Australian Government

Rural Industries Research and Development Corporation

Effect of salt intake
on feed intake and growth rate of fallow and red weaner deer

A report for the Rural Industries Research and Development Corporation

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April 2004

RIRDC Publication No 04/054
RIRDC Project No SAR-26A

ISBN 0 642 58764 7
ISSN 1440-6845

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Published in April 2004
Printed on environmentally friendly paper by Canprint

Foreword

Dryland salinity is a significant problem in southern Australia with a large area of land being affected. The high evaporation rate in summer results in saline drinking water for grazing animals. In these environments animals can ingest excessive amounts of salt from forage, drinking water and soil, leading to a reduction in growth rate. Studies were undertaken to assess salt tolerance of red and fallow deer and develop management strategies to avoid excessive intake of salt by deer.

The studies have shown that fallow weaner deer can tolerate up to 3% salt in feed when fresh water is available or 1.2% of salt in drinking water. Growth rate can be depressed when salt concentration in water is 1.5% for fallow weaners. Feed intake of red deer declines by 14% when the salt level in the diet increases from 1.5% to 6.0%. Providing drinking water containing 1.0% salt significantly reduces body weight gain of red weaner deer.

These data can be used as guidelines by deer farmers to manage deer on saline water and/or salty feed, especially in the salt-affected areas. It is suggested that deer farmers should monitor the general health of deer and regularly test the salt level in forage and drinking water to ensure guidelines for salt intake are met.

This project was funded from industry revenue which is matched by funds provided by the Australian Government and is an addition to RIRDC's diverse range of over 1000 research publications. It forms part of Deer R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian Deer Industry.

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Dr Simon Hearn
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Acknowledgments

The authors are grateful for the following support;

- Funding from the Deer Program of the Rural Industries Research and Development Corporation.

- Mr Michael Fischer, Mr Geoff Wyatt, Mrs Sandy Wyatt and Ms Kylee Swanson (SARDI-Livestock Systems) who conducted field trials and chemical analysis of pasture samples.

- Dr Zhihong Miao who assisted in literature review.

- Mr Maurice Malycha, Mr Andrew Polkinghorne and Mr Ian Rice (Farm Services, University of Adelaide) for their assistance in deer management and maintenance of the research equipment on the Roseworthy Deer Industry Farm.

- Mr Chris Tuckwell, Deer Industry Projects and Developments Pty Ltd, for his valuable advice during the project.

List of Abbreviations

Al	Aluminium
B	Boron
Ca	Calcium
Cd	Cadmium
Co	Cobalt
Cu	Copper
DE	Digestible energy
DM	Dry matter
Fe	Iron
K	Potassium
ME	Metabolisable energy
Mg	Magnesium
Mn	Manganese
Mo	Molybdenum
Na	Sodium
NaCl	Sodium chloride
Ni	Nickel
P	Phosphorus
S	Sulphur
Zn	Zinc

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Publications Arising from This Study

Ru, Y. J., P. C. Glatz and Z. H. Miao (2000). Impact of salt intake on red and fallow deer production in Australia (A Review). *Asian-Australasian Journal of Animal Science* **13**, 1779-1787.

Ru, Y. J., M. Fischer, P. C. Glatz, W. K. Peng and Y. M. Bao (2003). Effect of salt level in the feed on performance of red and fallow weaner deer. *Asian Australasian Journal of Animal Science* (submitted)

Ru, Y. J., M. Fischer, P. C. Glatz and Y. M. Bao (2003). Effect of salt concentration in water on feed intake and growth rate of fallow weaner deer. *Recent Advances in Animal Nutrition in Australia.* Vol. 14, pp. 1A.

Executive Summary

Under a typical mediterranean environment in southern Australia, the evaporation rate increases significantly in hot summers, resulting in highly saline drinking water for grazing animals. Also in the cropping areas, dryland salinity is a problem. Grazing animals under these environments can ingest excessive amount of salt from feed, drinking water and soil, which can lead to a reduction in growth rate. To understand the impact of high salt intake on the grazing deer, experiments were conducted to assess the effect of salt levels in feed or drinking water on feed intake and growth rate of red and fallow weaner deer.

Fallow weaner deer were offered lucerne chaff containing 0, 1.5, 3.0, 4.5 and 6% salt with fresh water being available *ad libitum*. Increasing the salt level in the diet from 0 to 6% did not affect feed intake, osmotic pressure and mineral concentration in blood of fallow deer, but deer drank more water to regulate their sodium metabolism. Body weight tended to be lower ($P=0.056$) for fallow deer when salt content was over 3%, suggesting fallow weaner deer can ingest over 15 g sodium/day without significant depression in both feed intake and growth rate if fresh water is available. While feed intake and blood osmotic pressure were similar ($P>0.05$) for red deer fed different levels of salt, feed intake declined from 1.91 to 1.67 kg/day as salt level in the diet increased from 1.5% to 6.0%. However, the decline in feed intake was not reflected in body weight gain. More comprehensive research is required before recommendations on high levels of salt intake can be made to the industry.

Fallow deer did not show any abnormal behaviour or sickness when salt level in drinking water was increased from 0-2.5%. Feed intake was not affected until the salt content in water exceeded 1.5%. Body weight gain was not affected by 1.2% salt in drinking water, but was reduced as salt content in water increased. These results suggest that fallow weaner deer can tolerate a salt level of 1.2% in drinking water.

Compared with deer on fresh water, the feed intake of red deer on saline water was 11-13% lower when salt level in drinking water was 0.4-0.8%. An increase in salt level in water up to 1% resulted in about a 30% reduction in feed intake ($P<0.01$). Body weight gain was significantly ($P=0.004$) reduced when salt level reached 1.2%. The deer on 1% salt tended to have a higher ($P=0.052$) osmotic pressure in serum. The concentration of P, K, Mg and S in serum was affected when salt level in water was over 1.0%.

The data obtained during this project also demonstrated that the data on salt tolerance derived from sheep may not be valid for deer and that a difference between red and fallow deer exists. When fresh water is available, fallow weaner deer can consume feed containing 3% salt. To maintain healthy growth, fallow weaner deer can tolerate 1.2% salt in the drinking water, but the red weaner deer can only tolerate 0.8%. The growth rate can be depressed when salt concentration in water is 1.5% for fallow weaners and 1.0% for red weaner deer.

The data obtained in this study can be immediately adopted by the deer farmers as guidelines for preventing excessive salt intake during the season. Farmers should not feed fallow deer feed/forage containing over 3% salt even if fresh water is available. The salt level in drinking water should be lower than 1.2% for fallow weaner deer and 0.8% for red weaner deer to avoid any reduction in feed intake. Deer farmers need to regularly test the salt levels in drinking water and forage on their farms to ensure that the salt intake of grazing deer is not over the levels that deer can tolerate.

1. Introduction

1.1 Background to the Project

Sodium is one of the main macro minerals required by animals, and plays an important role in maintaining osmotic pressure, rumen pH and regulating the volume of fluid in the body (Xu et al., 1994). For optimum growth, reproduction and other physiological functions, adequate amounts of sodium need to be supplied through feeds, drinking water and other sources. NRC (1980) reported that minimum concentrations of sodium in the diet are 0.7-0.9 g/kg DM for sheep, and 0.8-1.2 g/kg DM for cattle, with a significant variation between animal species, breeds within species, and maturity status. There is no data available on the sodium requirement of grazing deer, which is a significant disadvantage for deer producers in Australia. Farmers require information on sodium requirement of deer and the effect of high sodium intake on deer production, especially in southern Australia.

1.1.1 Environment conditions in cereal cropping areas in Australia

Southern and south-western Australia is a typical Mediterranean environment. The annual rainfall in this area ranges from 200 mm to 1000 mm, with 85% of the rain falling in winter. The distribution of annual rainfall exhibits marked variation between years and locations (Bellotti et al., 1992). For example, Geraldton receives 80-85% of annual rainfall in the growing season, but Merredin, Clare, Walpeup and Horsham receive about 66%, 61%, 59% and 58% of the annual rainfall during the growing season respectively. The temperature ranges from 9 ^oC in winter to above 40 ^oC in summer. Mid-winter temperatures are mild (12-15^oC) and mid-winter radiation levels are low, ranging from 9 $MJ/m^2/day$ to 11 $MJ/m^2/day$ (Perry, 1989). Evapotranspiration rates vary more in summer than in winter, contributing to the salinity problem in the cropping areas.

In the summer rainfall region, covering north-eastern region from central New South Wales to Queensland, rainfall is higher than in the south and increases in both amount and summer dominance to the north. For example, the average annual rainfall for Dubbo, Narrabri, Dalby, and Biloela are 531, 662, 614, and 705 mm, with 42%, 38%, 29% and 19% falling in the winter (May-October) growing season, respectively. Mid-winter day temperatures range 15-19 ^oC. Southeastern Australia is a high rainfall zone, with a significant amount of rainfall in both summer and winter. Mid-winter temperatures are about 10-12 ^oC and radiation levels range from 7 $MJ/m^2/day$ to 9 $MJ/m^2/day$ (Perry, 1989). However, the maximum temperatures in these regions can exceed 40 ^oC, with 20-40 days per year having a maximum temperature over 35 ^oC (Anon, 2000).

In the cropping region, there is a large amount of land with high salinity. In Western Australia in 1980, 263000 ha was salt-affected land with a further 2.45 million ha having the potential to become salt-affected (Henschke, 1980; Anon,1988a). By 1989, 315000 ha was salt-affected (Malcolm, 1989). Salinity also threatens 385 000 ha in Victoria (Anon, 1989), and 2.2% of the state in New South Wales (Anon,1988c) and affected 210,900 ha in South Australia (Anon, 1988b). Salt affected soils range from sands to clays and include all grades of soils. Except for the most acidic soils, all soils can grow *Puccinellia ciliata*, *Atriplex spp. Halosaarcia spp.* and *Maireana brevifolia* or combination of these species (Malcolm, 1989). The Department of Agriculture, Western Australia recommended strawberry clover, salt water couch, puccinellia, barley grass, tall wheat grass, saltbushes and others for soils with different salinities (Table 1, Malcolm, 1986).

Table 1. A guide to selecting salt tolerant forage plants for saltland types in the agricultural areas of Western Australia *

Saltland type and condition			Site severity		
			Mild	Moderate	Severe
Hillside seepage	Soil surface wet in summer		Strawberry clover, Paspalum, Couch, Kikuyu	Salt water couch	Salt water couch
	Soil surface dry in summer		Puccinellia, Barley, Tall wheat grass	Puccinellia	Puccinellia
Saline valley floors	Rainfall >375 mm		Puccinellia, Barley, Tall wheat grass	Puccinellia, Saltbushes**	Samphire
		Commonly flooded	Saltbushes, Puccinellia, Barley	Saltbushes, Puccinellia, samphire	Samphire
	Rainfall <375 mm	Seldom flooded	Barley, Bluebushe, Puccinellia, Saltbushes	Saltbushes, Bluebush, Puccinellia	Saltbushes, Samphire, Puccinellia
Dryland salinity	Rainfall <375 mm	Never flooded	Barley, Bluebush, Saltbushes	Bluebush, Saltbushes	Bluebush, Saltbushes

* The recommended plant is underlined. Others listed are also capable of reasonable growth,
** Saltbushes are only recommended in areas with less than 500 mm annual rainfall.
*** Source: Malcolm (1986)

1.1.2 Distribution of red (cervus elaphus) and fallow (dama) deer in Australia

Seventeen species or subspecies of deer were introduced into Australia during the last century by Acclimatisation Societies. Of these, only fallow, red, rusa, sambar, chital and hog remain today (SCA, 1980). While there are no accurate estimates of feral and farmed deer in Australia, the figures published in 1980 by the working party appointed by the Animal Production Committee of the Standing Committee on Agriculture are a reasonable guide.

Feral deer

There is a lack of accurate information on the total population of the feral herd. However, there are about 20,000 fallow and 11,000 red deer distributed in Australia. The largest populations of fallow deer are in Tasmania, with the rest being in South Australia, Victoria, New South Wales and Queensland. Two major feral populations in New South Wales are located at Rangers Valley in the Glen Innes district and Lake George on the South Tablelands. In South Australia, feral fallow deer are distributed in the Adelaide Hills and in the South-East. In Queensland, fallow deer are confined to the west of Stanthorpe between Pikedale and the Severn River, and the area between Warwick and the Dividing Range (SCA, 1980). Fallow deer are the most widespread and numerous in Australia.

Red deer have adapted to most environments and have adjusted from the sub-tropics to the temperate zone, from sea level to 1800 m, from near-desert conditions to more than 760 cm of rainfall, and from forests to open plains. Red deer are most numerous in the Brisbane River Valley of Queensland, the Mudgee-South Coast area of New South Wales, the Grampians of Victoria and in the Pinjarra region of Western Australia and the ACT (Anderson, 1984).

Farmed deer

While there are more than 40 recognised species and numerous subspecies of deer through the world, many are not suitable for modern agricultural husbandry and must be kept in an open environment. Farmed deer in Australia are limited to the six existing species, and estimated at 2,000 head on 300 farms in 1985 (Mackay, 1985) and 160,000 head in 1998 (Mackay, 1998). Of these 40% are red, 50% are fallow with 10% of other species. However, fallow deer are dominant species in New South Wales, Tasmania, Western Australia and South Australia, but Queensland has more red deer (English, 1984). The number of red deer has increased dramatically in South Australia over the last few years.

1.1.3 Salt intake of grazing deer

Animals can ingest salt from water, pastures, soils (Wilson, 1978) and other mineral supplements, making it difficult to quantify the salt intake under grazing conditions. Salt intake of grazing animals is often influenced by environmental conditions (temperature, rainfall), pasture management (grazing intensity, fertiliser application), and animal factors (maturity stage, selective grazing, species or breed etc.).

Pastures

Under a Mediterranean environment in southern Australia, pastures are dominated by annual species such as medics, subterranean clover, ryegrass and barley grass etc. During the vegetative stage, pastures generally have a low sodium content (Xu et al., 1994), which increases with plant maturation. Ru (1996) reported that sodium content (on dry matter basis) in subterranean clover increased from 0.3-0.5% in August to 0.8-1.6% in November, with a large variation among cultivars. Clover seeds have a low sodium content (0.06-0.11% dry matter).

In the cropping areas affected by salt, puccinillia (*Puccinellia ciliata*), tall wheat grass (*Thinopyrum ponticum*) and Chenopodiaceous plants (e.g. *Atriplex, Kochia and Bassia spp*) have been planted for the improvement of soil condition due to their low transpiration rate, high efficiency of water use, drought and salinity resistance (Sharma, 1978; Wilson, 1978; Leigh, 1986; Barrett-Lennard, 1999).

Puccinellia which originated from the west coast of Turkey, is a winter active perennial grass suited for saline and waterlogged land. It grows in areas with 300 mm or more annual rainfall and performs better on alkaline soils than on acid soils. This pasture is the key to production of grazing animals on salt affected land in Eyre Peninsula and in the Upper South East in South Australia. The dry matter digestibility of *Puccinellia* is over 70% during September and November, and protein content declines from 22% in September to 15% in November. While few grazing data are available, the palatability of this pasture varies between varieties. For example, Rottnest Island prostrate ecotypes are highly unpalatable, whereas the prostrate ecotype from Geraldton is highly palatable (Barrett-Lennard, 1999). Tall wheat grass, originated from Balkans, Asia Minor and southern Russia, is adapted to highly alkaline soils and salt seepage areas. It is less tolerant to salinity than *Puccinellia*. It grows in warmer months and requires a heavy rotational grazing system. It is only moderately palatable (Nichols, 1998). While it has been reported that on saline soils there are increases in salt uptake and in salt concentrations in the plant materials, and the increased salt concentrations in the shoots of waterlogged plants have adverse effects on plant growth and survival in the longer term (Barrett-Lennard and Nulsen, 1989), there is limited information on the salt intake of animals grazing these pasture species.

Chenopodiaceous plants supply a large amount of forage during drought periods and have remarkable capacity to remain leafy and viable under high radiation and temperature levels (Sharma, 1978). The common feature of *Atriplex* leaves is their vesiculated hairs, which are extremely rich in salt and perform functions such as absorption of water from the atmosphere, water storage, insulation against transpiration and salt secretion (Wood, 1925; Mozafar and Goodin, 1970). These shrubs are grazed by sheep and cattle, and the intake of *A. nummularia* (oldman saltbush) was sufficient to maintain sheep and to allow a small gain in weight. The bodyweight production per unit area was similar for sheep and cattle, but sheep selected more green grass than cattle which ate more dry grass and saltbush (Wilson, 1966a). While proximate analyses of the leaves of these shrubs show that they are high in crude protein and ash during summer, the high ash content up to 30% of the dry matter is a disadvantage, as high salt intakes may be detrimental to grazing animals (Wilson, 1966a; Wilson, 1978).

There is a variation in nutritional quality among species of saltbushes. Leaves of saltbushes have a crude protein content of 16.7-25.2%, crude fat of 1.0-1.6%, crude fibre of 7.8-10.4% and ash of 18.5-27.2% on a dry matter basis. Sodium content ranges 0.2-5.6% on a dry matter basis. Digestible dry matter ranges from 74.5% to 78.8% and digestible energy from 13.4 MJ/kg to 14.2 MJ/kg (Khlil et al., 1986). Rehman (1992) also found that among 8 saltbush species, the dry matter digestibility ranged from 33% to 62%, and nitrogen digestibility varied from 51% to 81%. Crude protein content in dry matter varies from 10% to 20% and ash content from 13% to 23%. There was no correlation between preference of sheep and the content of crude protein, ash content or sodium content of saltbush samples. The sodium content in saltbush is much higher than the 0.06% level recommended for beef cattle (NRC, 1976); the level of 0.5% recommended for goats (NRC, 1981) and 0.04-0.1% recommended for sheep (NRC, 1975). The digestible energy content is higher than those required to meet the needs of dry (9.2 MJ/kg) and lactating (10.5 MJ/kg) cows (NRC, 1976) and can meet the requirement of sheep and goats (NRC, 1975; 1981). However, the nutritional value of these bushes for deer and the impact of sodium content on deer production are not clear.

Water

Surface water supplies are not regarded as a major source of minerals for the grazing animal. However, evaporation, which is more significant in summer, from streams and lakes results in a concentration of the dissolved solids. Land management strategies also affect the salinity of surface water available for grazing animals. For instance, the replacement of deep-rooted trees by shallow rooting grasses in the clearing of native forests for agriculture in south-west Western Australia increased stream salinity. During the irrigation season, the concentration of salts may increase significantly in drought periods following prolonged floods (Anon, 1976). In the field situation, evaporation from troughs in summer can cause an increase of 10% in concentration of salts even though the troughs are cleaned regularly (Wilson, 1978).

Groundwater is more saline than surface water because it is in contact with soil and rock for longer periods and has been concentrated by plants through transpiration. Judson and McFarlane (1998) indicated that the quality of underground water is variable and significant quantities of Na, Ca and Mg salt may be consumed by grazing animals. Bore water in the Northern regions of Australia usually contain less than 5,000 mg/litre of total dissolved salts whereas in the southern parts of the country concentrations are in excess of 10,000 mg/litre of total dissolved salts. This concentration is near the maximum tolerable concentration for mature non-lactating livestock (Judson and McFarlane, 1998).

Holmes and Waterhouse (1983) reported typical concentrations of Na, Ca and Mg in groundwater from selected sites in the southeast of South Australia. The data indicate that water with the higher cation concentration could provide about 20-100% of Na and about 5-20% of the daily Ca and Mg needs of the mature animals. Total salinity is higher in summer than in winter (Table 2). However, in many places, especially in northeastern and central Australia, the salinity of ground water is unknown (Anon, 1976).

Table 2. Representative analyses of water in the southeast of South Australia (Holmes and Waterhouse, 1983)

Source	Main cations (mg/litre)			Total salinity (mg/litre)
	Na	Ca	Mg	
Unconfined aquifer, Mt Gambier	81	113	18	690
Coastal Spring, Ewens Ponds	46	73	20	387
Confined aquifer, Mt Gambier water supply	115	71	30	612
Unconfined aquifer, Padthaway	453	109	63	1678
Groundwater drain				
July	192	65	38	855
December	333	45	58	1224

Soils

Livestock cannot avoid ingesting soil during grazing. Factors influencing an increase in ingestion of soil are high stocking rates, areas of poor drainage, poor pasture growth, feeding root crops or grain supplements in mud or dust, and when stock are grazing stubbles and subterranean clover pasture where grain and clover burr are buried. On short pastures, cattle can ingest over 100g soil/kg herbage DM (Dewes, 1996) and sheep up to 300g soil/kg herbage DM (Thornton, 1983). Under normal grazing conditions, ingested soil can be a source of more minerals than ingested pasture (Healy, 1973). No studies have been undertaken to determine the intake of soil by deer while grazing.

1.1.4 Impact of salt intake on animal production

The salt intake has to match the requirement of deer for optimum production. It has been shown that sodium deficiency influences pasture selection and appetite, and increases appetite for salt or salty foods (Blaxter et al., 1974). Research conducted at the Rowett Research Institute also indicated that when supplementing sodium with salt blocks on pastures with low sodium content, stags licked salt blocks and hinds sometimes drank the urine of their sucking calves to increase their sodium intakes. The ratio of sodium and potassium is a valid index of sodium status in deer as in sheep (Blaxter et al., 1974). While there is little data available demonstrating the effect of sodium deficiency on deer production, research with other livestock species shows that growth rate, feed utilisation efficiency and milk yield can be depressed if sodium is limiting (Xu et al., 1994).

Although there are no reports on the impact of excessive sodium intake on the performance of grazing deer, the effect of high sodium intake on water intake, feed intake and consequently animal production of other livestock species such as sheep has been studied comprehensively.

Water intake

The water intake from forages of grazing animals is dependent on ambient temperature, forage moisture and forage mineral content. Inglis (1985) reported the normal water intake of animals (Table 3), but the type of diet has a significant influence on water requirement (Inglis, 1985; Wilson and Hindley, 1968). For example, water intake of red deer varies from 0.27 litre/kg DM intake for a grass diet to 3.82 litre/kg DM on concentrated pellets (Bonengel, 1969). Fallow deer require less water per unit of feed intake (Denholm, 1984).

Table 3. Normal water intakes of animals (Inglis, 1985)

Animal		Daily consumption (litres/day)
Merino ewe		Up to 3.7 in summer; 1.6 average over a year
Beef cow		Up to 53 in summer; 35 average over a year
Dairy cattle		70
Horses		45
Pigs		
	Sow and litter	23-27
	Sow (pregnant)	11-14
	Grower 23 kg	3-5
	45 kg	7
	68 kg	9
	90 kg	11
Poultry (100 birds)		
Laying hens		33
Broilers		30 (higher now)

Ingestion of excess sodium by stock may lead to a higher water requirement and a decreased tolerance to saline drinking water, especially in the salt affected cropping areas. In these regions saltbush and bluebush may comprise part of the available feed and stock are dependent wholly or partially on salty water. It was evident that when grazing saltbush, water intake of sheep increases. The maximum water intakes varied from 4 litre/day in the summer of a good season to 12 litre/day during a drought (Wilson, 1978).

Rumen digestion
Over 90% of the ingested sodium is excreted in the urine (Wilson, 1966b), and the kidney maintains fluid and electrolyte balance in animals drinking salty water, if sufficient fresh water is available. However, the digestive system is unable to cope with a large volume of saline water ingested to maintain fluid balance (Wilson and Dudzinski, 1973), and can lead to a higher osmotic pressure and a lower microbial population and activity in the rumen as found in sheep (Potter et al., 1972). The degree of change in osmotic pressure, microbial population and activity depends on the type of ration. For example, sheep have a higher tolerance to saline water when fed on lucerne chaff than on oaten chaff (Wilson and Dudzinski, 1973). There is no quantitative information on the effects of high sodium intake on the digestion in the rumen, but Elam (1961) recorded an increase in the rate of passage of feed through the gut when salt was added to the diet.

Feed intake and animal production
While there is no data on the feed intake and growth rate of deer at different levels of salt intake, studies with other animal species shows that increasing salt intake often leads to a higher water requirement and a reduction of feed intake, especially in hot weather, on saline vegetation or on a poor quality ration. Wilson (1966b) reported that the addition of 0.9 or 1.2% sodium chloride to the drinking water for sheep fed saltbush diets caused a marked decrease in intake and a substantial loss of body weight, with a small decrease in digestibility. Generally, total salt content of 1% in drinking water will not influence sheep performance. Saline water about 1.5% of total salts may not affect animal production if the environmental conditions are good. However, over 2% total salts in the drinking water is detrimental to production and survival of sheep (Wilson, 1978).

The response of animals to salt intake is dependent on the age of animals. For adult sheep, 1.6% of total salt in water significantly depresses weight gain in summer, but for lambs, 1.3% of total salt causes a reduction in body weight gain and wool growth, and increases the incidence of diarrhoae. Even water containing 1.0% of total salts causes some reduction in weight gain and wool growth of lambs (Wilson, 1975). Potter and McIntosh (1974) also reported that drinking water containing 1.3% sodium chloride increases lamb mortality at birth, particularly for twins.

Sheep on saline water have higher body water content and their carcases contain less fat, but more water and protein than sheep on fresh water (Walker et al., 1971). This might indicate that weight change, without determination of body composition, is probably not adequate for assessing the effect of saline water on animal production.

1.1.5 Salt tolerance of deer
Salt tolerance has been interpreted as the absence of a depression in the intake of a certain ration, and is well defined for most livestock species except for deer. Under grazing condition, animals may ingest excessive salt through feed, drinking water, and ingestion of soil (Howell, 1996). Excessive intake of sodium is one of the more commonly encountered problems and often causes loss of appetite, reduced milk production and reduced growth (Xu et al., 1994).

Water is one of major sources of salt for grazing animals. Wilson (1978) reported that sheep can tolerate 1.5% of sodium chloride in their drinking water, and Peirce (1959) recommended 1.3% as a safe maximum concentration, although 2.0% could be tolerated (Wilson, 1966b). However, Peirce (1957; 1962; 1966; 1968a; 1968b) found that water containing 1.0-1.3% soluble salts reduced appetite and caused some deaths in adult sheep, and sometimes reduced the number of lambs born and their growth rate, although saline water (1.3% NaCl) had no effect on the concentrations of sodium, potassium, calcium or chloride in the blood plasma (Peirce, 1959; 1963). Australian Water Resources Council recommended that the ground water might be suitable for some stock if the content of total dissolved solid is 3000-7000 mg/litre. If the content of total dissolved solid is over 14,000 mg/litre, this water cannot be used by any stock (Anon, 1976). Inglis (1985) summarised the salinity tolerance of livestock and poultry based on previous research (see Table 4). The salinity tolerance can vary with environmental conditions, type of feed, or physiological stages (see Table 5, Anon, 1969). Sheep and cattle grazing greenfeed can tolerate higher concentrations of salt in water than the same stock on dry feed. Stocks grazing on saltbush are less tolerant than those grazing other types of pastures. Pregnant, lactating or young animals have a poorer tolerance to saline water than dry mature animals (Inglis, 1985). Peirce (1957; 1962; 1966; 1968a; 1968b) and Wilson (1975) also reported that ewes and lambs are less tolerant of saline water than the non-pregnant and older sheep, and older sheep or sheep with previous experience of saline water are more tolerant than young and unexperienced sheep. Therefore, the safe values for salinity of 1.2% on grassland and 0.8% on saltbush were recommended by Wilson (1975), but these values should be further reduced for ewes and lambs, if lambs are born in summer.

Table 4. Salinity tolerance of livestock (mg total soluble salts/litre water)

Animal	Maximum concentration for health growth	Maximum concentration to maintain conditions	Maximum concentration tolerated
Sheep	6000	13000	Depends on type of feed
Beef cattle	4000	5000	10000
Dairy cattle	3000	4000	6000
Horses	4000	6000	7000
Pigs	2000	3000	4000
Poultry	2000	3000	3500

Source: Inglis (1985)

Table 5. Upper limits used by State Authorities for total salts in water (ppm) for livestock (Anon, 1969)

Class of livestock	New South Wales	Victoria	Queensland	South Australia	Western Australia	Northern Territory
Poultry	4000	3500	3500	3000a	3000	
Pigs	4000	4500	5500	3000a	4500	
Horses	7000	6000	5500b	7000	6500	6000
Cattle						
Dairy	10000	6000	5500b	7000	7000	6000
Beef	10000	7000	8500c	10000	10000	10000
Sheep						
Lamb, Weaners		4500			10000	
Ewes in milk		6000			10000	
Adult, on dry feed	14000	7000e	14500	13000	13000	12000
Adult, on green grass		15000	18500	18000	18500d	15000

Notes
a: 4000 ppm if on salt-free rations, 1500 ppm if on high salt diet.
b: 7000 ppm if on green feed.
c: 10000 ppm if on green feed.
d: for short period.
e: If unaccustomed to saline water; if accustomed, up to 15000 ppm.

There are large differences in salinity tolerance between animal species or breeds within species (NRC, 1980; Inglis, 1985; Judson and McFarlane, 1998). NRC (1980) reported that the maximum tolerable concentration were 35 and 16-35 g/kg DM for sheep and cattle, respectively. For sheep different tolerances are observed when fed on different rations or levels of intake due to individual differences in their ability to excrete or tolerate sodium chloride (Wilson, 1966b).

1.1.6 Potential deer farming in the arid and semi-arid areas

In the arid and semi arid regions which cover 70 to 75% of the continent (Ffolliott et al., 1995), with only 2-3% of the population (Mitchell, 1979), rainfall is variable and of low intensity. Typically the land is flat and only wide, shallow storage of water is possible. The high evaporation rates result from high radiation, high temperature and low humidity, especially in summer. Water quality, especially high concentrations of salts present some of the greatest limitations for the use of water by livestock (Anon, 1976; Goodspeed and Winkworth, 1978).

The development of deer farming in the arid and semi-arid areas of Australia offers diversification opportunities for existing farmers as well as new farmers. It has been well understood that deer are very adaptable and can be farmed in most parts of Australia (Mackay, 1998). The competition between cattle and deer for feed resources is minimal due to little dietary overlap between the two species (Ffolliott et al., 1995). More importantly, deer are more efficient converters of fodder to meat than cattle or sheep, have a dressing percentage of around 60% which is significantly better than either sheep or cattle (Anderson, 1984). Blaxter (1974) also reported that the first class meat obtained from a lean young deer carcass is 33% of its empty body weight. In sheep of a similar size the amount of first class meat obtained is only 18% of empty body weight. The feed conversion ratio was 2.8-3.8 which was half that usually found for cattle and better than that obtained in intensive lamb production. Drew and Greer (1977) estimated that pasture dry matter intakes for every kg carcass gain were 9.5 kg for red deer and 30 kg for lamb. Wilson (1984) also confirmed the potential advantage of deer meat production over traditional beef production and found that deer carcasses have little fat and most is subcutaneous, intermuscular and retroperitoneal.

The vegetation of large areas of arid and semi-arid Australia is dominated by species of the genera *Atriplex* (saltbush) and *Kochia* (bluebush). These shrubs are invaluable feed resources in summer of grazing sheep and cattle. While the nutritional value of these bushes has been evaluated by a number of researchers, the high salt concentration in leaves is a disadvantage to animal production. High salt intake of grazing animals from bushes and salty water in these regions, especially during drought periods, causes a higher water requirement, which may limit the expansion of the beef industry in these regions (Wilson, 1979). Thus the lower daily water requirement of deer in comparison with beef cattle offers a great opportunity to use this land for deer farming. However, farmers need information on salt tolerance of deer to optimise the production system and eliminate animal ethics concerns.

In summary, animals require sodium for growth, reproduction and other physiological functions. However, in southern Australia or in the salt-affected areas, excessive intake of sodium often occurs through drinking water, ingestion of salty feed and soil, especially in dry summers when temperature and evaporation rates are high. The impact of excessive sodium intake on feed intake, growth rate and water requirement has been well documented for most livestock species except for deer. While the salt tolerance levels of grazing animals have been defined, especially for sheep, there is no data available for grazing deer. More importantly, the tolerance level is influenced by species, breeds within species, physiological stages of animal, feed type, feeding level, and environmental condition. Therefore the data obtained from sheep and cattle cannot simply be applied to deer. To optimise deer production in southern Australia and to successfully develop the deer industry in the dry areas or salt-affected areas the following research is required;

- Basic information of sodium status of deer in these regions particularly from an animal health point of view,
- An understanding of the impact of excessive sodium intake on deer production,
- Tolerance levels of different deer species at various physiological stages.

1.2 Project Objectives

- To examine the effect of salt intake through drinking water and feed on feed intake and growth rate of fallow and red deer under grazing conditions,
- To disseminate research outcomes to deer farmers through field days, fact sheets, seminars, workshops and scientific publications,
- To improve profitability and sustainability of the deer industry.

2. Effect of salt level in the feed on performance of red and fallow weaner deer

2.1 Introduction

Sodium is one of the main macro minerals required by animals, and plays an important role in the acid-balance and osmotic regulation of the body fluids. Under grazing conditions, animals can generally obtain sufficient amount of sodium from water, pastures, soils and other mineral supplements. However it is difficult to quantify the intake of sodium under grazing conditions because sodium intake of grazing animals is often influenced by environmental conditions, pasture management and animal factors. In Australia, many cropping areas are affected by salt. In these regions, Chenopodiaceous plants, *such as Atriplex, Kochia and Bassia spp* have been planted to improve soil condition (Sharma 1978; Wilson 1978; Leigh 1986). These plants supply forage during drought periods for grazing animals (Sharma 1978), but their leaves are extremely rich in salt (Wood 1925; Mozafar and Goodin 1970). It is known that these shrubs are very valuable forage for animals in summer. Wilson (1966a) reported that the intake of *A. nummularia* (oldman saltbush) was sufficient to maintain sheep in summer and to allow a small weight gain. The bodyweight production per unit area was similar for sheep and cattle, but sheep selected more green grass than cattle which consumed more dry grass and saltbush. Proximate analyses of the leaves of these shrubs show that they are high in crude protein and ash during summer. The high ash content (30% of the dry matter) in these shrubs may be a disadvantage (Wilson 1966a; Wilson 1978), as high salt intake through ingestion of these shrubs could adversely influence electrolyte balance and cause water intoxication for grazing animals. The surplus Na^+ increases the blood osmotic pressure, which induces the grazing animal to consume more water to maintain electrolyte balance. While the deer industry has been successfully developed in these shrub-growing regions, the potential impact of excessive salt intake on deer production is unknown. The salt tolerance has been well defined for sheep, cattle and other livestock species, but the variation between animal species, breeds within species, maturity status and grazing environments makes it impossible to apply these values directly to deer. To optimise deer production and effectively use natural resources, it is essential to understand the salt tolerance of deer at different physiological stages and the effect of excessive salt intake on growth and reproduction of grazing deer. The objective of this study was to examine the effect of salt level in feed on feed intake and growth rate of fallow and red deer**.**

2.2 Materials and Methods

2.2.1 Paddocks

Ten paddocks (900 m^2) were fenced with 2 m high wire. Each paddock had a water trough (100 litre) and feeder (200 litre). The water trough was connected to a 200-litre tank, raised 1.5 m above ground to allow gravity filling of the trough. The water tank was calibrated by the manufacturer so that volume could be measured to a 0.5 litre accuracy. Water troughs and feeders were covered with corrugated iron 1 m above ground level to stop rainwater falling into the drinking water and feed. In June, the paddocks were sprayed with a mixture of Roundup® and Goal® to remove all growing plant materials.

2.2.2 Animals and management

The experiments were run from April 18 to August 1, 2002 on Roseworthy Campus, 60 km north of Adelaide and 10 km east of Gawler in South Australia. Thirty fallow weaners were selected from Roseworthy Deer Farm and divided into five groups (6 deer/group) based on body weight. The deer were fed on pure lucerne chaff for 3 weeks before introducing the experimental diets. From week 4, the five groups of fallow deer were fed on lucerne chaff with added salt content of 0, 1.5, 3.0, 4.5 and 6.0%, respectively. Mineral content of the five diets is listed in Table 1. At the end of the trial, two deer from each of the 0 and 6% salt treatments were slaughtered. Liver, muscle, lung, kidney and heart were sampled and freeze dried. Water content in the organs was measured after freeze drying.

For the experiment with red deer, 18 red calves were divided into three groups (6 deer/group) based on their body weight and fed on pure lucerne chaff for 3 weeks before feeding experimental diets. From week 4, the three groups of red deer were fed on lucerne chaff with added salt content of 1.5, 3.0 and 6.0%, respectively. Mineral content of these diets is listed in Table 1.

2.2.3 Measurements

Mineral content in pastures and water from the Roseworthy Deer Farm: Pasture and water samples were taken from Roseworthy Deer Farm in December, January and February. The pasture was a mixture of medics and ryegrass. Samples were oven dried and milled through a 0.5 mm sieve. Water samples were taken from troughs and mains. All samples were analysed for mineral profile using inductively coupled plasma (ICP) analyser (Zarcinas et al., 1987).

Feed and water intake: During the experimental period, deer were monitored daily for any abnormal behaviour and to ensure that feed was available all the time. Feed residues were collected weekly to measure feed intake. The water levels in the tank were read daily to an 0.5 litre accuracy for estimating water intake. The rainfall was measured during the trial and a correction for the water intake was calculated based on the surface area of the water trough.

Blood sampling: Blood samples were taken at the end of the trials using Vacutainer tubes. Deer were restrained in the crush and a blood sample was taken from the jugular vein. Samples were immediately placed on ice. Once sampling had been completed, blood tubes were returned to the laboratory and centrifuged for 10 minutes at 3000 rpm. Serum was extracted from the tubes and analysed for osmotic pressure and mineral content.

Bodyweight: Animals were weighed every three weeks after overnight fasting to monitor bodyweight changes.

2.2.4 Analysis

Minerals in the feed, animal tissue and blood samples were analysed using an inductively coupled plasma (ICP) analyser (Zarcinas et al., 1987). Osmotic pressure was measured using a Micro-Osmometer (model 3MO plus).

2.2.5 Statistics

The experiments were an unrepeated randomised design. The 10 paddocks were located in the same area with an identical microenvironment. The individual animals were used as replicates for data analysis. The main factor of these experiments was salt level in the diet. Anova from the Systat program (Wilkinson et al., 1992) was used to assess the effect of salt level in feed on performance of deer.

2.3 Results

The analysis of pasture and water samples showed a higher Na and K concentration in December and a higher Ca concentration in February in pastures based on medic and ryegrass. The Mg concentration in pasture was constant. There was an increase in Ca, K, Na and Mg in trough water from December to February. These minerals were significantly higher in trough water than in mains water (Table 1).

Table 1. Mineral content of water and pasture material based on oats and medics (ppm)

Date	Ca	Mg	Na	K
		Pastures		
December	7050.0	2000.0	8750.0	11200.0
January	8900.0	2140.0	2800.0	4450.0
February	10800.0	2150.0	970.0	2650.0
		Trough water		
December	36.3	20.2	173.5	9.5
January	52.3	50.0	355.0	25.2
February	64.9	63.9	490.0	38.1
		Mains water		
December	13.5	8.4	55.2	3.4
January	15.8	8.8	54.6	3.5
February	15.7	9.4	58.1	3.7

For fallow weaner deer, there was no difference in feed intake, water intake, body weight, blood osmotic pressure and blood mineral concentration prior to feeding salt diets. The experimental diets contained 0%, 1.5%, 3.0%, 4.5% and 6.0% salt, respectively (equivalent to 0.32%, 0.99%, 1.6%, 2.1% and 2.6% of Na, respectively). The Ca, Mg and K contents were similar for all experimental diets (Table 2). Adding 6% salt in the lucerne chaff did not affect feed intake, blood osmotic pressure and blood mineral concentration in fallow deer ($P>0.05$), but water intake was significantly higher ($P<0.05$) for deer fed diets containing over 3% salt (Table 3). The daily water intake per kg dry matter intake ranged from 1.65-4.06 litres as sodium increased in the diet from 0.32% to 2.6%. Body weight in July and August was lower when salt content was greater than 3% (Table 4). No difference was found in dressing percentage, water content and mineral concentration in liver, lung, kidney and muscle of deer fed 0% and 6% salt in the diet although a limited number of deer were slaughtered (2 from each group).

Table 2. Mineral content (ppm) of the experimental diets based on pure lucerne chaff fed to fallow and red deer

Diet	Ca	Mg	Na	K
0% Salt	12300	3200	3200	24000
1.5% Salt	12700	3200	9900	24000
3% Salt	13300	3300	16000	24000
4.5% Salt	12500	3100	21000	24000
6% Salt	11500	3000	26000	22000

Table 3. Feed intake, water intake and mineral content in blood of fallow deer fed different levels of salt in a pelleted diet based on pure lucerne chaff

	Salt level (%)	Stats

		0	1.5	3	4.5	6	*P value*	*SEM*
Feed intake (kg/day)		0.945	0.948	0.972	0.890	0.834	*0.439*	*0.057*
Water intake (L/day)		1.557b	1.58b	2.698a	2.943a	3.387a	*0.0001*	*0.250*
Osmotic pressure (Mosm)		299.5	301.2	301.8	303.7	304.0	*0.487*	*1.964*
Minerals in blood (ppm)								
	Ca	104.4	108.5	109.3	106.8	107.3	*0.610*	*2.264*
	Mg	18.7	19.7	18.1	17.8	19.5	*0.052*	*0.506*
	Na	3283.3	3300.0	3333.3	3300.0	3300.0	*0.839*	*30.732*
	K	209.1	227.8	235.2	246.7	241.7	*0.290*	*12.765*

[ab] Values followed with different letters within a row were different between treatments at P <0.05

Table 4. Body weight changes (kg) of fallow deer fed on different levels of salt in the pelleted diet based on pure lucerne chaff

Date	Salt level					*Stats*	
	0	1.5	3	4.5	6	*P value*	*SEM*
May_10*	25.7	26.9	27.3	25.0	26.1	*0.089*	*0.594*
May_29*	27.3	29.4	29.0	27.0	27.5	*0.121*	*0.746*
June_20	27.9	29.7	29.3	27.6	28.0	*0.279*	*0.765*
July_11	27.8	29.5	28.5	25.8	26.9	*0.007*	*0.656*
July_31	27.7	29.8	28.5	26.6	27.5	*0.056*	*0.707*
Aug_1*	26.8	28.8	27.7	25.8	26.7	*0.046*	*0.661*

* Bodyweight after fasted for 24 hours

For red weaner deer, there was no difference (P>0.05) in feed intake, water intake, body weight, blood osmotic pressure and blood mineral concentration prior to feeding salty diets. Feed intake and blood osmotic pressure were similar (P>0.05) for deer fed different levels of salt (Table 5) although the feed intake declined from 1.91 to 1.67 kg/day as salt level increased from 1.5% to 6.0% in the diet. While there was no difference in Mg and K concentration in blood, blood Na content tended to decline with increasing salt level in the diet. However, this did not result in any negative effect on performance. Water intake was significantly higher for deer fed diets containing over 4.5% salt (Table 5), but there was no difference in body weight during the experiment (Table 6).

Table 5. Feed intake, water intake and mineral content in blood of red deer fed different levels of salt in a pelleted diet based on pure lucerne chaff

		Salt level (%)			*Stats*	
		1.5	4.5	6	*P value*	*SEM*
Feed intake (kg/day)		1.910	1.841	1.669	*0.293*	*0.110*
Water intake (L/day)		2.733b	4.789a	4.776a	*0.008*	*0.509*
Osmotic pressure (Mosm)		311.3	306.4	301.6	*0.060*	*2.446*
Minerals in blood (ppm)						
	Ca	110.0ab	112.1b	107.5a	*0.036*	*1.133*
	Mg	19.3	17.5	18.0	*0.073*	*0.520*
	Na	3383.3a	3300.0ab	3216.7b	*0.004*	*29.187*
	K	268.3	260.0	276.7	*0.450*	*9.078*

[ab] Values followed with different letters within a row were different between treatments at P <0.05

Table 6. Body weight changes (kg) of red deer fed on different levels of salt in a pelleted diet based on pure lucerne chaff

Date	Salt level (%)			*Stats*	
	1.5	4.5	6	*P value*	*SEM*
May 10*	50.9	51.2	51.1	*0.998*	*3.21*
May 29*	56.1	56.7	56.7	*0.991*	*3.439*
June 20	55.4	56.0	55.0	*0.971*	*3.105*
July 11	54.5	51.9	54.1	*0.808*	*3.135*
July 31	54.5	53.9	54.1	*0.990*	*2.903*
Aug 1*	52.8	51.8	52.3	*0.972*	*2.867*

* Body weight after 24-hour fasting.

2.4 Discussion

The analysis of pasture and water samples revealed a seasonal change in the mineral concentrations in pastures and water troughs, although samples were taken only on three occasions. While it is expected that Na concentration would be high in December when it is summer in southern Australia, Ca concentration was higher in February. This might reflect the seasonal changes in botanical composition of pasture during the summer in southern Australia when selective grazing, trampling and decomposition occur. The mineral concentration in trough water increased from December to February, presumably due to concentration of salts through evaporation. This result only demonstrated the seasonal changes in mineral concentration in the fresh water used to fill the water troughs in this environment. The actual mineral concentration in trough/dam water could be much higher if the water is mainly from rain, especially in the salt affected areas.

During the experimental period, no abnormal behaviour and salt toxic symptoms were observed in deer. However, the body weight of deer declined over the period between end of May and July. Previous studies conducted on this site also showed similar results, presumably due to the low temperature and poorer quality of feed available at this period of year (Ru and Glatz, 2002). While lucerne chaff had a higher quality than other herbages available at this time of the year, the digestible energy content of lucerne chaff was only about 10.3 MJ/kg on an air-dry basis (Ru et al., 2002). The daily digestible energy intake was only about 9.7 MJ for fallow deer and 19.7 MJ for red deer in the lower salt treatment groups. The energy intake of fallow deer was only slightly higher than the maintenance requirement in June (8.22 MJ/day), but lower than the maintenance requirement in July (10.3 MJ/day) (Ru and Glatz, 2002). Similarly, the metabolisable energy intake of red deer on low salt level (16.2 MJ ME/day) was lower than the value (21 MJ ME/day) recommended by New Zealand researchers in winter (Fennessy et al., 1981), assuming the conversion ratio of digestible energy to metabolisable energy is 0.82.

Salt tolerance has been interpreted as the absence of a depression in the intake of a certain ration (Peirce, 1959). While deer can ingest salt from pastures, soils and water, the actual sodium intake from these sources in the current study is negligible and was similar for all treatment groups. However, fallow deer consumed 9.4, 15.6, 18.7 and 21.7 g sodium daily from lucerne chaff containing 1.5, 3.0, 4.5 and 6% salt, respectively, resulting in a significant increase in water intake, especially when salt content was over 3%. Feed intake declined by only 8% when salt level increased from 3% to 4.5%. Considering the changes in body weight, feed intake and water intake, it is obvious that fallow deer can tolerate 3% salt (1.6% sodium) in the diet. This clearly indicates that fallow deer can ingest over 15 g sodium/day without significant depression in both feed intake and growth rate if the fresh water is available. This result further demonstrated the key roles of fresh water in the regulation of sodium metabolism. However, when salt is ingested through drinking water, the rate of absorption and excretion of sodium could differ from the sodium ingested from feed, suggesting a more comprehensive assessment of the tolerance of deer to salt in drinking water is required.

Red deer responded differently to salt level in the diet compared to fallow deer in the current study. While the increment of salt level in the diet was larger for red deer than fallow deer, the feed intake was not different between all treatments although a 9% decline in intake occurred when salt level increased from 4.5% to 6%. It is surprising that red deer did not show any difference in body weight between these treatments, especially when the deer were fasted for 24 hours to reduce the amount of water retained in the gut. Whether the 24 hr period is long enough for red deer to empty the water retained in the digestive tract is not clear and no data on the water content in the tissue or water turnover were obtained for red deer in this study. If the salt tolerance is based only on feed intake and body weight gain, it can be concluded that red deer can be fed up to 6% of salt, equivalent to 2.6% sodium. However, the salt tolerance for red deer should be further assessed with a wide range of salt levels.

The current salt levels included in the diets were lower than those tested in sheep, making it difficult to directly compare the response to salt level by sheep and deer. The salt intake at the highest level in the current study were 50 g/day for fallow deer and 100 g/day for red deer, but Wilson (1966b) reported that sheep can ingest up to 97 g sodium/day when offered fresh water. Meyer and Weir (1954) also recorded an intake of 104 g sodium/day by sheep offered a pelleted ration containing 13.1% sodium chloride. The outcomes of the current study cannot answer the question whether deer are less tolerant than sheep, but performance of fallow deer may suggest that salt level over 3% will not be of benefit to fallow deer.

Chenopodiaceous plants, *such as Atriplex, Kochia and Bassia spp* are an important feed resource during drought periods for grazing animals in Australia because of their remarkable capacity to remain leafy and viable under high radiation and temperature levels (Sharma, 1978). However, the leaves of these shrubs have variable nutritional value. For examples, the ash content ranges from 18.5-27.2% on a dry matter basis and sodium content ranges from 0.2-5.6% on a dry matter basis (Khlil et al., 1986). Wilson (1966b) also reported 8% sodium in saltbush leaves in summer. It is believed that high salt content of saltbush is detrimental to grazing animals, but the impact of grazing saltbush on animal production is dependent on the amount of saltbush in the diet. Under grazing conditions, the diet of grazing animals often contains a variable amount of saltbush due to the difference in availability of other alternative feeds such as grasses which are relatively low in sodium, but in dry periods the saltbush content in feed intake often approaches 100% (Leigh and Mulham, 1967). More importantly, the availability of fresh water is a key factor influencing the responses of grazing animals to salty feed as shown in the current and early research (Wilson, 1966ab). For example, sheep were fed on diets containing 7.5, 11.25 and 15% added sodium chloride to simulate diets containing up to 100% saltbush. When access to water was restricted to once daily, there was a reduction in food intake, the reduction being more severe as the salt levels increased (Wilson and Hindley, 1968). The increased fresh water intake of deer fed on salty feed may help to excrete sodium through urine as Wilson (1966b) reported that 89-98% of the ingested sodium was excreted in the urine in sheep. However, no simple recommendation could be made for the utilisation of saltbush by grazing deer from this study because of the variable salt content of saltbushes and availability of fresh water.

3. Effect of salt level in water on feed intake and growth rate of red and fallow weaner deer

3.1 Introduction

It has been well documented that sodium is one of the key elements for grazing animals, but excessive intake of sodium could reduce feed intake and growth rate. This is particularly true in southern Australia where the temperature in summer can be over 40 ^{o}C. Under this environment, the evaporation of water in dams and water troughs often result in a high salt concentration in the drinking water. In field situations, this can cause an increase of 10% in concentration of salts even though the troughs are cleaned regularly (Wilson, 1978). The risk of excessive salt intake is more significant in the salt affected regions where grazing animals rely on the pastures and bushes (e.g. saltbush) as a major nutrient supply in dry summers. As the deer industry expands in these regions, the assessment of the impact of excessive salt intake on deer production will assist deer farmers to establish their management strategies to achieve maximum profit.

In the previous experiments, the effect of salt level in feed on feed intake and growth rate was assessed for red and fallow weaner deer. The results revealed that increasing the salt level in the diet from 0 to 6% didn't affect feed intake, osmotic pressure and mineral concentration in blood of fallow weaner deer, but deer drank much more water when fed diets containing more than 3% salt. Feed intake and blood osmotic pressure were similar for red deer fed different levels of salt although the feed intake declined by 14% when the salt level increased from 1.5% to 6.0% in the diet. There was no difference in body weight during the experiment. In these experiments, fresh water was available *ad libitum*, which may assist deer to excrete the excessive salt. However, under field situations, water is one of major sources of salt for grazing animals and salt level in water could have more significant impact on their growth. Wilson (1978) reported that sheep can tolerate 1.5% of sodium chloride in their drinking water, and Peirce (1959) recommended 1.3% as a safe maximum concentration, although 2.0% could be tolerated (Wilson, 1966b). Peirce (1957; 1962; 1966; 1968a; 1968b) found that water containing 1.0-1.3% soluble salts reduced appetite and caused some deaths in adult sheep, and sometimes reduced the number of lambs born and their growth rate. However, due to the difference in salt tolerance between animal species, these figures might not apply to grazing deer. The following experiments were designed to assess the effect of salt concentration in drinking water on feed intake and growth rate of red and fallow weaner deer.

3.2 Materials and Methods

3.2.1 Paddocks

Four paddocks (900 m^2) were fenced with 2 m high wire. Each paddock had a water trough (100 litre) and a feeder (200 litre). The water trough was connected to a 200-litre tank, raised 1.5 m above ground to allow gravity filling of the water trough. The water tank was calibrated by the manufacturer to be read at an accuracy of 0.5 litre. Water troughs and feeders were covered with corrugated iron 1 m above ground level to stop rainwater falling into the drinking water and feed. In June, the paddocks were sprayed with a mixture of Roundup® and Goal® to remove all growing plant materials.

3.2.2 Animals and management

The experiments were conducted from April 18 to August 1, 2002 for fallow deer and from April 28 to July 18, 2003 for red deer on Roseworthy Campus, 60 km north of Adelaide and 10 km east of Gawler in South Australia. A total of 40 fallow weaners were divided into 4 groups based on body weight. The average weights for each group were 21.97, 21.53, 22.25 and 23.15 kg, respectively. Each group had 5 male and 5 female deer. Deer were housed in paddocks without any pasture and only fed commercial deer pellets for 2 weeks before introducing to experimental treatments. From week 3, two groups of fallow deer were fed on commercial deer pellets containing 17% crude protein and about 10 MJ metabolisable energy/kg and offered bore water, while the other two groups were offered salt water with concentration being increased every two weeks to 0.3, 0.6, 0.9, 1.2, 1.5, 2.0 and 2.5% respectively. Mineral content in feed and water with different salt contents is listed in Table 1.

Table 1. Mineral content in pellet feed and water for the fallow deer trial

	Ca	Mg	Na	K
		Feed		
Pellet feed	12550.0	2350.0	1885.0	13550.0
Salt level (%)		*Water*		
0.0	40.0	20.0	105.0	<20
0.3	33.6	16.5	1370.0	<20
0.6	34.7	16.3	2500.0	<20
0.9	36.1	16.7	3700.0	20.6
1.2	35.5	16.2	5400.0	22.3
1.5	37.0	16.1	6200.0	37.5
2.0	44.2	15.5	7900.0	< 20
2.5	41.9	17.0	9500.0	< 20

For the red deer trial, a total of 20 red weaners were divided into 4 groups based on body weight. Each group consisted of 3 female and 2 male deer. The average weights for each group were 55.2, 55.2, 56.7 and 55.5 kg, respectively. Deer were housed in the same paddocks previously used for the fallow deer trial. There were no pastures in these paddocks and deer were only fed commercial deer pellets during the experiments. The commercial deer pellets contained 17% crude protein and about 10 MJ metabolisable energy/kg. After a 2-week introduction, two groups of red deer were fed on deer pellets and offered bore water, while the other two groups were offered salt water with concentration being increased every two weeks to 0.4, 0.8, 1.0 and 1.2%, respectively. Mineral content in feed and water with different salt contents is listed in Table 2.

Table 2. Mineral concentration (ppm) in feed and water for the red deer trial

	Ca	Mg	Na	K
		Feed		
Pellet feed	16500.0	1930.0	2200.0	12300.0
Salt level (%)		*Water*		
0.0	32.0	21.0	100.0	< 20
0.4	35.0	21.0	1850.0	< 20
0.8	38.0	21.0	3600.0	< 20
1.0	32.0	20.0	4800.0	< 20
1.2	39.0	22.0	5100.0	< 20

3.2.3 Measurements

Feed and water intake: During the experimental period, deer were monitored daily for any abnormal behaviour and feed was available at all times. Feed residues were collected weekly to measure feed intake. The water levels in the tank were read daily to an 0.5 litre accuracy for estimating water intake. The rainfall was measured during the trial and a correction for the water intake applied based on the surface area of the water trough.

Blood sampling: Blood samples were taken at the end of the trials using Vacutainer ® tubes for fallow deer. However, blood samples were taken during the week when salt level in water was 1.0% for red deer when feed intake and body weight gain started declining. Deer were restrained in a crush and a blood sample (9 ml) was taken from the jugular vein. Samples were immediately placed on ice. Once sampling had been completed, blood tubes were returned to the laboratory and centrifuged for 10 minutes at 3000 rpm. Serum was pipetted from the tubes and analysed for osmotic pressure and mineral content.

Bodyweight: Animals were fasted overnight and weighed fortnightly to monitor bodyweight changes, when salt levels were changed in the water.

3.2.4 Analysis

Minerals in the feed, animal tissue and blood samples were analysed using an inductively coupled plasma (ICP) analyser (Zarcinas et al., 1987). Osmotic pressure was measured using a Micro-Osmometer (model 3MO plus).

3.2.5 Statistics

The experiment was a randomised block design with two replicates per treatment. The four paddocks were located in the same area with an identical microenvironment. The main factor in these experiments was salt level in the diet. The general linear model test from the Systat program (Wilkinson et al., 1992) was used to assess the effect of salt level in drinking water on performance of deer.

3.3 Results

3.3.1 Fallow deer

No deer showed any abnormal behaviour or sickness during the trial. There was no difference in feed intake when salt concentration in water ranged from 0.3 to 1.2%. However, the feed intake was reduced significantly when salt content in water was greater than 1.5% (Figure 1). Adding salt in the water significantly increased water intake of fallow weaner deer. When salt level in water reached 2.5%, water intake was reduced (Figure 2). Body weight gain was not affected when adding up to 1.2% salt in drinking water, but was reduced by further increases in salt content in water (Figure 3). There was no difference in osmotic pressure and mineral content in blood between deer drinking water with 2.5% or 0% added salt except for Mg. Deer drinking salty water (2.5%) had a lower Mg content in the blood than those drinking bore water (0% salt treatment) (Table 3).

Table 3. Osmotic pressure and mineral content (ppm) in serum of fallow deer offered drinking water with 0 (Control) or 2.5% (Salt) salt content

Group	Osmotic pressure	Fe	Cu	Zn	Ca	Mg	Na	K	P	S
Control	303.0	5.5	0.9	0.7	101.5	18.0	3335.0	231.0	103.9	1013.5
Salt	303.1	5.2	0.9	0.7	101.2	16.8	3330.0	223.8	98.8	1003.5
SEM	1.30	0.89	0.02	0.02	0.71	0.32	9.79	4.81	2.72	6.71
P	0.96	0.81	0.26	0.34	0.72	0.01	0.72	0.30	0.20	0.30

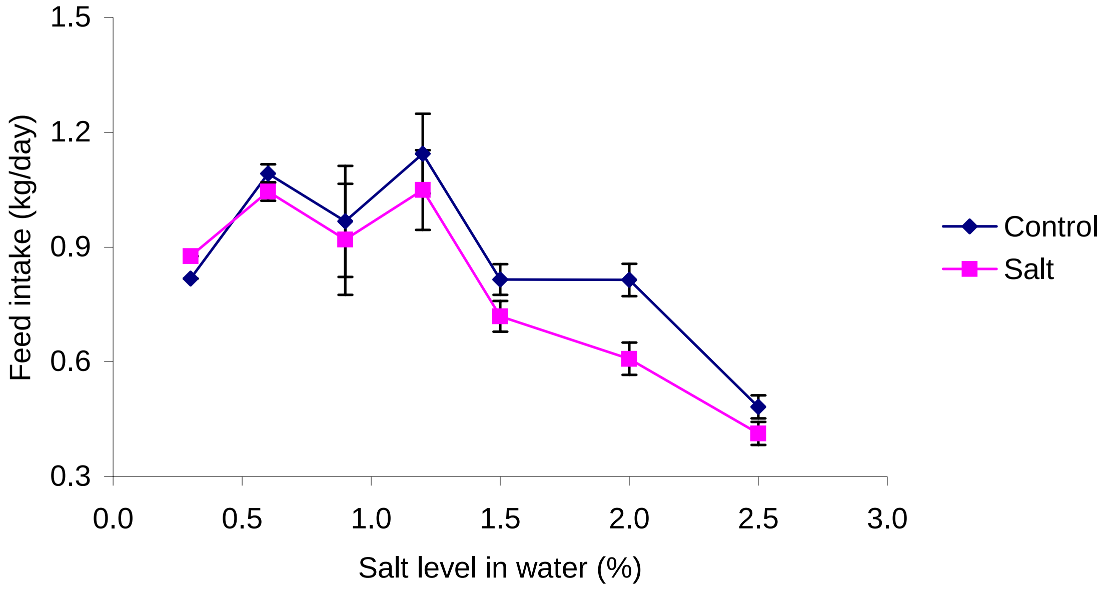

Figure 1. Feed intake of fallow weaner deer drinking water with different salt concentration

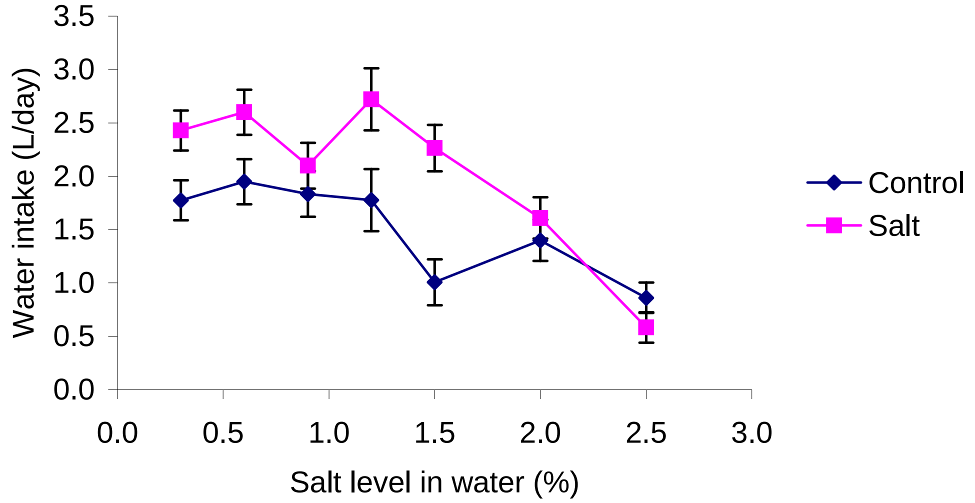

Figure 2. Water intake of fallow weaner deer provided drinking water with different salt concentration

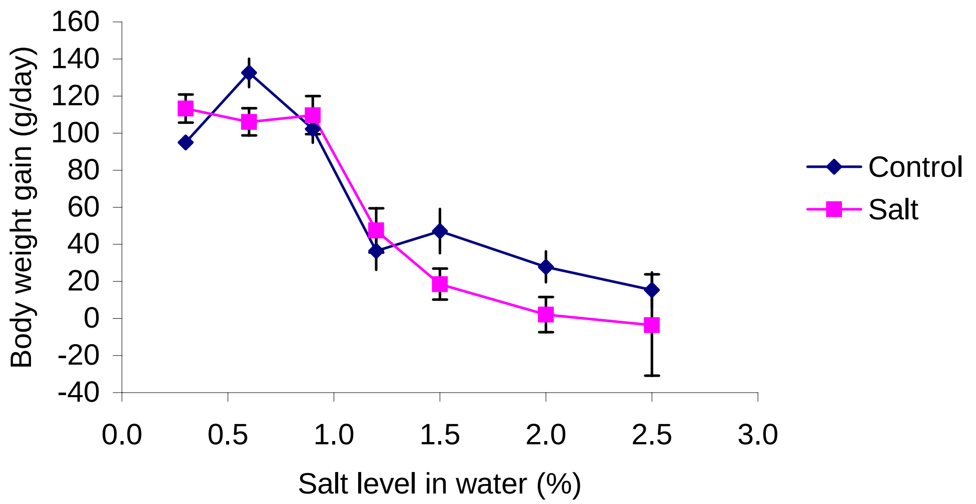

Figure 3. Body weight gain of fallow weaner deer provided drinking water with different salt concentration

3.3.2 Red deer

In the third week of the experiment, two deer from both the control and salt treatment groups escaped by jumping over the fence. These two deer were very sensitive and were excluded from the trial to ensure that other deer would not be disturbed. All deer were healthy and did not show any abnormal behaviour during the trial, but one deer was sick in the last week of the trial when the salt level in the water was 1.2%. Thus the experiment was terminated and the sick deer was euthanased. Samples of urine and blood were analysed for minerals. Kidney and liver samples were examined by a veterinarian. No significant changes or lesions were noted in the liver tissue. A moderate number of kidney tubules contained crystalline material that was consistent with oxalate crystals. Many of the convoluted tubules had also undergone degeneration (nephrosis) and the ducts in the medulla contained proteinaceous material, suggesting a mild oxalate poising. In grazing animals this is usually the result of eating plants such as Sour Sob, or one of the other oxalate containing plants. Even though the changes were mild, their effects may have been exacerbated by salty water. The sodium concentration was 4400 ppm in urine and 3500 ppm in blood, and osmotic pressure was 366 for urine and 318 for blood for this deer.

Compared with deer on fresh water, the feed intake of deer on salty water was 11-13% lower when salt level in drinking water was 0.4-0.8% ($P>0.05$; Figure 4). An increase in salt level in water up to 1% resulted in about 30% reduction in feed intake ($P<0.01$). Water intake was variable between treatment groups and days, depending on the weather. However, deer on salty water had a higher water intake than those on fresh water (Figure 5).

There was no significant difference ($P>0.05$) in body weight between groups at the start of the trial and the body weight increased in the first 4 weeks for all groups when the salt level in water was 0.4-0.8%. However, the body weight declined rapidly during June and July for all groups and the rate of decline was significantly higher ($P<0.05$) for the salt treatment group than the control (Figure 6).

The deer on 1% salt treatment tended to have a higher osmotic pressure in serum ($P=0.052$; Table 4). The concentration of P and K in serum tended to be higher ($P<0.1$) for deer drinking salty water. S concentration in serum was 75 ppm higher and Mg concentration was 2 ppm lower for deer on salty water than those on fresh water. However, there was no difference in the concentration of other minerals in serum ($P>0.05$) between control and treatment groups (1% salt in drinking water).

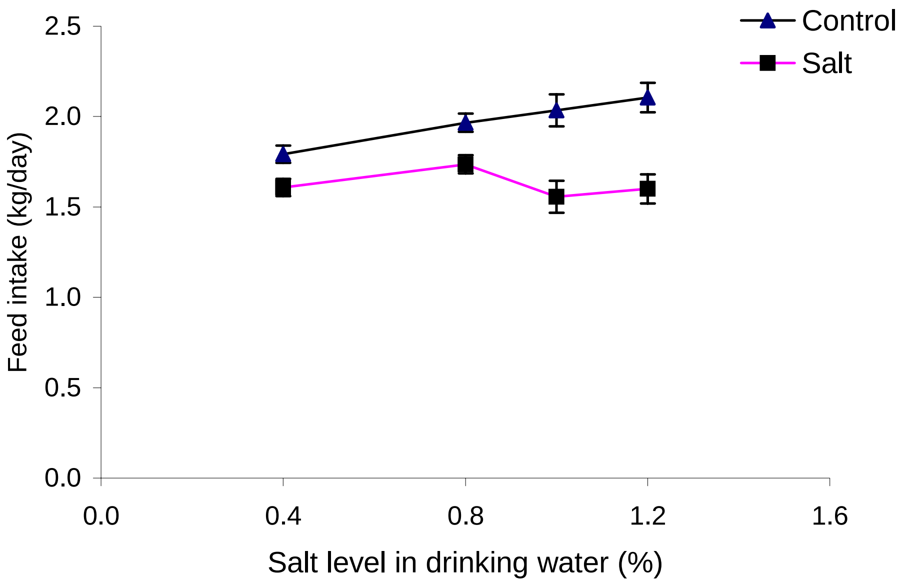

Figure 4. Feed intake (kg/day/deer) of red weaner deer offered fresh water or water with different levels of salt in April-July 2003

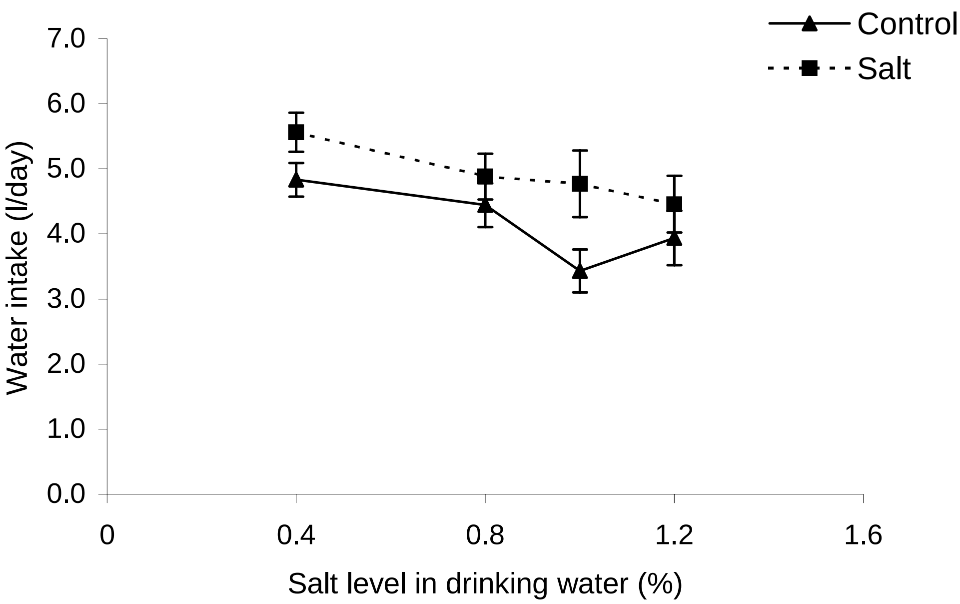

Figure 5. Daily water intake of red weaner deer offered fresh water or water with different levels of salt during April-July 2003

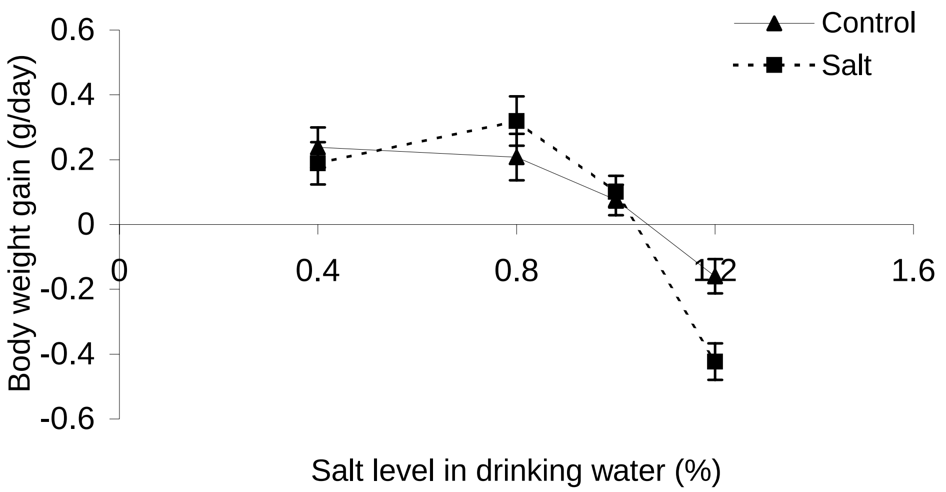

Figure 6. Body weight gain of red weaner deer offered fresh water or water with different levels of salt during April-July 2003.

Table 4. Osmotic pressure and mineral concentration (ppm) in serum of red deer drinking fresh water (control) or water containing 1% salt (Salt)

Treatment	Osmotic pressure	Fe	Cu	Zn	Ca	Mg	Na	K	P	S
Control	291.0	53.6	0.5	0.7	97.0	22.1	3112.5	473.8	97.5	1121.3
Salt	300.9	116.0	0.6	0.7	93.5	20.3	3037.5	681.3	114.3	1196.3
SEM	3.36	28.05	0.09	0.06	2.47	0.38	84.91	77.97	6.49	23.96
P value	0.057	0.138	0.762	0.993	0.33	0.004	0.542	0.081	0.089	0.044

3.4 Discussion

3.4.1 Salt tolerance of red and fallow weaner deer

While no fallow deer showed any abnormal behaviour or sickness during the trial, the feed intake and body weight gain was reduced when the salt concentration in drinking water was 1.5%. Based on the fact that salt tolerance can be interpreted as the absence of a depression in the intake of a certain ration, it can be concluded that fallow deer can tolerate 1.2% salt in the drinking water, equivalent to 5400 ppm sodium in water. The relationship between the depression of growth rate (X) and salt level (Y) in drinking water ($Y = -0.0306X + 1.2143$, $R^2 = 0.65$, n=6) also suggested that the salt level in the drinking water is 1.2% when the difference in body weight gain (X) between control and salt treatment groups is 0.

For red weaner deer, the feed intake was reduced by 10% when salt concentration was 0.8% and over 30% when salt concentration reached 1.0%. The reduction in feed intake was not reflected in body weight gain until the salt level in water reached 1.0%. If feed intake is used as an indicator for salt tolerance, the red deer can only tolerate 0.8%, equivalent to 3600 ppm sodium in water. However, a sodium concentration in drinking water should not be over 4800 ppm to avoid the reduction of growth rate of red weaner deer. This demonstrated the different responses to salty water by red and fallow deer. When converting the data into the daily salt intake per kg metabolisable liveweight ($W^{0.75}$) basis, the difference between red and fallow deer was more significant (1.74 g/kg $W^{0.75}$ for red deer *vs* 2.70 g/ kg $W^{0.75}$ for fallow deer) although the total salt intake through drinking water were slightly higher for red deer than fallow deer (39 g/day *vs* 33 g/day).

3.4.2 Difference between animal species

When comparing the data with those reported for sheep, it is clear that deer and sheep have different tolerance levels for salt. For example, based on the current study, the growth was depressed when drinking water contained over 1.2% and 1.0% salt for fallow and red deer, respectively, but Wilson (1978) reported that sheep can tolerate 1.5 % of sodium chloride in their drinking water, and Peirce (1959) recommended 1.3% as a safe maximum concentration, although 2.0% could be tolerated (Wilson 1966b). Wilson (1978) also reported that saline water (about 1.5% of total salts) may not affect animal production subject to the environmental conditions, but over 2% total salt in the drinking water is detrimental to production and survival of sheep. These levels are much higher than the levels defined for red and fallow weaner deer in the current study even after considering the minor contribution of about 100 ppm from other minerals, including Fe, Mn, B, Cu, Mo, Co, Ni, Zn, Ca, Mg, K, P, S, AI and Cd. Thus deer producers need to be cautious when using the recommended level of salinity tolerance for livestock (Inglis, 1985) as their guideline.

It is obvious that salt intake level of grazing fallow deer was not reflected in Na concentration in blood. Similar results were reported with sheep. For example, Peirce (1957; 1962; 1966; 1968a; 1968b) found that water containing 1.0-1.3% soluble salts reduced appetite and caused some deaths in adult sheep, and sometimes reduced the number of lambs born and their growth rate, but saline water (1.3% NaCl) had no effect on the concentrations of sodium, potassium, calcium or chloride in the blood plasma (Peirce, 1959; 1963). Red deer showed differences in S and Mg concentrations in serum between control and treatment groups and tended to have a high osmotic pressure, including high P and K concentrations in serum when drinking water containing 1% salt. However, there is not enough evidence to conclude that fallow deer have a better capability of maintaining the balance of minerals in serum than red deer.

3.4.3 Effect of environment conditions and feed resource on salt tolerance of deer

The results obtained from the current study can only be used as a guideline because the salinity tolerance of animals varies with environmental conditions, type of feed and stage of physiological development. Early research showed that sheep and cattle grazing greenfeed could tolerate higher concentrations of salt in water than the same stock on dry feed. Animals grazing on saltbush are less tolerant than those grazing other types of pastures (Inglis, 1985). Sheep have a higher tolerance to saline water when fed on lucerne chaff than on oaten chaff (Wilson and Dudzinski 1973). Pregnant, lactating or young stock have decreased tolerance to saline water than dry mature stock (Inglis, 1985). It was also reported that ewes and lambs are less tolerant of saline water than the non-pregnant and older sheep, and older sheep or sheep with previous experience of saline water are more tolerant than young and unexperienced sheep (Peirce, 1968a; 1968b; Wilson, 1975). Based on these facts, the outcomes of the current study cannot be extrapolated to adult deer.

It should also be pointed out that in this study, the tolerance level of red and fallow weaner deer to the saline water was estimated when deer were offered commercial pelleted feed with a sodium concentration of 0.2%. Salt intake through soil was not determined. Under field situations, grazing deer are always exposed to feed and soils containing high salt levels, especially in the salt-affected areas. In these areas, saltbush or other herbage with high sodium content are valuable feed for grazing deer. It was also recognised that animals cannot avoid ingesting soil during grazing. The amount of soil intake by grazing animals are dependent on stocking rate, pasture growth and the location of grain supplementation which could be dusty and muddy. For example, on short pastures, cattle could ingest over 100g soil/kg herbage dry matter (Dewes, 1996) and sheep up to 300 g soil/kg herbage dry matter (Thornton, 1983). Therefore, the contribution of soil and salty feed resources to total salt intake of deer cannot be ignored under grazing conditions. In addition, the current research was conducted over April to July when the temperature is low in southern Australia, associated with a low water intake compared with that in dry and hot summers. The maximum salt level in drinking water that deer can tolerate may be lower in summers.

4. Conclusions and Recommendations to the Industry

The major outcomes of this study were the determination of the salt tolerance level in feed and drinking water for red and fallow weaner deer. These data are required by the deer industry to develop management strategies to ensure that the weaner deer do not ingest excessive salt through feed or drinking water and still reach the marketable liveweight in a desired timeframe.

- When feed intake is used as the key indicator for salt tolerance of deer, it is obvious that fallow deer can tolerate 3% salt (sodium chloride) in the diet, suggesting an intake of 15 g sodium/day if the fresh water is available. This indicates that under field conditions, supplying fresh water will enable fallow deer to graze forages and/or shrubs (e.g. saltbush) containing high salt content. Red deer responded differently to salt level in the diet compared to fallow deer in the current study. Red deer did not show any difference in body weight when fed diet containing 1.5%, 3.0 and 6% salt. It seems that red deer can be fed up to 6% of salt, equivalent to 2.6% sodium. However, the salt tolerance level for red deer should be examined more comprehensively before recommendations on high levels of salt intake can be made to the industry.

- The difference in the tolerance to salt in feed between fallow weaner deer and sheep indicates that the data obtained with sheep cannot be applied to fallow weaner deer directly. For example, the salt intake through feed at the highest level in the current study were 50 g/day for fallow deer but Wilson (1966b) reported that sheep can ingest up to 97 g sodium/day when offered fresh water. Meyer and Weir (1954) also recorded an intake of 104 g sodium/day by sheep offered a pelleted ration containing 13.1% sodium chloride. However, this research cannot make recommendations on whether deer farmers should use data derived from sheep for their adult fallow and red deer.

- The excessive salt intake through drinking water can affect deer performance by reducing feed intake much quicker than through the feed. To maintain healthy growth, fallow weaner deer can tolerate 1.2% salt in the drinking water and the red weaner deer can only tolerate 0.8%. The growth rate can be depressed when salt concentration in water is 1.5% for fallow weaners and 1.0% for red weaner deer. While these data can be used as a guideline for managing deer, farmers should be aware that these levels have been defined in winter in southern Australia for weaners fed on a commercial pelleted diet. Under grazing conditions, deer are often exposed to high temperatures, salty feed (bushes) and salt-affected soils. Thus the actual salt level in water that deer can tolerate may be lower than the level currently recommended. Frequent observation and regular monitoring of the salt level in pastures and drinking water should be practiced to ensure the maximum growth of grazing deer. Farmers should also note when grazing deer ingest plants such as Sour Sob or other oxalate containing plants, the oxalate poising might not be significant if fresh water is available. However, drinking salty water can exacerbate oxalate poising and cause damages to kidney, resulting in mortality.

- As found in the feeding trial, there are differences in the tolerance to salt concentration in drinking water between deer and sheep. When salt levels in drinking water were over 1.2% for fallow and 1.0% for red weaner deer, the growth rate was depressed significantly. However, for sheep saline water about 1.5% of total salts may not affect animal production subject to the environmental conditions, but over 2% total salts in the drinking water is detrimental to production and survival of sheep (Wilson, 1978).

In summary, this study determined the salt tolerance levels for red and fallow weaner deer under a Mediterranean environment. Fallow deer can tolerate up to 3% salt in the feed if fresh water is available. Salt concentration in drinking water should not be over 1.2% for fallow weaner deer and 0.8% for red weaner deer to avoid the reduction in feed intake. For deer farmers, it is recommended that frequent observation of general health of deer and regular test of salt concentration in feed and drinking water should be practised to ensure that southern Australia deer farmers are producing quality venison cost-effectively. Through this research, the following areas have also been identified for further research and development;

- The assessment of salt level in both diet and drinking water on performance of red and fallow deer under grazing conditions. As discussed in the report, when deer are grazing in the salt-affected areas, they are exposed to salty feed, saline water and soils simultaneously. The salt tolerance level in water or feed could be interactive. Thus the critical data required by farmers would be the maximum salt intake that grazing deer can tolerate, although it is difficult to estimate salt intake through ingestion of soil.

- The determination of salt tolerance of breeding herds. The current research demonstrated that the data derived from sheep cannot be directly applied to weaner deer. More importantly, the data obtained for weaner deer may not be valid for breeding herds because research with sheep clearly showed the difference in the capability of coping with excessive salt intake between adult and young animals. Also adaptation to salt by deer may occur over time.

- The seasonal variability in salt tolerance of deer. Previous research with sheep and the current work with deer demonstrated that increases in salt concentration in water or feed resulted in a high water intake. Fallow deer also showed a decline in water intake when salt level in water was over 2.0%. It is well understood that under high temperature grazing animals require more water. This could further increase salt intake through drinking saline water. Although there was no accumulation of rainwater in the paddock, the tolerance levels defined in cold winter in the current study could be too high for deer in hot summers.

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