Chapter 11

Water Salinity Under Heat Stress in Grazing Conditions

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Additional information is available at the end of the chapter

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1. Introduction

Water is essential for animal survival under any environmental condition. Furthermore, it is becoming a limiting factor at a global level. Cattle water needs can be satisfied in three ways: 1. Metabolic water, from tissue and organic substrates oxidation; 2. Feed water; and 3. Drinking water.

Under any circumstances, drinking water is the most important source, mainly during summer months. When animals are in a hot environment, any factor limiting access to good quality water will directly affect milk production, which will dramatically fall, especially in high producing cows. Water restricted animals show higher body temperature, increasing heat stress, and immune system alterations. Besides, water restriction affects feed intake, since water and dry matter intakes are strongly related. This is true even under grazing conditions, regardless of the high water contents many fresh pastures have. Also, under hot conditions, ingestion of high volumes of water contributes to improve animal comfort, since reticulo-rumen temperature decreases.

It should be pointed out that water quality alone is not enough to avoid the effects of heat stress on lactating milking cows during hot weather. Other nutritional, as well as environmental strategies can be implemented to improve grazing dairy cattle performance and mitigate heat stress, and will also be discussed.

2. Dairy water intake and environment

No doubt water is the most essential element for the survival of animals. Water requirements for livestock can be met in three ways:

1. Metabolic water, derived from the oxidation of organic substrates and tissue
2. Water contained in food

3. Drinking water

In any event the latter route is the most important in the quantitative sense and in summer is by far the largest source. During this season o0f the year, any factor that limits access to water directly affect the production of milk, which will fall sharply, mainly in high-producing cows. Cows with water restrictions manifest higher body temperature, with a degree of heat stress higher than normal. Furthermore, water restriction causes a greater reduction in the consumption and ingestion of water and dry matter intake are closely related (National Research Council (NRC), 2001). Also, under intense heat, ingestion of large volumes of water affects comfort by reducing the temperature of the rumen reticulum.

Dairy cows normally drink large amounts of water, but with intense heat they could take more than 120 L/day. In a landmark study conducted in climatic chambers, it was recorded water consumption of lactating cows increasing by 29% when the temperature rose from 18 to 30°C. Concomitantly, fecal water loss decreased 33%, but losses via urine, skin and respiratory tract increased by 15, 59 and 50% respectively.

Regarding minerals, heat-stressed cows increase their need for Na^+ and K^+, due to the electrolyte imbalance generated at the cellular level. The higher needs of Na^+ are attributed to increased secretion of urine that reduces the plasma concentration of aldosterone. Instead, the increased demands for K^+ are attributable to an increased removal of this element with sweat.

In lactating cows fed a diet based on corn silage, hay and concentrates, typical of many production models, it was found that the main factors that determined water intake were: dry matter consumed; the level of milk production, temperature and Na^+ intake. The following equation (NRC, 2001) shows these relationships:

$$WI = 16 + \left[(1.58 \pm 0.271) * (DMI)\right] + \left[(0.9 \pm 0.157) * (MP)\right] + \left[(0.05 \pm 0.023 * (Na^+)\right] + \left[(1.20 \pm 0.106) * (T_{md})\right],$$

where

WI = Water intake (kg/day)
DMI = Dry matter intake (kg/day)
MP = Milk production (kg/day)
Na^+ = sodium (g/day)
T_{md} = daily minimum temperature (ºC)

3. Dairy water quality and milk production

The quality of drinking water is often one of the causes limiting its intake. Water quality is measured in chemical, bacteriological and physical terms, through laboratory tests. To avoid significant production losses each of these aspects must be carefully and regularly evaluated.

Regarding chemical composition, the concentration of total dissolved solids (TDS) and the prevalent salts represent the quality factors that can seriously limit milk production in many regions. There is controversy regarding the maximum levels of salts that affect the performance of dairy cows. Water with TDS> 7000 mg/L would not be suitable for high producing cows (>35 L/day), but would have little effect on low-producing animals (<25 L/day) (Bahman et al. 1993; NRC, 2001). Experiments conducted in Israel (Solomon et al., 1995) showed that water with TDS above 4000 mg/l produced negative effects on cows producing an average 35 l/day, when temperature was above 30°C.

All sulfate salts (Ca^{2+}, Na^{+}, Mg^{2+}), when exceeding 1500 mg/L, can decrease productivity because of their laxative effect, the most potent being sodium sulfate (Socha et al., 2003). However, livestock drinking water high in sulfates (1000 to 2500 mg/L) initially suffer diarrhea, but then a process of habituation begins. Moreover, ingestion of "light" water, i.e. very low in TDS, is also considered detrimental to productivity, especially when levels of sodium chloride are very low.

The temperature of drinking water could be another factor limiting intake. For example, in an experiment conducted in Texas (Wilks et al., 1990) it was observed that cows drinking water cooled to 10°C presented lower respiration rate (70 VS. 81 rpm), lower rectal temperature in the afternoon (39.8 vs. 40.2°C) and higher milk production (26.0 vs. 24.7 L/cow/day), as compared to animals drinking water at 27°C.

4. Water quality under Argentine grazing conditions

A recent study (Pérez Carrera et al., 2005) performed in the milking area of Cordoba (Argentina), showed that 37% of the samples from groundwater were non adequate for dairy cattle as assessed in terms of TDS. A similar situation was found in large areas of the Central Santa Fe milking region (Revelli et al., 2002). In the latter, 53% of the samples taken from dairy operations were considered unsuitable for lactating dairy cows and, therefore, were not recommended for animal intake. Both Cordoba and Santa Fe are within the most important milking region in Argentina. However, the information available in Argentina regarding lactating cows (Taverna et al. 2001; Valtorta et al., 2008) indicates that under grazing conditions, water with 7000-10000 mg/L of TDS, with 20-30% of sulfate, had little effect on productivity, for cows producing below 30 L/d.

Particularly, the trial by Valtorta et al. (2008) was performed at the Dairy Unit at Rafaela Experimental Station (INTA), Santa Fe, Argentina (31°11'S) from January 6th until April 2nd, 2005. Eighteen multiparous lactating Holstein cows, 9 ruminally cannulated, average days in milk 136.1±14.6 days, were randomly assigned to three treatments, consisting of water containing different levels of TDS (mg/L): Treatment 1=1,000; Treatment 2=5,000 and Treatment 3=10,000. Cows were balanced for milk production during the week previous to the beginning of the trial (31.9±4.1 L/cow/day), body weight (BW, 521±61 kg/cow) and body condition score (BCS, 2.3±0.24). Animals were arranged in a randomized complete block design with three 28-day experimental periods, which consisted of 3 weeks for water adaptation and one week for measurements.

Animals were milked twice a day, at 04:00 h and 16:00 h. From the pm to the am milking all cows were on an alfalfa pasture, in a daily strip grazing system. All experimental groups grazed within the same paddock and were separated by electric fences in a sub-paddock, where cows had access to their respective treatment water *ad lib*. Since the trial was performed during summer, when radiation and temperatures are high, each group was sent to a pen where the treatment water *ad lib* and shade were available, from 9:00 until the pm milking. There, the animals also received alfalfa hay and cottonseed wholes with lint. A mixed concentrate was offered in the milking parlor, during both milkings.

In order to formulate the water for the different treatments, the normal available water (2880 mg/L TDS) was treated with a reverse osmosis equipment (OSMOTIKA® Model OI-7.0-F; Entre Ríos, Argentina). The water for TDS 1,000 was prepared by mixing completely desalinated water with normal water, to obtain 1,000 mg/L TDS. On the other hand, treatments 5,000 and 10,000 mg/L TDS were obtained by adding and mixing controlled amounts of salts to the equipment refusal water (3.51 mg/L TDS). Drinking waters were formulated to have not less than 100, 850 and 2000 mg SO_4^{2-}/L for treatments 1,000; 5,000 and 10,000 mg/L TDS, respectively. Samples were taken every week in order to analyze TDS and concentrations of sulfate, bicarbonate, chloride, sodium, calcium and magnesium ions.

Individual water intake was recorded during two non-consecutive days by pairing cows in sub-groups, both on paddock and in the shaded pen. The volumes of water offered to and refused by every pair of cows were estimated from the height the water reached in each drinker, together with the drinker dimensions. The difference between both estimates (offered and refused) represented the total drunk water. Daily water group consumption was also recorded by measuring the volumes offered and refused, as described above.

Individual pasture dry matter intake (DMI) was estimated during two non-consecutive days on 40 m^2 paddocks (9 in total), where pairs of cows were located. Within each paddock, 5 samples of 0.10 m^2 of pre- and post-grazing pasture mass were taken, as described in Gallardo et al. (2005). The DMI of concentrate, hay and cottonseed were assessed every day, as the difference between the amounts offered and refused.

Water samples were taken from the drinkers, in 1,000-mL sterilized plastic bottles. Total soluble salts were determined by means of a Water Quality Checker U-10 Horiba (Kyoto, Japan), and SO_4^{2-}, CO_3^{2-}, Na^+, Cl-, Ca^{2+} and Mg^{2+} by Colorimetric and Volumetric methods (Merck, Darmstadt, Germany).

Representative pre-grazing pasture samples were taken by "plucking" for chemical analyses, following a protocol similar to that described by Roche et al. (2005). Pasture, hay, cotton seed and concentrate samples were analyzed for DM, CP, ash, and fat (AOAC, 1990), NDF, ADF, and lignin (Van Soest et al., 1991). Energy concentration (NE_L/kg DM) of the diet was estimated according to NRC (2001).

At the beginning of the study, and on day 28 of each experimental period, BW was measured and body condition was scored by three experienced independent observers using the five-point BCS scale (1 = thin, 5 = fat; Edmonson, 1989).

Milk production was recorded daily during the measurement periods by Waikato® milk meters (New Zealand). Milk samples were collected from 10 milkings (sequence am – pm) during the 7-day sample collection period and analyzed for fat, total protein, lactose, and milk urea nitrogen (MUN) with an infrared spectrophotometer (Foss 605B Milk-Scan; Foss Electric, Hillerød, Denmark).

For two consecutive days, 50-ml liquid samples were obtained from the rumen via a tube introduced in the ventral sac, at 08:00 h (immediately before feeding; time 0) and at times 3, 6, 12, 18 and 24. On those samples, pH was measured with a glass electrode and ammonia was analyzed by a colorimetric technique.

Sub-samples were utilized for VFA analyses. The sub-samples were filtered through two layers of gauze, acidified with m-phosphoric acid (24%) in 3 N H_2SO_4 and kept at -20ºC till analysis. Volatile fatty acids were determined with a Shimadzu gas chromatograph GC-14B (Shimadzu Corporation, Kyoto, Japan) using a 2 m glass column packed with 10% polyethylene glycol and 3% H_3PO_4 in chromosorb AW, and fitted with a flame ionization detector (Erwin et al., 1961). The working temperatures were 155ºC, 185ºC and 190ºEC for the column, injector and detector, respectively. A Shimadzu CR6A integrator was used for peak quantification and identification. The internal standard was 2-methyl valeric acid. For enumeration of protozoa, sub-samples from times 0, 3 and 6 samples were utilized. Equal parts of rumen fluid and a saline-formalin solution (20% formalin in 0.85% NaCl solution) were mixed and stored. Prior to counting, a 2 mL aliquot of the fixed rumen sample was stained for at least 4h with 2 mL of methyl green-formalin solution (Ogimoto and Imai, 1981). Protozoa quantification and generic composition were determined using a 1 mL counting chamber (Hausser Scientific Partnership, cat. No. 3800), following the procedures described by Dehority (1993).

At time 0, samples of rumen contents were collected for bacterial enumeration. Rumen solids and liquid (100 g + 100 mL) were homogenized under a CO_2 atmosphere and filtered through two layers of gauze. Samples were diluted in decimal series (10^{-1} to 10^{-10}). For total bacterial concentration, 10^{-6}, 10^{-7} and 10^{-8} dilutions were inoculated into 10 mL of RGCSA medium according to the procedure described by Grubb and Dehority (1976), which follows the roll tube procedure of Hungate (1966). Inoculated roll tubes were incubated for 5 d at 39ºC and counted under a dissecting microscope. Cellulolytic and amylolytic bacterial concentrations were estimated with a most probable number (MPN) procedure, using a basal medium with either cellulose (filter paper) or starch as the only added carbohydrate source (Bryant et al., 1958; Bryant and Robinson, 1961). All tubes were incubated at 39 ºC. Amylolytic bacteria were measured after 7 days, using Lugol's iodine reaction to determine starch digestion (Persia et al., 2002). After 15 d incubation, cellulolytic bacterial concentrations were determined by observing the disappearance of filter paper.

Air temperature and relative humidity data were obtained from a meteorological station located about 500 m from the experimental dairy farm. Average daily temperature humidity index (THI) was calculated after Armstrong (1994).

Data were analyzed using in cross-over randomized complete block design.

Table 1 presents the composition of the diet offered during the trial to animals in all treatments. It represents a typical grazing system diet, except for the addition of cottonseed wholes. The latter were included because of their high fat contents and, therefore, their beneficial effect for summer diets (Grummer, 1992).

Ingredient (% on a DM basis)	
Alfalfa pasture	57.7
Alfalfa hay	4.7
Cottonseed wholes with lint	7.4
Concentrate mixture (1)	30.2
Composition	
Dry matter (%)	31.0±2.75
Crude protein (%)	16.2±1.65
Neutral detergent fiber (%)	39.3±6.5
Acid detergent fiber (%)	21.0±4.1
Non-fibrous carbohydrates (2) (%)	34.7±6.15
Ether Extract (%)	4.7±0.7
NEL (3) (Mcal/kg DM)	1.56±0.17

(1) Ingredients: 87.3% corn grain; 9.5% corn germ; 3.2% mineral and vitamins premix: Calcium carbonate: 31.5%; Magnesium oxide: 18.5%; Di-calcium phosphate: 38.4%; Salt: 11.6% Vitamins-micro-minerals = Vit. A: 4620 UI/kg; Vit. D3: 920 UI/kg; Vit. E: 12 UI/kg; Cu: 4.5 mg/kg; Zn: 31 mg/kg; Fe: 33 mg/kg; I: 0.6 mg/kg; Se: 0.12 mg/kg; Co: 0.375 mg/kg

(2) NFC = 100 - (ash + CP + NDF + Fat)

(3) Net energy estimated according to NRC (2001)

Table 1. Composition of the diet offered during the trial, for treatments containing different amounts of total dissolved salts: 1,000; 5,000 and 10,000 mg/L in the drinking water.

More than 50 % of the diet was fresh grazed alfalfa, which usually has high levels of highly degradable protein and low fiber. Chemical composition of the water utilized during the trial is shown in Table 2.

Component (mg/L)	TREATMENT					
	1,000		5,000		10,000	
	Mean	SD	Mean	SD	Mean	SD
Total solids	1100	84	5280	390	9220	545
SO_4^{2-}	125	18	883	196	2088	253
CO_3^{2-}	19	31	57	86	125	40
Na^+	335	40	1628	186	2767	316
Cl^-	115	18	1425	124	2775	361
Ca^{2+}	9	09	64	6	85	9
Mg^{2+}	9	3	103	7	211	13

Table 2. Chemical composition of the water utilized during the trial, for treatments containing different amounts of total dissolved salts: 1,000; 5,000 and 10,000 mg/L in the drinking water.

Sulfates represented about 11% TDS in treatment 1,000; 17% in treatment 5,000 and 23% in 10,000. In treatment 1,000, Na^+ and Cl^- together represented about 40% TDS, while they were 60% TDS in treatments 5,000 and 10,000.

Table 3 presents pasture, concentrate and total DM intake for each treatment. No significant differences were observed in response to level of salinity. However, pasture dry matter consumption was significantly lower during the third experimental period, regardless of the water salinity level. During periods 1 and 2, DM intake averaged 10.6 ± 1.85 kg/cow/day, while in period 3 it was 8.8 ± 0.6 kg/cow/day.

Item	Treatment		
	1,000	5,000	10,000
Pasture (alfalfa based)	10.4 ± 1.0	9.8 ± 2.7	9.7 ± 1.7
Concentrate (1)	7.63	7.63	7.63
Total	18.03 ± 1.0	17.43 ± 2.7	17.33 ± 1.7

(1) Concentrate composition: 71.5 % concentrate mix; 17.5 % cottonseed wholes with lint; 11 % alfalfa hay

Table 3. Pasture, concentrate and total dry matter intake (kg /cow/day; mean ± SD), for treatments containing different amounts of total dissolved salts: 1,000; 5,000 and 10,000 mg/L in the drinking water.

Water intake data per treatment and period are presented in Table 4. It ranged between 97.5 and 202, 2 L/cow/day, with animals in treatment 10,000 showing the highest levels.

The water produced for each treatment presented the expected characteristics, as assessed in terms of TDS and SO_4^{2-} concentrations. According to the guidelines for TDS (NRC, 2001), treatment 1,000 represents a safe water for animal drinking. On the other hand, water containing 5,000 mg/L TDS should be avoided for pregnant or lactating animals, if maximum performance is the target, while water containing over 7000 mg/L TDS should never be offered to dairy animals, since they could present health problems or a poor production.

Pasture intake was lowest in the third period. This response could have been affected by the lower quality of the pasture offered in this period. Protein and NDF were 17.1 and 51.1%, as compared to 21.8 and 49.5% and 19.5 and 49.8% for periods 1 and 2, respectively. Also, during that period rainfall was much higher than during the previous ones (317.6 mm vs. 177.6 and 39.7 mm for periods 1 an 2, respectively). This environmental situation could have affected paddock conditions, so as to render grazing more difficult for the cows.

Surprisingly, animals in treatment 10,000 drunk more water than the others in all three periods. These results disagree with other reports where it was found that water intake for cows drinking desalinated water was higher, as compared to animals receiving salty water, defined as water presenting >1,000 mg/L TDS (Solomon et al., 1995). However, in that report TDS and ion composition differed from the treatments in the present work.

In Argentina, Revelli et al. (2005), found similar levels of water intake for animals drinking water with 1,000 and 10,000 mg/L TDS. However, their data were not obtained during the summer season. Warm environmental temperature (e.g., heat stress) is an important factor when evaluating water nutrition. Water intake increases as environmental temperature goes up (NRC, 2001; Holter & Urban 1992).

Week	Treatment		
	1,000	5,000	10,000
1: Jan 27th- Feb 2nd	97.5 ± 23.4[a]	123.2 ± 12.6[b]	169.6 ± 18.3[c]
2: Feb 24th - Mar 2nd	110.9 ± 32.1[a]	127.1 ± 9.5[a]	193.9 ± 22.93[b]
3: Mar 25th -Mar 31st	108.4 ± 41.0[a]	114.9 ± 8.0[a]	202.2 ± 28.2[b]

Within row different superscripts represent statistical significance ($P < 0.05$)

Table 4. Water intake during the three measurement weeks (L/cow/day; mean ± SD), for treatments containing different amounts of total dissolved solids: 1,000; 5,000 and 10,000 mg/L in the drinking water.

The meteorological data recorded during the 1-week measuring periods are shown in Table 5. Average temperatures corresponding to complete 28-days experimental periods were 26.1 ± 3.7, 24.3 ± 2.6 and 23.2 ± 3.6 ºC, for periods 1 to 3. The respective rainfall values were 177.6; 39.7 and 317.6 mm .

Week	Average temperature (ºC)			Average THI
	Mean	Max	Min	
1: Jan 27th- Feb 2nd	22.5 ± 5.9	31.3 ± 7.2	13.7 ± 4.6	70.9 ± 6.3
2: Feb 24th - Mar 2nd	24.1 ± 3.2	29.3 ± 3.9	17.0 ± 3.5	72.9 ± 5.8
3: Mar 25th -Mar 31st	22.1 ± 2.6	28.0 ± 3.8	17.2 ± 1.8	70.4 ± 4.1

Table 5. Temperature and temperature humidity index (THI) during the three measuring weeks, for treatments containing different amounts of total dissolved solids: 1,000; 5,000 and 10,000 mg/L in the drinking water.

Cows producing 20 L milk/day would intake about 90 L water/day at 16ºC and about 105 L water/day at 26ºC (Beede,1992). In the present study, the results for cows in treatment 1,000 fell within this range. Regarding treatments 5,000 and 10,000, it can be pointed out that diets high in salt, sodium or protein appear to stimulate water intake (Holter & Urban, 1992). Furthermore, sodium intake alone was found to increase water intake by 0.05 kg/day per gram of sodium intake (Murphy et al, 1983). The authors derived a prediction equation for water intake, where minimum temperature and sodium intake were among the predicting variables. On the basis of that equation, estimated overall average water consumption in the present trial resulted 91, 115 and 185 kg/cow/day, for treatments 1,000; 5,000 and 10,000, respectively. These values compare quite well with the actual overall averages: 106, 122 and 189 L/cow/day, for the respective treatments.

Table 6 presents milk production and composition and BCS change. No treatment effects were observed in any parameter.

Grazing diets generally tend to be unbalanced, because cows present a selective habit. Concentrate and cottonseed wholes were included to solve this problem, and to obtain a better balanced ration, as shown by the levels of milk yield. Milk yield and composition were not affected by treatment. Solomon et al. (1995) reported higher yields and milkfat percentages for cows receiving desalinated water, as compared to the levels obtained by animals drinking natural salty water. Those results disagree with the present report, where no treatment effects were detected on milk production and composition. However, that trial was performed in a desert climate on non-grazing cows and average milk production was higher than the levels obtained in the present study.

Item	Treatment			SEM	Effects	
	1,000	5,000	10,000		Treat	Period
Milk yield (kg/cow/day)	24.23	24.81	24.55	1.79	0.6304	<0.0001
Milk fat (%)	3.27	3.23	3.36	0.21	0.1939	0.0628
Protein (%)	3.40	3.34	3.36	0.17	0.6450	0.0004
Lactose (%)	4.92	4.90	4.91	0.13	0.9835	0.0662
MUN (mg %)	7.54	7.48	7.01	2.35	0.7641	<0.0001
BCS, change (1)	-0.11	0.05	-0.06	0.09	NS	NS

(1) Final BCS – Initial BCS

Table 6. Milk yield and composition and body condition score change for treatments containing different amounts of total dissolved salts: 1,000; 5,000 and 10,000 mg/L in the drinking water.

Under non-grazing conditions, Sanchez et al.(1994) found that milk production was reduced during the summer months in response to increasing intakes of chloride and sulfate. They also found that feeding high amounts of sodium does not reduce milk production or lactation performance.

Milk production was affected by period, the highest yield being recorded in period 1 (Figure 1). Different variables could have determined the period effects on milk production. First, total consumption was lower during period 3, as compared to the other periods. On the other hand, there is a natural trend to decrease in yield as lactation progresses. In any event, the levels obtained are quite good if considering the grazing based production system and the season. Also, the conversion efficiency was high: approximately 750 g DM/kg milk, with no BCS lost (Table 3).

Milkfat and protein presented low concentrations in all treatments. Similar results were obtained by Revelli et al. (2002, 2005). In treatments 1,000 and 5,000 fat and protein values were reversed. This response could indicate low effective fiber content in the ingested forage, possibly affected by pasture intake behavior, since grazing animals select leaves and tender stems**.**

Rumen bacteria and protozoa (Table 7), as well as pH, ammonia and VFA (Table 8), were not affected by treatment.

Rumen parameters and microbiology were not affected by water salinity. Those results show the incredible rumen buffer capacity, probably because of the effects of fresh alfalfa pasture, an important protein source, in the diet. The buffering system in the rumen includes not only the saliva, but also the feed (Van Soest, 1994). In the present trial, average

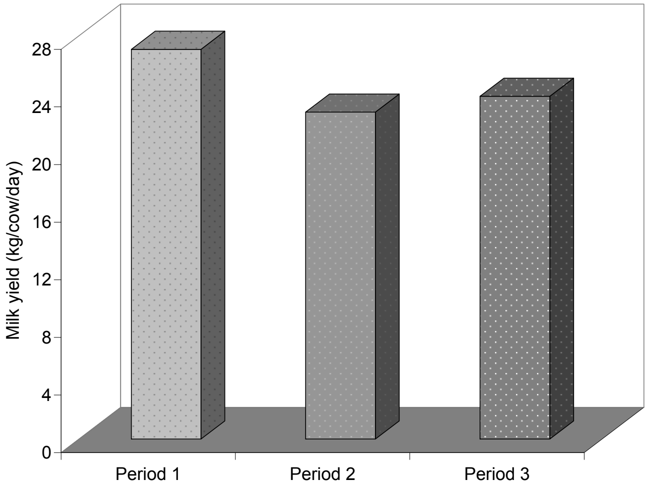

Figure 1. Milk yield for the three experimental periods in a trial with treatments containing different amounts of total dissolved salts (TDS): 1,000; 5,000 and 10,000 mg/L in the drinking water. Periods lasted 28 days each, and the different treatment waters were formulated to have not less than 100, 850 and 2000 mg SO_4^{2-}/L for treatments 1,000; 5,000 and 10,000 mg/L TDS, respectively. All animals were subjected to all treatments, since data were obtained and analyzed in a cross-over design.

Item	Treatment			Effects	
	1,000	5,000	10,000	T	P
Amylolytic bacteria (x10^9)	3.4	3.4	3.6	0.89	0.98
Cellulolytic bacteria (x10^6)	20.5	31.9	14.5	0.55	0.81
Protozoa (x10^3/ml)	9.3	13.8	12.9	0.46	0.25

Table 7. Ruminal amylolytic and cellulolytic bacteria and protozoa at sampling time 0 for treatments containing different amounts of total dissolved salts: 1,000; 5,000 and 10,000 mg/L in the drinking water.

Measurement	**Treatment**			**Contrast**				
	1,000	5,000	10,000	Per	Col	Treat	Hour	TxH
VFA, μmol/mL:								
Acetate (A)	76.51	74.03	75.29	0.42	0.46	0.71	<0.0001	0.90
Propionate (P)	24.7	24.4	23.3	0.16	0.17	0.66	<0.0001	0.98
Isobutyrate	1.61	1.74	1.45	0.14	0.92	0.32	0.0025	0.30
Butyrate	11.55	11.26	11.17	0.34	0.63	0.89	0.0002	0.94
Isovalerate	1.72	1.60	1.41	0.31	0.69	0.18	<0.0001	0.94
Valerate	1.21	1.20	1.07	0.10	0.76	0.45	0.0004	0.94
Total	117.5	114.6	113.9	0.27	0.35	0.79	<0.0001	0.95
pH	6.37	6.37	6.36	0.30	0.71	0.41	<0.0001	0.98
Ammonia, mg/dL	7.65	8.07	8.41	0.39	0.68	0.49	<0.0001	0.94

Table 8. Ruminal volatile fatty acids, pH and ammonia concentration for treatments containing different amounts of total dissolved salts: 1,000; 5,000 and 10,000 mg/L in the drinking water.

pH was quite constant and also relatively low, near 6. However, the values recorded for rumen ammonia (Table 8) agree with MUN (Table 6), and both indicate no excess in degradable protein in the diet.

There are very few reports on the effects of water salinity on rumen parameters. Potter et al. (1971) found no effects on VFA concentration when offering chaffed rations to sheep receiving either fresh water or a 1.3% sodium chloride solution. However, sheep are known to tolerate high amounts of salt in their drinking water (Peirce, 1957).

Figure 2 shows the temporal patterns of the Acetate/Propionate ratio, for all treatments. The values varied around 3 at every measuring time. Treatment 1,000 tended to be less variable.

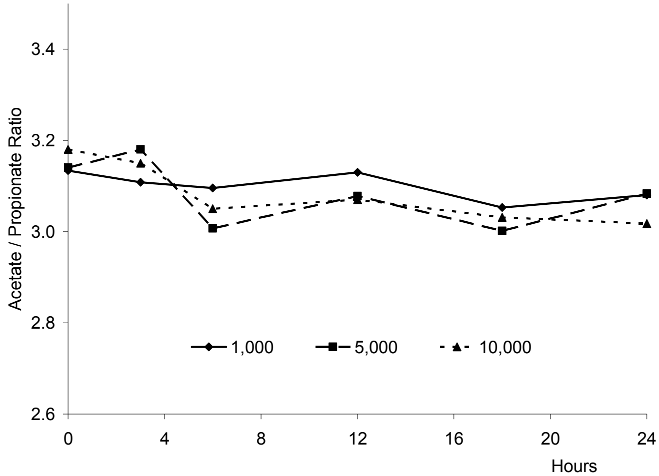

Figure 2. Acetate/Propionate Ratio in the rumen of cows in treatments containing different amounts of total dissolved salts: 1,000; 5,000 and 10,000 mg/L in the drinking water. All animals were subjected to all treatments, since data were obtained and analyzed in a cross-over design.

The lack of effect of drinking water salinity on milk production and composition and on rumen parameters is striking, especially if considering that treatment 10,000 had a TDS quite above the levels considered to be limiting for lactating dairy cows. These results indicate that the single consideration of TDS would be not enough to characterize drinking water quality. More studies should be performed in commercial farms in order to assess the impact of natural salty water on lactating dairy cow performance.

5. Modifications of the environment under grazing conditions. Animal response

5.1. Shades

During summer, the operations should consider the strategic enclosure in a shaded pen between milkings (Valtorta et al., 1996), so as to reduce the heat load and reduce the walking distances. In addition, the adequacy of milking schedules within this scheme would take advantage of both peaks as grazing pasture at night (Davison et al., 1996).

In a study performed in the central dairy area of Argentina (Valtorta et al., 1996) four groups of cows were compared. Two of them were locked between 09:00 and 16:00 in a pen adjacent to the parlor, which possessed an artificial shade structure and water *ad libitum*. The other two had no access to shade. Within each treatment, with and without shade, one of the groups received supplementation with concentrate, 3.5 kg / **v** cow/ d of corn grain. The strategic provision of shade improved the comfort of the grazing animals. The increase in rectal temperature between morning and afternoon had an average of 0.28 º C for animals with access to shade and 1.1 º C for those exposed to the sun. As for breathing rate, the differences were 10.5 and 23.4 rpm, respectively.

The strategic provision of shade had a similar impact to the energy supplementation, and the combination of both practices significantly increased milk production. The concentrate also produced an increase in the concentration of milk protein (Table 9).

Shade	**Concentrate**	MP, l/c/d	F, %	P, %
NO	**NO**	15.3	3.55	2.81
NO	**YES**	16.8	3.69	2.96
YES	**NO**	16.9	3.49	2.77
YES	**YES**	19.2	3.61	2.,85

Table 9. Milk production (MP) and milk fat (F) and protein (P) in milk of multiparous cows in late lactation, managed with and without access to shade (strategic shading from 09:00 to 16:00), and with or without concentrate in their ration (3.5 kg conc/c/d)

In this study, the grazing patterns adapted to confinement. Grazing time recovered during the peaks, especially during the early hours of the day.

The average maximum temperature was 29 º C and relative humidity 72%. The activity was concentrated in two well-marked periods: from dawn, at 05:00, and 09:00 and between 16:00 and 22:00. Enclosure time was offset by increased activity in those periods. Evening grazing, of somehow greater relative importance, ended after sunset, indicating some degree of nocturnal activity.

5.2. Animal cooling

With respect to the direct cooling of the animal, using a system as described, in Argentina the effectiveness of pre-milking refrigeration has been evaluated (Valtorta & Gallardo, 2004). Cows were cooled for 20 min prior to both milkings through a combination of sprinkling and continuous ventilation. Sprinklers produced large droplets that penetrated the coat, their water consumption being 30 l/h. The cooling system improved cow comfort, measured in terms of the significant decrease in rectal temperature and respiratory rate.

Cooled cows produced more milk with higher fat content and yield and protein (Table 10).

Production	NR	R	Difference, %
Milk, kg/c/d	22.14	23.18	4.69
Fat, %	3.44	3.75	9.01
Fat, kg/d	0.755	0.870	15.23
Protein, %	3.22	3.35	4.03
Protein, kg/d	0.713	0.784	9.96

Table 10. Productivity of cows with (R) or without (NR) a 20 min refrigeration in the holding pen before milkings

In Israel cows are cooled using a similar system, on the basis of increasing evaporation from the body surface and the respiratory tract. In that case, they use the combination of large drops that penetrate the animal coat, produced by sprinkler consuming 300 to 500 l / h and forced ventilation, both in the holding pen and in the resting area. The cooling is done in cycles in which combine spraying (30 sec) followed by ventilation (4.5 min), in cycles of 30-45 min. This system is used in Israel at 2-3 hours intervals, 6-10 times per day. High producing cows are maintained in situation of normal body temperature for most of the day. Also, significantly increases in milk production and reproductive efficiency are obtained (Flamenbaum, 2010, 2008; Flamenbaum & Ezra, 2007, 2003).

According to Flamenbaum (2008) in Israel it has being shown that this intensive cooling system, applied in transition cows, can reduce the loss that causes the hot season in the level of milk production and pregnancy rate.

During summer, the combination of a proper cold treatment with an adequate body condition at calving and a good feeding management to early lactation have the potential to enable production and fertility levels almost similar to those obtained in winter. In high production herds productive summer performance is 96 to 100% of that obtained in winter, while, if not intensive cooling is applied, this ratio varies between 86 and 88% (Flamenbaum, 2008).

The implementation of these management strategies in most dairy farms in Israel have had the potential to level up the supply of milk to the market throughout the year. These measures help to increase the efficiency of milk production, giving the Israeli dairy industry a greater degree of competitiveness against the threat of importing milk powder in the summer. In connection with the modification of environmental factors, they have tried to determine if intensive cooling can prevent productive and reproductive losses in high-producing cows (Flamenbaun & Galon, 2010). The results are presented in Table 11.

The results show that intensive cooling during summer reduced the decrease in conception rate by about 50%, even in extremely high production cows. Over the years the Israeli extensionists found the need to develop tools to monitor the effectiveness of cooling systems.

Also, if during late gestation, or dry period, the environment is manipulated, so as to ease the stress of summer, cows can increase the later milk production. In a study by Amaral et al. (2009), dry advanced pregnant cows that underwent a refrigeration system increased the subsequent production, as compared to untreated animals. In this study, cows were subjected to daily refrigeration for a period of 46 days pre-calving. After calving all cows were managed together in a barn equipped with sprinklers and fans. With this management cow milk production was significantly higher during the first 30 weeks of lactation.

	Production level			
Cooling intensity	**High**		**Low**	
	I	**M**	**I**	**M**
Winter, corrected milk (kg/day)	41-43	39-40	35-38	33-36
Summer production, as related to winter	.96-1.00	.86-.88	.97-1.03	.84-.90
Average corrected milk (kg/day)				
Winter	42.0	39.1	37.1	35.3
Spring	42.3	39.2	39.1	36.2
Summer	42.0	35.7	38.0	32.0
Fall	42.1	36.9	38.1	34.1
Conception rate (%)				
Winter	39	39	40	39
Summer	19	12	25	3

Table 11. Milk production and conception rate of low and high production cows with intensive (I) or moderate (M) cooling in Israel

Although the physiological mechanisms involved in such responses are not fully understood (Avendano-Reyes et al., 2010), various hormonal actions may be implicated.

In Argentina, these management systems may have special connotations, given the trend towards intensification in the dairies.

5.3. Combination of feeding and environmental management

Since both nutritional and environmental factors affect the performance of dairy cows in the central basin of Argentina, a trial was designed to evaluate the combined effects of diet and pre-milking cooling with sprinklers and fans (Gallardo et al., 2005). Responses of rectal temperature, respiratory rate, and milk production and composition were evaluated. Cows were assigned to four treatments, consisting of the combination of two diets: control (CD) and balanced (BD) with two levels of cooling before milkings: Sprinklers and fans (SF) or nothing (NSF).

In order to obtain different Forage: concentrate (F:C) ratios (about 80:20 in CD and 70:30 in BD) grazing in the DB group was restricted. The CD was prepared according to common practices in the area, while the DB was calculated to obtain better protein, energy and lipids balance. Based on the quality of its components, the energy density of diets was 1.48 Mcal of NEL / kg DM and 1.60 Mcal ENL / kg DM for CD and BD, as calculated according to NRC (2001).

In addition, SF animals received a combination of spray and ventilation for 20 min before the morning milking and 30 min before the afternoon milking in the holding pen.

Rectal temperatures (RT) and respiratory rate (RR) were recorded before and after the afternoon milking. As a result of cooling, both RT and RR were lower after milking in the SF groups, compared to non-refrigerated or NSF. The production and milk protein concentration were higher for the BD. The authors speculated that this increase in production could be due to the higher density of the diet, which would provide enough energy to increase production under conditions of heat stress. Similar results were observed by Drackley et al. (2003) when offering diets with 1.60 Mcal NE_L/kg DM to cows in mid lactation. The controls received a diet with 1.52 Mcal NE_L/kg DM during the summer.

No effects on the variation of body condition were detected, which would indicate that the factors acted in a way that energy was derived more efficiently to produce milk.

The diet did not affect urea-N in milk. However, this parameter was affected by cooling. Probably the cooling produced a decrease in the demand of energy to remove extra body heat, leaving more energy available for milk production. Also, the balance of the diet by manipulating the ratio F: C could have given greater availability of energy for microbial protein synthesis that may result in increased milk protein. It is possible that there was an increased use of ammonia in the rumen, also considering the increased consumption of protein in the BD. On the other hand, there might have been less use of amino acids as a source of energy in the refrigerated treatments.

These results show that under grazing conditions, the effects on production and milk composition are enhanced when diets are specially formulated for warm periods. All this environmental managements, together with the provision of large amounts of water, help improve the efficiency of water use in dairy cattle during hot periods.

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