PHYSIOLOGY OF DIGESTION IN THE MACROPODINE MARSUPIALS

A thesis submitted for the degree of Doctor of Philosophy of the University of New England

by

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PREFACE

The studies presented in this dissertation were completed by the author while a postgraduate student in the Department of Biochemistry and Nutrition, the Faculty of Science, the University of New England, Armidale, N.S.W., Australia. Assistance given by other persons is indicated in the text or in the list of acknowledgements. All references cited are included in a bibliography. The work is otherwise original.

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

I certify that any help received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

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LIST OF ABBREVIATIONS

ADF	-	acid-detergent fibre
CP	-	crude protein
CPC	-	caecum-proximal colon
^{51}Cr-EDTA	-	^{51}Cr complex of ethylenediaminetetra-acetic acid
d	-	day
DC	-	distal colon
DE	-	digestible energy
DM	-	dry matter
DOM	-	digestible organic matter
ET	-	excretion time
g	-	gram
h	-	hour
HS	-	hindstomach
I.L.	-	irreversible loss
k	-	fractional, rate constant
kgW^x	-	body weight, in kilograms, raised to the power of x.
l, ml	-	litre, millilitre
μCi	-	microcurie
min	-	minute
mM, M	-	millimoles, moles
N	-	nitrogen
NAN	-	non-ammonia nitrogen
OM	-	organic matter
RT	-	retention time
^{103}Ru-P	-	^{103}Ruthenium-labelled tris (1,10-phenanthroline)-ruthenium II chloride
s.e.	-	standard error
SFS	-	sacciform forestomach
SI	-	small intestine
$T_{\frac{1}{2}}$	-	half-time of a marker
TFS	-	tubiform forestomach
THO	-	tritiated water
TT	-	transit time
(U-^{14}C)	-	uniformly labelled compound
VFA	-	volatile fatty acids

GENERIC AND COMMON NAMES OF MACROPODINE MARSUPIALS

Macropus eugenii	-	tammar wallaby
M. giganteus	-	eastern grey kangaroo
M. parma	-	parma wallaby
M. parryi	-	whiptail wallaby
M. robustus cervinus	-	western euro
M. robustus robustus	-	eastern wallaroo
M. rufogriseus	-	red-necked wallaby
Megaleia rufa	-	red kangaroo
Petrogale penicillata	-	brush-tailed rock-wallaby
Setonix brachyurus	-	quokka
Thylogale billarderi	-	red-bellied pademelon
T. stigmatica	-	red-legged pademelon
T. thetis	-	red-necked pademelon
Wallabia bicolor	-	swamp wallaby
Dorcopsis luctuosa	-	New Guinea wallaby
Dendrolagus spp.	-	tree kangaroos
Largorchestes spp.	-	hare-wallabies
Onychogalea spp.	-	nailtail wallabies

SUMMARY

The macropodines (kangaroos and wallabies) are herbivorous marsupials with a digestive system comparable to the ruminants. Ingested food is subjected to extensive microbial fermentation and modification in a capacious forestomach and secondary fermentation occurs in the caecum-proximal colon. The macropodine stomach is essentially a long tubular structure, markedly different to that of the ruminants, and relationships between stomach structure and digesta flow have not been previously investigated. Similarly, little is known of the mode of microbial activity in the forestomach and quantitative estimates of the extent of microbial fermentation have not been reported.

The present comparative study was undertaken to examine some of these aspects of the physiology of fermentative digestion in three macropodine species; Thylogale thetis (red-necked pademelon), Macropus giganteus (eastern grey kangaroo) and Macropus eugenii (tammar wallaby). These species represent adaptation to widely different habitats. Reference was also made to other macropodine species and some direct comparisons were made with sheep.

1. Differences in structural features and dimensions of the stomach occurred among the three species and were defined. Radiographic techniques were used to determine the initial dispersion pattern of orally infused contrast medium in the forestomach of adult animals. This varied among the three species and was related, in particular, to the position of the cardia and the degree of development, or absence, of a gastric sulcus (oesophageal groove).

2. The dynamics of flow of the fluid and particulate phases of digesta along the digestive tract of the three species were defined. The pattern of flow

of digesta through the macropodine stomach was very different to that observed in sheep and defined as tubular flow. Ingested food entering the cranial regions of the stomach slowly traversed the length of the forestomach but total mixing of forestomach contents did not occur. In addition, the fluid phase of digesta traversed the forestomach more rapidly than the particulate phase but thiswas not due to preferential retention of larger dietary particles. A similar pattern of digesta flow was observed in both T. thetis and M. eugenii when fed either chopped lucerne hay or fresh Phalaris aquatica grass.

3. Parameters of intake and digestibility were measured in all three species, and sheep, fed chopped lucerne hay and in T. thetis and M. eugenii fed fresh Phalaris. All species were similar in efficiency of utilisation of acid-detergent fibre but less efficient than the sheep. M. eugenii maintained nitrogen balance on a much lower ad libitum intake of diet than observed in the other species.

4. The dynamics of ^{14}C-urea and tritiated water (THO) metabolism were examined in T. thetis and M. eugenii. In both species a similar proportion of urea was recycled to the digestive tract and degraded by microorganisms. This was observed on both diets. However, THO turnover was faster in T. thetis and independent of diet. Collectively, the results suggested that M. eugenii may have a lower standard metabolic rate than T. thetis, rather than a more efficient mode of fermentative digestion.

5. Quantitative estimates of the partitioning of digestion in the stomach and intestine were measured in the three species fed chopped lucerne hay. Apparent fermentation of dietary constituents in the forestomach were extensive and similar in all three species and comparable to published estimates for the sheep. A

pattern of decreasing rate of apparent digestion of dietary constituents along the length of the forestomach was defined and related to the tubular pattern of digesta flow. Among the three species, minor differences in the extent of digestion in different regions of the forestomach were related to stomach structure.

6. Estimates of microbial activity in the forestomach were obtained by _in vitro_ and _in vivo_ techniques. Microbial production of volatile fatty acids and ammonia and incorporation of ammonia nitrogen into bacterial protein were measured _in vivo_ in _T. thetis_ and _M. eugenii_ fed chopped lucerne hay. Estimates were similar for both species. The efficiency of microbial utilisation of dietary organic matter and nitrogen was similar in both species and although comparable to published estimates for the ruminants, the mode of microbial activity in the macropodine forestomach is very different.