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Free-ranging cattle water consumption in southcentral New Mexico[1]

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Abstract

Water-drinking behavior of 67 free-ranging protein supplemented and nonsupplemented beef cattle was examined between May 23 and 16 July 1986, in southcentral New Mexico. The lactating and nonlactating cows had a mean liveweight of 383 kg and were maintained as a single herd, and separated only during supplementation with an automated sorting and single animal electronic identification system. Mean daily water consumption was 57 l day^{-1} (16 l (100 kg liveweight)$^{-1}$) at a rate of 20 l min^{-1} under mean mid-range ambient air temperatures between 14 and 24°C. Water consumed by cows supplemented at 0.7 kg head^{-1} day^{-1} and 1.4 kg head^{-1} day^{-1} fed every 5.9 days and 3.5 days, respectively, was 14 l (100 kg liveweight)$^{-1}$ and 15 l (100 kg liveweight)$^{-1}$ ($P=0.7238$), respectively. In contrast, nonsupplemented cows consumed more ($P\leq0.0015$) water (17 l (100 kg liveweight)$^{-1}$) than supplemented cows. Lactating cows consumed more water ($P<0.0001$) than nonlactating cows (19 l (100 kg liveweight)$^{-1}$ and 12 l (100 kg liveweight)$^{-1}$, respectively). One drinking event every 24 h was sufficient to satisfy cows 94% of the time. Neither supplement level nor lactation affected ($P>0.05$) daily watering frequency. Water intake was negatively correlated to predrinking liveweight ($r=-0.19$; $P<0.01$) and the current day's maximum ambient air temperature if greater than or equal to 30°C ($r=-0.11$; $P<0.02$). Water intake was not correlated to temperatures ≥ 30°C. Water consumption was positively correlated to relative humidities between 15 and 86% ($r=0.17$; $P<0.01$). Water consumption was not correlated ($P>0.05$)

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with the mid-range or maximum ambient air temperatures of the current or previous day. Our findings indicate large feedings of protein reduced water consumption, probably as a consequence of lower forage intake. Lactation increased water requirements and liveweight was a poor predictor of water needs. Water consumption is affected by biotic and abiotic factors other than those we evaluated.

Key words: Drinking behavior; Cattle; Feeding; Nutrition; Grazing

1. Introduction

Water is the primary life-limiting nutrient in mammals (Nicholson, 1985), especially in arid environments where supply and distribution are limited (Kamel et al., 1982). Many factors influence the quantity and frequency of water consumed by livestock including forage availability (Squires, 1981), forage moisture (Castle and Thomas, 1975) and dry matter concentration (Sekine et al., 1989), nitrogen content of diets (Winchester and Morris, 1956), forage phenological state (Hancock, 1953), animal species (Lampkin et al., 1958; Wilson 1975), location of water (Wilson and Hindley, 1968), distance to water (Sneva et al., 1973) and ambient air temperatures (Daws and Squires, 1974). As ambient air temperatures rise, free-ranging livestock increase the volume of water consumed (Mullick et al., 1952; Roy et al., 1969; Wilson, 1974). Hyder et al. (1968) reported positive relationships between water intake and mean daily ambient air temperature ($r=0.64$; $P<0.01$) and mean daily ambient air temperature of the previous day ($r=0.59$; $P<0.01$), within a range of 11–24°C. Murphy et al. (1983) reported a positive influence between maximum daily ambient air temperature (mean = 19°C; range −2 to 31°C) and water consumption ($r=0.48$; $P<0.01$). However, Little and Shaw (1978) did not find a relationship ($P>0.05$) between water intake and 7–20°C ambient air temperatures. Above 25°C, water consumption rises sharply, apparently because of sweating and increased respiration rate (Johnson et al., 1960; National Research Council (NRC), 1981).

Ragsdale et al. (1953) reported that at ambient air temperatures less than 24°C, relative humidity had a negligible effect on cattle water consumption; however, at higher ambient air temperatures, water intake decreased as relative humidity increased. Conversely, Castle and Macdaid (1975) reported water intake by pastured dairy cattle in Scotland was not affected by relative humidities between 50 and 98%, where ambient air temperatures ranged between 12 and 27°C.

Increased water consumption during lactation is well-documented (Little et al., 1976, 1978; NRC, 1984). Pregnant and lactating females consume more water than nonpregnant, nonlactating females (NRC, 1981, 1984; Nicholson, 1985). Lactating cows require at least 900 ml of water to produce 1 l of milk (Winchester and Morris, 1956; Murphy et al., 1983); however, considering the metabolic heat generated in milk production, water requirements to produce 1 l of milk are probably even higher (Barrett and Larkin, 1974).

The objective of this study was to evaluate water intake of free-ranging beef cattle grazing arid rangeland between May and July. Protein supplement, physiological status (lactation vs nonlactation), ambient air temperature and relative humidity were considered in the evaluation of the data collected.

2. Animals, materials and methods

The study was conducted between 23 May and 16 July 1986, on the Jornada Experimental Range (32°37′N, 106°45′W) in Dona Ana County, New Mexico, at an elevation 1300 m above sea level. Climatological data were collected during the 55 day study at Jornada headquarters with federal Weather Bureau equipment. This arid ecosystem receives 230 mm precipitation based on a 61 year mean, with 52% occurring during the July–September growing season (Paulsen and Ares, 1962). Mean ambient air temperatures range from 13°C in January to 36°C in June. Vegetation included *Hilaria mutica* (Buckl.) Benth., *Scleropogon brevifolius* Phil., *Sporobolus airoides* (Torr.) Torr., *Sporobolus contractus* A. S. Hitchc., *Sporobolus flexuosus* (Thurb.) Rydb., *Prosopis juliflora* var. *glandulosa* Torr., *Psorothamnus scoparius* (Gray) Rydb. and *Yucca elata* Engelm.

The 67 lactating and nonlactating Hereford and crossbred cows of Angus, Hereford, Brahman and Santa Gertrudis breeding were randomly allotted within physiological status, breed, age (63 were more than or equal to 4 years of age) and liveweight to three supplementation treatments. Animals were individually fed cottonseed meal pellets (41% crude protein (CP)) between 16 April and 16 July at a rate of 5 kg $(24\ \mathrm{h})^{-1}$, based on their frequency to return to the headquarters location to drink water. Drinking frequency ranged between every 1.6 and 8.5 days (Anderson et al., 1992). The three treatments included 35 nonsupplemented cows, 17 supplemented cows that received a mean of 1.4 kg head^{-1} day^{-1} fed every 3.5 days and 15 supplemented cows that received a mean of 0.7 kg head^{-1} day^{-1} fed every 5.9 days.

Drinking behavior data were collected during daylight at ranch headquarters. The potable water was under 3.5–2.1 kg cm^{-2} pressure and was monitored through a Neptune® Triseal Model 8 meter (Schlumberger Technologies, Chesapeake, VA, USA) with 1.5 cm diameter inlet and discharge orifices. A Seraphin® (Seraphin Test Measure, Rancocas, NJ, USA) volumetric 19 l test carboy was used to verify the accurately of the water meter.

An electronic animal identification system manufactured by Pinpointer® (Agriculture Identification Systems, Cookeville, TN, USA) allowed cows to be individually managed. Each animal was given the opportunity to drink water to satiety from a 50 cm wide, 113 cm long, 24 cm deep trough, located in a one-directional maze which contained an automated sorting system that employed mechanical and electronically operated devices (Anderson et al., 1992). Once an animal exited the sorting system, the trough was allowed to refill before another animal was allowed to drink. Each animal's drinking duration was timed to the nearest minute.

Observations were made at a distance of about 3 m from the trough from behind a window covered with plastic, which allowed the concealed observer to see the cattle. When cows were observed drinking on more than one occasion in the same 24 h period, individual readings were totaled to calculate daily consumption.

The water intake data were analyzed in a completely randomized design using Statistical Analysis Systems Institute (SAS, 1985). In the AOV (Analysis of Variance), days were a sub-sampling term and level of supplement and physiological status were considered treatment factors in a 2×3 factorial arrangement. Daily water consumption was expressed as a percentage of liveweight to eliminate the possible effect liveweight differences might have had on water intake (Sekine et al., 1982). Lsmeans were calculated and were separated by the PDIFF option of the SAS GLM procedure when AOV F values had observed significance levels of less than or equal to 0.05 (SAS, 1985). The relationship between daily watering frequency and the level of supplement and physiological status was tested using the chi-square test of homogeneity. A similar analysis was done on drinking duration, which was categorized into 0–1, 2–4, 5–16 min. Mid-range daily ambient air temperature was derived from daily minimum and maximum temperatures (Hyder et al., 1968). Linear relationships between water intake, liveweight, mid-range, and maximum daily ambient air temperature and relative humidity were analyzed using correlation analysis (Draper and Smith, 1981).

3. Results and discussion

Fourteen precipitation events between 23 May and 16 July produced 10.1 cm of water. This amount of precipitation was substantially above the 61 year mean, 6.5 cm May through July. Water was observed to puddle on the sandy to fine sandy loam soils characteristic of the study area with single or cumulative precipitation of less than or equal to 0.5 cm (R.P. Gibbens, personal communication, 1992). Since the amount of precipitation received exceeded the 0.5 cm threshold between 29 May and 3 June (2.41 cm; 6 days), 23 and 26 June (6.78 cm; 4 days) and on 16 July (0.53 cm; 1 day), water drinking behavior may have been influenced. Even though no observations were made in the field of the animals drinking from puddles, Low et al. (1978) has documented that range cattle readily consume puddled water. Therefore, the frequency with which animals returned to headquarters to drink water may have been altered on 11 days over the 55 day study. Precipitation received during the remaining three events should not have produced puddled water, since each were isolated days where amounts ranged between 0.05 and 0.30 cm. Mean maximum, minimum and mid-range ambient air temperatures during the 55 day study were 32°C, 15°C and 24°C, respectively.

Based on 507 observations, mean daily water consumption for cows with a mean liveweight of 383 kg was 57 l (range 1–193). Cattle have been observed to drink as much as 104 l of water at a single drinking (Nicholson, 1985). Dehydrated cattle on a semidesert range can consume up to 40% of their body-weight without showing signs of intoxication (D.M. Hallford, personal communication, 1987). The NRC (1984) states that the water requirement of 364 kg cows is between 40 l day^{-1} and 57 l day^{-1}, at ambient air temperatures of 26° and 32°C, respectively. Mean daily water intake observed in this study, when expressed as percent of liveweight, was the same as the stated requirements for cows at 32°C (16 l (100 kg liveweight)$^{-1}$; NRC 1984). Mean daily water intake expressed as a percentage of cow liveweight by supplement level and physiological status is given in Table 1. No supplement level × physiological status interaction was found for either total daily water intake ($P=0.8571$) or water consumption expressed as a percent of liveweight ($P=0.3706$). The AOV showed an overall difference between supplementation treatments (0, 0.7 and 1.4 kg head^{-1} day^{-1}) for both daily intake ($P=0.0005$) and for daily intake as a percentage of body liveweight ($P=0.0039$). The Lsmean separation indicated supplemented cows, regardless of level (0.7 kg head^{-1} day^{-1} or 1.4 kg head^{-1} day^{-1} fed every 5.9 days and 3.5 days, respectively) drank similar ($P=0.7238$) volumes, but less than ($P\leq0.0015$) nonsupplemented cows (14 l (100 kg liveweight)$^{-1}$, 15 l (100 kg liveweight)$^{-1}$ and 17 l (100 kg liveweight)$^{-1}$, respectively). This occurred both for total daily water intake and water intake as a percentage of body liveweight (Table 1). The 5 kg of supplement administered per feeding may have reduced dry matter intake, hence water intake through latent displacement of forage (NRC, 1984). Adams et al. (1979) found supplementing steers with 2.7 kg of cottonseed meal every 3 days reduced ($P<0.01$) daily intake of a basal diet containing ground alfalfa hay and cottonseed hulls compared with 0.9 kg fed daily.

Table 1

Means with associated standard errors (SE) and correlation coefficients (r) with observed significance levels (OSL) between liveweight before drinking and total daily free-water intake in cows grazing semi-arid rangeland by supplement (cottonseed, 41% crude protein) level and physiological status between 23 May and 16 July 1986

	All animals	Supplement level[1] (kg head^{-1} day^{-1})			Physiological status	
		1.4	0.7	0	Lactating	Nonlactating
Liveweight (kg)						
Mean ± SE	383 ± 3.2	390 ± 5.7	363 ± 7.3	387 ± 4.5	350 ± 3.6	426 ± 4.3
Water intake total (l day^{-1})						
Mean ± SE	57 ± 1.0	52^{a} ± 1.7	53^{ab} ± 2.5	63^{b} ± 1.7	61^{a} ± 1.4	50^{b} ± 1.9
Range	1–193	2–193	1–123	9–101	1–193	2–123
% Liveweight (l day^{-1} 100 kg^{-1})						
Mean ± SE	16 ± 0.3	14^{a} ± 0.5	15^{ab} ± 0.7	17^{b} ± 0.5	19^{a} ± 0.4	12^{b} ± 0.5
Correlation						
Coefficients (r)	−0.19	−0.15	−0.26	−0.22	−0.03	−0.21
OSL ($P=$)	0.0001	0.0501	0.0061	0.0011	0.6700	0.0019
Number						
Animals	67	17	15	35	37	30
Observations	507	180	107	220	286	221

[1]There was not a significant ($P>0.05$) supplementation level by physiological status interaction for water consumption.

[a,b]Means within the same row with different letters differ ($P<0.05$) for each main effect.

Our lactating cows consumed 24% more ($P=0.0001$) water than nonlactating cows (Table 1). McDowell (1972) reported lactating cows consumed up to 44% more water than nonlactating cows, with intake a function of total milk yield. Hereford, Santa Gertrudis, Brahman and Angus crossbred cows produced an average of 4 kg of milk daily (Wistrand and Riggs, 1966; Melton et al., 1967; Reynolds et al., 1967). Based on this estimate, the lactating cows increased water consumption of 12 l day^{-1} above the nonlactating cows, was equal to the minimum amount of 3 l of water per kg of milk produced quoted by Barrett and Larkin (1974).

Table 2 shows the number of waterings when cows drank by supplement level and physiological status. In 94% of the observations, cattle were able to satisfy their water need with a single drink. This compares favorably with other research in which cattle pastured on grass drink from one to four times daily (Hancock, 1953; Arnold and Dudzinski, 1978). The number of drinking events was not affected ($P>0.05$) by either supplement level or physiological status. This is in contrast to MacLusky's (1959) findings, which indicated supplemented cattle drank more frequently than nonsupplemented cattle. Apparently, our experimental procedure to administer supplement immediately following drinking water did not disrupt normal behavior in these free-ranging cattle, in contrast to supplement feeding regimes that follow a rigid a.m. or p.m. schedule (Adams, 1985).

Time required for the 67 cows to drink, based on 507 observations, indicates 77% of the drinking events lasted between 2 and 4 min (Table 2). Water consumption was positively correlated to drinking duration ($r=0.42$; $P<0.01$). Cows consumed water at rates ranging from 14 to 28 l min^{-1}. These values compare

Table 2
Daily watering frequency and minutes of drinking by cottonseed supplemented (41% crude protein) and nonsupplemented lactating and nonlactating cows grazing arid rangeland between 23 May and 16 July 1986

Category	Daily watering frequency[1]						Minutes of drinking					
	1		2		3		0–1		2–4		5–16	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
Overall	478	94.3	27	5.4	2	0.4	38	7.5	389	76.7	80	15.8
Supplement level (kg head^{-1} day^{-1})												
1.4	163	32.2	16	3.2	1	0.2	16[a]	3.2	141[a]	27.8	23[a]	4.5
0.7	99	19.5	7	1.4	1	0.2	11[a]	2.2	82[a]	16.2	14[a]	2.8
0	216	42.6	4	0.8	0	0.0	11[a]	2.2	166[a]	32.7	43[a]	8.5
Physiological status												
Lactating	274	54.0	11	2.2	1	0.2	16[a]	3.2	232[a]	45.8	38[a]	7.5
Nonlactating	204	40.2	16	3.2	1	0.2	22[a]	4.3	157[b]	31.0	42[a]	8.3

[1]None of the percentages or frequencies differed using a chi-square test of homogeneity for supplement level vs frequency of watering and for physiological status vs frequency of watering ($P>0.05$).
[a,b]Means in the same column, within categories, with different letters differ ($P<0.05$).

favorably with drinking rates of 15 l min^{-1} for dairy cattle (Thomas, 1971; Castle and Thomas, 1975) and 26 l min^{-1} for Zebu cattle in Africa (Nicholson, 1985). Level of protein supplement did not affect ($P > 0.05$) amount of time required for cows to ingest water. A greater percentage ($P < 0.05$) of lactating cows consumed water within the 2–4 min time bracket than nonlactating cows, but no differences ($P > 0.05$) were found within the other time brackets (0–1 and 5–16 min).

The relationship between liveweight before drinking and water intake was evaluated; correlation coefficients within supplement level and physiological status are given in Table 1. Most of the correlations show a high significance, but this may result from the high *n* (sample size) making the *t*-test overly sensitive. Thus, it is unclear whether these correlations actually have biological significance. However, the small magnitude of the negative coefficients suggest liveweight before drinking is not a suitable predictor of daily water consumption in either lactating or nonlactating beef cattle, regardless of protein supplement level.

Daily water consumption plotted against various weather factors produced scatter diagrams with no quadratic or cubic tendencies. Ambient air temperature during the 55 day study ranged from 7 to 38°C, with a daily mid-range of 24°C; mean maximum ambient air temperature was 32°C (range 21–38°C), while mean minimum ambient air temperature was 15°C (range 7–20°C). Correlations between daily water consumption and mean mid-range daily ambient air temperature, mean maximum daily ambient air temperature, mean mid-range daily ambient air temperature, mean mid-range ambient air temperature of the previous day and mean maximum ambient air temperature of the previous day were not significant ($P > 0.05$). However, the correlation ($r = -0.11$) between water intake and mean maximum daily ambient air temperatures greater than or equal to 30°C was significant ($P = 0.02$).

Ambient air temperature alone usually is not the temperature directly affecting biological processes (Holm and Edney, 1973). Therefore, combining soil temperatures (Low, 1979) and radiant heat load (Yousef, 1990), a combined measure of the effects of radiant energy and air movement may provide a better measure of the warmth experienced by free-ranging animals. Low correlation coefficients suggest variation in water intake was not affected by mean mid-range daily ambient air temperatures (range 14–28°C) or maximum ambient air temperature at drinking or of the previous day. At temperatures above 30°C, water intake begins to vary between individuals, mainly in response to individual animal behavior (NRC, 1981). This may explain the low negative correlation between water intake and maximum daily ambient air temperatures greater than or equal to 30°C.

Relative humidity between 23 May and 16 July ranged between 15 and 86% (mean = 50%; standard error = 0.85). Water consumption was positively correlated with relative humidity on the day of drinking ($r = 0.17$; $P < 0.01$) and relative humidity of the previous day ($r = 0.14$; $P < 0.01$). Low relative humidity and wide variation in ambient air temperature (7–38°C) during this study probably account for these low correlations.

4. Conclusions

Mean water intake of mature beef cows grazing arid rangeland was 57 l day^{-1}, with 94% of the herd being able to satisfy this volume with a single drink. Cows consumed water at rates ranging from 14 to 28 l min^{-1}. Reduced water consumption with increased dietary protein levels observed may have been a consequence of reduced forage intake. Lactating cows consumed 24% more water than nonlactating cows. Liveweight was a poor predictor of water consumption. Low correlations between water intake, ambient air temperatures between 7 and 38°C and relative humidities between 15 and 86% indicate other biotic and abiotic factors play an important role in determining water consumption in free-ranging cows grazing arid rangeland.

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