais *et al.* (1993) in cattle did not find any change of feed efficiency with monensin supplementation. Monensin increased feed efficiency in cattle on both roughage and concentrate diet. Therefore, present findings are in accordance with these workers.

However, efficiency is termed as intake per unit gain but in this study reverse of this i.e. gain per unit intake was also depicted. Gain per Kg DM, CP, DCP and TDN was statistically significant ($P < 0.01$) in monensin treated group (T_2). It was revealed that monensin supplementation decreased feed requirements per unit gain in body weight through growing period in buffalo heifers.

Body Measurement

Growth is a complex phenomenon and is difficult to define in simple terms. Growth is often taken as an increase in body weight. However, an animal can show skeletal growth without putting on weight by losing water or fat from the body. Therefore, a combination of body weight and body measurement was employed. In this study, gain in body weight and size (length, height and chest

Table 5. Average daily increase in body measurements (cm) of animals under different dietary treatments during experimental period

Attribute	Treatments	
	T ₁	T ₂
Body length		
Initial length	118.16	116.33
	±1.66	±1.91
Final length	135.33	136.50
	±1.30	±1.57
Total increase	17.17	20.17
	±0.28	±0.56
Daily increase	0.140	0.170
	±0.003	±0.005
Body height		
Initial height	111.66	112.33
	±1.19	±1.37
Final height	125.50	125.16
	±1.01	±1.33
Total increase	10.84	12.83
	±0.60	±0.26
Daily increase	0.090	0.110
	±0.005	±0.002
Chest girth		
Initial girth	134.33	141.00
	±1.92	±1.91
Final girth	152.83	160.66
	±1.82	±1.75
Total increase	18.50	19.60
	±0.24	±0.44
Daily increase	0.160	0.163
	±0.002	±0.004

Each figure is an average of six observations.

Fig. 2. Average body length (cm) of heifers at fortnightly intervals during experimental period

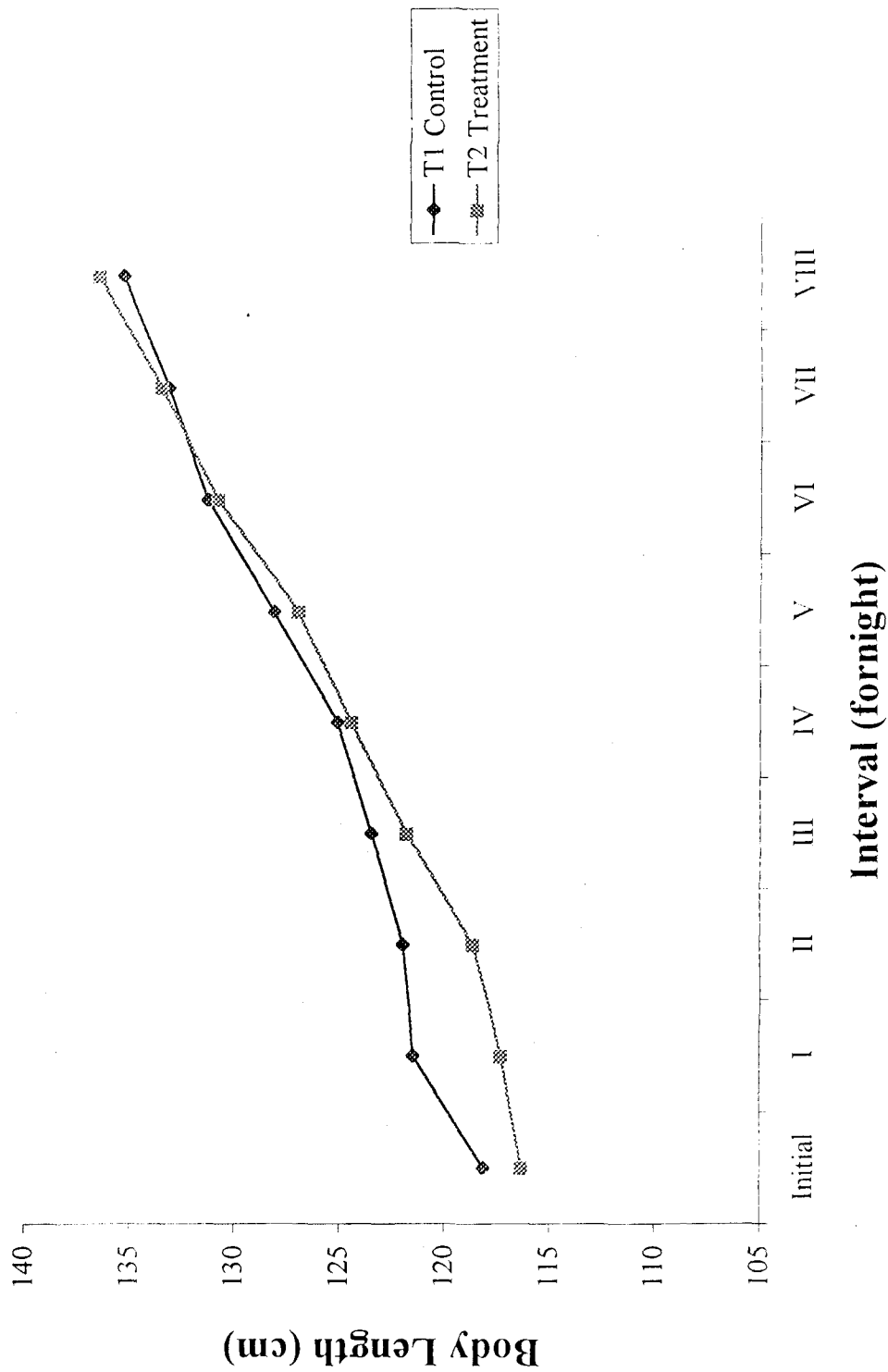


Fig. 3. Average body height (cm) of heifers at fortnightly intervals during experimental period

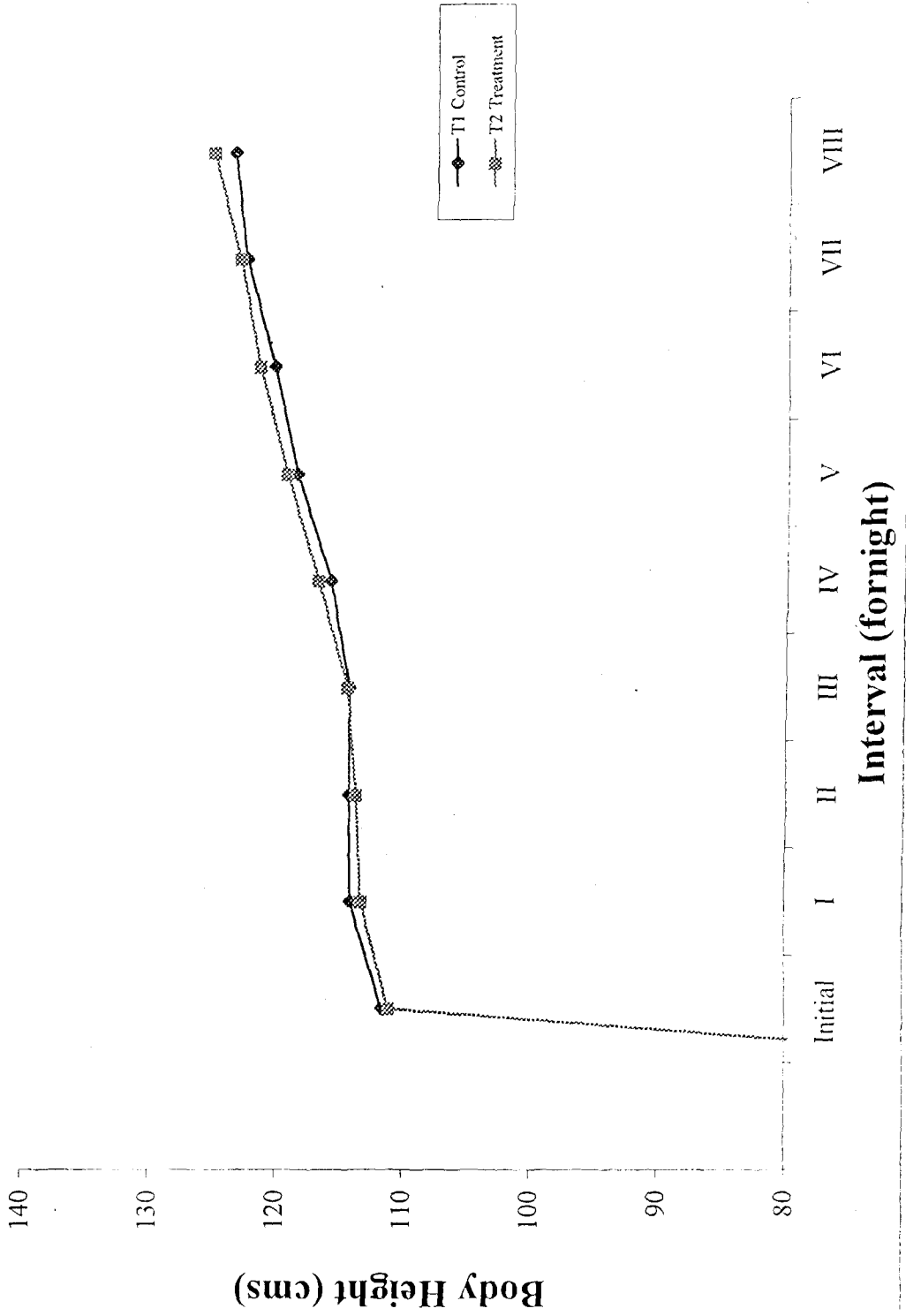
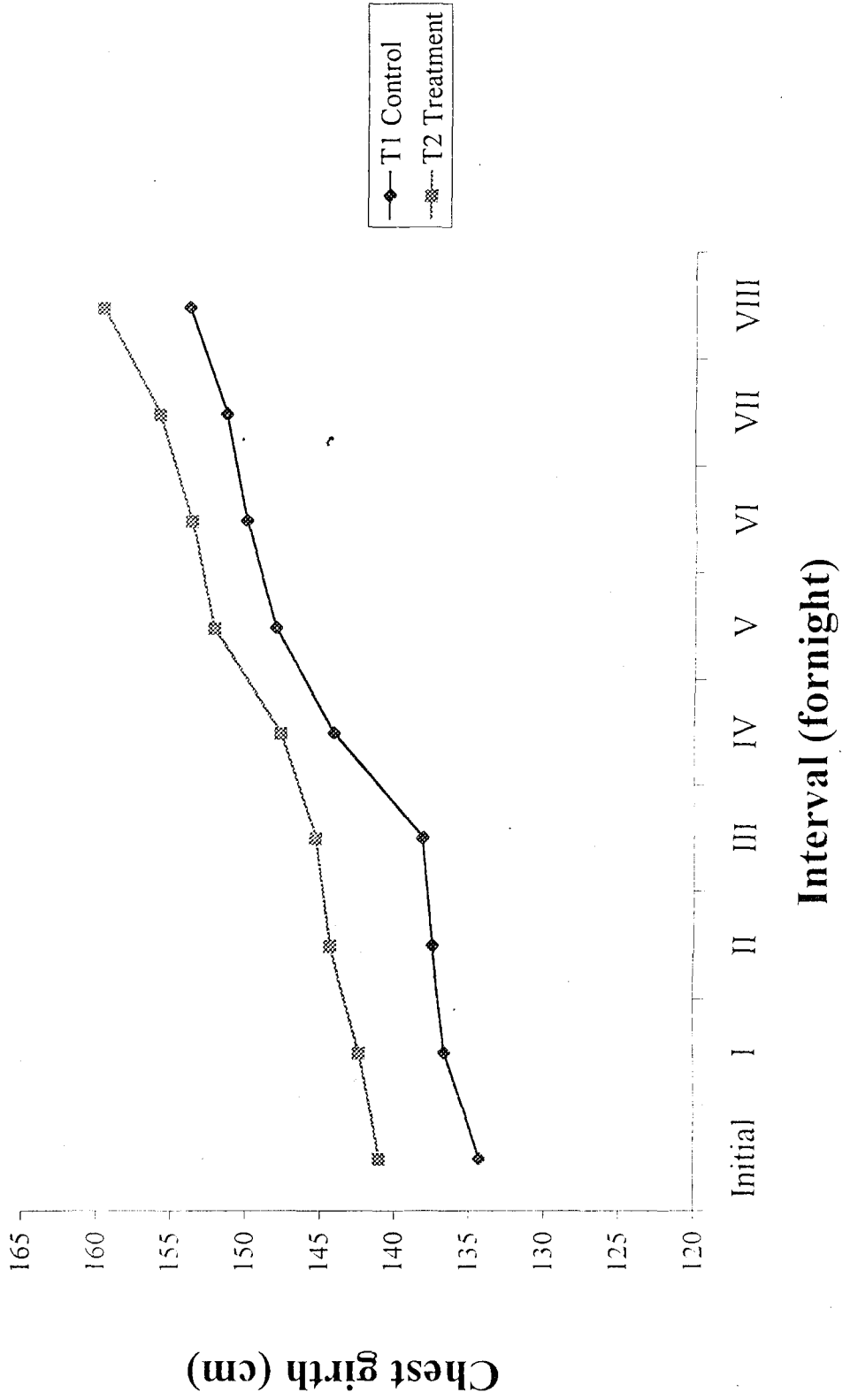


Fig. 4. Average chest girth (cm) of heifers at fortnightly intervals during experimental period



girth) were used as measurements of growth. The average daily increase in body length, height and chest girth of buffalo-heifers under the treatments have been presented in Table 5 and Figs. 2, 3 and 4. The average daily increase in body length was 0.140 ± 0.003 and 0.170 ± 0.005 cm in T_1 and T_2 treatments, respectively and the corresponding figures for body height and chest girth were 0.090 ± 0.005 and 0.110 ± 0.002 , and 0.160 ± 0.002 and 0.163 ± 0.004 cm respectively. Although the differences were not significant but an increasing trend in all the variable of body measurement was observed in heifers supplemented with monensin (T_2) as compared to control group (T_1). This increasing trend of body measurements in T_2 may be because of better feed utilisation by the heifers of this group. These findings are in accordance with Patil *et al.* (1996). However, Mooseley *et al.* (1977) reported significant change in heart girth of beef steers but no change in body length height when supplemented with monensin. In another experiment with high energy ration, he observed significant increase of body height and length but girth was affected with monensin treatment.

Nutrient Digestibility and Nutritive Value of Ration

The data pertaining to the digestibility of proximate principle by the buffalo heifers under treatments are presented in Table 7. The digestibility coefficient for DM, OM and NFE were highly significant ($P < 0.01$) while that of CP and EE were significant ($P < 0.05$) in monensin supplemented group (T_2) but CF digestibility was unaffected statistically due to monensin supplementation. DM digestibility

Table 6. Nutrient intake of experimental animals during the digestion trial under different dietary treatments

Attribute	Treatments	
	T ₁	T ₂
DM intake (Kg/day)	5.55 ±0.09	5.51 ±0.10
DM intake/ 100 Kg b.w. (Kg)	2.32 ±0.07	2.21 ±0.06
DM intake/W ^{0.75} Kg (g)	74.25 ±2.09	69.98 ±1.75
Total CP intake (g/day)	530.00 ±10.32	526.66 ±10.54
CP intake/100 Kg b.w. (g)	223.57 ±14.54	215.44 ±15.43
CP intake/ W ^{0.75} Kg (g)	8.74 ±0.38	8.52 ±0.45
DCP intake (g/day)	317.12 ±11.06	336.67 ±15.22
DCP intake/100 kg b.w. (g)	135.19 ±13.02	137.57 ±10.75
DCP intake/ W ^{0.75} Kg (g)	5.27 ±0.41	5.70 ±0.43
TDN intake (Kg/day)	2.83 ±0.06	3.00 ±0.08
TDN intake/100 Kg b.w. (Kg)	1.19 ±0.09	1.22 ±0.06
TDN intake/ W ^{0.75} Kg (g)	46.83 ±2.61	48.31 ±1.91

Each figure is an average of six observations.

has been reported to be increased significantly (Lee *et al.*, 1990; Araujo *et al.*, 1991; Patil *et al.*, 1996) while statistically not-significant but improved DM digestibility have been reported by Rogers *et al.* (1982) and Su *et al.* (1993). Depressed digestibility of DM was reported by Sun *et al.* (1991). Another reports by Poos *et al.* (1979) and Cottyn *et al.* (1983) explained a significant decrease in digestibility when wethers supplemented with monensin. Some earlier reports have shown no effect on digestibility coefficient for proximate principle (Dinius *et al.*, 1976; Lemenager *et al.*, 1978; Faulkner *et al.*, 1985; Ricke *et al.*, 1982).

Increased OM digestibility has been reported by Wedegarther *et al.* (1983), Faulkner *et al.* (1985), Beede *et al.* (1986), Fahiny *et al.* (1993) and Zinn and Borques (1993). These findings are similar to this experiment indicating higher OM digestibility.

CP digestibility was reported to be increased by Araujo *et al.* (1991), Zinn and Borques (1993). These earlier CP digestibility reports are in accordance with the findings of this work with monensin supplementation. Fibre digestibility was explained to be increased by Rogers *et al.* (1982), Thornton *et al.* (1981) and Gado *et al.* (1997). While Sun *et al.* (1991) reported decreased fibre digestibility with monensin treatment. Patil *et al.* (1996) reported no effect on fibre digestibility as well as ether extract (EE) digestibility with monensin supplementation in goats.

In our experiment digestibility coefficients of DM, OM, EE, CF have been found increased by monensin supplementation. This compound increases in

Table 7. Nutrient digestibility and nutritive value of rations under different dietary treatments

Attribute	Treatments	
	T ₁	T ₂
Digestibility coefficient (%)		
Dry matter	53.48 ±0.65	58.68** ±0.85
Organic matter	55.25 ±0.33	60.73** ±0.92
Crude protein	62.70 ±1.45	66.81* ±1.46
Ether extract	59.45 ±1.00	62.16* ±0.46
Crude fibre	41.28 ±0.97	43.81 ±1.16
Nitrogen-free extract	59.38 ±0.82	65.51** ±1.20
Nutritive value		
DCP (%)	5.71 ±0.14	6.10* ±0.13
TDN (%)	51.07 ±0.46	55.50** ±0.59
DE (Mcal/Kg DM)	2.18 ±0.01	2.37** ±0.02
ME (Mcal/Kg DM)	1.88 ±0.01	2.04** ±0.02

Each figure is an average of six observations.

** P < 0.01; * P < 0.05

rumen propionate molar concentration, depresses methanogenesis and has a protein spacing effect, which might be a supporting explanation for increased digestibility coefficients. These results were reflected by increased level of blood, total protein, blood glucose and decreased blood urea nitrogen level (Table 10) along with increased molar concentration of propionic acid in rumen (Table 8). CF digestibility was not affected significantly. As in the total experimental period of 120 days, during the digestibility trial DM, CP, DCP and TDN intake in treatment groups were similar (Table 6).

The per cent DCP values obtained are 5.71 and 6.10. The DCP values were significantly ($P<0.05$) higher. The per cent TDN values obtained are 51.07 and 55.50, and are highly significant ($P<0.01$) in T_2 . Similar trends were also observed for DE and ME contents in the treatments. DE and ME values were 2.18 ± 0.01 , 2.37 ± 0.02 , 1.88 ± 0.01 , 2.04 ± 0.02 in T_1 and T_2 groups, respectively. Both values were significant ($P<0.01$) in T_2 group with monensin supplementation.

Rumen parameters

Mean values for pH and individual volatile fatty acids of rumen liquor collected at 0 and 4 H (post feeding) are presented in Table 8.

pH of rumen liquor

The pH of the strained rumen liquor (SRL) varied from 6.90 to 6.95 in both the treatments. However, there were no significant differences in pH between

Table 8. Mean values of rumen pH and volatile fatty acids under different dietary treatments

Attribute	Treatments					
	0 hour		4 hour (Post-feeding)		Difference of 0 and 4 hour	
	T ₁	T ₂	T ₁	T ₂	T ₁	T ₂
pH	6.95 ±0.01	6.94 ±0.01	6.90 ±0.06	6.90 ±0.06	0.050 ±0.001	0.040 ±0.001
Acetate (Meq/l)	36.06 ±2.04	30.53 ±2.55	65.65 ±2.72	56.24* ±2.42	29.59 ±2.93	25.71 ±2.22
Propionate (Meq/l)	7.99 ±0.49	11.80** ±0.76	18.21 ±1.45	24.91** ±0.44	10.21 ±2.46	13.11* ±2.03
Butyrate (Meq/l)	3.98 ±0.52	4.30 ±0.30	6.17 ±0.81	6.89 ±0.62	2.18 ±0.87	2.59 ±0.84

Each figure is an average of six observations.

** P < 0.01; * P < 0.05

treatments. Normally pH of rumen is close to neutrality but it is influenced by diet composition and feeding practices. As the proportion of rapidly fermentable material entering the rumen is increased, the rumen pH is lowered. Rumen pH is also affected by feeding stage, reaching the lowest value at 2 to 6 hours post-feeding and closely related to production of volatile fatty acids. In present study, the ruminal pH at 4 h (post feeding) in monensin supplemented group T₂ was not affected. Similar findings were reported by Davis *et al.* (1976), Utley *et al.* (1976) and Yalin *et al.* (1995).

Molar proportion of volatile fatty acids (VFA)

The mean values of molar concentrations of acetate, propionate and butyrate at 0 and 4 h have been presented in Table 8. The differences of molar concentrations of individual VFA between 0 and 4 h have been presented in the same table (Table 8).

The acetate concentration at 4 h (post feeding) in monensin supplemented group (T₂) was significantly lower ($P < 0.05$) than the control. The propionate concentration was significantly ($P < 0.01$) higher both at 0 and 4 h in T₂ and difference at 0 and 4 hour ($P < 0.05$). Our findings corroborated with earlier workers (Richardson *et al.*, 1976; Lemanager *et al.*, 1978; Rogers *et al.*, 1982; Duff *et al.*, 1995). Butyrate concentration was not affected significantly, however, there was a slight depression. The decreased butyrate concentrations were reported by O'Kelly *et al.* (1988) in monensin supplemented group. The

depression in molar concentration and increase in propionate concentration was influenced by mode of action of monensin. Depression of formate and methane producing bacteria by monensin intraruminally enhances propionate production and depresses acetate production.

Blood Parameters

Haematological picture

The mean haematological values have been presented in Table 9. The all haematological values are within normal range with monensin supplementation. This indicates that the haemopoetic system has not been affected by monensin supplementation.

Blood biochemical constituents

Mean values of different biochemical constituents of blood viz., plasma glucose, total protein, cholesterol and urea are presented in Table 10. The mean glucose level increased 50.51 ± 2.77 to 64.05 ± 3.48 mg/dl in T₂. The mean values of plasma glucose were not significantly different between treatments, however, the apparently increased glucose level was found in monensin supplemented group. *This indicates more propionate utilisation for higher glucose level.* Propionate is a precursor for glucose. This result was found in conformity with Potter *et al.* (1976), Auri *et al.* (1994) and Krishan (1998). Walker *et al.* (1980) and Stephenson *et al.* (1997) reported non-significant differences in plasma concentration of glucose between monensin treated and control cows. Plasma

Table 9. Mean haematological values during experimental period under different dietary treatments

Attribute	Treatments	
	T ₁	T ₂
Hb (g/dl)	10.72 ±0.10	10.56 ±0.11
PCV (%)	32.12 ±0.29	32.86 ±0.32
TEC (10 ⁶ /cmm)	8.30 ±0.26	8.14 ±0.30
TLC (10 ³ /cmm)	9.70 ±0.35	8.96 ±0.29
MCV (fl) ⁺	38.43 ±0.62	41.20 ±0.54
MCH (pg) ⁺⁺	12.29 ±0.12	13.17 ±0.14
MCHC (%)	33.46 ±0.31	33.68 ±0.28
DLC		
Neutrophil	32.28 ±0.52	33.82 ±0.77
Lymphocyte	62.82 ±0.51	61.58 ±0.73
Monocyte	3.35 ±0.16	3.25 ±0.24
Eosinophil	1.52 ±0.08	1.30 ±0.14
Basophil	0.03 ±0.00	0.05 ±0.00

Each figure is an average of six observations.

++ pg – picogram (micro-microgram)

+fl – Femto litre (μ^3)

Table 10. Mean values of certain biochemical parameters during experimental period under different dietary treatments

Attribute	Treatments	
	T ₁	T ₂
Plasma glucose (mg/dl)	60.61 ±2.77	64.05 ±3.48
Plasma protein (g/dl)	6.09 ±0.17	6.61* ±0.19
Blood cholesterol (mg/dl)	92.81 ±2.77	88.62 ±2.83
Plasma urea (mg/dl)	38.62 ±2.27	35.67 ±2.24

Each figure is an average of six observations.

* $P < 0.05$.

protein concentration mean values of the buffalo heifers were 6.09 ± 0.17 and 6.61 ± 0.19 g/dl in T₁ and T₂, respectively.

Significantly ($P < 0.05$) increased level of plasma protein was found in monensin supplemented group. This finding is in harmony with Krishan (1998). However, Walker *et al.* (1980) reported non-significant effect of monensin on serum proteins in herd ford cows in contrast to the present study. In present study higher plasma proteins level in monensin supplemented group (T₂) reflects better feed protein utilisation as indicated by body weight gain (Lana *et al.*, 1997).

The plasma urea level was lower, although not statistically significant, in monensin supplemented group than the control group (Table 10). This finding was in agreement with Walker *et al.* (1980), Abe *et al.* (1994), Stephenson *et al.* (1997), Ramanzin (1997), Heggazy (1997) and Duffield *et al.* (1998). Present study reflects that protein was degraded at a slower rate by ruminal microorganisms and lower ammonia levels assimilated from rumen to blood circulation in monensin treated group (T₂). It also reflects increased utilisation *efficiency of peptides or amino acids absorbed post-feeding.*

The plasma cholesterol values (mg/dl) of buffalo heifers were 92.8 ± 2.77 and 88.62 ± 2.83 in T₁ and T₂ groups, respectively. Although the values were statistically not significant but lower values were obtained in monensin supplemented group (T₂). It seems monensin supplementation in animals has hypoholesterimic effect in the body and may be helpful in reducing the arterial

Table 11. Economics of feeding monensin during experimental period

Attribute	Treatments	
	T ₁	T ₂
Cost of feed/fodder fed to heifers (Rs.)	13753.00	13635.00
Cost of monensin tablets	Provided free of cost	
Assuming the cost of monensin dosage/day/heifer as		i) Rs. 720/-
(i) Rs. 1/- (ii) Rs. 2/- (iii) Rs. 3/- (iv)		ii) Rs. 1440/-
Rs. 4/- and (v) Rs. 5/-. The additional		iii) Rs. 2160/-
cost of monesin supplementation during		iv) Rs. 2880/-
120 days to this group will be :		v) Rs. 3600/-
Total cost (Rs.)	13753.00	i) Rs. 14355/- ii) Rs. 15075/- iii) Rs. 15795/- iv) Rs. 16515/- v) Rs. 17235/-
Daily feed cost/animal (Rs.)	19.10	i) Rs. 19.93 ii) Rs. 20.93 iii) Rs. 21.93 iv) Rs. 22.93 v) Rs. 23.93
Cost/Kg gain (Rs.)	31.00	i) Rs. 27.83 ii) Rs. 29.23 iii) Rs. 30.62 iv) Rs. 32.02 v) Rs. 33.42

The cost of concentrate mixture, green jowar and wheat straw was Rs. 530, 53 and 130 per quintal, respectively.

blocks caused by excess cholesterol level. This result is similar to Krishan (1998). However, Yalin *et al.* (1995) reported no effect of monensin on serum cholesterol in merino lambs. Cholesterol low level may be reflected due to depressed acetate molar concentration in rumen which is a cholesterol precursor.

Economics of Monensin Supplementation

Feed cost per Kg body weight gain by the animals and the daily feed cost per animal are presented in Table 11. As the monensin tablets were provided free of cost, it is difficult to calculate the exact cost per Kg gain. However, assuming that the cost of monensin dosage per day/heifer as Rs. 1, 2, 3, 4 and 5, the cost per Kg gain has been arrived at Rs. 27.83, 29.23, 30.62, 32.02 and 33.42 as compared to Rs. 31.00 in control group. It clearly shows that if the cost of monensin dosage is upto Rs. 3.00, it is economical to supplement monensin for better growth in buffalo heifers.

It may be inferred that monensin supplementation is beneficial for growth in buffalo heifers without any ill effect.

SUMMARY AND CONCLUSIONS

An experiment was conducted to assess the effect of supplementation of monensin on growth and nutrient utilization, certain rumen parameters and blood constituents on twelve Murrah buffalo heifers. The animals were randomly divided into two groups of six each on the basis of nearness in their body weight. The experiment was carried out for a period of 120 days. An adjustment period of 15 days was given before experiment. Animals were kept under similar managerial conditions. The animals in control group (T₁) were fed conventional concentrate mixture @ 2 Kg per head per day with green sorghum and wheat straw as per their requirements. In treatment group (T₂) in addition, monensin was supplemented @ 100 mg/day/animal. The following salient features were concluded from this study:

During experimental period average DM intake expressed either in absolute amount (Kg/day) as per 100 Kg body weight per Kg metabolic body size was statistically not significant between groups. DM intake (Kg) per day was 4.96±0.10, 4.88±0.09 in T₁ and T₂, respectively. DM intake (Kg) per 100 Kg body weight was 2.40±0.05, 2.29±0.06 and DM intake (g) per metabolic size was 90.28±1.30, 87.06±1.91 in T₁ and T₂ groups, respectively. However, not significant but there was a depression in DM intake with monensin supplementation. Similarly intake of DM during digestion trial was 5.55±0.09,

5.51±0.10 Kg/day in T₁ and T₂, respectively. It also reflected depression in DM intake but not significant with monensin supplementation. DM intake per 100 Kg body weight and per metabolic body size was 2.32±0.07, 2.21±0.06 Kg and 74.25±2.09, 69.98±1.75 g respectively in T₁ and T₂ groups. There were not significant differences among treatments. Same trend was observed with CP intake either in absolute amount or per 100 Kg body weight or per metabolic body size. CP intake daily, per 100 Kg body weight, per metabolic body size was 530.00±10.32, 526.66±10.54; 223.57±14.54; 215.44±15.43; 8.74±0.38, 8.52±0.45 g in T₁ and T₂, respectively. DCP intake daily, per 100 Kg body weight and per metabolic body size were 317.12±11.06; 336.67±15.22; 135.19±13.02; 137.57±10.75; 5.27±0.41; 5.70±0.43 g in T₁ and T₂, respectively. TDN intake daily and per 100 Kg body weight was 2.83±0.06, 3.00±0.08; 1.18±0.09, 1.22±0.06 Kg respectively in T₁ and T₂ groups. TDN intake per metabolic size was 46.83±2.61, 48.31±1.91 g in T₁ and T₂, respectively. DCP and TDN intake was not significant yet there was noted an improvement of intake in monensin supplemented group (T₂).

Total body weight gain per animal and average daily gain were 74.10±5.08, 86.00±2.92; 0.616±0.042 and 0.716±0.024 Kg respectively in T₁ and T₂ groups. Total body weight gain and average daily gain were highly significant (P<0.01) in monensin supplemented group (T₂). DM intake was 9.26±0.13 and 7.71±0.27 Kg per Kg gain in T₁ and T₂ treatments. It was highly significant (P<0.01) in T₂ group

with monensin supplementation. DM intake per Kg gain was decreased significantly ($P<0.01$), CP intake was 884.83 ± 73.66 , 750.83 ± 23.96 g per Kg gain. The intake was decreased significantly ($P<0.01$) in T_1 and T_2 groups.

DCP intake was 528.50 ± 12.69 , 469.33 ± 10.90 g per Kg gain in T_1 and T_2 , respectively. DCP intake was increased significantly ($P<0.01$) in monensin fed group. TDN intake was 4.73 ± 0.38 , 4.28 ± 0.187 Kg in T_1 and T_2 , respectively. TDN intake per Kg gain was reduced significantly ($P<0.01$) with monensin supplementation.

Body measurements (Body length, girth and height) were not affected with monensin supplementation. There were not significant differences among treatment groups.

Digestibility of DM, OM and NFE was estimated as 53.48 ± 0.65 ; 58.68 ± 0.85 ; 55.25 ± 0.33 ; 60.73 ± 0.92 ; 59.38 ± 0.82 ; 65.51 ± 1.20 per cent in T_1 and T_2 groups, respectively. DM, OM and NFE digestibility was increased significantly ($P<0.01$) in monensin supplemented buffalo heifers. EE digestibility was 59.45 ± 1.00 , 62.16 ± 0.46 in T_1 and T_2 groups, respectively. It also increased significantly ($P<0.05$) in monensin treated heifers. CP digestibility was 62.70 ± 1.45 , 66.81 ± 1.46 in T_1 and T_2 respectively. It was significant ($P<0.05$) increased in monensin given group (T_2). CF digestibility was not changed significantly with monensin supplementation.

DCP and TDN values of ration fed were 5.71 ± 0.14 , 6.10 ± 0.13 ; 51.07 ± 0.46 ; 55.50 ± 0.59 per cent, respectively in T_1 and T_2 groups. DCP was significant ($P < 0.05$) in monensin treated group (T_2) while TDN was highly significant ($P < 0.01$) in monensin treated group (T_2). DE and ME values of ration were 2.18 ± 0.01 , 2.37 ± 0.02 , 1.88 ± 0.01 , 2.04 ± 0.02 Mcal/Kg DM respectively in T_1 and T_2 groups, respectively. DE and ME values of ration were significant ($P < 0.01$) with monensin supplementation. These nutritive values reflect better feed utilization when monensin supplemented with feed to buffalo heifers.

The pH values of strained rumen liquor (SRL) were not affected by monensin supplementation. The pH values varied 6.90 ± 0.001 to 6.95 ± 0.005 between treatments. Ruminal acetate concentration was found significantly ($P < 0.05$) decreased at 4 h (post feeding) in T_2 while propionate concentration was found increased both at 0 and 4 h (post feeding) which was highly significant ($P < 0.05$) at 0 as well as 4 h (post feeding) in monensin supplemented group. These observations indicates better energetic efficiency with increased propionate concentration in rumen which is a precursor of glucose.,

Monensin supplementation did not change haematological values significantly. So it can be used without any ill effect in heifers as in T_2 group. Blood plasma glucose levels were 60.61 ± 2.77 and 64.05 ± 3.48 (mg/dl) in T_1 and T_2 groups. There were not significant differences among treatments. However, there was increasing trend of glucose level in blood with monensin treatment in

buffalo heifers. Blood plasma protein levels were 6.09 ± 0.17 , 6.61 ± 0.19 g/dl in T_1 and T_2 groups, respectively. Protein level was increased significantly ($P < 0.05$) in monensin supplemented heifers. This result provides support for better feed protein utilisation with monensin supplementation. Blood cholesterol and urea levels were not significantly changed with monensin supplementation. However, there was hypocholesteremia in monensin treated heifers and there was a slight decreasing trend in blood plasma urea levels in monensin supplemented animals.

As the monensin tablets were provided free of cost, it is difficult to calculate the exact cost per Kg gain. However, assuming the cost of monensin dosage/day/heifer as Rs. 1, 2, 3, 4 and 5, the cost per Kg gain has been arrived at Rs. 27.83, 29.23, 30.62, 32.02 and 33.42 as compared to Rs. 31.00 in control group. It clearly shows that if cost of monensin dosage is upto Rs. 3.00, it is beneficial to supplement monensin for better growth in buffalo heifers.

It may be inferred that monensin supplementation is beneficial for growth in buffalo heifers without any ill effect.

LITERATURE CITED

- Abe, M.; Iriki, T.; Inoue, Y. and Funaba, M. 1992. Effects of intravenous administration of ionophores on metabolism in steers. *Animal Science and Technology*. **63**: 947-954.
- Abe, N.; Lean, I.J.; Rabice, A.; Porter, J. and Graham, C. 1994. Effects of sodium monensin on reproductive performance of dairy cattle. II. Effects of metabolites in plasma, resumption of ovarian cyclicity and oestrus in lactating cows. *Australian Veterinary Journal*. **71**: 277-282.
- Abou-Akkadda, A.R.; El-Fouly, H.A. and Khalil, A.A. 1973. Effect of environmental temperature on the protein fractions and electrolytes in the serum of laying hens. *Alex J. Agric. Res.* **21**: 15.
- Adams, D.C.; Galyean, M.L.; Kiesling, H.E.; Wallace, J.D. and Finkner, M.D. 1981. Influence of viable yeast culture, sodium bicarbonate and monensin on liquid dilution rate, rumen fermentation and feedlot performance on growing steers and digestibility in lambs. *Journal of Animal Science*. **53**: 780.
- *Ak, I.; Filya, I.; Akgunduz, U. and Deligozoglu, F. 1995. Effects of monensin on fattening performance of merino lambs subjected to

intensive farming. *Lalahan-Hayvancilik-Arastirma-Enstitusu-Dergisi*. **35**: 30-46 (Abstr.).

Ali Haimoud, D.; Vermay, M.; Bayourthe, C. and Moncoulon, R. 1995. Avoparcin and monensin effects on the digestion of nutrients in dairy cows fed a mixed diet. *Journal of Animal Science*. **75**: 379-385.

Annison, E.F. 1954. Some observations in volatile acids in sheep's rumen. *Biochemical Journal*. **57**: 400-404.

Anonymous. 1999. Indian milk comes at the top. *Indian Farmer Times*. **16**: 8-10.

AOAC, 1995. *Official Methods of Analysis*. 15th edn. Association of Official Analytical Chemists. Washington, D.C.

Austin, A.R. and Wilde, R.M. 1985. The effect of sodium monensin on pregnant ewes. *British Veterinary Journal*. **141**: 628-634.

Badaway, S.A.; Younis, M.; Shalash, M.R.; Nawito, M.F.; Mansour, A.S.; Wasfy, M.A. 1996. Effect of monensin on metabolic profile testing in buffalo heifers. *Egyptian Journal of Veterinary Science*. **30**: 27-41.

Baile, C.A. and Della-Fera, M.A. 1981. Nature of hunger and satiety control system in ruminants. *Journal of Dairy Science*. **64**: 1140-1152.

Baile, C.A.; McLaughlin, C.L.; Chalupa, W.V.; Synder, D.L.; Pendulam, L.C.

- and Potter, E.L. 1982. Effects of monensin fed to replacement dairy heifers during the growing and gestation period upon growth, reproduction and subsequent lactation. *Journal of Dairy Science*. **65**: 1941-1944.
- Ballard, F.J.; Hanson, R.W. and Kronfeld, D.S. 1969. Gluconeogenesis and lipogenesis in tissue from ruminant and non ruminant animals *Fed. Prod.* **28**: 218.
- Beede, D.K.; Schelling, G.T.; Mitchell, G.E.Jr.; Tucker, R.E.; Gill, W.W.; Koenig, S.E. and Lindsey, T.O. 1986. Nitrogen utilisation and digestibility by growing steers and goats of than contain monensin and low crude protein. *Journal of Animal Science*. **62**: 857-863.
- Ben, A.A.; Ilan, D.; Levy, M. and Holzer, Z. 1982. A note on the effect of monensin supplementation on growth and food utilisation in young calves. *Animal Production*. **35**: 163-164.
- Bernard, G.C. and Boueque, C.V. 1968. Rapid method for the gas-chromatic determination of volatile fatty acids in rumen fluid. *Journal of Agricultural Food Chemistry*. **16**: 105-109.
- Bhatia, S.K.; Ahja, A.K.; Poonia, R.S. and Rao, A.R. 1972. A note on the comparative study of some blood constituents of Haryana and cross-bred (Holstein-Friesian x Haryana) calves raised on high plane of nutrition. *Indian Veterinary Journal*. **72**: 568-571.

- Blaxter, K.L. 1962. *The Energy Metabolism of Ruminants*. Charles C. Thomas, Springfield, Illinois.
- Boling, J.A.; Bradley, N.W. and Campbell, L.D. 1977. Monensin levels for growing and finishing steers. *Journal of Animal Science*. **44**: 867.
- Bolsen, K.K.; Corah, L. and Riley, J.G. 1975. Milo stover silage and monensin for growing calves. *Journal of Animal Science*. **41**(392 (Abstr.).
- Brown, D.L. and Hogue, D.E. 1987. Effect of feeding monensin to lactating goats. *Journal of Dairy Science*. **70**: 823-830.
- Brown, H.; Carroll, L.H.; Elliston, N.G.; Grueter, H.P.; McAskill, J.W.; Olson, R.D. and Rathmacher, R.P. 1974. Field evaluation of monensin for improving feed efficiency in feedlot cattle. Proc. Western Sec. *American Society of Animal Science*. **25**: 300.
- Chalupa, W.; Carbett, W. and Brethour, J.R. 1980. Effects of monensin and amicloral on rumen fermentation. *Journal of Animal Science*. **51**: 70.
- *Cinar, A. and Sulu, N. 1995. The effects of monensin on growth and development in calves. *Turk-Veterinerlik-ve-Hayvancilik-Dergisi*. **19**: 281-289 (NAR).
- Clary, E.M.; Brandt, R.T. Jr.; Harmon, D.L. and Nagaraja, T.G. 1993. Supplemental fat and ionophorce in finishing diets : Feed lot

performance and ruminal digester kinetics in steers. *Journal of Animal Science*. 71: 3115-3123.

Collins, R.M. and Pritchard, R.H. 1992. Alternative day supplementation of corn stalk diets with soybean meal or corn gluten meal fed to ruminants. *Journal of Animal Science*. 70: 3899-3908.

*Cottyn, B.G.; Fiems, L.O.; Boucque, C.V.; Aerts, J.V. and Buysee, F.X. 1983. Effect of monensin sodium and avoporcine digestibility and rumen fermentation. *Zeitschrift-fur-Tierphysiologie, Tierernahrung-und-Futtermittelkunde*. 49: 277-286 (Abstr.).

Cross, D.L.; Caldwell, W.J.; Strickland, J.R. 1994. Efficacy of drought-stressed whole corn plants as a feed for ruminants. 2. Effect on digestibility and performance of ruminants consuming whole corn plant. *International Journal of Animal Science*. 9: 317-324.

Dartt, R.M.; Boling, J.A. and Bradley, N.W. 1978. Supplemental protein withdrawal and monensin in corn silage diets for finishing steers. *Journal of Animal Science*. 46: 345.

Davis, G. 1975. Effects of feeding monensin and implanting diethylstilbestrol on performance of finishing feedlot steers. Exp. Sta. Rep. Kansas Agr. Exp. Sta. Garden City.

Davis, G.V. and Erhart, A.B. 1975. Effects of feeding monensin and implanting diethylstilbestrol on the performance of finishing

steers. Cattle Feeders' Day. Kansas Agr. Exp. Sta. Rep. Prog. 243. p. 3.

Davis, G.V. and Erhart, A.B. 1976. Effects of monensin and urea in finishing steer rations. *Journal of Animal Science*. 43: 1-8.

Dinius, D.A.; Simpson, M.E. and Marsh, P.B. 1976. Effect of monensin fed with forage on digestion and the ruminal ecosystem of steers. *Journal of Animal Science*. 42: 229-234.

Ducker, M.J.; Rosemary, A.; Haggett, W.; Fisher, J.; Mornat, S.V. and Glenys, A. Bloomfield. 1985. The effect of level of feeding in late pregnancy and around the time on insemination on the reproductive performance of first lactation dairy heifers. *Animal Production*. 41: 1-12.

Duff, G.C.; Galean, M.L. and Branine, M.E. 1995. Effect of adaptation to lasalocid, monensin or a daily rotation of lasalocid and monensin on *in vitro* fermentation of 90% concentrate diet. *Journal of Animal Science*. 75: 129-134.

Duff, G.C.; Galyean, M.F. and Branine, M.E. 1995. Effects of adaptation to lasalocid, monensin or a daily rotation of lasalocid and monensin on *in vitro* fermentation of a 90% concentrate diet. *Canadian Journal of Animal Science*. 75: 129-134.

Duff, G.C.; Galyean, M.L.; Branine, M.E. and Hallford, D.M. 1994. Effect of lasalocid and monensin plus tylosin on serum

- metabolic harmones and clinical chemistry profiles of beef steers fed a 90% concentration. *Journal of Animal Science*. 72: 1049-1058.
- Duffield, T.F.; Sandals, D.; Leslie, K.E.; Lissemore, K.; McBride, B.W.; Lumsden, J.H.; Dick, P. and Bagg, R. 1998. Effect of prepartum administration of monensin in a controlled release capsule on post partum energy indicators in lactating dairy cows. *Journal of Dairy Science*. 8: 2354-2361.
- Embry, L.B. and Swan, W.S. 1974. Effects of monensin on feedlot performance of growing and finishing steers. S. Dakota Sta. Univ. Anim. Sci. Series 74-5. p. 19.
- Eskeland, B.; Pfander, W.H. and Preston, R.L. 1974. Intravenous energy infusion in lambs : effects on nitrogen retention, plasma free amino acids and plasma urea nitrogen. *British Journal of Nutrition*. 31: 201.
- F.A.O. 1994. *FAO Year Book*, Food and Agricultural Organisation, United Nations, Rome. 48: 189.
- Fahmy, S.T.M. and Klopfenstein, T.J. 1993. Treatment with different chemicals and their effects on the digestibility of maize stalk, intake and *in vivo* digestibility as affected by chemical treatment and monensin supplementation. *Animal Feed Science and Technology*. 45: 309-316.

- Farlin, S.D.; Clanton, D.C. and Heldt, J.D. 1975. Monensin, a new feed additive for beef cattle. Nebraska Beef Cattle Rep. EC 75-218 p. 8-9.
- Faulkner, D.B.; Klopfenstein, T.J.; Trotter, T.N. and Britton, R.A. 1985. Monensin effects on digestibility, ruminal protein escape and microbial protein synthesis on high-fiber diets. *Journal of Animal Science*. 61: 654-660.
- Fontenot, J.P. and Huchette, H.M. 1993. Feeding sorbitol alone or in combination with monensin to finishing cattle. *Journal of Animal Science*. 71: 545-551.
- Fredrickson, E.L.; Galyean, M.L.; Branine, M.E.; Sowell, B. and Wallace, J.D. 1993. Influence of ruminally dispensed monensin and forage maturity on intake and digestion. *Journal of Range Management*. 46: 214-220.
- Fuller, J.R. and Johnson, D.E. 1981. Monensin and lasalocid effectson fermentation *in vitro*. *Journal of Animal Science*. 53: 1574.
- Gado, H. 1997. Nutrients utilisation and growth performance of Baladi goats kids fed monensin sodium supplementated ration. *Egyptian Journal of Nutrition and Feed Special*. 91-98.
- Gallaway, D.L. Sr.; Goetsch, A.L.; Patil, A.; Forster, L.A. Jr. and Johnson, Z.B. 1993. Feed intake and digestion by holstein steer calves consuming low-quality grass supplemented

- with lasalocid or monensin. *Canadian Journal of Animal Science*. **73**: 869-879.
- Garza, J.D. and Owens, F.N. 1990. Effect of monensin and lasalocid on water intake rumen volume, liquid passage rate, and ruminal dry matter in feed lot heifers. *Animal Science Research Report*. **129**: 109-113.
- Gianti, A.S. 1983. Veterinary clinical pathology. 3rd edition. CBS Publishers and Distributors Pvt. Ltd. p. 1-24.
- Gill, R.D.; Martin, J.R. and Lake, R. 1976. High, medium and low corn silage diets with and without monensin for feed lot steers. *Journal of Animal Science*. **42**: 363-368.
- Grings, E.E. and Malcs, J.R. 1988. Performance, blood and ruminal characteristics of cows receiving monensin and a magnesium supplement. *Journal of Animal Science*. **66**: 566-573.
- Haimoud, D.A.; Bayourthe, C.; Mancoulon, R. and Vernay, M. 1996. Avoparcin and monensin effects on digestive function in cows fed a high forage diet. *Journal of Science and Food Agriculture*. **70**: 181-189.
- Hale, W.H.; Theurer, B.; Marchello, J.A.; Taylor, B. and Kuhn, J. 1975. The effect of monensin on growing and finishing cattle. Arizona Cattle Feeder's Day, May 1, Series p. 36.

- Haney, M.E.Jr. and M.M. Heohn. 1967. Monensin, a new biologically active compound. *Antimicrobial Agents Chemotherapy*. 1: 349.
- Hegazy, M.A. 1997. Influence of monensin on blood metabolites and reproductive performance of suckled buffalo-cows. *Assuit Veterinary Medical Journal*. 36: 313-325 (NAR).
- Herod, E.L.; Bartley, E.E.; Davidovich, A.; Bechtle, R.M. and Sapienza, D.A. and Brent, B.E. 1979. Effect of adaptation to monensin or lasalocid on rumen fermentation *in vitro* and the effect of these drugs on heifer growth and feed efficiency. *Journal of Animal Science*. 47(Suppl. 1): 424.
- Hong, G.W.; Owens, F.N.; Armbruster, S.L.; Stevens, V.L. and Scott, M.L. 1977. Monensin for wheat pasture stockers : Ruminal fermentation, forage intake and performance. Oklahoma Agr. Exp. Sta. Anim. Sci. Res. Rep. p. 35.
- Horn, G.W.; Mader, T.L.; Armbruster, S.L. and Frahm, R.R. 1981. Effect of monensin on ruminal fermentation, forage intake and weight gains of wheat pasture stocker cattle. *Journal of Animal Science*. 52: 447.
- Horton, G.M.J.; Bassendowski, K.A. and Keeler, E.H. 1980. Digestion and metabolism in lambs and steers fed monensin with different levels of barley. *Journal of Animal Science*. 50: 997-1008.

- Hungate, R.E. 1966. *The Rumen and Its Microbes*. Academic Press, New York. p. 245-280.
- Hussain, Nissar; Sharma, D.D.; Khirwar, S.S. and Rao, M.V.N. 1975. Studies on growth rate and blood constituents of buffalo calves raised on different levels of dietary protein. *Indian Journal of Dairy Science*. **28**: 6.
- ICAR, 1998. *Nutrient Requirement for Livestock Poultry*. Indian Council of Agricultural Research, New Delhi. pp. 3-9.
- James, A.T. and Martin, A.J.P. 1951. Gas liquid partition chromatography : The separation and micro estimation of volatile fatty acids from formic acid to dodeconoic acid. *Biochemical Journal*. **50**: 679.
- Johnson, D.D.; Mitchell, G.E.; Tucker, R.E. and Muntifering, R.B. 1986. Pancreatic amylase, plasma glucose and insulin responses to propionate or monensin in sheep. *Dairy Science*. **69**: 51-57.
- Kaneko, J.J. and Cornelius, C.E. 1970. *Clinical Biochemistry of Domestic Animals*. Vol. 1, 2nd end. Academic Press, New York.
- Krishan K. 1998. Studies on the effect of dietary supplementation with rumensin for milk yield and its composition in Murrah buffalo heifers. M.V.Sc. Thesis, CCS Haryana Agricultural University, Hisar.

- Lana, R.P.; Fox, D.G.; Russell, J.B. and Perry, T.C. 1997. Influence of monensin on Holstein steers feed high concentrate diets containing soybean meal or urea. *Journal of Animal Science*. **75**: 2571-2579.
- Lebzien, P.; Rohr, K.; Breves, G. and Holler, H. 1986. Effect of monensin sodium (rumensin) on nitrogen conversion and net synthesis of thiamin in the forestomachs of ruminants. *Journal of Animal Physiology and Animal Nutrition*. **55**: 177-186.
- Lee, S.K.; Lee, B.D.; Jung, K.K. and Park, H.S. 1990. Effect of feeding monensin on the feed intake, nutrient utilisation and ruminal fermentation of Korean native goat. *Korean Journal of Animal Science*. **32**: 74-82.
- Lemenager, R.P.; Owens, F.N. and Robert, T. 1978. Monensin and extruded urea-grain for range beef cows. *Journal of Animal Science*. **47**: 262.
- Lemenager, R.P.; Owens, F.N.; Lusby, K.S. and Robert, T. 1978. Monensin forage intake and lactation of range beef cows. *Journal of Animal Science*. **47**: 247-254.
- Lemenager, R.P.; Owens, F.N.; Shockey, B.J.; Lusby, K.S. and Robert, T. 1978. Monensin effects on rumen turn over rate, twenty four hour VFA pattern, nitrogen components and cellulose disappearance. *Journal of Animal Science*. **47**: 255-261.

- Leng, R.A.; Steel, J.W. and Luick, J.R. 1967. Contribution of propionate to glucose synthesis in sheep. *Biochemical Journal*. **103**: 785.
- Lindsay, D.B. 1970. *Carbohydrate metabolism in the ruminant*. In A.T. Phillipson (Ed.) *Physiology of Digestion and Metabolism in the Ruminant*, Oriel Press, p. 438.
- Lober, U.; Geinitz, D.; Richter, G.; Flachowsky, G. and Hennig, A. 1986. Effect of the rumen fermoregulator 'monensin' on selected parameters of metabolism in fattening bulls. *Nutrition Abstract Review*. **56**: 6593.
- Males, J.R.; Hunt, C.W. and Lee, D.D. Jr. 1979. Monensin supplemented winter pasture for growing feeder calves. *Journal of Animal Science*. **48**: 1295.
- Malik, J.K.; Chand, N.; Singh, R.V.; Bahga, P.P. and Sud, S.C. 1974. Hematology of male buffalo calves. *Indian Veterinary Journal*. **51**: 95-96.
- McCarter, M.M.; Randel, R.D. and Carrell, L.H. 1979. Dietary alteration of ruminal fermentation on efficiency of growth and onset of puberty in Brangus heifers. *Journal of Animal Science*. **48**: 488-494.
- McClure, W.H.; Fontenot, J.P.; Webb, K.E. and Lucas, D.M. 1980. Feed lot performance of cattle fed different salinomycin levels. *Journal of Animal Science*. **5**(Suppl.1): 380.

- McMillan, W.H.; Oakley, A.P. and Hewitt, W. 1995. Effect of monensin capsule on blood metabolites in twin pregnant and single-pregnant beef cows. *Animal Production*. **55**: 265-267.
- Mooseley, W.M.; McCartar, M.M. and Raudel, R.D. 1977. Effects of monensin on growth and reproductive performance of beef heifers. *Journal of Animal Science*. **45**: 961-968.
- *Morais, C.A.C.; Fontes, C.A.A.; Lana, R.P.; Soares, J.E.; Queiroz, A.C. and Campos, J.M.S. 1993. Effect of monensin on gain and feed intake on feed conservation in castrated and entire cattle. *Revista-da-Sociedade-Brasileira-de-Zootecnia*. **22**: 64-71 (Abstr.).
- *Morounek, M.; Skrivanova, V. and Machanova, L. 1989. Effect of monensin on digestibility of nutrients, ruminal volatile fatty acids and blood parameters in young calves. *Landwirtschaftliche-Forschung*. **42**: 273-280 (N.A.R.).
- *Nowakowski, P. and Sokola, B. 1986. Growth performance and health of lambs fattened semi-intensively using monensin. *Biuletyn-Infarmacyjny-Przemyslu. Paszowego*. **25**(4): 35-38 (Abstr.).
- O'Kelly, J.C. and Spiers, W.G. 1988. Monensin induced metabolic changes in cattle fed a restricted intake of lucerne hay. *Journal of Agricultural Science*. **111**: 403-406.
- Oliver, W.M. 1975. Effect of monensin on gains of steers grazed on Coastal bermudagrass. *Journal of Animal Science*. **41**: 999.

- Pandey, M.D. and Roy, A. 1968. Studies on the effect of high environment temperature on the physiological response of buffalo serum protein content of buffalo cows exposed to summer conditions. *Agra University Journal of Research*. 17: 63-68.
- Patil, N.V. and Honmode, J. 1994. Growth and nutrient utilisation in lambs as influenced by dietary monensin. *Journal of Animal Science*. 11: 237-239.
- Patil, N.V.; Deshmukh, G.B.; Honmode, J.D.; Rekhate, D.H. and Takarkhede, R.C. 1996. Effect of monensin on growth rate of malpura lambs. *Livestock Advisor*. 21: 3-10.
- Patil, N.V.; Rekhate, D.H.; Deshmukh, G.B. and Takarkhede, R.C. 1996. Effect of monensin feeding on body measurements of malpura lambs. *Livestock Advisor*. 21: 24-27.
- Pendlum, L.C.; Boling, J.A. and Bradley, N.W. 1980. Nitrogen sources and monensin levels for growing steers fed corn silage. *Journal of Animal Science*. 50: 29.
- Perry, T.W.; Beeson, W.M. and Mohler, M.T. 1975. Effect of rumensin on beef cattle performance. 1975. Annu. Indian Cattle Feeders Day, Purdue Univ. p. 29-32.
- Perry, T.W.; Beeson, W.M. and Mohler, M.T. 1976. Effect of monensin on beef cattle performance. *Journal of Animal Science*. 42: 761-765.

- Pomar, C.; Bernier, J.F.; Seoane, J.R. and Latrille, L. 1989. High roughage rations with or without monensin for veal production. 2 Ration digestibility. *Canadian Journal of Animal Science*. **62**: 403-410.
- Pond, K.P. and Ellis, W.C. 1981. Effects of monensin on fecal output and voluntary intake of grazed coastal Bermudagrass, beef cattle. Research in Texas. Texas Agr. Exp. Sta. p. 31.
- Poos, M.I.; Hanson, T.L. and Klopfenstein, T.J. 1979. Monensin effects on diet digestibility, ruminal protein by pass and microbial protein synthesis. *Journal of Animal Science*. **48**: 1516-1524.
- Potter, E.L.; Cooley, C.O. and Richardson, L.F. 1979. Effect of narasin upon the performance of feed lot cattle. *Journal of Animal Science*. **49**(Suppl. 1): 397.
- Potter, E.L.; Cooley, C.O.; Raun, A.P.; Richardson, L.F. and Rathmacher, R.P. 1974. Effect of monensin on daily gain of cattle on pasture. Proc. Western Sec. *American Society of Animal Science*. **25**: 343.
- Potter, E.L.; Cooley, C.O.; Richardson, L.F.; Raun, A.P. and Rathmacher, R.P. 1976. Effect of monensin on performance of cattle fed forage. *Journal of Animal Science*. **43**: 665-669.
- Potter, E.L.; Muller, R.D.; Wray, M.I.; Carroll, L.H. and Meyer, R.M. 1986. Effect of monensin on the performance of cattle on pasture or fed

harvested forages in confinement. *Journal of Animal Science*. **62**: 583-592.

Potter, E.L.; Raun, A.P.; Colley, C.O.; Rathmachar, R.P. and Richardson, L.F. 1976. Effect of monensin on carcass characteristics carcass composition and efficiency of converting feed to carcass. *Journal of Animal Science*. **43**: 678-681.

Puri, J.P.; Kapoor, P.D.; Gupta, M. and Rao, A.R. 1994. Effect of feeding monensin on some rumen metabolites and blood glucose in buffaloes. *Journal of Animal Science*. **64**: 88-90.

Raghavan, G.V. and Mullick, D.N. 1962. Effect of air temperature and humidity on the blood composition of buffalo bulls. *Indian Journal of Dairy Science*. **15**: 61.

Ramanzin, M.; Bailoni, L.; Schiavon, S. and Bittante, G. 1997. Effect of monensin on milk production and efficiency of dairy cows fed two diets differing in forage to concentrate ratios. *Journal of Dairy Science*. **80**: 1136-1142.

Raun, A.P. 1975. New method of improving the efficiency of cattle on various types of rations Oklahoma Cattle Feeders Seminar. Oklahoma State Univ., Stillwater D-1 D-8.

Raun, A.P.; Cooley, C.O.; Potter, E.L.; Rathmacher, R.P. and Richardson, L.F. 1976. Effect of monensin on feed efficiency of feedlot cattle. *Journal of Animal Science*. **43**: 670-677.

- Raun, A.P.; Cooley, C.O.; Potter, E.L.; Richardson, L.F., Rathmacher, R.P. and Kennedy, R.W. 1974. Effect of monensin on feed efficiency of cattle. *Journal of Animal Science*. **39**: 259 (Abstr.).
- Raun, A.P.; Cooley, C.O.; Rathmacher, R.P. Richardson, L.F. and Potter, E.L. 1974. Effect of different levels of monensin on feed efficiency, ruminal and carcass characteristics of cattle. *Proc. Western Sec. Amer. Soc. Anim. Sci.* **25**: 346.
- Richardson, L.F.; Raun, A.P.; Potter, E.L.; Cooley, C.O. and Rathmacher, R.P. 1976. Effect of monensin on rumen fermentation *in vitro* and *in vivo*. *Journal of Animal Science*. **43**: 657-654.
- Ricke, S.C.; Berger, I.L.; Vander Aar, P.J. and Fahey, G.C. Jr. 1984. Effects of lasalocid and monensin on nutrient digestion, metabolism and rumen characteristics of sheep. *Journal of Animal Science*. **58**: 194-202.
- Ricke, S.C.; Berger, L.L.; Aar, P.J.V. and Fahey, G.C. Jr. 1984. Effects of lasalocid and monensin on nutrient digestion, metabolism and rumen characteristics of sheep. *Journal of Animal Science*. **58**: 194-202.
- Rogers, J.A. and Davis, C.L. 1982. Rumen volatile fatty acid production and nutrient utilisation in steers fed a diet supplemented with sodium carbonate and monensin. *Journal of Dairy Science*. **65**: 944-952.

- Rogers, J.A. and Davis, C.L. 1982. Rumen volatile fatty acid production and nutrient utilisation in steers fed a diet supplemented with sodium bicarbonate and monensin. *Journal of Dairy Science*. **65**: 944-952.
- Rook, J.A.F. and Line, C. 1961. The effect of the plane of energy nutrition of the cow on the secretion in milk of the constituents of the solid-not-fat fraction and on the concentrations of certain blood plasma constituents. *British Journal of Nutrition*. **15**: 109-119.
- Russell, B.; Theurer, M.B.; Swingle, R.S. and Hale, W.H. 1980. Effect of monensin on nitrogen utilisation and digestibility of concentrate diets by steers. *Journal of Animal Science*. **50**: 930-936.
- Satchidonandam, V. and Venkatayam, S. 1962. Blood sugar level in buffaloes. *Indian Veterinary Journal*. **39**: 544-548.
- *Schiemann, R.; Nehring, K.; Hoffman, L.; Jentsch, W. and Chuddy, A. 1971. Energetische Futter bewertung and Energinormen VEM Dentsch Lant Wirte Chaftsverlag, Berlin.
- Senedcar, W.G. and Cochran, G.W. 1989. *Statistical Methods*. Iowa University Press, Ames, Iowa.
- Shaw, J.C.; Ensor, W.C.; Tellechea, H.F. and Lee, S.D. 1960. Relation of diet to rumen volatile fatty acids, digestibility, efficiency of gain and degree of unsaturation of body fat in steers. *Journal of Nutrition*. **71**: 203.

- Shell, L.A.; Hale, W.H.; Brent, T. and Swingle, R.S. 1983. Effect of monensin on total volatile fatty acid production by steers fed a high grain diet. *Journal of Animal Science*. 57: 178-185.
- Sherrod, L.B.; Kellison, R.L. and Klett, R.H. 1975. Monensin levels in growing and finishing steer rations. Texas Tech Univ. Agr. Res. Series, AS: 75-4. p. 43.
- Simpson, M.E. 1978. Effects of certain antibiotics *in vitro* cellulose digestibility and volatile fatty acid production by ruminal microorganisms. *Journal of Animal Science*. 47(Suppl. 1): 429.
- Simpson, M.E.; Marsh, P.B. and Dinius, D.A. 1976. Effect of monensin and other antibiotics on *in vitro* digestion of cellulosic substrates in ruminal fluid from steers not previously exposed to antibiotics. Proc. North East Sec. ASAS.
- Smith, G.E. 1971. *Digestive Physiology and Nutrition of Ruminants*. Vol. 2, D.C. Church (Ed.), Oregon State University Book Store, Corvallis.
- Stephenson, K.A.; Lean, I.J. and O'Meara, T.J. 1996. The effect of monensin on the chemotactic function of bovine neutrophils. *Australian Veterinary Journal*, 74: 315-317.
- Stephenson, K.A.; Lean, I.J.; Hyde, M.L.; Curtis, M.A.; Garvin, J.K. and Lowe, L.B. 1997. Effect of monensin on the metabolism

of periparturient dairy cows. *Journal of Dairy Science*. **80**: 830-837.

Stephenson, K.A.; Lean, I.J.; Hyde, M.L.; Curtis, M.A.; Gorvin, J.K. and Lowe, L.B. 1997. Effects of monensin on the metabolism of periparturient dairy cows. *Journal of Dairy Science*. **80**: 830-837.

Stock, R.A.; Laudert, S.B.; Stroup, W.W.; Larson, E.M.; Parrot, J.C. and Britton, R.A. 1995. Effect of monensin, monensin and tylosin combination on feedintake variation of feed lot steers. *Journal of Animal Science*. **73**: 39-44.

Su, A.; Yan, S.; Su, A.K. and Yan, S.S. 1997. Effect of monensin and wax supplementating levels on the growth performance of hybrid goats. *Journal of Taiwan Livestock Research*. **30**: 151-159.

Su, A.K.; Yan, S.S. and Wu, S.C. 1993. Effect of monensin concentration in diets on growth performance and propionate concentration in rumen of cross bred kids. *Journal of Taiwan Livestock Research*. **26**: 297-306.

Sun, W.; Goetsch, A.L.; Forster, L.A.Jr.; Gallaway, D.L. Sr. and Johnson, Z.B. 1991. Feed intake and digestion by Holstein steer calves consuming bermudagrass or rye grass - wheat hay and supplemented with alfalfa, corn or monensin. *Animal Feed and Science Technology*. **34**: 241-254.

Thonney, M.L.; Heide, E.K.; Duhaime, D.J.; Hand, R.J. and Perosio, D.J.

1981. Growth, feed efficiency and metabolites concentrations of cattle fed high forage diets with lasalocid or monensin supplements. *Journal of Animal Science*. **52**: 427-433.
- Thornton, J.H. and Owens, F.N. 1981. Monensin supplementation and *in vivo* methane production by steers. *Journal of Animal Science*. **52**: 628-634.
- Tom, L.H. and Terry, K. 1979. Monensin, protein source and protein levels for growing steers. *Journal of Animal Science*. **48**: 474-479.
- Tsankova, M.; Stefanova, S.; Dimor, K. and Tosov, A. 1985. Effect of amount of protein in the diet on the productive quality and some haematological indices in buffalo dairy cows. *Nutrition AbstractReview*. **55**: 1961.
- Tsankova, M.; Stefanova, S.; Dimor, S.; Tosev, K. 1984. Effect of different amounts of energy in the diet on milk production of dairy buffalo. *Nutrition Abstract Review*. **54**: 5312.
- Utley, P.R.; Hellwig, R.E.; McCormick, W.C. and Butler, J.L. 1982. The effect of treating coastal bermudagrass pellets with sodium hydroxide and monensin on forage utilization and growth of beef calves. *Canadian Journal of Animal Science*. **62**: 499-505.
- Utley, P.R.; Newton, G.L.; Ritter, R.J. III and McCormick, W.C. 1976. Effects of feeding monensin in combination with zeranol and testosterone-estradiol implants for growing and finishing heifers. *Journal of Animal Science*. **42**: 754-760.

- Vagnoni, D.B.; Craig, W.M.; Gates, R.N.; Wyatt, W.E. and Southern, L.L. 1995. Monensin and ammoniation or urea supplementation of bermudagrass hay diets for steers. *Journal of Animal Science*. **73**: 1793-1802.
- Wahle, K.W.J. and Livesey, C.T. 1985. The effect of monensin supplementation of dried grass or barley diets on aspects of propionate metabolism, insulin secretion and lipogenesis in sheep. *Journal of Science of Food and Agriculture*. **36**: 1227-1236.
- Walker, P.M.; Weichenthal, B.A. and Cmarik, G.F. 1980. Efficacy of monensin for beef cows. *Journal of Animal Science*. **51**(3): 532-538.
- Wedegaertner, T.C. and Johnson, D.E. 1983. Monensin effects on digestibility, methanogenesis and heat increment of a cracked corn-silage diet fed to steers. *Journal of Animal Science*. **57**: 168-177.
- White Stone, H.D.; Davis, C.L. and Bryant, P. 1981. Effect of monensin on breakdown of protein by ruminal microorganisms *in vitro*. *Journal of Animal Science*. **53**: 803-809.
- Wilson, L.L.; Hatfield, E.E. and Hixon, D.L. 1975. The effectiveness of different levels of monensin on the feedlot performance of finishing steers. Illinois Beef Cattle Day Bull. AS-669.
- Wolin, M.J. 1960. A theoretical rumen fermentation. *Journal of Dairy Science*. **43**: 1452.
- Wyatt, W.E.; Craig, W.M.; Gates, R.N.; Hembry, F.G. and Thompson, D.L.Jr. 1989. Effects of ammoniated bermudagrass hay and monensin

supplementation on heifer post weaning growth. *Journal of Animal Science*. 67: 1698-1706.

*Yalcin, S.; Kucukersan, K. and Kucukersan, S. 1995. The effect of monensin added to the diet of fattening lambs on some blood and rumen fluid metabolites. *Turk-Veterinerlik-ve-Hayvancilik-Dergisi*. 19: 297-302 (Abstr.).

Zinn, R.A. and Borques, J.L. 1993. Influence of sodium bicarbonate and monensin on utilisation of a fat supplemented, high energy growing finishing diet by feed lot steers. *Journal of Animal Science*. 71: 18-25.

Zinn, R.A.; Plascencia, A. and Barajas, R. 1994. Interaction of forage level and monensin in diets for fed lot cattle on growth performance and digestion function. *Journal of Animal Science*. 72: 2209-2215.

Zorilla, R.J.; Garja, F.J.D. and Owens, F.N. 1991. Effect of daily rotation of ionophores on ruminal fermentation in cattle fed concentrate diets. Anim. Res. Report Agric. Exp. Sta. Oklahoma State Univ. MP-134 250-255 (Abstr.).

*Original not seen.

Appendix – I

Procedure for estimation of plasma glucose

Principle : Glucose is converted by glucose oxidase (GOD) into gluconic acid and hydrogen peroxide which in the presence (POD) oxidizes the chromogen (4-aminoantipyrine/phenol) to a proportional to the concentration of glucose in the sample and is measured at 510 nm.

Reagents:

1. Buffer/enzymes GOD, POD/chromogen/phenol
2. Glucose standard (100 mg/dl)

Preparation of solution

Allow the vial to attain room temperature. Dissolve the contents of vial using deionised water free from contaminants. Make up the volume upto 200 ml or 500 ml depending upon the pack size and transfer into a clean and dry amber coloured bottle.

Assay procedure

Pipette into tubes marked	Blank	Standard	Test
Working reagent	1000 ul	1000 ul	1000 ul
Distilled water	10 ul	-	-
Standard	-	10 ul	-
Sample	-	-	10 ul

Mix well and incubate for 15 minutes at 37°C. Switch on the instrument, thermostat for 5 minutes. Allow sipping from each tube, turn by turn. Instrument provides value of glucose (mg/dl) concentration in each sample as follows:

$$\text{Glucose mg/dl} = \frac{\text{Absorbance of sample}}{\text{Absorbance of standard}} \times \text{Concentration of standard (mg/dl)}$$

Appendix – II

Procedure for estimation of plasma total protein

Principle : The peptide bonds of protein react with copper II ions in alkaline solution to form a blue violet complex (so called biuret reaction). Each copper ion complexing with 5 or 6 peptide bonds. Tartarate is added as a stabiliser, while iodide is used to prevent auto-reaction of alkaline copper complex. The colour formed is proportional to the protein concentration and is measured at 546 nm.

Reagents

- A. Copper II sulphate/potassium sodium tartarate/potassium/iodide/sodium hydroxide
- B. Total proteins standard (6.0 g/dl)

Reagent preparation : ready for use

Assay procedure

Pipette into tubes marked	Blank	Standard	Sample
Working reagent	1000 ul	1000 ul	1000 ul
Distilled water	20 ul	-	-
Standard	-	20 ul	-
Sample	-	-	20 ul

Incubate for 10 minutes at 37°C. Switch on the instrument, thermostat for 5 minutes. Allow sipping from each tube, turn by turn. Instrument provides value of total protein (g/dl). Concentration in each sample as

$$\text{Total protein (g/dl)} = \frac{\text{Absorbance of sample}}{\text{Absorbance of standard}} \times \text{concentration of standard (g/dl)}$$

Appendix – III

Procedure for estimation of blood urea

Principle : Urea is converted by urease to ammonia which in presence of glutamate dehydrogenase (GLDH) combines with α -ketoglutarate (α -Kg).

Reagents

1. 2-oxoglutarate.NADH/Urease/GLDH/ADP/Triss Buffer
2. Urea standard (50mg/dl)

Reagent preparation :

Allow the reagent and Aqua-4 (supplied in Kit) to attain room temperature. Add the amount of aqua-4 indicated on the label to dissolve the contents of each bottle of substrate and mix gently. Don't shake vigorously.

Assay procedure

Pipette into tubes marked	Blank	Standard	Sample
Working reagent	1000 μ l	1000 μ l	1000 μ l
Standard	-	20 μ l	-
Sample	-	-	20 μ l

Mix well each tube contents and test immediately with the help of instrument. Determine absorbance changes (ΔA) for the standard and unknown samples by using formula :

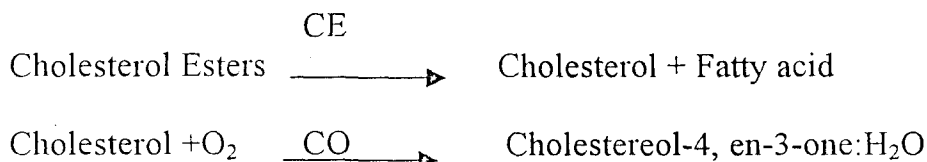
$\Delta A = A_1 - A_2$ (Where A_1 and A_2 are two absorbance readings respectively from one sample by two sippings).

$$\text{Urea conc. (g/dl)} = \frac{\Delta A \text{ of sample}}{\Delta A \text{ of standard}} \times \text{concentration of standard (mg/dl)}$$

Appendix – IV

Procedure for estimation of cholesterol

Principle : The absorbance of chromophare (aminoeimine) is directly proportional to the cholsterol concentration in the sample. The absorbance is measured at 510 nm.



CE : Cholesterol esterase

CO : Cholesterol oxidase

Reagents

1. Buffer/enzymes/chromogen
2. Cholesterol standard 200 mg/dl

Reagent preparation:

Allow the reagent bottle and the aqua-4 (supplied in the kit) to attain room temperature. Add the amount of aqua-4 indicated on the label to contents of each vial. Swirl to dissolve, don't shake vigorously.

Assay procedure

Pipette into tubes marked	Blank	Standard	Sample
Working reagent	1000 μ l	1000 μ l	1000 μ l
Distilled water	20 μ l	-	-
Standard	-	20 μ l	-
Sample	-	-	20 μ l

Mix well. Incubate at 37°C for 10 minutes. Switch on the instrument, thermostat for five minutes, first aspirate blank solution then standard followed by sample solutions from each tubes respectively. Readings for concentration of cholesterol

in sample (mg/dl) are noted automatically on paper by instrument and formula used is :

$$\text{Cholesterol (mg/dl)} = \frac{\text{Absorbance of sample}}{\text{Absorbance of standard}} \times \text{concentration of standard (mg/dl)}$$

