

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

**EFFECTS OF MONENSIN DELIVERED BY A SLOW RELEASE  
DEVICE ON ASPECTS OF PERFORMANCE IN DAIRY HEIFERS**

**A THESIS PRESENTED IN PARTIAL FULFILMENT  
OF THE REQUIREMENTS FOR THE DEGREE  
OF MASTER OF PHILOSOPHY IN VETERINARY  
CLINICAL SCIENCES AT MASSEY UNIVERSITY**

**GERARDO AUGUSTO ARIAS NAVARRO**

**1993**

## Abstract

Two series of trials (from August 1991 to February 1992 and from April to July 1992) were conducted to evaluate the effect of monensin on the growth, reproductive performance and *Eimeria* oocyst counts of dairy heifers in New Zealand. Two hundred heifers were divided according to their weight into two groups at the beginning of the trials. Heifers with similar weights were assigned randomly to either of two treatments: with or without monensin boluses that delivered 200 mg of monensin per day. Monensin had no effect on weight gains in both parts of the trial. A significant increase in height was observed during the second part of the trial. Monensin significantly decreased ( $p < 0.05$ ) the oocyst counts in both parts of the trial and plasma progesterone levels 100 days after the first administration of boluses. Although conception rates and age of heifers at calving were not affected by monensin, the weight of calves was significantly increased by the ionophore. These results indicate that monensin can influence reproductive performance of heifers without affecting their body weight. In addition, its properties as a coccidiostat were confirmed.

## Acknowledgements

I would like to thank my supervisor, Professor Norm Williamson for his guidance, patience and help during the whole length of my research. I would also like to thank my co-supervisors, Professor Tony Charleston and Dr. Gavin Wilson for their suggestions.

I would like to thank the New Zealand Government for their financial support through the ODA scholarship fund.

I would like to thank ELANCO New Zealand for their interest and support for this project.

My acknowledgement to Dr. Hugo Varela Alvarez for the statistical guidance he offered me in the analysis of my work.

Special thanks to Jenny Edwards at the Computing Services Building for her help and suggestions to improve this work.

Special thanks to Dr. Max Merrall and his students for his assistance during the sampling period.

To all the farmers that participated in this study, I am very grateful for their cooperation and assistance in making this research possible.

To the technicians at the Veterinary Parasitology laboratory, Shirley Calder and Barbara Adlington for their assistance in the analysis of faecal samples.

To Jane Candy, technician at the RIA laboratory, Department of Physiology and Anatomy for her guidance in the progesterone analysis.

I wish to express my appreciation and sincere gratitude to the people who helped me during the sample collection periods. Special acknowledgement to Chindarat Sincharoenkul, Edith Fernández Baca, Susan R. Lamb, Lois Broadbent, Clare Doyle, Armindo Maia, Leo Lerios and Waiss Samim.

I would like to thank and dedicate this thesis to my family and friends in Colombia. Their communications encouraged me to keep going.

Finalmente, quiero agradecerle a Dios por la energía y disciplina que siempre me ha brindado y su ayuda extra para completar este trabajo.

**Table of Contents**

<b>Chapter</b>	<b>Description</b>	<b>Page No.</b>
	<b>Abstract</b>	<b>i</b>
	<b>Acknowledgements</b>	<b>ii</b>
	<b>Table of Contents</b>	<b>iv</b>
<b>I</b>	<b>Effect of Monensin in Dairy Heifers</b>	<b>1</b>
1.1	Introduction	1
1.2	Discovery of Ionophores	2
1.3	Mechanism of Ion Complexation of Ionophores	4
1.3.1	Evaluation of the Transport Selectivity of the Carboxylic Ionophores	7
1.3.2	Conformational Changes During Ion Capture and Membrane Transport in Ionophores	9
1.4	Biosynthesis of Monensin	10
1.5	Biological Applications of Ionophores	14
1.5.1	Use of Carboxylic Ionophores as Food Additives	15

	v
1.6.1 Energy Transactions in Ruminants	15
1.6.2 Effect of Monensin on Ruminal End Products	18
1.6.3 Effect of Ionophores on Rumen Protozoa	23
1.7 Effect of Ionophores on Energy Metabolism	24
1.8 Effect of Ionophores on Nitrogen Metabolism and Mineral Absorption	29
1.9 Effect of Monensin on Coccidia	32
<b>II Effect of Monensin on Weight Gain and in Height Increase of Heifers</b>	<b>34</b>
2.1. Introduction	34
2.1.1 Influence of the Type of Diet on the Effect of Monensin	34
2.1.2 Monensin and Feed Intake	35
2.1.3 Monensin and Feed Efficiency	36
2.1.4 Monensin and Digestibility	37
2.1.5 Monensin Ruminal Delivery Device	37
2.1.6 Monensin in Heifers	39
2.2. Materials and Methods	40

	vi
2.2.1 The Rumensin ABC	40
2.2.2 Administration of the Rumensin ABC	41
2.2.3 The Study Population	43
2.2.4 Weighing Procedure	48
2.2.5 Measurement of Height	48
2.2.6 Statistical Procedure	51
2.3 Results	51
2.4. Discussion	60
2.5. Conclusion	62
<b>III Effects of Monensin on <i>Eimeria</i> spp. (Apicomplexa: Eimeriidae) of Heifers</b>	<b>63</b>
3.1 Introduction	63
3.1.1 Life Cycle of <i>Eimeria</i> species	64
3.1.2 Coccidia of Cattle	65
3.1.3 Epidemiology of <i>Eimeria</i> Infection	66
3.1.4 Factors Affecting the Number of Oocysts Produced by an Infected Animal	67

		vii
3.1.4.1	Immunity and Resistance	67
3.1.4.2	The Crowding Factor	68
3.1.4.3	Nutrition	68
3.1.4.4	Stress	68
3.1.4.5	Cocciostats	69
3.1.5	Conditions Affecting Sporulation and Survival of Oocysts	69
3.1.6	Physical and Biological Dispersal of Oocysts	70
3.1.7	Pathogenesis of Coccidial Infections	71
3.1.8	Main Features of the Disease Caused by <i>Eimeria zuernii</i> and <i>Eimeria bovis</i>	72
3.1.9	Control of Coccidiosis in Cattle with Monensin	74
3.2	Experimental Procedure	75
3.2.1	Examination of Samples for Coccidia	76
3.2.1.1	Oocyst Counting	76
3.2.1.2	Separation of Oocysts for Sporulation	76
3.2.1.3	Identification of Species	78

	viii
3.2.2 Data Analysis	83
3.3 Results	83
3.3.1 Oocyst Counts	83
3.3.2 Classification of Species	84
3.4 Discussion	94
3.5 Conclusion	95
<b>IV. Effect of Monensin on Reproductive Performance of Heifers</b>	<b>97</b>
4.1 Introduction	97
4.1.1 Physiology of the Oestrous Cycle	98
4.1.2 Effect of Monensin on Puberty of Heifers	102
4.1.3 Effect of Monensin on In Calf Rate and Weight of Calves Born	103
4.2 Materials and Methods	106
4.2.1 Blood Sampling for Progesterone Assay	107
4.2.2 Collection of Data for Conception Rate, Weight of Calves at Birth and Age at Calving	108
4.3 Results and Discussion	109

		ix
4.4	Conclusion	116
<b>V.</b>	<b>General Discussion and Conclusions</b>	117
	<b>References</b>	120
<b>VI.</b>	<b>Appendices</b>	141
<b>VI.1</b>	<b>Appendix I Statistical Model</b>	141
<b>VI.2</b>	<b>Appendix II Commands for the SAS<sup>TM</sup> programme</b>	142
VI.2.1	Analysis of Weight and Height	142
VI.2.2	Analysis of Oocyst Counts	143
VI.2.3	Analysis of Progesterone Levels	144

**List of Tables****Page No.**

1.	Cation Transport Selectivities in Biological Test Systems	9
2.	Requirements for Monensin Synthesis by a Fermentation Process	11
3.	Results of a Column Chromatogram for Monensin and Closely Related Compounds Produced During the Fermentation	12
4.	Properties of Monensin and Closely Related Compounds Produced During Fermentation	13
5.	Biological Effects of Monensin in the Rumen	16
6.	Effect of Monensin on Ruminal Volatile Fatty Acid Production (mM/ml)	19
7.	Methane Production in Steers Fed Monensin at Three Levels of Roughage	20
8.	Energy Subdivision When Fed Monensin and Three Roughage Levels	24
9.	Apparent Digestibility of Energy in Ruminants Fed Monensin or Lasalocid (% Digestibility)	25
10.	Effect of Monensin on Rumen Turnover Rate and Rumen Fill	26
11.	Intake, Rumen Turnover and Rumen Volume of Steers Fed Harvested Dry Winter Range Grass	27
12.	Performance of Steers Fed Salinomycin or Lasalocid	28

13.	Apparent Digestibility (%) of Nitrogen in Ruminants Fed Monensin or Lasalocid	29
14.	Effect of Monensin on the Extent of Escape (%) from Ruminal Degradation of Various Protein Sources	31
15.	Effect of Lasalocid and Monensin on Apparent Absorption of Magnesium and Phosphorus in Cattle	32
16.	Performance of Growing Friesian Heifers Fed Monensin for 448 Days	36
17.	Influence of Intraruminal Monensin Administration and Oestradiol 17 $\beta$ Implants on the Average Daily Gain (lb/d) of Steers Grazing Early - Summer Bluestem Range at Three Stocking Rates (steer/acres)	38
18.	Distribution of Animals over the 6 Farms that Participated in the Current Trial	45
19.	Changes in the Number of Animals per Farm at the Beginning of the Second Part of the Trial	46
20.	Mean (SE) of the Effect of Monensin on Weight and Height During the First Part of the Experiment (August 1991 to February 1992)	52
21.	Mean (SE) of the Effect of Monensin on Weight and Height During the Second Part of the Experiment (April - July 1992)	53
22.	Mean (SE) of the Effect of Monensin on Weight Gain and Increment in Height between Initial (August 1991) and Final Measurements (July 1992)	54

23.	Morphological Characteristics of Sporulated Oocysts of <i>E. alabamensis</i> , <i>E. auburnensis</i> and <i>E. bovis</i>	79
24.	Morphological Characteristics of Sporulated Oocysts of <i>E. brasiliensis</i> , <i>E. bukidnonensis</i> and <i>E. canadensis</i>	80
25.	Morphological Characteristics of Sporulated Oocysts of <i>E. cylindrica</i> , <i>E. ellipsoidalis</i> and <i>E. pellita</i>	81
26.	Morphological Characteristics of Sporulated Oocysts of <i>E. subspherica</i> , <i>E. wyomingensis</i> and <i>E. zuernii</i>	82
27.	Mean (SE) of Oocyst Counts (OPG) in the First Part of the Experiment	85
28.	Mean (SE) of Oocyst Counts in the Second Part of the Experiment	86
29.	Predominance of Coccidia Species in Heifer Faecal Samples for All Farms	87
30.	Serum Concentration of Hormones in Prepuberal and Puberal Heifers	101
31.	Average Reproductive Traits in Heavy and Light Heifers Fed 200 mg Monensin per Day	103
32.	Cow Reproductive Performance and Monensin Administration	104
33.	Effect of Monensin on Reproductive Performance of Heifers and Calf Weight at Birth	105
34.	Effect of Monensin (200 mg/head/day) on Calf Weight (kg)	105

35. Mean (SE) Levels of Progesterone (ng/ml) in Untreated and Treated Heifers at Three Different Samplings 111
36. Mean (SE) of the Effect of Monensin on Conception Rate, Days between Birth and Calving and Weight of Calf in Dairy Heifers 112

**List of Figures****Page No.**

1.	Ionophore Transport Modes	5
2.	Schematic Representation of the 1:1 Ag <sup>+</sup> /Monensin complex	7
3.	Structure of Monensin	12
4.	Conversion of Carbohydrates to Pyruvate in the Rumen	17
5.	Conversion of Pyruvate to Volatile Fatty Acids in the Rumen	18
6.	A schematic Representation of the Hypothesized Mechanism by which Monensin and Lasalocid Alter Rumen Fermentation by Altering the Microbial Community	23
7.	Rumensin ABC and Administration	42
8.	Administration of the Rumensin ABC	44
9.	Location of the Six Different Farms Used in this Experiment	47
10.	Scales Used for the Measurement of Weight	49
11.	Measurement of Height	50
12.	Effect of Monensin on Heifers' Weight Gains. Part 1 of the Trial. Days 0 and 45 after administration	55
13.	Effect of Monensin on Height Increment. Part 1 of the Trial. Days 100 and 200 after administration	56

	xv
14. Effect of Monensin on Heifers' Weight Gain. Part 2 of the Trial	57
15. Effect of Monensin on Height. Part 2 of the Trial	58
16. Overall Effect of Monensin on Weight and Height Measurements from the First and Second Part of the Trial	59
17. Eimeria Life Cycle	65
18. Effect of Monensin on Oocyst Counts. Part 1 of the Trial. Days 0 and 45 after administration	88
19. Effect of Monensin on Oocyst Counts. Part 1 of the Trial. Days 100 and 200 after administration	89
20. Effect of Monensin on Oocyst Counts. Part 2 of the Trial	90
21. Predominance of Coccidial Species in Faecal Samples	91
22. Photomicrograph of Sporulated Bovine <i>Eimeria</i> Oocysts	92
23. Photomicrograph of Sporulated Bovine <i>Eimeria</i> Oocysts	93
24. Effect of Monensin on Some Reproductive Parameters	113