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Impact of water quality on performance, health, and productivity in dairy cattle: A review

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ABSTRACT
Water is the wonder of nature which is an essential source of nutrients for all forms to sustain life. Water is necessary for digestion, energy metabolism, absorption, transportation of nutrients and metabolites to and from body tissues, cellular functions, elimination of waste materials from our bodies (humans and animals), and excess heat from the body. Furthermore, water plays an important role in the bodies thermoregulatory and electrolyte health, and the performance of the fluidity and cushioning environment for the developing fetus in the human and animals. The quality of water determines the health and productivity of milk and its quality, and results in the bioaccumulation of water solutes in the milk and body tissues. Therefore, its property has to be good for the optimum health, and performance of dairy cattle. The high-altitude environments have restricted surface and groundwater resources and are more dependent on snow precipitations, very deep bore well groundwater, and Mountain Rivers. Recently, the quality of high-altitude water resources has become questionable because of more environmental pollution, climate change, and high anthropogenic activities at high altitudes. Therefore, there is an ongoing requirement to monitor water quality, dairy product quality, and cattle health for the prevention and control of waterborne diseases. This review reveals the water property and the probable effects on the health performance of dairy cattle with a particular emphasis on high-altitude regions. From this review, we can that global warming and an increase in tourists in high-altitude regions have caused the deterioration of water quality, which may affect the health, reproduction, and production of quality dairy products. This may lead to the bioaccumulation of some toxic molecules and metals into the higher food chain and affect public health.

تاثير جودة المياه على الاداء و صحة و انتاجية ابقار الحليب

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الخلاصة

الماء هو من عجائب الطبيعة و هو مصدر اساسي للعناصر الغذائية لجميع اشكال الحياة و استدامتها . الماء ضروري للهضم, استقلاب الطاقة , الامتصاص , نقل العناصر الغذائية والايضية من و الى انسجة الجسم , الوظائف الحيوية , التخلص من الفظلات و الطاقة الزائدة في اجسامنا و صحة الكترولايت . يلعب الماء دورا رئيسيا في تنظيم درجة حرارة الجسم و توفير السيولة لبيئة الجنينن النامى سواء في الانسان او الحيوان و تحدد جودة الماء صحة و انتاجية الحليب و جودته و تؤدى الى التجمع الحيوي للمواد المذابة في الحليب و انسجة الجسم و تحدد صحة و اداء ابقار الحليب . تقيد البئات المرتفعة موارد المياه الصطحية والجوفية العميقة و تعتمد بشكل اساسي على تساقط الثلوج اصبحت جودة المياه وجودة منتجات الحليب موضع شك بسبب تزايد التلوث البيئى , تغيير المناخ و الانشطة البشرية في المرتفعات حيث هناك مطلب مستمر لمراقبة جودة المياه منتجات الالبان و صحة الابقار للوقاية من الامراض المنقولة عن طريق المياه و مكافحتها٠تبين هذه المراجعة عن خاصية المياه و التاثيرات المحتملة على الاداء الصحي لابقار الحليب و من هذه الاستعراض يتبين ان الاحتيباس الحراري و تزايد السياح في المناطق المرتفعة تسبب تدهورجودة المياه مما يؤثر على صحة الابقار و تكاثرها و انتاج حليب عالي الجودة و ان التراكم البيولوجي لبعض الجزيئات السامة و المعادن في السلسلة الغذائية تؤثر على الصحة العامة .

الكلمات المفتاحية: صحة الابقار- جودة المياة - استهلاك المياه - الانتاحية-- منتجات الحليب

INTRODUCTION

Water intake is closely related to feeding intake in both kinds of beef cattle (Shil et al., 2019) and dairy cattle (Meyer *et al*., 2004b.), water is necessary to sustain productivity, such as milk production (Breede, 2006) and body weight, as well as extrinsic factors such as climate conditions (Moyer *et al*., 1994), feed dry matter content, and through design, all influence voluntary water intake (Machado Filho *et al*., 2004). Water loss occurs via saliva, urine, feces, milk, sweating, by evaporation from body surfaces and the respiratory tract. The amount of water gone from the body of cattle is influenced by animal activity, air temperature, humidity, respiratory rate, water intake, feed consumption, milk production, and other factors. Water is everywhere within the body and is an excellent solvent. It is chemically neutral thus, ionization of most substances occurs more freely in water than in other Media. Water serves as a medium for the dispersion or suspension of colloids and ions within the body and is necessary for maintaining osmotic balance (Michele Vitolo., 2021). It provides a medium for the movement of nutrients, metabolites, hormones, and gases and is a lubricant and support for various organ systems and the fetus. A special role is in heat exchange and maintenance of heat balance because of its high thermal conductivity, allowing rapid transfer of heat. Water balance is influenced by total water intake and losses through urine, feces, milk, saliva, sweating, and vaporization from respiratory tissues. Although cattle can survive for days without food, a supply of clean, fresh water is important to keep animals alive and to prevent digestive problems following a calamity (Wakchaure *et al*., 2015), As a result, determining what is considered typical water consumption is difficult. On average, 19 to 41 L/day for beef cattle (Akanda., 2012) and 54 to 114 L/day for lactating dairy cattle (Krysanova et al., 1998) (Xu *et al*., 2016) are recorded in the literature, distributed among 3 to 7 drinking bouts (Cardot et al., 2008).

The property of the water will be influenced by its source and contamination from abiotic and biotic factors as a result of either dissolved nutrients or direct deposition of urine or faces containing nutrients and possibly parasites (Lardner *et al*., 2005). Depending on the geology of the surrounding area, rainfall, flora, and topography, groundwater may include dissolved salts. Water quality will be influenced by human activity near water sources. Depending on the source of the water, water from off-stream and reticulated sources may have varying temperatures, which might affect animal production. In both beef and dairy cattle, the effects of water temperature have been widely researched. Chilled drinking water has been shown to increase feed intake and milk production in dairy cattle (Hatvani *et al*., *2011*) and live weight gains in beef cattle. However, there have been reports of no influence on milk output, for example (Kanwar et al., 1988). When given a choice, the cattle prefer to drink water that is nearer to ambient temperature (Hatvani *et al*., 2011) and drink less cold water (Kanwar *et al*., 1988), although chilled water has advantageous for production in the summer.

The Importance of Water for Animal Body:

Water plays a structural role in the body as the main component; it participates in all metabolic processes; it is the substrate of all biochemical reactions in the body (hydrolysis, redox, hydration, and imbibition); and it is a source of calcium, magnesium, sodium, potassium, and other useful substances, but it can also be a source of unwanted elements (toxic substances, pathogenic agents). (Murphy *et al*., 2010), controls acidity levels. Water is the main solvent of organic substances intra- and extracellular (Bhat *et al*., 2020), contributes to the balancing of homeostasis, is important for various processes, such as absorption, transference, dispersal, osmosis, excretion, carriers of substances, and heat energy in the body, nutrition roll, antitoxic, participates in thermoregulation. Why is water so crucial to the human body? Animals without food but with access to water may lose the most glycogen, all lipid stores, 50% of proteins, and up to 40% of body weight, in which case survival in the absence of feed can last up to 40 days and recovery is still feasible when feed is reintroduced (El Mahdy *et al*., 2016). Water and administering a dry feed, the animals lose 2-3iidays 10% of body weight concomitantly with the occurrence of serious disorders, and, a loss of 20-30% by weight dependent on the species and age it is lethal (Dennison *et al*., 1993). Water loss occurs via saliva, urine, feces, milk, sweating, by evaporation from body surfaces and the respiratory tract. The amount of water gone from the body of cattle is influenced by the activity of the animal, air temperature, humidity, respiratory rate, water intake, feed consumption, milk production, and other factors. Water is everywhere within the body and is a great solvent. It is chemically neutral thus, ionization of most substances occurs more freely in water compared in other media. Water serves as a medium for the dispersion or suspension of colloids and ions within the body and is necessary for maintaining osmotic balance. It provides a medium for the movement of nutrients, metabolites, hormones, and gases and is a lubricant and support for various organ systems and the fetus. A special role is in heat exchange and maintenance of heat balance because of its high thermal conductivity, allowing rapid transfer of heat. Water balance is influenced by the total water intake and losses arising from urine, feces, milk, saliva, sweating, and vaporization from respiratory tissues. Cattle can survive for days without food, and a supply of clean, fresh water is essential to keep animals alive and to prevent digestive problems following a calamity (Wakchaure *et al*., 2015). Poor quality water animals do not accept easily,

which results in less water and feed intake, both water quality, and water intake are important and often related, and poor feed conversion ratio ultimately decreased growth and production, poor performance, and non-specific disease conditions (Faries., 2007). Evaporation, which occurs continually at the skin and lung level even when the ambient air temperature is low, is another way to lose water from the body. Because the animal's sweat contains 95 to 99.5 percent water, it is hypotonic (Horablaga *et al*., 2020).

Water requirements:

Water serves as the fluid matrix of the animal body, Water gives form and structure and provides protection from environmental stress. As with everything about livestock, livestock water should meet the nutritional needs of the animal. Adequate and safe water supply is essential for healthy animals and is extremely important for milk production,

Dairy grazing lush grass that contains 70% water needs much less additional water than cattle fed dry feeds or hay containing only 10 percent water, cattle cannot adapt to water restriction and feed intake greatly decreases if water is restricted. Water is required for homeostasis, as well as for growth, reproduction, lactation, digestion, metabolism, excretion, hydrolysis of nutrients, transport of nutrients and waste, joint lubrication plus many other functions. The most important aspect of water as a nutrient is generally the quantity consumed. Water consumption varies widely, depending on physiological and environmental conditions, for example, the type and size of the animal, if the feed contains much water (for example juicy grass), they need less to drink. If they are active, they need more, and if they are lactating, they need much more.

Likewise, weather conditions will influence their need for water: heat, humidity, and wind will all influence the water need. Water (and shelter) should be available at all times (except for camels, they can do with water every 5-8 days) and be clean and fresh.Young animals also need water! Even when they are milk-fed, it is not always fulfilling their needs for liquids, especially not if active and if it is warm or hot and dry, or maybe even windy. The amount of water that an animal needs will depend on its physiological stage, activity, age, rate of gain, rate of respiration, environment, type of feed, and feed intake.

A pregnant or lactating animal, for instance, will need more water than a dry animal. This is because a lactating animal is constantly producing milk, of which about 85% is water, one liter of milk needed 3-4 liters of water. Animals that graze on veld with a high water content will not need to be supplemented with as much additional water as animals that are fed a diet that contains only 10% moisture. Cattle: For temperatures over 35 °C, cattle should be supplied with 8 to 15 liters of water per kg of dry matter that they consume. Dairy cattle consumed water 30-80 liter per head depending on the stage of production & Insufficient water intake lowers cattle performance more dangerously than any other nutrient deficiency. (Beaver *et al*., 1989), body size (Pandey *et al*., 1989), and dry matter intake (Hicks *et al*., 1988).

The normal rate of water requirement & consumption for Dairy cattle has been summarized in table1&2 as below:

Table 1: Water requirements (gallons per head per day) for dairy cows based on level of production

Class	Age	Milk Production (Ibs milk/day)	Water intake
Calves	1to4 Month		1.3 to 3.5
Heifers	5-24 Month		3.8 to 9.6
Milking cows	24+Month	30	18 to 22
Milking cows	24+Month	50	23 to 27
Milking cows	24+Month	80	30 to 36
Milking cows	24+Month	100	35 to 46
Dry cows	24+Month		9 to 13

Meehan et al, 2015. NDSU Extension Service July 2015

Table 2: Water Consumption by Dairy Cattle

Dairy Cattle Type	Level of Milk Production (kg milk/day)	Water Requirement Range(L/day)	Water intake
Dairy calves (1to4 Month)	-	4.9-13.2	9
Dairy heifers (5-24 Months)	-	4.4-36.3	25
Milking cows	13.6	68-83	115
Milking cows	22.7	87-102	115
Milking cows	36.3	114-136	115
Milking cows	45.5	132-155	115
Dry cows	-	34-49	41

Ministry of Agricultural, Food and Rural Affairs, 2022. http://www.omafra.gov.on.ca/english/engineer/facts/07-023.htm.(Last accessed 30/11/2022)

Water intake was predicted from the following equations:
1-Water intake, (Ib/day) = 35.2 +1.58 DM intake (Ib/day) + 0.90 x milk production (Ib/day) + o.11 x sodium intake (g/day) + 2.64 weekly mean minimum temperature (degrees C).Murphy et al.,1983. Murphy, M. R., C. L. Davis, and G. C. McCoy. 1983. Factors affecting water consumption by Holstein cows in early lactation. J. Dairy Sci. 66:35.
2-Water intake = -18.67 + (0.3937 x MT) + (2.432 x DMI) - (3.870 x PP) - (4.437 x DS) Hicks et al., 1988.
3-Water intake (kg/day) = 16 +1.58*DMI +0.9 * milk produced (kg/day) +1, 2 * minimum temperature. (Livestock-water interaction: status and issues, SJ Phansalkar, 2006. https://publications.iwmi.org/pdf/H043949.pdf).(last accessed 26.11.2022)

Common Contaminants of Drinking Water:

The water available to livestock for drinking may be adulterated by several contaminating determinants including minerals [TDS], manure, microorganism, chemicals then algae. Salinity is careful as a basic quality parameter affecting palatability and health status along with performance. Contaminants may be biotic or abiotic making the water quality parameters. Biotic factors include Bacteria, Viruses, Protozoa, Algae, and Fungus while biotic factors include: Salinity TDS /TSS [Total Soluble Salts]/ EC [electric conductivity], minerals and complexes [nitrates, sulfates, phosphates], suspended particles, hardness, livestock sources i.e. manure, urine, grazing runoff, Accidental spills of petroleum, pesticides, and fertilizers, temperature, taste, and odor. Biotic factors such as bacteria, viruses, and parasites are killed by ultraviolet rays from sunlight except for algae, which seem to resist it (Table 3).

Effect on Performance and Productivity:

The economy is the most important aspect of livestock production, and it is directly related to animal productivity and performance. Livestock producers can enhance the health, productivity, and performance of their animals by improving the characteristic of the water being offered; just small mitigations in water quality may show surpassed performance and growth (Brew et al., 2009). The animal grows well when it is healthy and has no stress. Low water quality causes health problems that result in retarded growth and decreased performance. Every contaminant influences water quality in its way and subsequently on growth and performance, but mostly water quality results in reduced intake of water and feed ultimately reducing reproductive potential, milk production, and weight gain (Beede, 2006) (Umar *et al*., 2014). Suspension of material i.e. algae, clay, silt, and other organic material] results in turbidity and it makes water unpalatable above 5ppm. Manure is a usual contaminant of livestock drinking water, abundant in the pond where cattle may spend time loitering. Animals carry manure stuck to their hooves and shed in water-drinking places. It affects the intake by altering the taste and odor. Manure also contains excessive nutrients that allow algal and phytoplankton growth and also becomes a hotspot for bacterial and fungal growth in water resulting in changed water quality (Wakchaure et al., 2015, Pfost *et al*., 2001). Animals cast off pathogens spores and parasite eggs in feces and urine and leaching of nitrates and salts also happens (Harter *et al*., 2002). Manure level doesn't impact consumption until it is more than 0.25% in water. Studies have shown that livestock offered manure-contaminated water doesn't grow wellies compare to those having free access to clean water (Willms *et al*., 2002), (Schütz, 2012).

Water Consumption and influence of Water Restriction on Animal performance:

Water intake is closely related to feeding intake in both beef (Parenti *et al*., 2014) and dairy cattle and it is thus essential to provide palatable water to livestock to sustain productivity. Factors that affect voluntary water intake include animal factors, such as milk yield (Meyer *et al*., 2004a) and body weight as well as exterior factors, such as climate conditions, dry matter content of the feed, and trough design (Luís *et al*., 2009). As a result, determining what is considered typical water consumption is difficult. (Brew *et al*., 2009) reported values ranging from 19 to 41 L/day for beef cattle depending on the season, and 54 to 114 L/day for lactating dairy calves (Xu et al.,

2016), divided into 3 to 7 drinking bouts on average (Beede, 2012). New Zealand's water intake (Morris *et al*.,2010) found that in mid-lactation, Holstein-Friesian and crossbred cows produced 41 and 78 L/day, respectively, depending on whether they were on pasture (daily highest temperature was 21°C) or housed indoors (daily highest temperature was 27°C). Water intake is influenced by feeding management; cows fed a total mixed ration (TMR) drank more frequently (5.2 times/24 h) and had greater water intakes (TMR: 73 L/cow/day, grass: 53.7 L/cow/day, respectively) than cows on a pasture diet (3.5 times/24 h). Similarly, water consumption is affected by climate and increases in warm weather (Arias et al., 2019), in particular, if the animals have no access to shade (Hu et al., 2004). Water deprivation affects the health, behavior, and performance of cattle. Severe water restriction may decrease dry matter intake, milk yield, and body weight (Reddy and Sutton, 1984) and cause a change in behavior, such as increased aggression around the water trough and less lying. From a regulatory and welfare perspective, in the New Zealand Animal Welfare Act 1999, managers of livestock in New Zealand are required to provide "proper and sufficient foods and waters" and "protection against, and rapid diagnosis of, any significant injury or disease, appropriate to the species, environment, and circumstances and by both good practice and scientific knowledge

Effects of water quality on performance and productivity:

Water for livestock can be sourced from surface water, such as streams and ponds, and/or groundwater. The property of the water will be influenced by its source and contamination from microbes, parasites, minerals, and various other toxic substances, such as pesticides, abiotic and biotic factors as a result of either dissolved nutrients or direct deposition of urine or faces containing nutrients and possibly parasites (Lardner *et al*., 2005). The places that are most heavily affected by pollution are the places and resources that everyone uses in common, Kılıç Z.2020. Groundwater contains levels of dissolved salts, depending on the geology of the surrounding area, rainfall, vegetation, and topography. Human activities around the water sources will also influence the water quality. There are several published guidelines for water quality. Water quality tests often include values for salinity (mostly sodium chloride), hardness (mostly calcium and magnesium), pH, microbiological quality, algae, and nitrate and nitrite levels, among other things. Different water qualities, such as salinity (primarily sodium chloride), hardness (primarily calcium and magnesium), pH, microbiological quality, algae, and nitrate and nitrite levels, are generally measured.

Although there seems to be a consensus that water quality affects the palatability and water consumption of animals, there have been surprisingly few studies investigating the effects of water quality on livestock health and production. High salt contents could influence water and feed intake and subsequent growth rates (Lardner *et al*., 2005), however. Potential effects of the hardness of the water were investigated in the 50"s, but these studies showed no effect of hardness (190 and 290 ppm compared to 0 ppm) on dairy cow milk production, weight gain, or water consumption. Outrageous nitrate levels in water are not common but may occur and are often associated with extensive use of nitrogen fertilizers and manures, intensive and livestock operations, and can affect the quality and palatability of water (Colford Jr *et al*., 2007), The quality of water determines the health and productivity of milk and their quality, as it causes bioaccumulation of water solutes in

the milk and body tissues. Therefore, its quality has to be good for the optimum health, and performance of dairy cattle, global warming and an increase in tourists in high-altitude regions have caused the deterioration of water quality, which may have an influence on High nitrate levels in water health, reproduction, and production of quality dairy products. The main causal factors of water quality at high altitudes bear upon cattle health include excess mineral levels, high bacterial load, persistent organic pollutants, and high levels of heavy metals. The poor availability and property of drinking water would affect dairy cattle health and production in both high-altitude and low-altitude regions, Therefore, it is the earliest time to prevent such alteration of water quality by inventing some ameliorative measurements so that cattle herd health and productivity may be protected for quality dairy produce production. This will help in better health of dairy produce consumers and minimize bioaccumulation of some toxic molecules and metals into the higher food chain and affecting public health (Arup Giri *et al*., 2020).

Effects of the water temperature on the cattle performance:

The water provided in off-stream and reticulated sources may have different temperatures, depending on the source of the water, and this may influence animal productivity. The effects of water temperature have been extensively studied in both beef and dairy cattle. In hot weather (ambient temperatures in the trials ranged between 20 and 35°C), chilled drinking water (10°C vs. 27-28°C) lowered heat load by lowering body temperature and respiration rate (Hatvani *et al*., 2011), but the evidence is not always consistent (Kanwar *et al*., 1988). Chilled drinking water has been shown to increase feed intake and milk production in dairy cattle (Willms *et al*., 2002) and live weight gains in beef cattle, however, there have also been reports of no effects on for example milk production.

Effects of the water temperature on the cattle performance:

The water provided in off-stream and reticulated sources may have different temperatures, depending on the source of the water, and the effects of high-salt water on dairy cattle:
Cattle performance and health can be harmed by high-salt water in three ways:
(1) Intake of water and feed is reduced;
(2) Toxic levels of sulfur ingestion; and
(3) Induced trace mineral deficiencies. Beef cattle may voluntarily consume less low-quality water, resulting in lower dry matter consumption (Poole *et al*., 2004). Reduced dry matter consumption, and hence nutrient intake, has a direct and noticeable impact on cow output. The extent to which poor water quality impacts water intake and productivity may be determined by water needs. Size, dry matter consumption, physical effort, lactation, and temperature are among the factors that influence water consumption. The effects of temperature are especially important, as water requirements can double as temperatures increase from 40 to 90 degrees F (Poole *et al*., 2004). Since water is required to regulate body temperature, reduced water consumption can have substantial impacts when temperatures are elevated.

CONCLUSION

Alongside minerals in the feed, the contribution of minerals in the water is essential. Ensuring water quality has as result maintained the welfare, health, production, and reproduction

of dairy cows. It required regular testing of the water quality administered to livestock, certain compounds that are found in excess having a negative impact, anti-nutritive, and challenging of changes in the health status of the animals. The presence of calcium in excess has negative repercussions on health, through installing of digestive and skeletal disorders, being closely related to increasing the hardness of the water. It is heady necessary to make laboratory analyses for both: food and water, regarding the biogenic elements based on nitrogen: nitrates, and nitrites because excess leads to poisoning. The reproductive sphere is especially affected by high amounts of iron present in water sources and must be continuously monitored particularly in terms of microbiological parameters, because, waterborne diseases affect all animals that consume contaminated water. It is preferred that the watering to do from rivers, not from a stagnant water source whose quality degrades and occurs blooming algae, with serious repercussions on health, especially by ingestion of blue-green algae. Finally, Water should meet the nutritional needs of the animal. Adequate and safe water supply is essential for healthy animals and is extremely important for milk production, always make sure clean and fresh water is easily accessible to all your cows.

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