The Sheep

ANZCCART Facts Sheet

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Introduction

Sheep *(Ovis aries)* have been domesticated for over 10,000 years and figure prominently in the story of civilisation and human survival, as evidenced by numerous biblical references, religious practices and symbols and cultural rituals that involve this species, not to mention their importance to agriculture over several millennia. Sheep are widespread across the world, having adapted to many different climatic conditions and econiches (Ryder, 1983). During this century, sheep have also been the subject of considerable research from the viewpoint of physiological function and animal production, and after humans, dogs and cats have been one of the more studied mammalian species.

Many different breeds of sheep have evolved and intensive breeding for particular purposes has resulted in many strains. The size of different breeds of sheep varies, with typical body weights of ewes ranging from 30 kg for Welsh Mountain sheep, 45 kg for Merinos, 55 kg for Clun Forest breed, 65 kg for Cheviots, 75 kg for Dorset Horns and 90 kg for Lincolns (Hecker, 1983). It is worthwhile understanding some of the background of the various breeds of sheep and the specialisations which they may possess. For example, the ancestors of the Merino, famous throughout Australia as a producer of fine wool, derive from Spain and North Africa and are highly adapted to a hot arid environment. As such, they have kidneys capable of concentrating urine and therefore conserving water to a much greater degree than strains that evolved in colder climates of Northern Europe (McFarlane, 1968). Another well-known feature of the Merino is the copious folds of skin around its neck.

Sheep have been used as experimental subjects in such diverse fields of study as endocrinology and reproductive physiology, cardiovascular physiology, fluid and electrolyte homeostasis, immunology, neurophysiology and neuroanatomy, thermoregulation, haematology, ingestive behaviour, nutrition and gastro-intestinal physiology. In regard to the last, being ruminants with specialised four-chambered stomachs, sheep have been studied extensively in their own right, with much knowledge accruing in regard to ruminant nutrition and animal production. The study of the sheep foetus has also been extensive, and much of our knowledge of foetal physiology derives from these studies. Another aspect of the sheep is the availability of post-mortem sheep tissues from abattoirs. This has enabled the collection (in vast numbers) of organs such as the pituitary from the sheep, enabling the discovery and characterisation of a number of new hormones eg. the various hypothalmic releasing hormones which control the secretion of growth hormone, luteinising hormone and adrenocorticotropin.

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Advantages of using sheep for experimentation

There are several reasons why sheep make excellent experimental subjects for physiological studies. Their body weight and size approximates to that of a human, and they adapt rapidly and extremely well to a laboratory situation. In general they have a placid nature and relate positively to handlers and experimenters, possibly a result of their adaptation to domestication which has occurred over many generations. After an introduction of a sheep to the laboratory pen or metabolism crate, and one to two weeks of regular daily handling, patting and food rewards, together with the company of other sheep, there results a confident, unstressed, healthy animal, with a strong bond often developing between sheep and experimenters. This enables experiments investigating physiological function in conscious, unstressed animals to be performed successfully. The size of the sheep enables ease of introduction of catheters or cannulas (using either local or general anaesthesia) into various blood vessels, bladder, rumen, salivary duct or cerebral ventricles for the purpose of obtaining samples of blood or other body fluids for chemical analysis. Their size also enables sufficient blood to be withdrawn for chemical and hormonal analysis with minimal effects on cardiovascular function, which is not always possible in small rodents. Sheep recover robustly from anaesthesia and experimental surgery and provided appropriate care is taken are not usually troubled by post-operative or post-experimentation infection (Hecker, 1974). Great care is necessary in preserving asepsis when the brain or foetus are involved in order to avoid life-threatening infections. Compared to rodents, sheep are long-lived and in this country are relatively inexpensive for their size. With the provision of adequate food and water, well-maintained and well-cleaned facilities, and sympathetic handlers and experimenters, sheep can thrive in a laboratory and thoughtful, well executed experiments can yield a wealth of physiological information relevant to human and animal physiology and medicine.

Nutrition

Apart from being adequate in amount and composition to meet requirements for protein and energy, feed for sheep must also satisfy a set of interrelated behavioural and physiological factors. Ruminants have cyclical activities which are geared to demands for water and food and the repose necessary for the processes of rumination and digestion. Sheep apply an impressive array of behavioural adaptations to their herbivorous mode of life. For example, their exploration of feed and their learned and innate preferences and selectivities are being investigated only now but should be borne in mind in the laboratory environment.

Sheep possess a complex digestive system to deal with their mixed diet of digestible plant components and relatively indigestible cellulose. Feed takes 25-35 hours to pass through the gut and is exposed to microbial fermentation in the rumen during this time, which provides micro-organisms and the products of cellulose breakdown for digestion. Sieving processes are involved, with large particles being regurgitated for re-mastication by the process of rumination (or ‘chewing the cud’) and smaller particles of less than one to two mm passing into the stomach. Sheep ruminate for six to seven hours per day and this readily observable activity is a guide to health and well-being. Side benefits of ruminal fermentation include accessory food factors such as water-soluble vitamins and protein elaborated by microbes from simple nitrogen compounds.

Feeding standards for sheep have been published in the UK, the USA and Australia. The Australian treatise (Corbett, 1990) has a comprehensive experimental and theoretical framework. Requirements of digestible organic matter, energy, crude protein and bypass protein, fibres, minerals and vitamins given in these standards are average values. Under practical conditions, however, individual responses of sheep must be accounted for and animals have to be fed according to effect.

Two simple and well accredited rations for laboratory sheep are a 50% mixture of lucerne and wheaten chaff, and a pelleted ration composed of lucerne chaff (50%), wheat grain (10%), bran (18%), pollard (20%), and crude salt (2%) (to control urinary calculi by increasing fluid intake). Although lucerne chaff is valuable for its high concentration of calcium as well as protein, its quality can vary considerably and is a factor to consider if performance is unexpectedly low. In most other rations, calcium demands have to be met by the addition of ground limestone. Nutritional deficiencies have not been observed with the two rations described above. A guide to the weekly feed requirements for maintenance of different classes of sheep is given in Table 1.

Table 1

Class of sheep	**Hay**	**Oats**	**Wheat**
	kg	kg	kg
Weaners	4.0	2.6	2.2
Adult dry sheep	5.4	3.5	3.0
Ewes in late pregnancy	7.4	4.9	4.1
Lactating ewes	14.0	11.0	9.5

The maintenance requirement for a 35 kg wether is 5.2 megajoules per day. This is provided by a weekly intake of 2.8 kg of maize, 3.0 kg of either wheat, barley or sorghum or 3.6 kg of oats, which indicates the relative energy of these grains. At a practical level, the addition to these grains of 15% by weight of lupins gives an impressive lift in feed value because of its high content of non-degradable or bypass protein. Factors such as adequate trough space to prevent competition and storage conditions to protect feed against contamination are important components of good feeding practice. Work on the effect of olfaction on feed selection in the USA has shown that only 5% of feed contaminated by faecal odours of coyote, fox or cougar was eaten compared with 95% of similar pellets without contamination.

Some merino sheep can survive for up to 10 days without water and can lose one-third of their liveweight in the process. Requirements range from 2.4 litres per day for growing sheep of 30 kg body weight to 12 litres per day for 60 kg ewes in early lactation. Water requirements for sheep in the laboratory are met by *ad libitum* access to clean water. The same imperatives apply whether troughs or self-drinkers are used. Water must be clean, free-flowing and algae-free throughout the animal house. Faecal contamination and faecal odours may inhibit drinking and predispose to urinary calculi. Water supply throughout a sheep house must be able to cope with peak demand on a hot day.

Housing

Sheep breeds vary widely in their capacity to adapt to heat and cold. Like all mammals, sheep are forced to increase heat production to maintain core body temperature as environmental temperature drops. The critical temperature at which this occurs varies from 0^0C for adult sheep in full fleece to 20-25^0C for newly shorn animals to 30-36^0C for new born lambs. Shorn adult merinos can bring peak metabolism into play to withstand ambient temperatures of -60^0C. At the other extreme, merinos are farmed for wool production under dry conditions with peak daily ambient temperatures of 49^0C. Coping mechanisms are stretched to withstand these extremes and give no guidance to the conditions required in sheep houses.

Sheep can be housed simply but require full protection against wind, rain, extremes of temperature and humidity. Timber, even though rough-cut bush timber, can be used for construction and is probably superior to metal. However, it may not be acceptable for housing off-farm where presentation is important. Fittings must not provide injurious hazards when sheep are being moved. The commonly available metal floors are unsuitable for long term housing of sheep because sheep become footsore on them and show hesitancy in moving and lying down. Traditional slatted hardwood floors as used in shearing sheds are satisfactory and superior to concrete. One consideration is to have slats run opposite to, and not parallel with, the direction in which sheep move in lanes. If sheep gain the impression of height, they baulk.

Space allowance should be determined from basic principles. Areas of 1.2 square metres per sheep are suggested as a guide. However, literal application of space allowances is an undesirable scenario for developing considerate animal care because it diverts attention from the animals themselves. Unless there are specific experimental requirements, sheep ought to be able to move around in an individual pen and be able to lie in an orientation they choose. Groups of more than 12 in a pen may lead to erratic results in experiments. Groups of eight may be acceptable. Experiments in which groups of 50-60 sheep are held in single large pens are probably invalid because of the behavioural tensions which occur.

In spite of possessing a fleece, sheep have limits to their heat and cold tolerance. Roof extractor fans are important for the summer heat. Sheep should not be housed in contact with corrugated iron walls that face the summer sun. Even sheep which are fully fleeced will die if exposed to cold wet winds. Thought must be given to sleet and gales blowing up though slatted floors.

Management

Virtually all sheep in Australia have fleeces rather than hair and must be shorn each year. If housed sheep are dipped immediately after shearing to control lice, mortalities of 10-15% from septicaemia can be expected and the surviving sheep will have hepatic, splenic and pulmonary abscesses.

Overgrown hoofs occur when sheep are housed. Trimming should cause no bleeding and conform to the anatomy of the foot so that sheep can stand and walk normally. Feet bleed when the living tissue involved in the hoof growth tissue is cut and healing of this damaged tissue will distort the foot. Competent trimming and inspection of feet cannot take place unless the sheep is held in a cradle.

Diseases

Sheep may be affected by many different diseases of an infectious, parasitic, nutritional or neoplastic nature. It is beyond the scope of this article to examine these. Disease is not a major concern in well-housed sheep which have been vaccinated against the common clostridial diseases and are free of footrot and lice at the outset. However, sheep in sheep houses can become fly-blown. Infection with *Strongyloides papillosus* can occur where animals are held on concrete which is hosed down and there is a reservoir of this nematode parasite in the cohabiting population of rats. Posthitis can be a problem and requires early intervention where it occurs. Urolithiasis occurs relatively frequently in some animal houses and should prompt a complete review and overhaul of the watering system to ensure that sheep have access to abundant clean, cool water.

Dietetic disorders can occur in housed sheep and are most commonly associated with high grain diets, which entail the risk of lactic acidosis, particularly if sheep unused to grain are allowed to engorge. Some animals appear to be incapable of adapting to pelleted rations with a high grain content. Copper toxicity has been reported in housed sheep and can be controlled by access to soil to provide molybdenum. For further information see Brightling (1988) and Blood and Radostits (1989).

Zoonoses

A few diseases can be transmitted to people who are in contact with sheep tissue or in the environment of sheep. These include Q-fever (a respiratory disease which may have life-threatening consequences) and scabby mouth, a mild skin eruption. The dog tape worm *Echinococcus granulosus* can infect various organs of the sheep. The cysts in sheep are harmless to humans, but sheep offal should not be fed to dogs. For further information on zoonoses of sheep and other species see Stevenson and Hughes (1988).

Anaesthesia and some general experimental techniques

Sheep respond well to and recover quickly from general anaesthesia. General anaesthesia can be induced by an injection of sodium thiopentone (19 mg/kg body weight), into the jugular vein and after intubation of the trachea, anaesthesia can be maintained at the correct depth for several hours by inhalation of a gas mixture of either isoflurane or halothane with air/oxygen. Prior to general anaesthesia, animals should be deprived of water and food for 24 hours to limit regurgitation. The most convenient blood vessel for making an intravenous injection or for obtaining blood samples is the jugular vein. It is important to make sure that this region of the neck has been well shorn. Skin should be cleaned and sterilised before needles are inserted into the vein. An iodine-alcohol solution is satisfactory for this purpose and as a surgical skin preparation. Indwelling venous cannulas can also be conveniently inserted into the jugular vein through a needle. Local anaesthesia around the point of insertion should be utilised when larger gauge needles are introduced into a vein. Indwelling cannulas should be removed as soon as possible after use to minimise thrombus formation. Urine may be continually collected from a retention catheter inserted into the bladder. By using a speculum to expose the urethral opening, bladder catheterisation is a simple procedure in ewes, but catheters should not be left in the bladder for more than 2-3 days as discomfort will ensue. Saliva from the parotid duct may be continually sampled from a polyethelene cannula inserted into the parotid duct and brought to the surface through the cheek (Abraham *et al*., 1976).

A number of surgical procedures have been adopted successfully in sheep to prepare them for experiments some weeks later. These preparations allow access to blood vessels or specific organs in the conscious, undisturbed animal during experiments. For example, the carotid artery (s) can be enclosed in loops of skin in the neck (Denton, 1957), allowing access to arterial blood for sampling or for easy measurement of arterial blood pressure. The copious skin folds of the neck of the Merino make this breed or its cross-breeds ideally suited for this purpose. This also applies to autotransplantation of glands such as the adrenal gland (Goding and Wright, 1964) or ovary (Goding *et al*., 1967) into the neck for ease of access. This technique has been utilised successfully for studying adrenal and reproductive physiology of sheep. Stereotaxic frames (Radford, 1967) and atlases (Richard, 1967; Welento *et al*., 1969; McKenzie and Smith, 1973) have also been described for use in neurophysiological studies in sheep, and cerebrospinal fluid samples can be obtained or intracerebroventricular infusions made through guide tubes permanently implanted into the lateral or third cerebral ventricles or cisterna magna (Mouw *et a*l., 1974). Rumen fistulae can be prepared to gain access to the rumen (Hecker, 1974).

Euthanasia can be performed by intravenous injection of sodium pentobarbitone (at least 100 mg/kg).

Table 2. Useful physiological data on sheep. Some data have been adapted with modifications from Hecker (1983) and Scoggins et al., (1984)

Heart rate	50-80 beats/min
Maximum heart rate	260-280 beats/min
Mean arterial pressure	70 mm Hg
Cardiac output	115-133 ml/kg/min
Stroke volume	74 ml/beat
Extracellular fluid volume	246 ml/kg
Plasma volume	37 ml/kg
Blood volume	49 ml/kg
Interstitial fluid volume	190 ml/kg
Packed cell volume	20-45%
Haemoglobin	9-15 g/100 ml
Whole blood clotting time	7-13 min
Rectal temperature	38-39.5^{0}C
Respiratory rate	15-40 breaths/min
Maximum respiratory rate	350 breaths / min
Respiratory dead space	100 ml
Tidal volume	4-9 ml/kg
Glomerular filtration rate	1.2 ml/kg
Effective renal plasma flow	7.6 ml/kg

Table 3. Concentrations of some ions and molecules in plasma, cerebrospinal fluid (CSF), parotid saliva and bile of sheep. Some measurements were adapted with modifications from Hecker (1983) and Scoggins et al., (1984).

	Plasma	CSF	Parotid saliva	Bile
Sodium mM	142-148	150	30-185	150
Potassium mM	4.0-5.0	2.8	4-100	4.2
Calcium mM	2.4	1.2	0.2	-
Magnesium mM	0.9	0.9	-	-
Chloride mM	105-110	131	9-16	118
Bicarbonate mM	27	24	103-125	-
Phosphate mM	1.5	0.4	25-64	-
Osmolality mosm/L	290	290	284	-
Glucose mM	3	3		
pH	7.42	7.45	8	-

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