Minerals composition of wells water in Karak, Jordan and their relation to tolerance limits in dairy cattle

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Abstract

Drinking water is of extreme importance for lactating dairy cattle due to its role in many biological functions in animal body. The purpose of this study is to investigate the chemical composition of the water from different wells (local water source) in the governorate of Karak, Jordan and to discuss the outcomes in relation to safe limits in dairy cattle nine samples of wells water (three replicates) were obtained from nine villages (Adir, Al-Yarot, Al-Khowaer, Shihan, Al-Lajjun, Al-Simakiyah, Al-Rabba, Al-Rawda, and Ai) and were analyzed for their cation (Sodium (Na), Potassium (K) and Calcium (Ca)) and anions (Flourine (F), Chlorine (Cl), Nitrite (NO_2), Boron (Br), Nitrate (NO_3), Phosphate (PO_4) and Sulfate (SO_4)) concentrations. The highest variations were found in both K (CV%=237.66) and NO_3 (CV%=220.12). The levels of Na, K, Ca, F, NO_2, Br, NO_3, PO_4, and SO_4 in water samples were found suitable for dairy cattle consumption. This study showed that two of the nine water samples (water samples obtained from Al-Rabba and Al-Rawda) were not within the acceptable/safe range for water consumption of dairy cattle. It can be concluded from this study that regular analysis of wells water should be performed to determine water suitability for dairy cattle in Karak Governorate.

Keywords: Drinking water; Cation; Anion; Dairy cattle; Karak; Jordan

Introduction

In arid and semi-arid regions like those in Jordan, livestock production has been reported to have considerable social and economic importance where water availability represents one of the biggest challenges (Araújo et al., 2010). The governorate of Karak has a semi-arid climate condition at elevation of 770 m above sea level with total area of 2850 km^2 (Salman, 2016) and average annual rainfall is about 300 mm (Al-Khamaiseh, 2014). Dams, channels, springs valleys, and artesian wells are considered the primary water resources. Survey studies carried out by the Department of Statistics indicate that 12.4% of total livestock recourses in Jordan are in Karak Governorate where cows constitute about 0.82% of the total number of cows in Jordan (Department of Statistics, 2015). Drinking water is of extreme importance for lactating dairy cattle due to its role in many biological functions: digestion, absorption, metabolism, milk production, sweat secretion, urine and feces production and heat balance (National Research Council, 2001). Hence biologists, dairy producers, nutritionists, dairy specialists and veterinarians have concerns about the impact of quality of the drinking water for dairy cattle and the effect of water quality has on dairy performance and wellbeing (Ensley, 2000). Drinking water quality is evaluated using five measurements (Beede et al., 1994). These measurements include: organoleptic factors, physio-chemical factors, substances present in excess, toxic compounds and microflora. From nutritional prospective, water has been reported to be an important source of minerals for ruminants (Soder and Dyer, 1972; Manera et al., 2016). However, high minerals concentrations in water can be toxic and can cause many biological disorders (National research Council, 2001). The main objective of this study was to evaluate mineral concentrations in water wells across the governorate of Karak and discuss the suitability of these resources for dairy cattle water consumption.

Materials and methods

Water samples were collected from drilled wells distributed in Karak Governorate in October, 2016. Nine samples of wells water (three replicates) were obtained from nine villages (Adir, Al-Yarot, Al-Khowaer, Shihan, Al-Lajjun, Al-Simakiyah, Al-Rabba, Al-Rawda, and Ai (Table 1). The mineral composition of all water samples was determined at the Department of Chemistry-Faculty of Science at Mutah University. The concentration of Sodium (Na), Potassium (K), and Calcium (Ca) were determined by using flame photometry (Microprocessor Flam Photometer Model (FP902-5) PG Instruments limited, UK). Flourine (F), Chlorine (Cl), Nitrite (NO_2), Boron (B), Nitrate (NO_3), Phosphate (PO_4) and Sulfate (SO_4) were determined by using Ion Chromatography (DX-100 Ion Chromatograph, Dionex Corp, USA). The concentration of both cations and anions in the water were measured in triplicate, and presented as mg/L. Descriptive statistics was the method used to present the measurements and observations of this study (means and standard deviation). To compare the concentration heterogeneity among the different minerals, coefficient variation (CV%) was used and calculated as follows:

$$\text{CV\%} = \text{Standered deviation } \times 100\%/\text{Mean}$$

Results and Discussion

Cations and anions concentration

Cations (K, Na and Ca) concentration levels obtained from different well locations are shown in Table 1. Among the investigated cations concentrations, Na had the highest concentration (68.10mg/L) while K had the lowest concentration (9.89 mg/L). Ca recorded the intermediate level (42.02 mg/L). High variation existed in cations concentrations between different well locations and was the highest in K (CV%=237.66). It was almost similar for both Na (CV%=41.17) and Ca (CV%=40.33). Anions (F, Cl, No2-, Br, NO_3, PO4, and SO4) concentration levels obtained from different well locations are shown in Table 1. Among all the investigated anions, SO_4 had the highest concentration (179.42mg/L) while both NO_2 and PO_4 were not detected in all investigated wells. High variation existed in anions concentration between different well locations and was the highest in NO_3 (CV%=220.12) and lowest in Cl (CV%=31.62).

Drinking water safety guidelines

Cations and anions concentrations measured in wells in Karak governorate were compared with concentrations that indicate potential toxicity in cattle (Table 1). All of the nine water samples showed that Na, Ca, Cl, Br, and F were below the upper limit listed in the guideline that may cause possible potential toxicity to dairy cattle. However, one of the nine samples (Al-Rabba) showed a NO_3 concentration above the upper limit guide line suggested by National research Council (1974) as shown in Table 1. Nitrates in wells water can be originated from different sources such as contamination with nitrogenous fertilizers (Beede (2006) and/or industrial contamination (Hegedus, 2006). At certain level, and depending on NO_3 level in complete diet, rumen bacteria can utilize nitrogen from NO_3 to synthesis microbial protein (Lin et al., 2013). However, NO_3 can be reduced to NO_2 in rumen which has been reported to be more toxic than NO_3 (Dawson and Allison, 1988). Symptoms of acute NO_3 or NO_2 poisoning are asphyxiation and labored breathing, rapid pulse, frothing at the mouth, convulsions, blue muzzle and bluish tint around eyes and chocolate-brown blood (National Research Council, 2001). Variation in NO_3 concentrations in well water can be influenced by many factors such as time of the year, sampling depth of wells, and fertilizer applications (Beede, 2006). Furthermore, feed type and feed storage conditions can increase NO_3 intake by dairy cattle (El Mahdy et al., 2016). The contribution of some water supplies could be harmful if NO_3 concentration in animal feed was near the toxic level (Soder and Dyer, 1972). Previous mentioned factors should be taken in concern when evaluating the effect of water NO_3 in dairy cattle.

Table 1. Comparison of cations and anions concentrations (mg/L) measured in wells in Karak Governorate, and comparison to mineral concentrations that indicate potential toxicity in cattle.

	Minerals									
	Cation			Anions						
Well Source	Na	K	Ca	F	Cl	NO_2	Br	NO_3	PO_4	SO_4
Adir	42.03	1.98	26.97	ND[a]	83.1	ND	ND	ND	ND	65.70
Al-Yarot	22.7	1.01	28.00	ND	64.77	ND	ND	40.96	ND	29.14
Al-Khowaer	45.23	1.23	28.10	ND	77.26	ND	1.41	12.73	ND	53.56
Shihan	80.1	2.4	37.03	0.56	128.55	ND	1.76	3.35	ND	103.97
Al-Lajjun	80.73	2.83	37.47	0.10	156.99	ND	ND	1.67	ND	108.3
Al-Simakiyah	97.76	1.95	52.33	ND	121.41	ND	1.75	2.52	ND	167.41
Al-Rabba	86.2	73.16	62.93	ND	176.95	ND	1.17	275.41	ND	129.35
Al-Rawda	104.33	4.2	73.46	1.39	143.45	ND	0.09	0.93	ND	909.62
Ai	53.83	0.98	31.86	ND	128.94	ND	0.12	6.95	ND	47.72
Mean	68.1	9.98	42.02	0.69	120.16	-[b]	1.06	43.07	-[b]	179.42
SD	28.04	23.71	16.94	0.65	38.00	-[b]	0.76	94.8091	-[b]	277.33
CV%	41.14	237.66	40.33	95.48	31.62	-[b]	72.47	220.123	-[b]	154.57
Min	22.7	0.98	26.97	0.10	64.77	-	0.10	0.94	-	29.14
Max	104.23	73.17	73.47	1.39	176.96	-	1.77	275.41	-	909.62
Safe limit	2000 [c]	-	1000 [c]	2.0 [d,e]	3000 [c]	-	5.0 [d,e]	44.0 [d]	-	500 -1000 [f]

[a] Not detected; [b] Not measured; [c] Beede (2006); [d] National Research Council (1974); [e] National Research Council (1980); [f] National Research Council (1980)

One of the nine samples (Al-Rawda) showed also a SO_4 concentration above the upper limit guideline (Table 1) suggested by National research Council (2001) especially when water is offered to calves. When SO_4 exceeds 500 mg/L, the specific salt form of sulfate should be identified to determine toxicity (National Research Council, 1980). Common forms of sulfate in water are calcium, iron, magnesium, and sodium salts, however, hydrogen sulfide is considered the most toxic (National Research Council, 2001). Patterson et al. (2003) showed a reduction in average daily gain, dry matter intake, and feed conversion (i.e gain/feed) in steers when water SO_4 increased from 400 to 4700 mg/L. Cattles offered high SO_4 water had a steep reduction in liver copper stores in growing cattle (Wright et al. 2000). Risks of offering high SO_4 water to cattle can be minimized by suitable supplementation strategies and grazing management (Wright and Patterson 2005). For example, minimizing feeding silage or hay cut during drought periods can reduce SO_4 intake when high SO_4 water is offered to ruminants (German et al., 2008). To prevent increase of certain minerals in water, Manera et al (2016) suggested two approaches: reduce evaporation rate of water in reservoirs and by the treatment of drinking water through fresh water and/or rain water.

Conclusion Different water wells showed variation in mineral levels with high proportion of Na, Ca, Cl and SO4, however, these sources showed low levels of K, F, B, NO_2 and PO_4. Within the investigated minerals concentration, this study showed that two of the nine water samples (water samples obtained from Al-Rabba and Al-Rawda) were not within the acceptable/safe range for water consumption by dairy cattle in Karak Governorate, Jordan. Regular analysis of wells water should be performed frequently to determine water suitability for dairy cattle in this region.

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