

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.

STUDIES
ON THE ABSORPTION OF VOLATILE FATTY ACIDS
IN CALVES

A thesis presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Nutrition at Massey University of Manawatu.

RAMSAY HANNA KHOURI

1966

ACKNOWLEDGEMENTS

I would like to express my thanks and appreciation to:-

Professor D.S. Flux for his guidance and encouragement, and for the statistical analysis of the experimental data;

Professor D.A. Titchen for his advice and enlightening discussions;

Dr. G.W. Butler of the Plant Chemistry Division, D.S.I.R., for assistance in the radio-isotope analyses;

Dr. C.S.W. Reid of the Plant Chemistry Division, D.S.I.R., for his many helpful suggestions;

Mr. I.P.M. McQueen and the farm staff for their cooperation in the management of the experimental animals;

Mr. G.H. Burns for the reproduction of the tables and figures;

Miss M.G. Campbell and the library staff for their helpful cooperation;

Mr. B. Barnett, Miss I. Coxhead, Mr. D. Dellow and Mr. M. Wilson for their technical help;

My wife, Soumaya, for her moral support and patience during the course of this study, and for her diligence in typing this Thesis.

TABLE OF CONTENTS

Chapter	Page
<u>INTRODUCTION</u>	1
The Rumen in Adult Bovines	2
The Rumen in Calves at Birth	4
Volatile Fatty Acid Absorption Studies in Calves Based on the Analysis of Rumen Contents	5
Volatile Fatty Acid Absorption Studies in Calves Based on the Analysis of Blood	6
SECTION I	
VOLATILE FATTY ACID ABSORPTION STUDIES IN CONSCIOUS CALVES	
I. <u>POST-PRANDIAL CHANGES IN THE VOLATILE FATTY ACID AND GLUCOSE CONCENTRATIONS OF PORTAL BLOOD IN CONSCIOUS CALVES</u>	12
REVIEW OF LITERATURE	13
Volatile Fatty Acid Absorption Studies in Mature Conscious Ruminants Based on the Analysis of Portal Blood	13
Volatile Fatty Acid Absorption Studies in Young Conscious Calves Based on the Analysis of Portal Blood	15
MATERIALS AND METHODS	15
Experimental Design	15
Surgical Methods	18
- Anaesthesia	18
- Surgical procedure for the fistulation of the rumen	18
- Surgical procedure for the catheterization of the portal vein	19
- Post-operative medication	19
- Care of portal vein catheters	19
- Introduction of catheters into the jugular vein	20
Chemical Methods	20
- Blood volatile fatty acids	21
- Blood glucose	23
- Rumen liquor volatile fatty acids	24

Chapter	Page
I. RESULTS	26
Changes in the Volatile Fatty Acid Concentration and pH of Rumen Liquor Following Milk Feeding and Following Grazing	26
Changes in the Volatile Fatty Acid and Glucose Concentrations of Portal Blood Following Milk Feeding and Following Grazing	34
Differences in the Glucose and Volatile Fatty Acid Concentrations of Portal and Jugular Blood Following Milk Feeding and Following Grazing	39
DISCUSSION	40
Changes in the Volatile Fatty Acid Concentration and pH of Rumen Liquor Following Milk Feeding and Following Grazing	41
Changes in the Volatile Fatty Acid and Glucose Concentrations of Portal Blood Following Milk Feeding and Following Grazing	44
Differences in the Glucose and Volatile Fatty Acid Concentrations of Portal and Jugular Blood Following Milk Feeding and Following Grazing	47
SUMMARY	48
II. <u>GLUCOSE: A SOURCE OF STEAM VOLATILE FATTY ACIDS IN THE BLOOD OF CALVES</u>	50
REVIEW OF LITERATURE	51
EXPERIMENTAL	52
<u>Experiment I.</u> A Hyperglycaemia Induced by the Feeding of Skim Milk Supplemented with Lactose	52
Materials and Methods	52
Results	54
- Changes in the volatile fatty acid concentration and pH of rumen liquor following the feeding of whole milk and following the feeding of skim milk supplemented with lactose	54
- Changes in the glucose and volatile fatty acid concentrations of portal blood following the feeding of whole milk and following the feeding of skim milk supplemented with lactose	56
<u>Experiment II.</u> A Hyperglycaemia Induced by the Intravenous Injection of Glucose	57
Materials and Methods	57
Results	61
- Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of 50 % (w/v) D-glucose and following the intravenous injection of 0.9 % NaCl	61

Chapter	Page
II. <u>Experiment III. A Hyperglycaemia Induced by the Intravenous Injection of Adrenaline</u>	62
Materials and Methods	62
Results	66
- Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of adrenaline and following the intravenous injection of 0.9 % NaCl	66
DISCUSSION	67
<u>Experiment I. A Hyperglycaemia Induced by the Feeding of Skim Milk Supplemented with Lactose</u>	67
<u>Experiment II. A Hyperglycaemia Induced by the Intravenous Injection of Glucose</u>	69
<u>Experiment III. A Hyperglycaemia Induced by the Intravenous Injection of Adrenaline</u>	69
General	71
SUMMARY	73
III. <u>STUDIES ON THE ABSORPTION AND METABOLISM OF PREFORMED VOLATILE FATTY ACIDS IN CONSCIOUS CALVES BY THE ANALYSIS OF JUGULAR BLOOD</u>	75
REVIEW OF LITERATURE	77
Absorption of Preformed Volatile Fatty Acids from the Rumen of Conscious Calves Studied by the Analysis of Jugular Blood	77
Metabolism of Preformed Volatile Fatty Acids in Consoious Calves Studied by the Analysis of Jugular Blood	77
EXPERIMENTAL	80
Experimental Animals	80
Fistulation of the Rumen	83
Catheterization of the Jugular Vein	83
<u>Experiment IV. Absorption of Preformed Volatile Fatty Acids from the Rumen of Conscious Calves Studied by the Analysis of Jugular Blood</u>	84
<u>Experiment V. Metabolism of Preformed Volatile Fatty Acids in Conscious Calves Studied by the Analysis of Jugular Blood</u>	86
RESULTS	87
Fasting Levels of Volatile Fatty Acids in Jugular Blood	87

Chapter	Page
III. <u>Experiment IV.</u> Absorption of Preformed Volatile Fatty Acids from the Rumen of Conscious Calves Studied by the Analysis of Jugular Blood	91
- Changes in the volatile fatty acid concentration of rumen contents following the introduction of preformed salts of these acids into the rumen	91
- Changes in the volatile fatty acid concentration of jugular blood following the introduction of preformed salts of these acids into the rumen	91
<u>Experiment V.</u> Metabolism of Preformed Volatile Fatty Acids in Conscious Calves Studied by the Analysis of Jugular Blood	95
- Changes in the volatile fatty acid concentration of jugular blood following the injection of preformed salts of these acids into the jugular vein	95
Health and Growth Rate of the Calves	95
DISCUSSION	97
Fasting Levels of Volatile Fatty Acids in Jugular Blood	97
<u>Experiment IV.</u> Absorption of Preformed Volatile Fatty Acids from the Rumen of Conscious Calves Studied by the Analysis of Jugular Blood	98
<u>Experiment V.</u> Metabolism of Preformed Volatile Fatty Acids in Conscious Calves Studied by the Analysis of Jugular Blood	100
Health and Growth Rate of the Calves	101
SUMMARY	103

SECTION II

VOLATILE FATTY ACID ABSORPTION STUDIES

IN ANAESTHETIZED CALVES

IV. <u>CHANGES IN THE VENO-ARTERIAL VOLATILE FATTY ACID CONCENTRATION DIFFERENCE OF RUMINAL BLOOD FOLLOWING THE INTRODUCTION OF PREFORMED VOLATILE FATTY ACIDS INTO THE RUMEN OF ANAESTHETIZED CALVES</u>	105
REVIEW OF LITERATURE	106
Volatile Fatty Acid Absorption Studies in Mature Anaesthetized Ruminants	106
Volatile Fatty Acid Absorption Studies in Young Anaesthetized Ruminants	109

Chapter	Page
IV. MATERIALS AND METHODS	109
Experimental Animals	109
Experimental Design	109
Surgical Preparation of the Calves	112
Experimental Procedure	114
Preparation of the Buffered Volatile Fatty Acid Solution	117
Chemical Methods	118
RESULTS	126
Absorption of Volatile Fatty Acids from the Rumen	126
Blood Flow Through the Right Ruminial Vein Catheter	129
pH of Rumen Contents	131
Rumen Capacity	133
Growth Rate of the Calves	133
DISCUSSION	133
Absorption of Volatile Fatty Acids from the Rumen	134
Blood Flow Through the Right Ruminial Vein Catheter	136
pH of Rumen Contents	137
Rumen Capacity	138
Growth Rate of the Calves	139
SUMMARY	140
V. <u>THE APPEARANCE OF ACETATE-1-C¹⁴ IN RUMEN EFFLUENT AND CAROTID BLOOD FOLLOWING THE INTRODUCTION OF PREFORMED VOLATILE FATTY ACIDS INTO THE RUMEN OF ANAESTHETIZED CALVES</u>	141
REVIEW OF LITERATURE	141
MATERIALS AND METHODS	142
Experimental Animals	142
Experimental Design	142
Experimental Procedure	142
RESULTS	145
DISCUSSION	147
SUMMARY	148
<u>CONCLUSION</u>	149
<u>REFERENCES</u>	150
<u>APPENDIX</u>	160

LIST OF TABLES

Chapter

I. POST-PRANDIAL CHANGES IN THE VOLATILE FATTY ACID AND GLUCOSE CONCENTRATIONS OF PORTAL BLOOD IN CONSCIOUS CALVES

Table	Page
1 Rearing and surgical details of calves used in milk and pasture feeding absorption experiments	16
2 The age, weight, duration of fasting, quantity of milk consumed and time spent on pasture in milk and pasture feeding absorption experiments	17
3 Blood volatile fatty acid determination repeatability experiment. Results of eight volatile fatty acid analyses on the same sample of bovine blood	22
4 Blood volatile fatty acid determination addition experiment. Results of eight volatile fatty acid analyses on bovine blood to which known quantities of acetic acid were added	22
5 Blood glucose determination repeatability experiment. Results of ten glucose analyses on the same sample of bovine blood	23
6 Blood glucose determination addition experiment. Results of five glucose analyses on bovine blood to which known quantities of glucose were added	23
7 Rumens liquor volatile fatty acid determination repeatability experiment. Results of ten volatile fatty acid analyses on the same sample of bovine rumens liquor	24
8 Rumens liquor volatile fatty acid determination addition experiment. Results of ten volatile fatty acid analyses on bovine rumens liquor to which known quantities of volatile fatty acids were added	24
9 Changes in the volatile fatty acid concentration and pH of rumens liquor following milk feeding	27
10 Changes in the volatile fatty acid concentration and pH of rumens liquor following grazing	27
11 Changes in volatile fatty acid and glucose concentrations of portal blood following milk feeding	31
12 Changes in volatile fatty acid and glucose concentrations of portal blood following grazing	31

Chapter	Table	Page
I.	13 Differences in glucose concentration of portal and jugular blood following milk feeding	35
	14 Differences in glucose concentration of portal and jugular blood following grazing	35
	15 Differences in the volatile fatty acid concentration of portal and jugular blood following milk feeding	36
	16 Differences in the volatile fatty acid concentration of portal and jugular blood following grazing	36
II.	<u>GLUCOSE: A SOURCE OF STEAM VOLATILE FATTY ACIDS IN THE BLOOD OF CALVES</u>	
	Table	
	17 Changes in the volatile fatty acid concentration and pH of rumen liquor following the feeding of whole milk and following the feeding of skim milk supplemented with lactose	54
	18 Changes in the glucose and volatile fatty acid concentrations of portal blood following the feeding of whole milk and following the feeding of skim milk supplemented with lactose	56
	19 Details concerning the breed, age, weight and age at weaning of the calves that were used in the intravenous glucose infusion experiments	58
	20 Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of 50 % (w/v) D-glucose and following the intravenous injection of 0.9 % NaCl	58
	21 Details concerning the breed, age, sex and weight of the calves used in the adrenaline experiment	62
	22 Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of adrenaline	63
	23 Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of 0.9 % NaCl	63
III.	<u>STUDIES ON THE ABSORPTION AND METABOLISM OF PREFORMED VOLATILE FATTY ACIDS IN CONSCIOUS CALVES BY THE ANALYSIS OF JUGULAR BLOOD</u>	
	Table	
	24 Trace mineralized salt mixture, Feed Trade Manual Edition No.6, 1957, published by National Miller Publication Inc., 6E McDonald Rd., Prospect Heights, Ill.	81

Chapter	Table	Page
III.	25 Details concerning the growth rates of the calves together with the haemoglobin concentrations and the packed cell volume of their blood	82
	26 The chemical composition of 5 lit of the volatile fatty acid solution introduced into the rumen	85
	27 The composition of 1 lit of the volatile fatty acid solution used in the volatile fatty acid tolerance tests	87
	28 The volatile fatty acid concentration of jugular blood following 24 hours of fasting off milk and 48 hours off pasture	87
	29 Changes in the volatile fatty acid concentrations of jugular blood and rumen liquor following the introduction of a buffered test solution of volatile fatty acids into the rumen, together with the amount of 5 N phosphoric acid required to maintain the pH of the rumen between 6.00 and 6.20	88
	30 Changes in the volatile fatty acid concentration of jugular blood following the injection of a 4 M solution containing 85 % acetic and 15 % propionic acid into the jugular vein	92

IV. CHANGES IN THE VENO-ARTERIAL VOLATILE FATTY ACID CONCENTRATION DIFFERENCE OF RUMINAL BLOOD FOLLOWING THE INTRODUCTION OF PREFORMED VOLATILE FATTY ACIDS INTO THE RUMEN OF ANAESTHETIZED CALVES

Table

31	The ages, birth weights and weight gains of the calves used in the acute experiments	108
32	Time course of the sampling schedule followed during the acute volatile fatty acid absorption experiments	117
33	Composition of 25 lit of volatile fatty acid rumen infusion	118
34	Volatile fatty acid concentration of blood collected simultaneously from the right ruminal vein and carotid artery	120
35	Volatile fatty acid concentration of arterial carotid blood for different groups in different periods. Samples taken 15 minutes after the introduction of test solutions into the rumen	121
36	Volatile fatty acid concentration of arterial carotid blood for different groups in different periods. Samples taken 30 minutes after the introduction of test solutions into the rumen	122

Chapter	Table	Page	
IV.	37	Veno-arterial volatile fatty acid concentration differences of blood collected simultaneously from the ruminal vein and carotid artery	123
	38	Veno-arterial volatile fatty acid concentration differences for different groups in different periods. Samples taken 15 minutes after the introduction of test solutions into the rumen	124
	39	Veno-arterial volatile fatty acid concentration differences for different groups in different periods. Samples taken 30 minutes after the introduction of test solutions into the rumen	125
	40	Blood flow rates through the right ruminal vein catheter during acute volatile fatty acid absorption experiments	127
	41	Mean blood flow rates through the right ruminal vein catheter	128
	42	Changes in the pH of rumen contents during the acute volatile fatty acid absorption experiments	130
	43	Rumen capacity of experimental calves	132

V. THE APPEARANCE OF ACETATE-1-C¹⁴ IN RUMEN EFFLUENT AND CAROTID BLOOD FOLLOWING THE INTRODUCTION OF PREFORMED VOLATILE FATTY ACIDS INTO THE RUMEN OF ANAESTHETIZED CALVES

Table

44	The age and body weight of the calves	142
45	Volatile fatty acid concentration and radio-activity of blood collected simultaneously from the right ruminal vein and carotid artery	143
46	Blood flow rates through the right ruminal vein catheter during the acute volatile fatty acid absorption experiments in which radio-active acetate was introduced into the rumen	146

APPENDIX

Table

47	Analysis of variance of the volatile fatty acid concentration of arterial carotid blood for different groups in different periods. Samples taken 15 minutes after the introduction of test solutions into the rumen	160
----	---	-----

Table	Page
48 Analysis of variance of the volatile fatty acid concentration of arterial carotid blood for different groups in different periods. Samples taken 30 minutes after the introduction of test solutions into the rumen	160
49 Analysis of variance of the veno-arterial volatile fatty acid concentration differences for different groups in different periods. Samples taken 15 minutes after the introduction of test solutions into the rumen	161
50 Analysis of variance of the veno-arterial volatile fatty acid concentration differences for different groups in different periods. Samples taken 30 minutes after the introduction of test solutions into the rumen	161
51 Analysis of variance of the mean blood flow rates through the right ruminal vein catheter	162

LIST OF FIGURES

Chapter	Page
I. <u>POST-PRANDIAL CHANGES IN THE VOLATILE FATTY ACID AND GLUCOSE CONCENTRATIONS OF PORTAL BLOOD IN CONSCIOUS CALVES</u>	
Figure	
1 Thrombus encapsulating the portal vein catheter	25
2 Changes in the volatile fatty acid concentration and pH of rumen liquor following milk feeding	28
3 Changes in the volatile fatty acid concentration and pH of rumen liquor following grazing	29
4 Changes in the volatile fatty acid and glucose concentrations of portal blood following milk feeding	32
5 Changes in the volatile fatty acid and glucose concentrations of portal blood following grazing	33
6 Differences in glucose concentration of portal and jugular blood following milk feeding	37
7 Differences in glucose concentration of portal and jugular blood following grazing	37
8 Differences in the volatile fatty acid concentration of portal and jugular blood following milk feeding	38
9 Differences in the volatile fatty acid concentration of portal and jugular blood following grazing	38
II. <u>GLUCOSE: A SOURCE OF STEAM VOLATILE FATTY ACIDS IN THE BLOOD OF CALVES</u>	
Figure	
10 Changes in the volatile fatty acid concentration and pH of rumen liquor following the feeding of whole milk	53
11 Changes in the volatile fatty acid concentration and pH of rumen liquor following the feeding of skim milk supplemented with lactose	53
12 Changes in the glucose and volatile fatty acid concentrations of portal blood following the feeding of whole milk	55

Chapter	Figure	Page
II.	13 Changes in the glucose and volatile fatty acid concentrations of portal blood following the feeding of skim milk supplemented with lactose	55
	14 Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of 50 % (w/v) D-glucose	59
	15 Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of 0.9 % NaCl	60
	16 Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of adrenaline	64
	17 Changes in the glucose and volatile fatty acid concentrations of jugular blood following the intravenous injection of 0.9 % NaCl	65
	18 The formation of acetic acid from acetyl coenzyme A	70
III.	<u>STUDIES ON THE ABSORPTION AND METABOLISM OF PREFORMED VOLATILE FATTY ACIDS IN CONSCIOUS CALVES BY THE ANALYSIS OF JUGULAR BLOOD</u>	
	Figure	
	19 Changes in the volatile fatty acid concentrations of rumen contents and jugular blood following the introduction of preformed volatile fatty acids into the rumen of the Milk Fed Calves	89
	20 Changes in the volatile fatty acid concentrations of rumen contents and jugular blood following the introduction of preformed volatile fatty acids into the rumen of the Pasture Fed Calves	90
	21 Changes in the volatile fatty acid concentration of jugular blood following the injection of preformed volatile fatty acids into the jugular vein of the Milk Fed Calves	93
	22 Changes in the volatile fatty acid concentration of jugular blood following the injection of preformed volatile fatty acids into the jugular vein of the Pasture Fed Calves	94
	23 The rumen wall in a 15-week-old milk-fed calf	102
	24 The rumen wall in a 15-week-old pasture-reared calf	102

Chapter		Page
IV.	<u>CHANGES IN THE VENO-ARTERIAL VOLATILE FATTY ACID CONCENTRATION DIFFERENCE OF RUMINAL BLOOD FOLLOWING THE INTRODUCTION OF PREFORMED VOLATILE FATTY ACIDS INTO THE RUMEN OF ANAESTHETIZED CALVES</u>	
	Figure	
	25 Entry into the abdominal cavity	110
	26 Ruminal cannula in position	110
	27 Catheterization of mesenteric vein radical	111
	28 The right ruminal vein	111
	29 An absorption experiment in progress	113
	30 Schematic diagram of the experimental procedure used in the acute volatile fatty acid absorption experiments	115
	31 Outline of venous network in the rumen wall following the injection of methylene blue	116
	32 Recording of blood pressure taken during one of the absorption experiments	119
V.	<u>THE APPEARANCE OF ACETATE-1-C¹⁴ IN RUMEN EFFLUENT AND CAROTID BLOOD FOLLOWING THE INTRODUCTION OF PREFORMED VOLATILE FATTY ACIDS INTO THE RUMEN OF ANAESTHETIZED CALVES</u>	
	Figure	
	33 Radio-activity of rumen effluent and carotid blood samples	144