Long-term effects of electrochemically activated drinking water on milk yield, milk composition and somatic cell counts in dairy cows: a field study

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ABSTRACT

The objective of this study was to determine the effects of electrochemically activated drinking water (ECW) on milk yield, milk composition and somatic cell counts (SCC) in dairy cows. In Farm 1, as a controlled study, two groups of lactating cows were offered regular drinking water (n = 27) and ECW (n = 27) water dosed with 4 ppm of 29 mg/L of chlorate (Neuthox®). The 54 cows were grouped into two groups, balanced by stage of lactation (111 ± 67 DIM) and parity (2.2 ± 0.4). Cows received water with or without ECW for 6 months. In Farm 2, a longitudinal study was undertaken with 140 lactating cows that were offered ECW for 5 months. Monthly records from milk yield and milk components were analysed from both farms. In Farm 1, SCC were lowered by ECW (162 ± 42 × 10³/mL) compared to no ECW animals (411 ± 202 × 10³/mL). In Farm 2, milk yield (from 35.5 to 32.7 kg of energy corrected milk) and milk protein (from 3.52 to 3.33 g/100 g) contents decreased across the months while SCC tended to decrease. Results showed that ECW could be useful for reducing SCC without detrimental effects on milk production and milk composition.

Highlights

- Electrochemically activated drinking water can reduce milk somatic cell counts
- Electrochemically activated drinking water does not affect milk yield
- Electrochemically activated drinking water does not affect milk composition

Introduction

Although water is essential for health and performance in dairy herds (NRC 2001), water quality is often disregarded and farmers focus on other aspects of cattle production, thus failing to consider it as a possible source of disease and low herd performance. Water quality can vary substantially and has an impact on animal performance (Carlson 2018). Water quality can be improved by several methods (i.e. suspended ion exchange, ozonation, in-line coagulation, ceramic microfiltration, granular activated carbon; Lundqvist et al. 2019) and electrochemically activated water (ECW) has been regarded as a novel sanitizer in recent years (Qi et al. 2018). Koide et al. (2011) reported that ECW can be used for the prevention and control of microorganisms and it is feasible to use because it is relatively easy to produce continuously through electrolysis using commercial equipment. The principle of ECW is that hypochlorous acid and sodium hydroxide are formed during electrolysis of ordinary tap water with dissolved salt (sodium chloride). Hypochlorous acid is a weak acid that will dissociate to form hypochlorite. Sodium hypochlorite and sodium hydroxide are used as disinfectants, in soaps and detergents and drinking water. In dairy farms, it has been previously reported (Vargas-Bello-Perez et al. 2020a, 2020b) that dairy cows drinking ECW results in milk chlorate and perchlorate contents of <0.002 mg/kg which is below the recommended chlorate residue of 0.1 mg/kg allowed in all foodstuhs and drinking water according to the European Food Safety Association (EFSA 2015). In addition, in the same study, ECW resulted in chlorate and perchlorate contents of <2 and <0.5 µL, respectively.

Somatic cells are indicators of both resistance and susceptibility of cows to mastitis and are used to monitor the level of occurrence of subclinical mastitis in herds or individual cows (McParland et al. 2019). Public concern over the use of antibiotic usage in agriculture has become a trigger for research focused on alternatives. In this regard, we reported (Vargas-Bello-Perez et al. 2020a) that when cows were offered ECW, milk yield was not affected but decreased somatic cell counts (SCC). Therefore, the use of ECW may be an alternative to control mastitis incidence instead of antibiotics use. The data previously reported was based on a short-term study that lasted for 2 months and was based on data from 5 cows. In this regard, until now, it is unknown what the long-term effects of using ECW in dairy cattle are. Thus, the objective of this study was to determine the long-term effects of ECW on production performance and somatic cell counts in dairy cows. The hypothesis of this study was that ECW would improve water quality, increase milk yield and decrease SCC for dairy cows drinking this water without affecting milk composition.
Materials and methods

Animals, farms and management

All experimental procedures were conducted according to the Danish Ministry of Justice Law No. 474 (May 15, 2014) concerning animal experimentation and the care of experimental animals. The study was carried out with two different protocols in two Danish farms; as a longitudinal survey and as a controlled study. In both farms, water intake was calculated to be approximately 100 L/d/cow.

Farm 1 (controlled study): Fifty-four cows were chosen out of a herd of 250 Red Danish cows that were given the treatments. The 54 cows were grouped into two groups, balanced by stage of lactation (111 ± 67 DIM) and parity (2.2 ± 0.4). From 125 cows, one group (n = 27) was chosen and was offered regular drinking water and another group (n = 27) was only offered ECW water dosed with 4 ppm of 29 mg/L of chlorate (Neuthox®, Danish Clean Water, Denmark). The formation of the chlorate was undertaken by on-site electrolysis of water and saltand dose controlled by water flow. Water flow and dosing were continuously monitored. Animals received water with or without ECW for 6 months. Animals received the same mixed ration ad libitum based on maize silage (36.2% DM), grass silage (43.6% DM), rapeseed cake (10.1% DM), wheat grain (5.5% DM), wheat straw (2.6% DM) and vitamin and minerals premix (2% DM). Animals were milked by automatic milking robots (one robot per group) according to their daily milk yield. Animals had free access to water at all times.

Farm 2 (longitudinal survey): One hundred and forty lactating cows (80% Holstein, 17% crossbreed and 2% Red Danish) were offered ECW for 5 months. The ECW dose was the same as in Farm 1 with free access to the water. Animals were milked two times daily in a 2 × 16 herringbone milking parlour. Animals were fed on a total mixed ration based on maize silage (43.3% DM), grass silage (15.4% DM), sugar beet pulp silage (4.2% DM), wheat hay (3.3% DM), rapeseed meal (16.3% DM), rapeseed cake (14.8% DM), sodium bicarbonate (0.3% DM), saturated fat (0.8% DM) and vitamins and minerals premix (1.6% DM).

Milk samples

For both farms, monthly records from milk production, and data regarding milk composition, and somatic cell counts were extracted from the Danish Dairy Management System (SEGES, Landbrug & Fødevarer, Denmark). In farm 1, at the beginning of the study, animals from ECW group had a milk yield of 35.4 kg of energy corrected milk (ECM), 4.32 g/100 g of milk fat, 3.80 g/100 g of milk protein, and 91 × 10³/mL SCC. Whereas the no ECW group had 35.0 kg of ECM, 4.27 g/100 g of milk fat, 3.75 g/100 g of milk protein, and 199 × 10³/mL SCC.

Water samples

The oxidation–reduction potential (ORP) measurements were recorded monthly at each farm from fixed sites of the water pipes. Samples were taken from the pipes, before and after the addition of ECW. In farm 1, there were 6 automatically refilling drinking troughs per group whereas farm 2 had 10 automatically refilling troughs to which the animals had free access.

The ORP values were determined with a sensiON+ PH31 meter (HACH®, Loveland, CO, USA). The ORP is a water quality parameter that is measured as the voltage between a platinum measuring electrode and a reference electrode and is used to determine the level of oxidants. Low ORP values are found in contaminated water, while high ORP values can be considered as indicators of clean water. Common oxidants used in drinking water treatment for microbial disinfection and oxidation of inorganic and organic contaminants include free chlorine (hypochlorous acid and sodium and hypochlorite), monochloramine, and ozone (Copeland and Lytle 2014). In this study, the ECW biocide formed during electrolysis of saltwater contained both hypochlorous acid and sodium hypochlorite, thus, ECW will be expected to have higher ORP values compared to tap water. Water samples (500 mL) from the drinking troughs were analysed for bacterial conditions at a certified laboratory (Eurofins, Vejen, Denmark) at the onset and at the end of the experiments.

Statistical analysis

The GenStat (12th ed.) statistical package (VSN International Ltd., Oxford, UK) was used to analyse data from both experiments. For Farm 1, a model including treatment, month, and treatment × months as fixed effects and cow within treatment as a random effect was used to determine differences in milk yield and milk composition. Data on milk yield and milk composition from Farm 2 were analysed as repeated measurements across months with the month as fixed effect and cow as the random effect. For both farm data, significance was considered at P < 0.05. All the results are expressed with a standard error of the mean.

Results

Milk yield, milk composition and somatic cell counts

In Farm 1, milk yield, milk fat and milk protein were similar between treatments (Table 1). Before the experimental periods, except for SCC(lower in animals offered ECW), milk components were similar. SCC increased across months (Figure 1) and were significantly lower for ECW cows at the 2, 3, and 4 months.

| Parameter            | Treatment               | P-value | T × M | SEM |
|----------------------|-------------------------|---------|-------|-----|
| Milk yield, kg of ECM | No ECW | ECW | SEM | Treatment (T) | Months (M) | T × M |
| 32.7                  | 31.7                  | 0.59    | 0.144 | <0.001 | 0.584 |
| Fat, g/100g          | 4.63                   | 4.58    | 0.07  | 0.178  | 0.002 | 0.475 |
| Protein, g/100g      | 3.83                   | 3.94    | 0.05  | 0.064  | 0.467 | 0.937 |
| SCC, ×10³/mL         | 354                    | 154     | 41.2  | <0.001 | 0.043 | 0.290 |

Note: SEM = Standard error of the mean.

*Energy corrected milk (ECM) yield is determined according to the Nordic feed evaluation system (NorFor; Volden 2011). Significance was declared at P < 0.05.
3rd, 5th, and 6th month measurements. Milk yield decreased across months from 35.2 to 29.1 kg/ECM. Milk fat content increased across the months from 4.3 to 4.6 g/100. There were no interactions between treatment and months. In Farm 2, milk yield and milk protein contents decreased across the months while SCC did not change ($P=0.08$) (Table 2).

**Water bacterial conditions**

The oxidation–reduction potential from different sites from the water treatments is shown in Figure 2. The tap water in Farm 1 remained stable over the months (462 mV). The pipeline (620 vs. 257 mV) and drinking troughs (401 vs. 224 mV) with ECW had higher ORP values compared with no ECW, and a clear increase in ORP was seen after the commencement of dosing. In Farm 2, the ORP values for tap water and drinking troughs with ECW remained constant over the 5 months (334 and 204 mV, respectively). In this farm, the ORP records from the pipeline with ECW in the first month were 245 mV and then remained constant from month 2 until month 5 at a mean level of 689 mV. The initial increases in OPR seen at both farms after the first dosing with Neuthox® indicate the effect of the biocide.

**Discussion**

The decreases in milk yield observed across the months in both farms were expected as the animals were in advancing lactation stages. This was also observed in our previous experiment where cows were fed with ECW over 60 days (Vargas-Bello-Perez et al. 2020a). The increases in milk fat content from Farm 1 may be related to a concentration effect because of the decrease in milk yield over the months and this may also explain why SCC increased without respect to ECW during the study. However, Boland et al. (2013), found no evidence of a dilution effect between SCC and milk yield. They explained that several factors such as the parity, milk yield and type of pathogens (i.e. *Staphylococcus aureus*, *Streptococcus uberis* and *Escherichia coli*) would need to be accounted in order to ascertain a dilution effect. Other studies suggest that lactation stage has an effect on SCC being higher in late lactation (Hagnestam-Nielsen et al. 2009).

The decrease in milk protein contents, observed in Farm 2, may be explained by a disruptive effect at the rumen level. Although, Capuco et al. (2005), reported that the rumen of the dairy cow might serve as a biological filter for chlorinated compounds (i.e. perchlorate). In the long-term, ECW may have caused a negative effect on the protein metabolism. It is possible that rumen microbial protein was reduced by ECW and this was later reflected in the protein secreted in the milk. This effect warrants further attention.

The use of ECW improved the bacterial conditions from the drinking troughs (Table 3). In both farms, coliform bacteria at 37°C, *Escherichia coli*, bacterial counts at 22°C and bacterial counts at 37°C decreased with ECW. This antimicrobial effect warrants further attention.

![Figure 1. Monthly variations in milk somatic cell counts from cows (Farm 1) fed with or without electrochemically activated water (ECW). Error bars denote standard error of the mean. The SCC is based on data from 27 cows per treatment.](image)

![Table 2. Milk production, milk composition and somatic cell counts from (Farm 2) cows (n = 140) fed with electrochemically activated water (ECW).](table)

| Parameter          | Months | SEM | P-Value |
|--------------------|--------|-----|---------|
| Milk yield, kg of ECM* | 1 2 3 4 5 | 1.04 | 0.013 |
| Fat, g/100g        | 3.85 3.94 3.91 3.94 3.94 | 0.08 | 0.117 |
| Protein, g/100g    | 3.52 3.54 3.58 3.49 3.49 | 0.04 | <0.001 |
| SCC, $\times 10^3$/mL | 466 183 243 181 276 | 112 | 0.089 |

Note: SEM = Standard error of the mean.

*Energy corrected milk (ECM) yield is determined according to the Nordic feed evaluation system (NorFor; Volden 2011).

Means with the same letter are not significantly different at $P<0.05$. 
was expected as ECW is based on chlorinated compounds. These chemical elements are capable of disrupting multiple cellular components in different environments (Gray et al. 2013).

Conclusions and implications

It is noteworthy mentioning that the use of ECW in dairy farms is an interesting approach that, until now, remains almost unexplored from a scientific point of view. Our data show that ECW improves the water quality and this may show as a delayed effect on the SCC. Overall, results suggest that ECW reduces somatic cell counts. However, with regard to milk production and milk composition a long-term controlled trial with more animals is advised in order to obtain more conclusive data. The reported data could be useful when assessing the long-term effects of ECW in dairy farms. Under the conditions of both experiments, it was not possible to assess the effects of ECW on different metabolites in blood, milk, urine and feces. These analyses are crucial to understand the long-term impacts of ECW on general body metabolism and mammary gland health. In addition, the specific mechanism whereby ECW decreases milk SCC remains unknown.

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No potential conflict of interest was reported by the author(s).

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