WATER AND ELECTROLYTE TRANSFERS IN RUMINANTS

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LIST OF ABBREVIATIONS

ACTH	adrenocorticotrophic hormone
ADH	antidiuretic hormone
B.P.	blood pressure
CSF	cerebrospinal fluid
DOCA	deoxycorticosterone acetate
ECF	extracellular fluid
Fig	figure
GFR	glomerular filtration rate
gm	gram
Hb	haemoglobin
ICF	intracellular fluid
i/v	intravenous
kg	kilogram
l	litre
m-equiv	milliequivalent
min	minute
ml	millilitre
mosm	milliosmole
M	molar
O.P.	osmotic pressure
PAH	para-amino hippuric acid
PCV	packed cell volume
P.D.	potential difference
RBF	renal blood flow
S.G.	specific gravity
[ ]	concentration of

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PREFACE

At the present time, the economy of New Zealand is largely dependent upon the health and well-being of the ruminant animal. The national loss due to primary water and electrolyte disturbances, and to those secondary to other diseases, is of considerable importance. Deficiencies in our knowledge of water and electrolyte metabolism in the ruminant have become apparent, even of the principal cations sodium and potassium.

The specialized form of nutrition in the ruminant has entailed some changes in the water and electrolyte economy. In adapting to a diet of plant material rich in cellulose, they have developed a large forestomach, the reticulo-rumen, where a symbiotic population of bacteria and protozoa is maintained and exploited. Microbial fermentation breaks down plant cellulose, and converts carbohydrate to volatile fatty acids, principally acetic, propionic and butyric acids, which are rapidly absorbed by the host for use as an energy source. Microbial protein and certain vitamins are also made available further down the gastro-intestinal tract.

The development of the reticulo-rumen has resulted in an increase in the content and daily turnover of gut water and electrolytes. A major source of this content of the reticulo-rumen liquor, which provides a well-buffered medium for the microbes, is the copious salivary flow. The rumen of the sheep may contain 500-800 m-equiv of Na^+, approximately half that in the extracellular fluid. The daily digestive cycle of salivary secretion and later reabsorption may involve double this amount of Na^+.

The maintenance of water and electrolyte balance in the face of this digestive cycle, coupled with the low Na^+-high K^+ content of the diet, suggests that the ruminant has efficient homeostatic mechanisms in operation. Whether or not these are identical with those seen in other species, or have features unique to the ruminant, is not clear. While the enlarged digestive cycle would appear to impose an extra load on the regulatory mechanisms, the presence of the reticulo-rumen might confer advantages during times of stress, when rumen fluid can be called upon as a reserve of water and electrolyte. During dehydration, the ECF can draw upon gut fluids (Macfarlane, Morris and Howard, 1963; Hecker, Budtz-Olsen and Ostwald, 1964); and the rumen forms a Na^+ store which can be drawn upon during reduced dietary intake (Denton, 1957; Kay and Hobson, 1963). The ability to repair a water deficit of up to 10% body weight (more in camels) within minutes would be an advantage in the natural environment.

Investigation in ruminants of the overall regulation of water and electrolyte metabolism has not been extensive. Most of our knowledge has been derived from studies of man, rodents and the dog. In the ruminant, more commonly, the longer term adjustments to dietary deficiency or supplementation, or to altered environmental conditions have been followed; less often, short-term water and electrolyte redistributions and mechanisms of elimination and conservation in varying physiological situations have been studied.

Some properties of the ruminant digestive tract, particularly regions of net addition and absorption, and the characteristics of rumen epithelial transport have been identified. However, in many cases the particular experimental situations employed make generalization uncertain. Thus, net transport is commonly estimated using a simple solution in an isolated, emptied and washed rumen or rumen pouch, a procedure providing an abnormal environment for the rumen mucosa, and which can alter its transport properties (Masson and Phillipson, 1951; Armstrong, Blaxter and Graham, 1957; Ash and Dobson, 1963). Studies in the intact organ under physiological conditions present practical difficulties because of the continuous inflow of saliva and outflow to the omasum, and the lack of uniformity of composition of the contents in different regions of the reticulo-rumen. Accurate estimation of the rumen volume at any particular time is not an easy task. Direct measurement by total removal has a limited application, and marker dilution is only accurate during periods of relative constancy. In addition, to calculate a change in total electrolyte content an average ruminal concentration is required, although a uniform electrolyte concentration in the rumen is not usually a physiological reality.

The present thesis is concerned with short-term transfers, especially water and electrolyte movements between the contents of the reticulo-rumen and body fluid compartments. The rumen water and electrolyte status was altered rapidly in two ways: by once-daily feeding whereby there was net gain in the rumen at the expense of body fluids; and by infusion of known amounts of electrolyte. Net gain or absorption from the rumen has been followed by observing changes in urinary excretion and in blood composition. The rumen itself has not been sampled; it was considered that the advantages of direct rumen observations would be outweighed by the experimental errors and by the disturbance to the animal caused by the sampling. In the undisturbed sheep, relative plasma volume estimations can be inferred from the PCV and [Hb].

Urine and blood changes associated with a single daily feed (Chapter 2) have confirmed and extended the observations of Stacy and Brook (1964), and are in agreement with later observations from that group. An attempt was made to gain further information about the homeostatic mechanisms involved by the use of the diuretic, acetazolamide, and by restriction of drinking water. The relevance of these to variations seen in ad libitum fed animals was examined (Chapter 3).

Prior to the present experiments only isolated water and electrolyte infusions had been performed in ruminants (Sellers and Roepke, 1951; Lysov, 1960; Anderson and Pickering, 1962a) although more reports have appeared while the work was in progress (Potter, 1966, 1968; Keynes and Harrison, 1967; Dewhurst, Harrison and Keynes, 1968). A series of intraruminal infusions of water, NaCl and KCl has been carried out (Chapter 4), integrated with the intraduodenal infusion of NaCl (Chapter 5) and the intravenous administration of sodium and potassium salts (Chapter 6). It would appear that, with the exception of sodium, net water and electrolyte movements across the rumen mucosa in physiological situations may be small in magnitude. Should this be so, then sensory receptors in the forestomach may be involved only in regulating the functions of the digestive tract itself, and not in the overall regulation of water and electrolyte metabolism. Thus, the homeostatic mechanisms in the ruminant may more closely approach those in the monogastric than would be likely if the rumen permitted freer exchange with the internal body fluids.