

Water

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INTRODUCTION

The importance of water to mammalian life is highlighted by water constituting 98 to 99% of the molecules in the body. Animals may derive needed water from numerous sources such as water contained in or on feedstuffs, snow, ice, drinking water contained in surface or underground supplies, and oxidation of nutrients. Animals can lose water by excretion in urine and feces, by secretion in products such as milk and eggs, and through the insensible losses of perspiration and respiration. This article discusses the fundamental chemistry of water, water partitioning in the body, and the influences of dehydration during animal transport and water mineral composition on water balance and performance of ruminants.

CHEMISTRY OF WATER

Water functions as a critical solvent for ions and metabolites involved in osmoregulation and for digestion, metabolism, absorption, transport, and excretion of nutrients. The unequal sharing of electrons in a water molecule facilitates interaction between polar and ionic groups on molecules, and contributes to water possessing the highest dielectric constant among common solvents.^[1] The dielectric constant represents the effectiveness of a solvent to reduce attraction between oppositely charged molecules by surrounding each charged species with a layer of (water) molecules, allowing the charged species to coexist in solution.^[1] As a result of these characteristics, water can generally move freely between body water compartments in response to hydrostatic and osmotic pressure exerted by minerals, protein, and other ions. The high heat of vaporization (9.72 kcal/mole) and high heat capacity (1.00 cal/gram per 1°C) of water confer the ability to dissipate heat effectively and buffer core body temperature by absorbing large amounts of heat.

BODY WATER

Water content of the body is a function of body composition, and body composition varies with species, stage of production, and body condition. Body water content of animals range from approximately 40 to 80% of body weight. Neonates and lean, growing animals have the highest body water content, whereas obese animals have less body water due to displacement by adipose tissue. Adipose tissue and bone contain approximately 20% water, whereas other tissues in the body typically contain 70 to 80% water.

Total body water is partitioned into that contained within cells (intracellular) and that located outside cells (extracellular; Fig. 1). The intracellular pool comprises approximately 60% of body water and the remainder is in the extracellular pool. Extracellular water is further divided into the interstitial, plasma, and transcellular pools. Fluids contained in the digestive tract, cerebrospinal and synovial fluid, aqueous humor of the eye, bile, and renal filtrate compose transcellular fluid. The plasma pool normally represents approximately 5 to 7% of body weight, and the interstitial pool represents approximately 15% of body weight.

FATE OF INGESTED WATER

Recommendations for drinking water needs by several livestock species have been recently addressed.^[2] However, majority of water in the rumen seems to be derived from saliva. Saliva secretion by cattle depends on feed intake (thus, animal weight and stage of production) and dietary forage content and form, but can range from approximately 30 to 300 L/day. However, water is also transferred rapidly from plasma and other extracellular spaces to the gastrointestinal tract in ruminants during a meal.^[3] Limited data^[4] suggest that only 60 to 80% of water consumed by drinking may be delivered to the

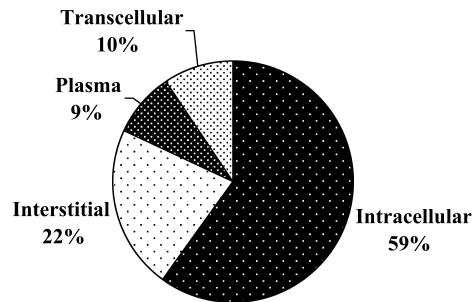


Fig. 1 Typical body water compartments (% of total body water).

rumen; the remaining proportion is presumably directed to the omasum. Within the remainder of the ruminant gut, quantitative net water absorption is greatest in the proximal small intestine, followed by the omasum and large intestine.^[5] Recent data^[6] indicate that the lower net water absorption in the large intestine by cattle than by sheep results from a reduced ability to retain absorbed water because more absorbed solvent/solute is drawn back into the lumen through the larger paracellular pores between colonic cells in cattle.

TRANSPORTATION-INDUCED DEHYDRATION

Transport of animals on semitrailer trucks from the site of birth to the site of growing and finishing can involve periods of up to 24 hours or more without access to water, and variable magnitudes of dehydration can occur. Feeder calves seem to lose approximately 3.3% of body weight during the loading and unloading process and can lose an additional 0.3 to 0.4% of body weight/hour of transport.^[7,8] Weight losses of feeder pigs during transport can be up to 0.6% of body weight/hour.^[9] Loss of gastrointestinal tract contents and carcass weight has accounted for 48 and 32%, respectively, of transport shrink by feeder steers^[8] and has accounted for 62 and 27%, respectively, of transport weight loss by feeder pigs. Feces, urine, and respiration accounted for 12.6, 26, and 60% of the water loss.^[10] Water accounted for 80% of weight lost by wethers during 48 hours of feed and water deprivation.^[11] Of total body water loss, 57% was from the intracellular compartment and 29% was from the gastrointestinal tract. In steers deprived of water for 4 days, thiocyanate space (assumed to be extracellular space) accounted for 47% of the weight lost (total loss=16% of body weight).^[12] Thiocyanate space decreased 23% and plasma volume decreased 28% during the 4-day period without water. The exchange of water within the body in response to dehydration is depicted in Fig. 2.

Water Mineral Composition

Drinking water is a source of various minerals that are generally readily available for absorption unless complexed by an interfering nutrient. Minerals ingested in water and feed are a variable mix of positively and negatively charged ions that contribute to the dietary cation-anion difference of consumed material (DCAD) and have a direct influence on fluid and acid-base balance. The DCAD is calculated as the milliequivalents (mEq) of Na^+ , K^+ , Ca^{++} , and Mg^{++} minus the mEq of Cl^- , S^- , and P^- .^[13] As anion consumption and concentration in the body increase, cellular acidosis can occur. As the DCAD increases from negative to positive (e.g., -20 to $+100$ mEq/kg), feed intake and performance are generally increased. However, the parturient dairy cow is one exception to the generalization. Inducing mild metabolic acidosis by feeding anionic diets before calving has been an effective means of preventing milk fever by potentiating calcium resorption from bone before the dramatic calcium needs at parturition arise.^[13]

Few data are available on the contribution of water minerals to overall DCAD. Socha et al.^[14] reported average mineral profiles of more than 3600 drinking water

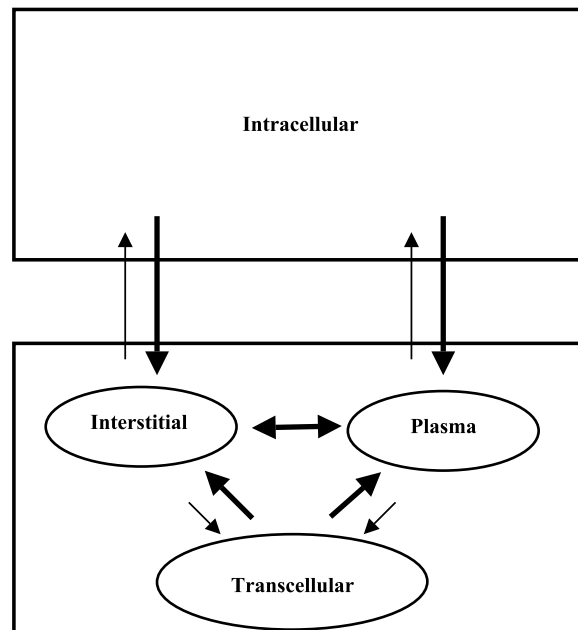


Fig. 2 Water change between body compartments during dehydration. Water is osmotically drawn from transcellular and intracellular compartments to interstitial and plasma compartments during dehydration, in response to losses by urinary and fecal excretion and insensible routes. The magnitude of reduction in compartmental volumes is dependent on the degree of dehydration.



samples collected across the United States. Assuming that a growing feedlot steer weighing approximately 300 kg and consuming 9 kg of a mixed diet (>85% dry matter) meeting mineral requirements would drink 30 L of water/day,^[2] this steer would consume twice as much weight in water compared to the weight of feed consumed, and approximately 3 to 7% of calcium, sodium, and sulfur consumed would be derived from water. However, approximately 20% of chloride consumed would be derived from drinking water in this example. The DCAD calculated for the surveyed samples^[14] was approximately 0.4 mEq/kg. Estimates of the contribution of drinking water minerals to overall DCAD are needed.

CONCLUSION

The polarity and ability of water to facilitate hydration of polar and ionic molecules are central to the flow of water and metabolites within the body. Saliva appears to be a greater proportion of ruminal fluid than previously thought, considering recent observations that some water consumed by drinking in nonsuckling cattle bypasses the rumen, but more intensive study is needed. The ability of sheep to form drier feces than cattle results from tighter junctions between colonic cells and a greater ability to establish an osmotic gradient to retain absorbed water. Cattle may lose approximately 3% of body weight during loading and unloading for transport, plus an additional 0.3 to 0.4% of body weight per hour of transport. Indirect data suggest that water may constitute up to 80% of this weight loss. Estimates of the contribution of drinking water minerals to overall cation–anion difference and of the influence of water cation–anion difference on animal performance are needed.

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