Application of water medication technology in the northern Australian beef industry

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Summary

Water medication, whereby nutritional supplements are delivered via drinking water, is becoming widely used for extensive beef herds in northern Australia. However, there is surprisingly little objective data on this technology and on animal responses to it. Water medicators are either electronic or water–powered proportional dispensers, and are equipped with a variety of safety devices to minimise risks of toxicity through accidental over dosage of supplements such as urea. Knowledge of the water intake of cattle is required so that supplement concentrations can be adjusted to ensure optimal supplement intakes. Techniques for modifying water quality are important because water quality can have a significant effect on the efficiency of supplement delivery. Water medication is mainly used to supply nitrogen (as urea), sulphur and phosphorous supplements, but it is used to supply trace minerals and electrolytes in some cases. New technological developments such as telemetric monitoring can enhance the reliability and safety of water medication. Water medication technology is not appropriate for situations in which access by cattle to good quality water cannot be controlled, and is not appropriate for all producers because of the high level of management expertise required.

Keywords: water medication, beef cattle, nutritional supplement, water intake, water quality, management

Introduction

Cattle grazing most northern Australian pastures experience significant variations in nutrient intake because of seasonal variations in pasture quality and quantity. Nutritional supplementation to address these imbalances between supply and demand, to enhance production, or to supply specific limiting nutrients is a widely used management tool in northern Australia. There is an extensive body of literature on traditional supplements, supplementation techniques and supplementation strategies appropriate for use in northern Australia (Winks 1984; McLennan *et al.* 1991; Dixon *et al.* 1996; Leng 2003). Common supplement delivery methods include loose dry mixes, liquid sources (urea–molasses mixtures) and compressed lick blocks. However, with some of these traditional delivery methods, irregular and variable intake of supplement often occurs, which results in considerable variation in production responses (McLennan *et al.* 1981, 1991; Eggington *et al.* 1990; Dixon *et al.* 1997).

During the early 1980s, research workers and producers began to examine alternative supplement delivery methods. Water medication strategies were examined in several studies (Stephenson *et al.* 1981; Stephenson 1983; Stephenson and Hopkins 1985) in which supplements, particularly non–protein nitrogen (NPN) sources, were provided in solution at levels proportional to water intake. The rationale for this approach is that ruminants of a particular physiological state drink according to metabolic requirements. This rationale is also based on the premises that alternative sources of water are not available to the animals, that the water intake (and consequently, the water–soluble nutrient intake) of animals of similar type or status varies little between individuals and that soluble and safe nutrient sources are available.

Water medication is used increasingly in the northern beef industry and current estimates suggest that there are in excess of 600 users. Although there is considerable anecdotal evidence on responses to this form of supplementation, there is a dearth of objective and reliable information. In this article, we present a description of water medication technology and a discussion of published and anecdotal information on animal responses and the factors that influence them.

Modes of action of currently available commercial water medicators

The most commonly used water medicators are electronic proportional dispensers such as the

NORPRIM® and NUTRIDOSE®. They have a small electric pump that is used to inject an adjustable amount of nutrient concentrate, which is stored in an adjacent tank, into the pipeline or water trough. This is accomplished by an electronic flow sensor or mechanical water meter, which measures water flow in the supply line and triggers the nutrient pump. Power is usually supplied by a rechargeable 12–volt DC battery. Units are supplied in various sizes depending on flow rate, water pressure and the number of animals for which they are intended. These units are equipped with safety features such as electronic cutout valves and anti–siphon devices to minimise the possibility of urea toxicity. In more advanced versions, provision has been made for a link between electronic circuitry and telemetry equipment, which will enable activation of alarm systems in the event of a malfunction and remote sensing of trough and tank water levels, medicator operation and nutrient concentration in the water trough.

Proportional medicators that are powered by water pressure include the DOSATRON® and DOSOMATIC® units, which were originally developed for plant agriculture. These were widely used in extensive livestock systems and are still preferred by a minority who are concerned about electronic failure. These medicators utilise a water–driven reciprocating piston to inject the concentrate solution into the water line, and the proportional injection of nutrients is governed by the rate of flow of water into the pipeline or trough. Safety devices such as an in–line filter on the inlet and an anti–siphon device are usually installed. Because these units require a high operating head, they are not appropriate for all watering systems or for instances in which water consumption is low.

Regardless of the type of unit, hazards exist when water medication is used for dispensing potentially toxic NPN sources such as urea. These hazards are not only associated with system malfunctions but also with human error, excessive water intake caused by thirst or elevated ambient temperature, incorrect installation or modification of medicators, availability of alternative water sources, poor water quality, poor cattle husbandry or combinations of these factors.

There are also potential problems related to the corrosive nature of some highly concentrated nutrient solutions containing urea, sulphur and some sources of phosphorous, particularly when the water is of poor quality. Corrosion damage to metal pipes, fittings and pump components can lead to unit malfunction. Therefore, polythene rather than metal pipes and fittings are recommended, and an in–line filter on the inlet line from the concentrate tank is usually installed to prevent sediment and crystals from entering the pump. The manufacturers of electronic units also provide warnings and training on the danger of allowing nutrient solutions to contaminate the unit when monitoring outputs or adjusting the controls.

Water intake

Information on water intake is required in order to adjust supplement concentrations for optimal supplement intake. However, there is limited data on the water intake of beef cattle. Animal factors such as mass, physiological status, genotype and degree of stress, as well as a range of environmental, seasonal and topographical factors (ambient temperature, humidity, wind speed and direction, pasture dry matter content, water quality, distance between water points) are known to affect daily water intake (McFarlane and Howard 1974), but the magnitude of these effects is not well documented.

A water intake equivalent to 10% of bodyweight is widely used for calculating water needs of livestock. Thus for a 450 kg animal, the average daily water intake is estimated to be 45 L (QDPI 1982). Sheep and cattle drink about 4 L/d per kilogram dry matter (DM) consumed (NRC 1996), which gives a theoretical daily water intake of 45–50 L for a 450 kg steer, similar to the estimate mentioned previously. The between–animal variation in water intake is more difficult to predict. However, both anecdotal and published information indicate that the range is considerably wider than that estimated from NRC (1996) values. Luke (1987) calculated seasonal variations in water consumption from data for several locations in the pastoral zones of Western Australia. On an adult equivalent (AE = 400 kg steer) basis, daily consumption rates were estimated to range from 9–53 L/AE. In the southern USA, daily water intakes of lactating beef cows ranged from 62–72 L for average maximum temperatures of 20–32°C (Winchester and Morris 1956); the corresponding range for 450 kg steers was 29–78 L. There is anecdotal evidence from central Queensland (J. McTaggart, personal communication) that daily water intakes of lactating cows exceed 100 L during periods of high ambient temperature (>42°C).

In summary, the available data and experience of many cattle producers indicates a range of 45–55 L for daily intake of water of reasonable quality by mature animals weighing about 450 kg. However, these estimates should be increased by at least 25% for lactating cows and for cattle exposed to high temperature.

Water quality

Water quality has a significant effect on daily water intake (Carson 2000). On several properties in central Queensland where breeders consumed poor quality water, daily intakes during winter months dropped to as low as 9–12 L, but improved to 25 L when water quality was improved (S. Waterton, R. Thieme, personal communication). The impact of water quality on water intake, feed intake and animal production is not well understood, but poor water quality would probably have negative effects. Water quality parameters of importance include pH, total dissolved solids (TDS), electrical conductivity (EC, an index of TDS) and total alkalinity (TA). Satisfactory values are pH 6–8, TDS<10,000 mg/L and EC<15 dS/cm.

There are experimental and anecdotal reports that loss of urea from the concentrate tank or trough is associated with alkaline water (>pH 8.0) that has a high Ca content. Although the exact nature of the chemical reaction is not well defined, it is probable that the urea is hydrolysed to ammonia and carbon dioxide. Ammonia will inhibit water consumption if it is present in sufficiently high levels at the trough (Hirst 1996). At Katherine in the NT, where highly alkaline water was present, about 85% of the urea added to the concentrate tank was lost over a 24–week period (Andison 1994). Nitrogen concentrations were also greater at the bottom of the tank than at the top, which could have a negative effect on livestock productivity.

When present in high levels in water, carbon dioxide reacts with Ca to form calcium carbonate, which precipitates and forms scale deposits in pipes and fittings. Scale build–up can reduce flow rate and can sometimes impair the functioning of the float valve and water medicator. In alkaline water in which the concentrations of both Ca and Mg ions are high, addition of supplements that contain P may result in precipitation of calcium and magnesium ammonium phosphates. This will result in lower than anticipated soluble P levels in medicated water and flocculates in the water or scale in pipelines and fittings.

The addition of sources of P and N to highly alkaline water that is exposed to sunlight is conducive to algal growth, which can have an adverse effect on water consumption and water medication. Some algal blooms are toxic. For these reasons, sealed light–coloured polythene concentrate tanks are preferred to dark–coloured plastic, fibreglass or metal tanks; storage of medicated water in open–top or earth tanks is not recommended. Light–coloured polythene tanks minimise corrosive effects, reduce heating of concentrate solutions and minimise penetration of UV rays.

Water quality must be assessed before deciding whether to use water medication. Some water is of such poor quality that acidifiers, magnets and other water–quality improvement techniques will not prevent adverse reactions involving urea and phosphorus from occurring. In such cases, alternatives such as loose licks, blocks or molasses–based mixtures should be considered.

Irrespective of water quality, concentrate solutions should not be stored for long periods. Small concentrate tanks holding only 7–10 days' supply should be used, and frequent and thorough mixing of the concentrate should be applied to prevent concentration gradients from occurring. Water pH should be monitored routinely. There are a number of cheap, reliable and effective portable pH and EC meters available, which many producers now use. The importance of monitoring and improving water quality cannot be over–emphasised, since this practice may determine the success of this technology.

Methods for improving water quality

There are a number of approaches to improving water quality for use in water medicators. For highly alkaline water (pH>8.0–8.2), acidification using hydrochloric acid, phosphoric acid, or urea phosphate has been used. When water is acidic, phosphates are soluble and scale problems do not occur. Several acid injector pumps are commercially available and have been used successfully.

More recently, magnets have been used to enhance water quality (McCosker 2000). There is limited scientific data on the mode of action and efficacy of magnets applied to water pipelines. However, proponents have suggested that electro–magnetic energy enhances anion–cation exchange, transmits positive energy to the water, reduces surface tension of water molecules and reduces calcium deposition and scale build–up. Anecdotal evidence suggests that although this technology has a reasonably good record of accomplishment, it has proved ineffective in some situations. A better understanding of the principles involved could result in more efficient use of this somewhat expensive and controversial technique.

Considering the wide variation in the quality of water consumed by cattle, topics that warrant additional research are the influence of water intake on productivity and the interaction between water quality and the effectiveness of water medication.

Supplements for water medication

The primary use of water medication technology is to provide supplementary N, P and S to grazing cattle. In some areas, water medication is also used to provide supplementary essential trace minerals, and some proprietary supplement formulations contain trace elements. Water medication is also used to provide electrolytes and glucose to minimise the effects of stress during road or sea transport, to enhance meat quality and to reduce the stress of weaning and associated morbidity (A. Henderson, M. Perkins, personal communication). There are anecdotal reports that substances such as seaweed extract, bloat control compounds, soluble energy sources and organic anthelmintics have been supplied in water.

Nitrogen and sulphur sources

Urea is by far the most common NPN source used for water medication. It is usually mixed with ammonium sulphate to provide S (McLennan *et al.* 1981, 1991; Hirst 1996; McCosker 2000). Urea is rapidly hydrolysed to ammonia in the rumen, which is then available for microbial protein synthesis. The effect of urea on rumen microbial activity and protein synthesis is regulated by the supply of available carbohydrate (Nolan and Leng 1972). Urea improves performance by increasing feed intake, which effectively increases stocking rate, places additional pressure on pastures and can cause rangeland degradation. Although this effect will not cause problems in areas where pasture DM availability is not limiting, reduced performance has been observed in many areas of northern Australia (McLennan *et al.* 1991).

The optimal amount of urea needed by cattle grazing dry–season pastures has been established from numerous experiments, and ranges from about 30 g/d for weaners and yearlings to 45–60 g/d for lactating females (Winks *et al.* 1979; Dixon 1994). These requirements have been adopted for water medication technology (Bawden 1997, Hill 2003). No previous studies have determined the optimal level of urea for water medicators, but work on the Barkly Tablelands (S. Petty, personal communication) is currently addressing this.

The potential for urea toxicity is well recognised and mortalities due to medicator malfunction, human error or poor management (e.g., access of naive or thirsty cattle to water containing more than 2 g/L urea) have occurred (McLennan *et al.* 1991; Hirst 1996), some of which have been devastating in extent. Depressed water and feed intakes also occur when urea concentrations exceed 2 g/L (Holm *et al.* 1981). Several methods for testing urea concentrations, including a colour–reaction test kit similar to swimming pool chlorine test kits, are now available. A more sophisticated testing system currently under development involves an electronic monitoring probe in the water trough to detect urea concentrations, which can activate a safety cutout system on the medicator unit (Wood 2003).

The most commonly used S source is technical grade ammonium sulphate[1], although other products such as GRAN AM®, a granulated AS source containing an appreciable amount of N, are available. Sulphur is usually added to provide an N:S ratio of about 10:1, but there is evidence that indicates that the optimal ratio ranges from 5:1 to 20:1 (Underwood and Suttle 1999). Because ammonium sulphate may sometimes form precipitates in poor quality water, thorough and frequent mixing is needed.

Phosphorous sources

For areas in northern Australia where clinical and subclinical P deficiencies occur, there is general agreement that responses to P supplementation can only be expected when cattle are gaining weight (Ternouth 1990; Winks 1990; Coates 1994; Miller *et al.* 1997). Thus, P is primarily supplemented during the wet season (Coates 1994). Recommended sources of P for water medication include food grade phosphoric acid, urea phosphate fertiliser (Magnum P–44®) or technical grade mono–ammonium phosphate (MAP). The appropriate choice of supplement depends on cost and the pH of the water. Fertiliser grade MAP does not always dissolve completely and tends to form sludge in the concentrate tank. Other P supplements used in dry lick formulations such as rock phosphate, superphosphate and Kynofos are not sufficiently water–soluble and should not be used in water medicators.

Although most producers prepare mixes on–farm (Adams and Savage 1996), commercial pre–mixes containing N, P and S are available. Provided landed costs are comparable, labour savings and potential reductions in human error make these an attractive option. Several liquid N and S supplements are available, but there is no scientific information on responses to these products; anecdotal evidence suggests that they are not suitable for all situations. The cost of supplementation of N, S and P using water medication is estimated to be half to one third of that of traditional forms of supplementation (Bawden 1998; Hill 2003), but this potential saving should be weighed up against the capital investment required to set up a water medication unit. While labour savings are often cited as an advantage of water medication, these may be more imagined than real, since regular checking of bores, watering facilities and equipment involves labour and transport. Development of more effective remote sensing equipment could result in further cost savings in this respect.

Water medication strategies

It is generally recommended that NPN supplements be fed to cattle grazing dry season pastures that are low in protein content (Winks *et al.* 1979; McCosker *et al.* 1991). While the traditional approach (Winks *et al.* 1979) is to commence urea supplementation when faecal nitrogen content falls below 1.3%, there are several unconfirmed reports from central Queensland of positive production responses to supplementation of high–quality wet season pastures with low levels (10–25 g) of urea (T. McCosker, R. Sparke, personal communication). It is probable that these responses occur during the wet–dry transitional period when pasture N levels have started to fall, rather than throughout the entire wet season.

When urea is supplied via water medication, it is recommended that urea intakes should be increased progressively in order to minimise potential toxicity problems (McLennan *et al.* 1991; Hill 2003). For lactating breeders, an initial daily intake of about 10 g is widely used; this is increased to 45–60 g over a 2–3 week period. However, anecdotal evidence suggests that

[1]Fertilizer grade usually has a coarser granular structure, is less soluble and may contain more contaminants than technical grade.

cattle can adjust more rapidly to a higher initial daily urea intake of 20 g.

The accepted strategy has been to feed P supplements during the wet season (Miller *et al.* 1997), but in some regions in the north where soil and pasture P status is very low, year–round supplementation is the norm (Savage 1997). Provision of P supplements during the dry season may minimise losses due to botulism, which is a consequence of bone chewing in cattle deficient in P. Additionally, most northern herds practice continuous mating, and approximately 30% of the breeder herd may lactate during the dry season. When pastures are deficient in P, lactating breeders require P supplementation during the dry season. Phosphorus supplementation using water medication is usually 10 g/d for lactating cows.

Responses to water medication

Although there is an extensive body of literature on responses of grazing cattle to traditional N, S and P supplementation (see reviews by Ternouth 1990; Winks 1990; McCosker *et al.* 1991; Miller *et al.* 1997; Leng 2003), there is a paucity of data on responses to water supplementation. Although several studies have compared responses between traditional and water medication strategies, most data on water medication are derived from unreplicated observational studies. There are also a considerable number of anecdotal reports in the popular press by users of water medication, which usually indicate that positive responses were obtained.

In an unreplicated three–year producer demonstration site (PDS) trial in the 'desert' country of central Queensland (Bawden 1997), supplementary N, S and P were offered as a dry lick or via a water medicator. During the dry season, urea and P intakes were higher for cattle offered medicated water than for those offered a dry lick. A similar trend was observed for P intake during the wet season. The pregnancy rate was 15% higher for breeders offered medicated water than for those offered a dry lick, even though there was only small difference (15 kg) in mean breeder weight. Weaning weight did not differ significantly between treatments. These differences could be due to lower individual variation in supplement intake from water medication or lower supplement intake from dry licks. At an unreplicated PDS in central Australia, lactating cows that received supplements (N, S and P) via a water medicator were compared to controls that did not receive any supplement (Hill 2003). Supplemented cows were significantly heavier (35 kg), in better body condition and had slightly higher pregnancy rates (53% vs. 42%) than unsupplemented cows. Although average weaning weight did not differ, the total weight of weaned calves was higher in the supplemented group because of a higher pregnancy rate. In a second phase, in which heifers were allocated to a water medication group or an unsupplemented group, pregnancy rates were 21% higher in the water medication group, even though there was no difference in heifer weight. Pregnancy rates were 30% higher in lactating heifers. Average weaning weight was similar, but total weight weaned was higher in the water–medicated group. In both studies, cost/benefit analyses indicated that positive responses were achieved. The central Australian study suggested a benefit/cost ratio of about 9:1, $213 per lactating breeder cow year.

In a study on the Mitchell grass associations of the Barkly Tablelands in the Northern Territory, Petty (personal communication) recorded a liveweight gain advantage of water medication for weaners relative to unsupplemented controls of 0.3 kg/d in the early dry season and 0.1 kg/d over the entire dry season.

Additional objective research is warranted to quantify the magnitude of responses to water medication and to define factors critical to responses. Biological and economic analysis of such data would facilitate optimal application of the technology.

Conclusions

This paper has highlighted some of the known applications, advantages and limitations of water medication systems used for grazing beef cattle. While water medication has been mainly used to deliver limiting macro and micronutrients, various other compounds could be delivered using this technology. These include electrolytes and sugars for minimising stress and enhancing meat quality, anti–tannin compounds for enhancing digestion of fibrous or less digestible plant material, compounds for stimulating immune responses or controlling internal and external parasites, anti–bloat compounds and organic formulations for satisfying standards for organically produced food.

Water medication in the northern Australian beef industry provides an additional dimension to supplementation and management strategies on a potentially large number of properties where control of watering points is possible. However, the technology is not suitable for all producers, nor is it applicable to all situations. The successful use of water medication technology requires a good appreciation and understanding of nutritional principles and of the timing and levels of supplementation required to achieve optimal responses. A good understanding of water intake and water quality issues and of the effects of interactions of water components with supplements is essential for successful application of the technology. Finally, a significant capital investment in high quality water facilities is required together with a high level of management expertise, an understanding of the underlying technology and a commitment to continual maintenance and monitoring of the system.

Technological improvements have enhanced the safety and reliability of water medication. Additional research commissioned by MLA to investigate water quality and water chemistry issues may provide solutions to some problems. A number of commercially available technologies for water quality modification and improvement, some of which are quite expensive, are frequently used in a 'band–aid' manner. The efficacy and efficiency of these methods has not been established. Better definition of the mode of action of some of these devices and of the situations in which they would be of benefit would result in cost savings for users.

There is considerable interest among current users in technology for monitoring water medication systems. One commercially available unit has the capacity to integrate with a radio telemetry system to facilitate monitoring and to activate alarms for parameters such as water flow, level of liquid in the trough, concentrate and supply tank, and medicator function. A large northern pastoral company is also conducting research on telemetry systems for water supply and water medication units. In the near future, these developments will lead to further commercial applications, which will enhance the safety and reliability of the technology, facilitate time and labour savings, and may increase the extent to which water medication is used on extensive northern properties.

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