THE EFFECTS OF DIET AND FEEDING ON SMALL INTESTINAL DEVELOPMENT IN PIGLETS DURING THE FIRST 24 HOURS AFTER BIRTH

A thesis presented in partial fulfilment of the requirements
for the degree of Doctor of Philosophy
in Physiology and Anatomy at
Massey University

Prapaporn Tungthanathanich

1994

Nothing in the world is perfect
In accepting with understanding,
there is peace in the heart.
No one in the world is perfect
In forgiveness with compassion,
there is peace in the heart.

THE EFFECTS OF DIET AND FEEDING ON SMALL INTESTINAL DEVELOPMENT IN PIGLETS DURING THE FIRST 24 HOURS AFTER BIRTH

VOLUME I

TEXT

(Volume II contains the Figures and Appendices)

ABSTRACT

To study the effects of feeding and diet on postnatal development of the small intestine in newborn piglets during the time 0 - 24 hours after birth, three studies were conducted:

1. Unsuckled newborn piglets were fed from a bottle with colostrum or milk from either sows or cows, infant formula, or water. After 24 hours intestinal development was compared with that in piglets at birth and others naturally suckled. Sow colostrum caused greater increases in weight and length of the small intestine than did any of the other diets. The increases were due to mucosal cell swelling caused by cellular protein accumulation, hyperplasia and, in the duodenum, hypertrophy. Feeding sow colostrum increased mucosal lactase activity. Cow colostrum caused decreases in mucosal RNA levels. Increases in the DNA content of the intestinal mucosa occurred in all groups, including the water fed group. Colostrum feeding also enhanced pancreatic growth and feeding infant formula increased liver weight.

2. The effects of enteral feeding on small intestinal development were investigated by feeding nutrient solution to unsuckled newborn piglets by orogastric tube or parenterally. Both groups after 24 hours had greater intestinal development than did the piglets at birth. The development was most pronounced in the duodenum and lower ileum. Apart from a greater small intestinal length in the orogastrically fed piglets there were no significant differences between the orogastrically and parenterally fed groups.

3. To investigate the effects of sucking *per se* on small intestinal development, groups of unsuckled piglets were fed for 24 hours with either sow colostrum or infant formula by orogastric tube or being allowed to suck from a bottle. Sucking did not affect intestinal development whereas colostrum, regardless of how it was fed, had significantly greater effects on intestinal development than did infant formula. For the colostrum fed piglets the intestinal length, tissue weight, circumference, wall thickness, villous height and width, RNA content, protein:DNA ratio and RNA:DNA ratio were all significantly greater than for those fed infant formula. In the duodenum the estimated cell migration rate was faster and mucosal cell replacement time was shorter than in

other parts of the small intestine, regardless of the diet fed. The greater villous height in the piglets fed sow colostrum was most likely due to the combined effects of cellular swelling and an increase in the number of villous cells.

These results indicate that (a) sow colostrum causes cellular swelling related to colostral protein accumulation, cell hyperplasia and, in the duodenum, hypertrophy, (b) there is a basal rate of mucosal cell division which contributes to mucosal growth regardless of diet and method of feeding, (c) the duodenum exhibits a greater growth and sensitivity to the trophic effects of colostrum compared to other parts of the small intestine, (d) feeding cow colostrum to newborn piglets causes a pronounced decrease in mucosal RNA content and (e) diets affect postnatal development of the small intestine whereas the route or method of feeding has no significant effects on small intestinal development in piglets during the first 24 hours after birth.

ACKNOWLEDGEMENTS

I am in debted to the New Zealand Ministry of External Relations & Trade for granting me a Ph. D. Scholarship, the Physiology & Anatomy Department and the Massey University Pig Research Center for the research facilities made available to me.

My warmest thanks go to my chief supervisor, Dr. G. W. Reynolds, for his advice, guidance and encouragement during the course of my study. I am grateful to other supervisors, particularly Professor D. J. Mellor, Head of the Physiology & Anatomy Department, for his skilled academic guidance, and also Dr. H. V. Simpson for her advice and encouragement. I wish to acknowledge the help of my colleagues, Dr. R-J Xu and D. Shu for their assistance with the collection of tissue samples.

I woul like to thank the following people for their contributions to my work:

Mr. M. J. Birtles and Mr. R. Sparkman for their advice in histological and immunocytochemical techniques and photomicrographic assistance;

Professor R. E. Munford, Professor P. J. Moughan, Dr. P. C. H. Morel and Dr. S. Ganeshanandam for their statistical guidance;

Dr. L. M. Schollum for her assistance in milk analysis at the Dairy Research Institute, Palmerston North;

Mrs. L. Cosgrove and Mrs. S. Marr for their assistance with the typing of the appendices.

I acknowledge the friendly support and encouragement of Dr. H. C. Grady, Dr. D. H. Carr, Dr. K. R. Lapwood and Ms. D. J. E. Anthony.

Finally, special thanks are extended to all monks at the Bodhinyanarama Buddhist Monastery, Stoke Valley, Wellington, members of Massey University Buddhist Association, and Mrs. K. B. L. McDonald for their unfailing support, encouragement and understanding.

TABLE OF CONTENTS
(Volume I)

LIST OF FIGURES
(Volume II)

LIST OF TABLES
(Volume I)

LIST OF APPENDICES
(Volume II)

LIST OF ABBREVIATIONS

Abbreviation		
B	=	at birth
BrdU	=	5-bromo-2'-deoxyuridine
BSA	=	bovine serum albumin
bw	=	body weight
^{o}C	=	degree Celcius
CC	=	cow colostrum
CCK	=	cholecystokinin
CD	=	crypt depth
CI	=	confidence interval
CM	=	cow milk
CMR	=	cell migration rate
cm	=	centimetre
$CoCl_2$	=	cobalt chloride
conc.	=	concentration
cont.	=	content
contd.	=	continued
$CuSO_4.5H_2O$	=	copper sulfate pentahydrate
CW	=	cell width
CWP	=	percentage increase in villous width
DAB	=	diaminobenzine
DNA	=	deoxy ribonucleic acid
DUO	=	duodenum
EGF	=	epidermal growth factor
Fig(s).	=	figure(s)
g	=	gramme
g	=	gravity
GIP	=	gastric inhibitory polypeptide
hr(s)	=	hour(s)
H_2O	=	water
H_2O_2	=	hydrogen peroxide
I.D.	=	inner diameter
IF	=	infant formula
Ig	=	immunoglobulin
IGF	=	insulin-like growth factor

ILE	=	ileum
JEJ	=	jejunum
kg	=	kilogramme
KH_2PO_4	=	potassium phosphate
kJ	=	kilojoule
KOH	=	potassium hydroxide
L	=	litre
LOI	=	lower ileum
LOJ	=	lower jejunum
mg	=	milligramme
min(s)	=	minute(s)
ml	=	millilitre
mm	=	millimetre
mmol	=	millimole
mol	=	mole
mOsm	=	milliosmole
MUC	=	mucosa
MUS	=	muscle
N	=	normality
NaCl	=	sodium chloride
Na_2CO_3	=	sodium carbonate
Na_2HPO_4	=	disodium phosphate
NaOH	=	sodium hydroxide
NiCl	=	nickel chloride
nm	=	nanometre
NS	=	naturally suckled
N.S.	=	no statistically significant difference
OD	=	optical density
O.D.	=	outer diameter
OGF	=	orogastric feeding
PBS	=	phosphate buffer saline
PP	=	pancreatic polypeptide
%	=	percent
RMD	=	relative migration distance
RNA	=	ribonucleic acid
RT	=	replacement time

S	=	sucking
SC	=	sow colostrum
S.D.	=	standard deviation
S.E.	=	standard error
SI	=	small intestine
SM	=	sow milk
sq.um	=	square micrometre
TGO	=	Tris-glucose-oxidase
TPN	=	total parenteral nutrition
µg	=	microgramme
UPI	=	upper ileum
UPJ	=	upper jejunum
µm	=	micrometer
µmol	=	micromole
VH	=	villous height
VHP	=	percentage increase in villous height
vs	=	versus
W/W	=	weight by weight

ANIMAL ETHICS APPROVAL

The protocols for using live animals for the experiments described in this thesis have been approved by the Massey University Animal Ethics Commitee.