

**NUTRITIONAL EFFECTS ON MAMMARY
DEVELOPMENT AND MILK PRODUCTION:
THE EFFECTS OF PREPARTUM PROTEIN
SUPPLEMENTS**

**A thesis submitted in partial fulfilment of the requirements for Master of Science
in Agriculture of the University of New England**

by

JANTIMA RESKSUPAPHON

**The Department of Animal Science,
The University of New England
Armidale, NSW. 2351
AUSTRALIA**

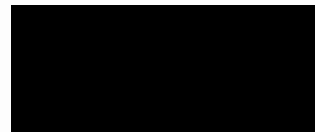
1996

PREFACE

I certify that the substance of this thesis has not already been submitted for any degree and is not currently being submitted for any other degree.

I certify that to the best of my knowledge any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

August, 1996

A solid black rectangular box redacting the signature of the author.

Jantima RESKSUPAPHON

ACKNOWLEDGMENTS

I wish to express my profound gratitude and sincerest thanks to my supervisors, Dr. Geoff Hinch and Professor James Rowe for their interest and encouragement during the period of my studies at the University of New England. In particular, I owe my thanks to Dr. Geoff Hinch for his advice, patience, comments and assistance throughout the experimental work and the writing of this thesis.

Sincere thanks are expressed to Mr. Chris Brodbeck for care and handling of the animals and to Mr. Michael Raue for technique assistance throughout the period of my experiment. Appreciation is due to Mr. Simon Stachew and Mr. Evan Thomson for their laboratory analysis.

Special gratitude is due to Dr. Geoff Hinch for his excellent assistance with the statistical analysis.

The friendship and discussions with fellow Post-Graduates, especially Dahlanuddin, James Hills, Tahir Iqbal, Ngueng Xuan Trach, Nguyen The Hoang and Freweini Tedla, and other members of staff at UNE is also recognised with gratitude. Thanks are also expressed to ALL FRIENDS in Armidale for their kindness and encouragement. Special mention should be made of Thippawan Uppakankaew, Jatuporn Wanchid, Chan Yodle, Sakorn Saiban and Kanna Suzuki for their support during my unending work.

Finally but most of all I offer my profound gratitude to my Mum and Dad for giving me the opportunity to undertake these studies in Australia, and also to my brothers and sister for their love, support and encouragement whilst I was studying in Australia.

To my late grandmother.

TABLE OF CONTENTS

Preface.....	ii
Acknowledgments.....	iii
Table of Contents.....	v
List of Tables.....	viii
List of Figures.....	ix
Abbreviation.....	x
Summary.....	xi
CHAPTER 1. GENERAL INTRODUCTION.....	1
CHAPTER 2. PHYSIOLOGY OF MAMMARY DEVELOPMENT AND MILK PRODUCTION.....	3
2.1 INTRODUCTION.....	3
2.2 Anatomy of the Mammary Gland.....	3
2.2.1 External Appearance.....	3
2.2.2 Internal Appearance.....	5
2.3 Development of the Mammary gland.....	6
2.3.1 Foetal Growth.....	6
2.3.2 Growth from Birth to Prepuberty.....	8
2.3.3 Growth during Puberty.....	9
2.3.4 Growth during Pregnancy.....	11
2.3.5 Growth during Lactation.....	14
2.4 Hormonal Control of Mammary Development and Lactation.....	16
2.4.1 Steroid Hormones.....	16
2.4.1.1 Oestrogen.....	16
2.4.1.2 Progesterone.....	18
2.4.2 Polypeptide Hormones.....	19
2.4.2.1 Prolactin.....	19
2.4.2.2 Placental Lactogen.....	20
2.4.2.3 Growth Hormone.....	21
2.5 CONCLUSION.....	23
CHAPTER 3. FACTORS AFFECTING MAMMARY DEVELOPMENT AND MILK PRODUCTION.....	24
3.1 INTRODUCTION.....	24
3.2 Non-Nutritional Factors: Effects on Mammary Development and Milk Production.....	24
3.2.1 Physiological Factors.....	24
3.2.1.1 Genetic Selection.....	24
3.2.1.2 Age at First Calving.....	25
3.2.1.3 Stage of Lactation.....	25
3.2.1.4 Dry Period.....	26
3.2.2 Environmental Factors.....	26
3.2.2.1 Environmental Condition.....	26
3.2.2.2 Milking Practice.....	27

3.3 Nutritional Factors Influencing Mammary Development and Milk Production.....	27
3.4 Feeding Management for the Pregnant Animal.....	28
3.4.1 Feeding during Early Pregnancy.....	28
3.4.2 Feeding during Late Pregnancy.....	29
3.4.3 Feeding during the Lactation Period (Postpartum).....	31
3.5 Feeding Requirements in Late Pregnancy.....	32
3.5.1 Energy Requirement.....	33
3.5.1.1 Energy Nutrition.....	33
3.5.1.2 Effects of Dietary Energy.....	34
3.5.2 Protein Requirement.....	36
3.5.2.1 Protein Nutrition.....	39
3.5.2.2 Use of Different Sources of Protein Supplement.....	40
3.5.2.2.1 Soluble Protein.....	40
3.5.2.2.2 Protected Protein.....	40
3.5.2.2.3 Non-Protein Nitrogen.....	40
3.5.2.3 Effects of Dietary Protein.....	41
3.5.3 Nitrogen and Energy Ratio (P:E Ratio).....	44
3.6 CONCLUSION.....	45

CHAPTER 4 (Experimental)

PROTEIN SOURCES FED PREPARTUM AND THEIR EFFECTS ON MAMMARY DEVELOPMENT AND MILK PRODUCTION OF

EWES.....	46
4.1 INTRODUCTION.....	46
4.2 MATERIALS AND METHODS.....	47
4.2.1 Experimental animals.....	47
4.2.2 Treatments.....	48
4.2.3 Measurements Made during the Experiment.....	49
4.2.3.1 Protein Degradability Measured Using Nylon Bags.....	49
4.2.3.2 Ewe Body Condition Score and Liveweight.....	50
4.2.3.3 Mammary Gland Development.....	50
4.2.3.3.1 Linear Dimensions.....	50
4.2.3.3.2 Displacement of Water.....	51
4.2.3.4 Dry Matter Intake.....	51
4.2.3.5 Supplement Intake.....	52
4.2.3.6 Lamb Weight and Growth Rates.....	54
4.2.3.7 Yield of Milk and Milk Composition.....	54
4.2.4 Statistical Analysis.....	55
4.3 RESULTS.....	56
4.3.1 Protein Degradability of Supplements.....	56
4.3.2 Ewe Body Condition Score.....	57
4.3.3 Ewe Liveweight Pre- and Postpartum.....	58
4.3.4 Mammary Gland Development.....	59
4.3.4.1 Linear Dimension (cm ³).....	59
4.3.4.2 Water Displacement (ml).....	61
4.3.5 Lamb Birth Weight and Growth Rates.....	62
4.3.6 Feed Intakes.....	64
4.3.6.1 Dry Matter Intakes.....	64

4.3.6.2 Supplementary Crude Protein Intakes.....	65
4.3.7 Milk Yield and Composition.....	66
4.3.7.1 Milk Yield.....	66
4.3.7.2 Milk Protein Yield.....	67
4.3.7.3 Milk Fat Yield.....	69
4.4 DISCUSSION.....	71
4.5 CONCLUSION.....	81
BIBLIOGRAPHY.....	83

LIST OF TABLES

- Table 2.1:** Changes in total amount of mammary DNA (DNA_t) and incorporation of [^3H] thymidine into mammary tissue during pregnancy, lactation, and mammary gland involution in mice.
- Table 2.2:** Percent mammary growth during pregnancy and early lactation in various species.
- Table 3.1:** The net accretions of protein in the gravid uterus and udder, i.e. net protein requirements for pregnancy (NPR_p) in relation to the corresponding ME requirements ME_p (g/MJ).
- Table 4.1:** Chemical composition of lupins, cottonseed meal and formaldehyde treated sunflower meal (Norpro) consumed by ewes during the experimental period.
- Table 4.2:** Body condition scores (Mean \pm SE) for ewes on various prepartum protein supplements.
- Table 4.3:** Liveweight and weight changes (Mean \pm SE) for ewes on various prepartum protein supplements.
- Table 4.4:** Effects of supplements and litter size interaction on liveweight change (g/d) during the lactation phase (Mean \pm SE).
- Table 4.5:** Mean (\pm SE) of mammary gland development of ewes bearing single or twin lambs (cm^3) measured by linear dimensions.
- Table 4.6:** Mean (\pm SE) of mammary gland development of ewes bearing single or twin lambs (ml) measured by water displacement.
- Table 4.7:** Lamb data (birth weight and weight during 4 weeks after birth) for lambs from ewes carrying single and twin lambs (Mean \pm SE).
- Table 4.8:** Total dry matter (kg) after adjustment to the same liveweight of 52 kg and supplement crude protein intake (g) of the animals during the experimental period (Mean \pm SE).
- Table 4.9:** Average milk yield (g) during the 4 weeks of lactation for ewes rearing single and twin lambs (Mean \pm SE).
- Table 4.10:** Effects of litter size on milk protein yield (g) during the 4 weeks of lactation (Mean \pm SE).

LIST OF FIGURES

- Figure 2.1:** Diagram of a cross section of a cow caudal to the rear teats and showing the position of the lateral and median suspensory ligaments.
- Figure 2.2:** Total mammary DNA content in growing heifers.
- Figure 2.3:** The concentrations of hormones for 30 days before and 5 days after parturition in the cow.
- Figure 3.1:** The relationships between dry matter intake, milk yield and liveweight.
- Figure 3.2:** The net protein needs of the gravid uterus and udder (NPR_p) in single and quadruple-bearing ewes. Upper and lower lines refer to quadruplets and singletons, respectively.
- Figure 3.3:** An illustration of the effects of age, level of production and physiological state on the net requirements for amino acid nitrogen.
- Figure 3.4:** The effects of the degradation of protein in the rumen and net requirements for amino acid nitrogen on the crude protein needed in the diet.
- Figure 4.1:** Mammary gland development of animals in 4 different treatments measuring by linear dimension (cm^3) method. (Error bars show SE).
- Figure 4.2:** Mammary gland development of animals in 4 different treatments measuring by water displacement method (ml). (Error bars show SE).
- Figure 4.3:** Lambs birth weight and liveweight (kg) from ewes in 4 feeding treatments prepartum. (Error bars show SE).
- Figure 4.4:** Mean lamb growth rate during the experimental period (4 weeks) from each ewe treatment group (kg). (Error bars show SE).
- Figure 4.5:** Mean milk yield (kg/l) for lactating ewes fed various supplements. (Error bars show SE).
- Figure 4.6:** Mean milk protein yield for ewes supplemented during prepartum period (g). (Error bars show SE).
- Figure 4.7:** Mean (\pm SE) milk fat yield for ewes fed various diets (g). (Error bars show SE).

ABBREVIATIONS

ATP	- Adenosine triphosphate
BCS	- Body condition score
BW	- Body weight
CHO	- Carbohydrate
CP	- Crude protein
CSM	- Cottonseed meal
DCP	- Digestible crude protein
DFFT	- Dry fat free tissue
DM	- Dry matter
DMI	- Dry matter intake
DNA	- Deoxyribonucleic acid
EGF	- Epidermal growth factor
FCM	- Fat correct milk
FGF	- Fibroblast growth factor
GH	- Growth hormone
GHRH	- Growth hormone-releasing hormone
IGF	- Insulin-like growth factor
ME	- Metabolisable energy
N	- Nitrogen
NEFA	- Nonesterified fatty acids
NPN	- Non-protein nitrogen
NPRp	- Net protein requirement for pregnancy
NS	- Nonsignificant
P:E	- Protein : energy ratio
rbPL	- Recombinant bovine placental lactogen
RDP	- Rumen degraded protein
RNA	- Ribonucleic acid
SE	- Standard error
ST	- Somatotropin
TGF	- Transforming growth factor
UDP	- Undegraded dietary protein

SUMMARY

Sixty mature crossbred ewes were grouped into four different feeding treatments on day 110 of pregnancy until lambing to evaluate the effect of prepartum protein intake on mammary development and subsequent productive performance. Treatments were similar for the amount of crude protein (60 g/h/d) and differed in the quality of protein content. Following parturition, all ewes were fed the same feed.

Ewes did not differ in initial body weight and body condition score. Ewes fed the protein diets exhibited greater liveweight gain during gestation and then increased weight loss after lambing. Mean liveweight for the protein fed ewes at parturition was greater than the controls. Change in body condition score was greater for the high UDP group than for the low UDP group at lambing, but not in early lactation. Lamb birth weight and growth rate did not differ significantly between treatments.

Prepartum diets influenced mammary development and subsequent milk production. Ewes given lupin supplement produced more milk ($P < 0.05$) with highest milk protein ($P < 0.05$) production. Milk and milk fat production were influenced by prepartum undegradable protein. Supplemental protein prepartum may improve postpartum performance by minimising mobilisation of maternal labile protein pools to meet foetal and maternal growth requirements in late gestation and subsequently improve lactation performance.