THE REGULATION OF THE VOLUNTARY INTAKE OF FOOD BY SHEEP

A thesis presented in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Animal Science at Massey University

by

A. W. F. DAVEY

1973

LIST OF CONTENTS

LIST OF FIGURES

ABSTRACT

Experiments were conducted with the main objectives of studying:

1. the extent to which the voluntary food intakes of sheep receiving diets, differing in physical form and digestible energy concentration, change with an increase in energy demand of the sheep
2. the effect of differences in body condition and an increase in energy demand on the voluntary food intake of sheep
3. the effect of an increase in the energy demand of sheep on measurements such as the retention time of food residues, alimentary tract fill and weight of alimentary organs
4. the extent to which increases in the energy intake of sheep equate with increases in energy demand.

The increase in energy demand was achieved by shearing Romney sheep, held at an ambient temperature of 13°C.

A section of the work also compared the retention times of food residues using various diets stained with safranine, treated with radiocerium ^{144}(Ce), or potassium permanganate (Mn). There were considerable differences in mean retention times depending on the method used. Because the variation in mean retention time was lower within and between sheep for ^{144}Ce than for the other methods, and because retention times could be determined rapidly with ^{144}Ce, the decision was made to use it in subsequent experiments.

Following shearing, there was a consistent increase in the voluntary intakes of sheep receiving chopped hay or ground hay of low digestible energy concentration. The increase in voluntary intake, with the exception of that for a hay of low protein content in one experiment, to a considerable extent met the increased energy expenditure when the sheep were shorn.

An increase in the amount of dry matter in the reticulorumen and a decrease in mean retention time was observed with sheep receiving chopped hay and ground hay. Evidence was also obtained of hypertrophy of the gut, measured as an increase in weight of the empty alimentary organs, when sheep receiving chopped hay or ground hay were shorn. No evidence was obtained of cause and effect, but it appeared that increases in intake were accomplished through a range of physical changes.

Evidence was also obtained that reticulorumen fill, in terms of the amount of dry matter, was unimportant in limiting the intake of chopped hay.

Following shearing, the increase in the voluntary intake of sheep receiving ground hay was greater than that of sheep receiving chopped hay. The increase in the intake of sheep receiving ground hay more than met the increase in energy expenditure following shearing. The result is consistent with the postulation that the rate of removal of dry matter from the reticulorumen imposed a limitation on the voluntary intake of sheep receiving chopped hay. This observation was further supported by the greater amount of dry matter caudal to the reticulorumen, with the shorn sheep receiving ground hay, than that of the unshorn sheep.

Voluntary intakes were invariably higher with sheep receiving foods of high digestible energy concentration, than with those receiving foods of low concentration, but the response in terms of changes in voluntary intake following shearing were variable.

In some of the experiments, increases in the voluntary intakes of sheep receiving dried grass were small, after shearing. However in an experiment which compared the effects of body condition, and of shearing on voluntary intake, fat sheep increased their energy intake of dried grass following shearing to about the same extent as the increase in energy expenditure. In the same experiment, the greatest increase in intake following shearing occurred with the thin sheep, and it appeared that the effects of shearing, in increasing voluntary intake, were reinforced by the condition of thinness.

The voluntary intakes of unshorn sheep receiving dried grass decreased as the experiments progressed. Physical restriction of the abdominal cavity by fat did not appear to be the cause of the decrease.

Measurements of oxygen consumption in two experiments (values converted to heat production) were obtained before and after shearing, with Romney wethers receiving dried grass or ground hay. Heat production increased after shearing, the increase being greater for the sheep receiving dried grass than for those receiving ground hay. The evidence obtained showed that, particularly with sheep receiving hay in the intake experiments, the increase in intake following shearing would have met the increase in energy expenditure in many cases. Changes in feeding behaviour and activity of the sheep occurred

following shearing. The effects of these changes on energy expenditure were discussed.

It was concluded that, even where voluntary intake is predominantly limited by physical factors, these can be overriden by changes in energy demand.

ACKNOWLEDGEMENTS

It is a pleasure to record my gratitude to the many people who assisted in this work. My sincere thanks are extended to the following:

Prof. D.S. Flux, Dr M.J. Ulyatt and Dr C.C. Balch for their continuing guidance and encouragement, as my supervisors;

Dr C.W. Holmes who provided the calorimentry equipment and close assistance in the measurement of oxygen consumption of the sheep;

Mr T. Cooper who carried out the tedious task of integrating the oxygen consumption charts;

Prof. R.E. Munford for statistical advice and for the computer analysis of much of the data for Chapters 3, 4 and 5;

Drs G.F. Wilson and J.A. Bines who read the script and suggested improvements;

Mr N.A. Thomson in the earlier sections of the work, followed by Mr. G.C. Jukes and from time to time Mr J.A. Raven, for skilled technical assistance with the animals and with chemical analyses;

The late Mr L. Hawthorne, followed by Mr L.J. Robertson for assistance in the feeding and care of the sheep;

Mr P. Vlieg for carrying out some of the rumen fistulations with the assistance of Mr J.E. Ormsby;

Messrs P. Livingstone, R.S. McClenaghan and M.J. Byford who assisted at the time of peak periods of work, when the sheep were slaughtered;

Mr P.H.Whitehead who supplied the sheep;

Mrs M. McComish and Miss A. Muschamp who drew the graphs;

Mrs E.M. Self for typing the draft and final copy of the thesis;

To my wife and family for their continued support and understanding throughout the work.

PREFACE

The amount of food consumed by animals largely determines their productive output, and an understanding of how they regulate voluntary food intake is of fundamental importance in the field of animal nutrition.

The factors controlling food intake are complex and are not fully understood. The problem is not made simpler in the ruminant, with its close integration with the microbial population of the reticulorumen. The multifactorial nature of voluntary food intake presents many difficulties, in attempts to synthesise a system. Experimental approaches aimed at eliminating one control, in an attempt to understand the system, have often shown that the eliminated control is dispensable and that other control mechanisms are invoked to maintain food intake.

In both monogastrics and ruminants much of the research into the control of food intake has been concerned with the nature of the stimuli which signal the nervous system, in response to the ingestion of food. Many investigations have been directed towards establishing relationships between the amount of food consumed and the amount of digesta in the alimentary tract, or between food consumed and changes in the products of digestion in the alimentary tract and in the blood. The interpretation of these relationships is often difficult because of the inability to distinguish between cause and effect. In further efforts to understand the mechanisms involved, techniques such as the intravenous and intraruminal administration of various energy metabolites have been used. Generally, the response measured has been a decrease in voluntary intake, the interpretation of which could be complicated by the fact that, possibly the first symptom of metabolic stress is a decline in food intake.

Whilst the nature of the mechanisms controlling food intake remain unclear, there is considerable evidence to show that with roughage diets, in the long form, and of low digestible energy concentration, voluntary intake is controlled in ruminants by factors related to the capacity of the alimentary tract. In contrast, with foods of high digestible energy concentration, voluntary intake is related to the energy demand of the animal and the levels of the products of digestion.

It was considered that worthwhile advances towards understanding factors controlling food intake could be made under conditions where the energy demand of animals varied widely. This was achieved by shearing sheep, held at an environmental temperature of 13°C, which, from available evidence, was considerably below the critical temperature of shorn sheep.

The questions posed in this thesis were:

1. What effect would changes in the energy demand of sheep have on their voluntary intakes, when they were offered foods differing in physical form, and digestible energy concentration?
2. What effect would changes in the energy demand of sheep have on measurements (such as the retention time of food residues and alimentary tract fill) associated with the physical control of food intake?
3. To what extent would the change in the energy intake of sheep equate with the change in heat production, when they were shorn?

All experiments were carried out at the Animal Physiology Unit, Massey University.