A Seminar Paper

on

Significance of Water Quality on Dairy Cattle Performances

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ABSTRACT

Waterisanessentialsourceofnutrientforallformsoflife.Goodqualityofwaterhelpsindigestionoff ood,metabolismofenergy,transportofnutrientsandmetabolites,andexcretionofwastematerial sfromourbodyandanimals.Thequalityofwaterdeterminesthehealthandproductivityofmilkand theirquality.Waterqualityhastobegoodforoptimumhealth,andperformanceofdairycattle.Qual ityofwaterresourceshasbecomequestionableduetoclimatechangeandmoreenvironmentalpol lution.Forpreventionandcontrolofwaterbornediseases,thereisacontinuousrequirementtomo nitorwaterqualityandcattlehealth.Thisreviewrevealssignificanceofthewaterqualityondairycat tleperformances.Fromthisreview,itcanbesaidthatprovidegoodqualityofwatertodairycattlewh ichcanimprovethehealthofcow,helpinreproduction,andincreaseproductionofqualitydairypro ducts.

KeyWords:

Waterquality,Milkproduction,Reproduction

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CHAPTER 1

INTRODUCTION

Water has the top priority for livestock because it constitutes a major part of the molecules in their body. Doubtless, water is the most important dietary essential nutrient. Loss of about 1/5 of body(Chambers, et. al., 2019; Spivey Fox, 2017). Lactating dairy cows need larger proportions of water relative to body weight than most livestock species because water comprises 87% of milk(Ross, 2005). In addition, water isvital for all of livestock's life's processes, including growth, lactation, reproduction, andcushioning their nervous system(Sowlatet. al., 2011; Hamill & McBride, 2013).

Lactating dairy cattle require largeamounts of water, roughly 100 L every day (Kramer et al., 2018). Therefore, it is essential to provide adequate drinking water for dairy cattle.In addition to the quantity of water that dairy cattle need, the quality of their drinking water is also important, because it affects the productivity and health of dairy cattle, and has implications for their water intake(Sharmaet. al., 2019). The quality of drinking waterprovided for dairy cattle is usually evaluated according to five major aspects, including the water's organoleptic properties (odor and taste), its physiochemical characteristics (including pH, total dissolved solids (TDS), total dissolved oxygen, and Hardness)(Huuskonenet. al., 2011), the presence of toxic compounds (including heavy metals, toxic minerals, organophosphates, hydrocarbons, and pesticides)(Nordberg & Nordberg, 2018), the presence of excessive amounts of minerals (such asnitrates, sodium, sulphates, iron, phosphate, and fluoride)(Hillman et. al., 2019), and finally the microbial contents and contaminants in the water (Sharmaet. al., 2019). Among all of these five components, toxic compounds are the most detrimental agent lowering the quality of the drinking water(Chang,et. al., 2011; Hillman et. al., 2019). Heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb), and mercury (Hg) tend to accumulate in cattle's various organs and products(Di & Cameron, 2012; Challis, et. al., 2017). From there, these heavy metals can potentially transfer to human's body through their consumption of animal products, and in turn causing adverse effects on the health of both dairy cattle and humans(Murphy, 2012; Lee, 2014).

It has been clearly established that water quality in agricultural catchments is often worse than in forested (native or exotic) catchments, Dawson & Haslam, (2013)concluded that agricultural runoff from intensively grazed pastures may have significant detrimental effects on lowland water quality in streams, rivers and coastal lakes. Changes in stream habitat, shading,siltation and channel modifications can cause changes in the physical, chemical and microbial attributes of water quality. Gustafson & Kessel, (2019) showed a direct link between water quality variables, e.g. dissolved reactive P, oxidized N, and dissolved oxygen, and increased number deaths of dairy cows.

Based on the above discussion, the present study has been conducted aiming the following objectives-

- To analyze the drinking water quality for optimum performance of dairy cattle.
- To study the effect of water quality on dairy cattle behavior and milk production.

CHAPTER 2

MATERIALS AND METHODS

This seminar paper is exclusively a review paper. Therefore, all the information was collected from secondary sources like various relevant books, journals,research articles etc. For collecting recent information, internet browsing was also practiced. Good suggestions, valuable information and kind consideration were taken from honorable seminar course instructors, major professor and other resource personnel to enrich this paper. After collecting all the available information, it has been compiled and arranged chronologically as per the objectives of this paper.

CHAPTER 3

REVIEW OF FINDINGS

3.1 Quality Water for Dairy Cattle

Drinking or free water intake satisfies80 to 90 percent of the dairy cows' total water needs. The amount of water a cow will drink depends on her size and milk yield, quantity of dry matter consumed,(Yager&Filev, 2014) temperature and relative humidity of the environment, temperature of the water, quality and availability of the water, and amount of moisture in her feed(Takagi& Hayashi, 2011). Water is an especially important nutrient during periods of heat stress. The physical properties of water are important for the transfer of heat from the body to the environment(Chambers, et. al., 2019).For example, a 1,500-pound non-lactating cow consuming28 pounds of dry matter containing 12 percent moisture and12 percent crude protein would consume 96 pounds (11.6 gallons) of water per day at air temperatures between 50°F and 80°F. Water intake may be 1.2 to 2-fold greater during periods of heat stress (Table1)(Yager&Filev, 2014).

Table 1: Estimated daily water consumption for a 1,500-pound lactating cow producing 40 to 100 pounds of milk daily

Milk Production (lbs/day)	Estimated DM Intake (lbs/day)	Weekly Mean MinimumTemperature				
		40°F	50°F	60°F	70°F	80°F
		Gallons per day				
40	42	18.4	20.2	22.0	23.7	25.5
60	48	21.8	23.5	25.3	27.1	28.9
80	54	25.1	26.9	28.7	30.4	32.2
100	60	28.5	30.3	32.1	33.8	35.6

Source: Yager&Filev, 2014

3.2 Factors of Drinking Water Quality for Dairy Cattle

Primary anti-quality factors, in excessive concentrations, known to affect water intake and(or) metabolism of dairy cattle include TDS, sulfur, sulfate and chloride (both biologically active anions), nitrate, iron, manganese, and fluoride. Other constituents typically listed in water analyses reports and specified as potential risk factors for humans (e.g., arsenic) have not been studied or documentedunder field conditions to affect dairy cattle performance or health(Huuskonenet. al., 2011). Primary examples of factors not believed to be of concern include pH, total hardness, calcium, and magnesium(Sowlatet. al., 2011). It is always possible that isolated cases of higher than normal concentrations of mineral elements, or other toxic compounds may be present and deleterious to cattle (Table 2 and 3)(Simeonovet. al., 2003). However, typically these cases are extremely difficult to identify and to prove cause and effect. The anti- quality factors (constituents) in drinking water that are known from research reports or experience to cause problems are addressed below. Those forwhich no negative effects have been found or reported in research are summarizedsubsequently.

Table 2: Water quality criteria considered safe concentrations of some potentially toxic nutrients in water for cattle

Nutrients	**Threshold(mg/literorppm)**
Aluminum	5.0
Arsenic	0.2
Boron	5.0
Cadmium	0.05
Chromium	1.0
Cobolt	1.0
Copper	0.5
Flourine	2.0
Lead	0.1
Mercury	0.01
Nickel	1.0
NO_3-N+NO_2-N	100
NO_2-N	10.0
Selenium	0.05
Vanadium	0.1
Zinc	25.0
Salinity (total soluble salts)	3000.0

Source: Simeonovet. al., 2003

The effects of modern agriculture on the widerenvironment are causing concern for a number ofreasons. Pollution arising from agricultural activities has increased mainly as a result of the intensification of food production systems(Sharmaet. al., 2019). The demand for food production has been met by acombination of high yielding crop varieties andgreater reliance on pesticides, fertilizers, and imported animal feedstuffs(Ocampo-Duqueet. al., 2006). Moreover, the intensification of livestock production withits associated increased demand for fodder hasencouraged farmers to rely more heavily onchemical fertilizers and imported feeds, and veryoften the waste is considered as a disposal problem rather than a useful source of plant nutrients(Caruso, 2010).Consequently, quantities of farmyard manure andslurry far in excess of crop requirements arefrequently applied to soils, with storage andweather considerations often determining thetiming and rates of application, rather thanagronomic interests(Ocampo-Duqueet. al., 2006). The livestock wastes containvaluable quantities of N, P, K and other micronutrients and their methods of use requiresrationalization in order to complement the benefits derived from fertilizers. Practices including manure slurry applications at times when theirbeneficial effects cannot be fully realized alsohave detrimental implications for the wider environment, including water quality(Parket. al., 2014).

Table 3: Water quality criteria considered safe concentrations of some potentially toxic contaminants in water for cattle

Contaminants	**Threshold(mg/literorppm)**
Aldrin	0.001
Chlordane	0.003
DDT	0.05
Dieldrin	0.001
Endrin	0.0005
Heptachlor	0.0001
Heptachlorepoxide	0.0001
Lindane	0.005
Methoxychlor	1.0
Toxaphene	0.005

Carbamate andorganophosphoruspesticides	0.1
Toxic algae	No heavygrowth

Source: Simeonovet. al., 2003

3.3 Sources of Drinking water for Dairy Cattle

A major factor of water consumption is that its safety to use. For animal as water consists of the major portion of its body its requirement is the most for proper functioning of daily processes(Sharmaet. al., 2019). Majorly for livestock farming the farmers depends on the freshwater sources like, ground water or river water. But in terms of water quality measurements there are several factors to consider. And thus, the water sources are mainly classified into three broad class (Fig-1) depending on their chemical constitution and origin source(Huuskonenet. al., 2011).

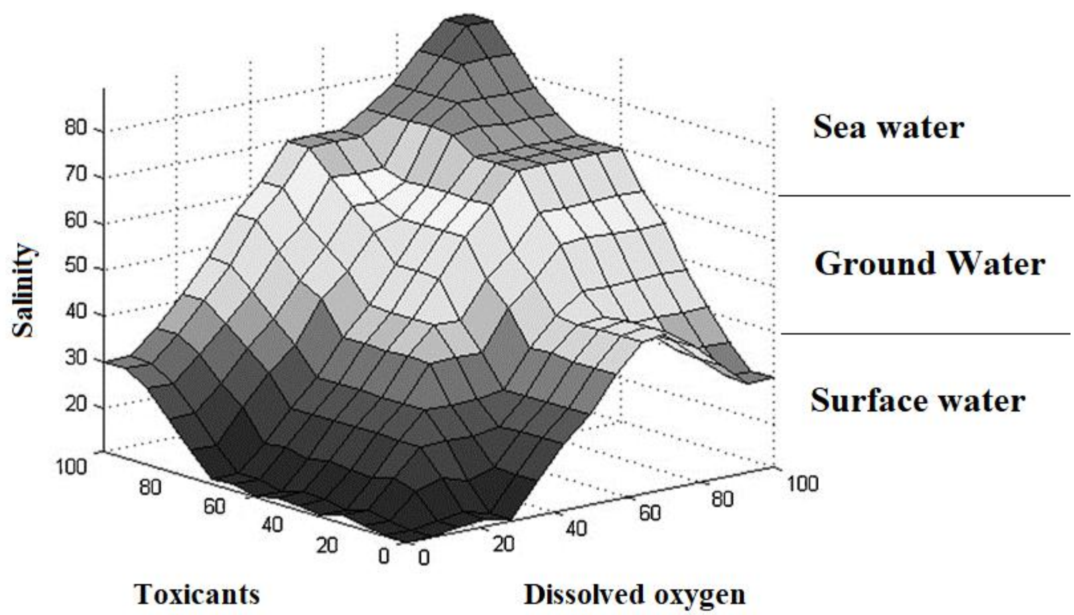

Fig 1: Source of available drinking water for livestock and their quality measurement index. Source: Huuskonenet. al., 2011

3.4 Water Selection Criteria for Dairy Cattle

For measurement of the water quality Total Dissolved Solids (TDS) is a general term defining the sum of all inorganic matter dissolved in water (Beede, 2015); TDS also indicates the salinity of water(Mahaffey, 2015). High amounts of TDS generally are considered an unwanted characteristic(Chambers, et. al., 2019). However, TDS per se may not provide much information aboutwater quality or the specific individual constituents of concern. For example, the TDS concentration couldbe quite high, influenced mainly by high concentrations of calcium and magnesium, yet little or no influence on water nutrition or cattleperformance would be expected (Table-4)(Yang, 2013).

Table4: Concentration of nitrates Total Dissolved Solids (TDS)in dairy cattle drinking water and expected response

TotalDissolved solids(ppm)	**Comments**
Less than 1,000	Presentsno serious burdento livestock
1,000 to 2,999	Shouldnotaffecthealthorperformance, butmaycausetemporarymilddiarrhea
3,000 to 4,999	Generallysatisfactory,butmaycause diarrheaespeciallyuponinitialconsumption
5,000 to 6,999	Canbeusedwithreasonablesafetyfor adult ruminants; should be avoided for pregnant animals and baby calves
7,000 to 10,000	Shouldbeavoidedifpossible;pregnant, lactating,stressedoryounganimalscan be affected negatively
over 10,000	Unsafe,shouldnotbeusedunderany conditions

ppm = parts per million, Source: Yang, 2013

Since 1950 the consumption of N fertilizers has increasedmore than six-fold. Increasing use of fertilizersand imported feeds results in larger soil nutrientpools, potentially increasing the risk of nutrientlosses e.g. nitrogen N and phosphorous through leaching and runoff(Sowlatet. al., 2011).Nitrate (NO3) is a potential problem when present in excess in drinking water for dairy cattle(Davies-Colley &Nagels,2012). Nitrate can pollute a water source via contamination of groundwater or runoff into surface waters. A likely potential source of nitrate is from crop or pasture land that has been fertilized(Nordberg & Nordberg, 2018).

Nitrate has been linked to reproductive problems of lactating dairy cows(Cooke, 2018). A 35-month study tested theinfluence of nitrate on reproductive and productive efficiency in Wisconsin (Kahler et al., 1974). During the first20 months of the study, there was no difference in reproductive performance. However, in the last 15 months cows drinking the high-nitrate water had more services per conception, lower first service conception rates, and longer calving intervals(Cooper & Thomsen, 2018).There can be some variation in nitrate concentrations in well water; presumably influenced by time of year, amount of precipitation (short-term and longer term), depth of wells and change in aquifer levels, and fertilization practices.Table 5 lists guidelines for nitrate concentrations in drinking water for livestock(Collins, et. al., 2017).

Table 5: Concentration of nitrates (NO_3) and nitrate nitrogen(NO_3 -N) in drinking water and expected response

NO_3(ppm)	**NO_3-N(ppm)**	**Comments**
0-44	10	No harmful effects
45-132	11-20	Safe, if diet is low in nitrates and nutritionally balanced
133-220	21-40	Couldbeharmfulifconsumedover a long period of time
221-660	41-100	Dairy cattle at risk; possible death losses
661-800	101-200	High probability of death losses
Over 800	Over 200	Unsafe

ppm = parts per million, Source: Collins, et. al., 2017

3.5 Effect of Water Quality on Physical Behavior of Dairy cattle

Lack of adequate water hinders its internal processes leading to expression of several external symptom hence noticed by swing in eating quantity(Huuskonenet. al., 2011).

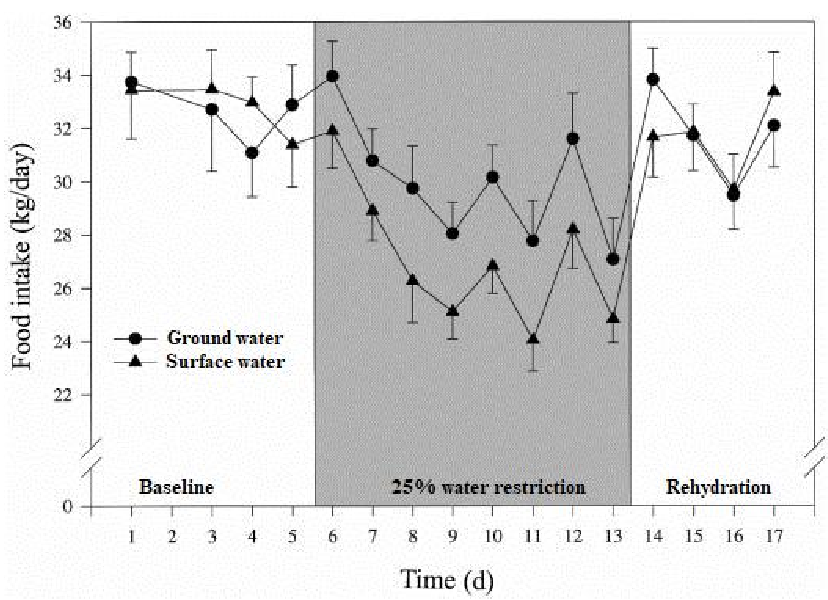

Fig2: Mean effect of quality ground water and fresh water diet on the food intake behavior of dairy cattle over time. (Source: Gustafson & Kessel, 2019)

Waterisacrucialelementforoptimumdigestionanddailyfoodintakedecreased(Ross,2005)inrelationtothewaterrestrictionlevel(Fig.2)duringthefirst3-4daysofwaterrestrictionandfluctuatedaroundan11and21%(with25%waterrestriction)lowerlevelfortheremainderoftherestrictionperiod.Foodintakeimmediatelyreturnedtothebaselinelevelonrehydration(Gustafson&Kessel,2019).

Meal pattern analysis revealed a particularly strong effect of water restriction (25% restriction) on the size of the first meal after the presentation of fresh food in the morning (Fig. 3)(Parket. al., 2014; Gustafson & Kessel, 2019). The first meal during water restriction started at about the same time as during baseline, but, from the third restriction day onward, it was smaller (effect of day: P, 0.05) and shorter (effect of day: P, 0.05, data not shown) than baseline meals. The size of the first meal was not affected on the firstwater restriction day because at that time the cows had not yet experienced any waterrestriction(Smithet. al., 2008). With 25% water restriction, they consumed more or less similar number of meals per day. On rehydration, the size of the meals rapidly reached the baseline level again(Gustafson & Kessel, 2019).

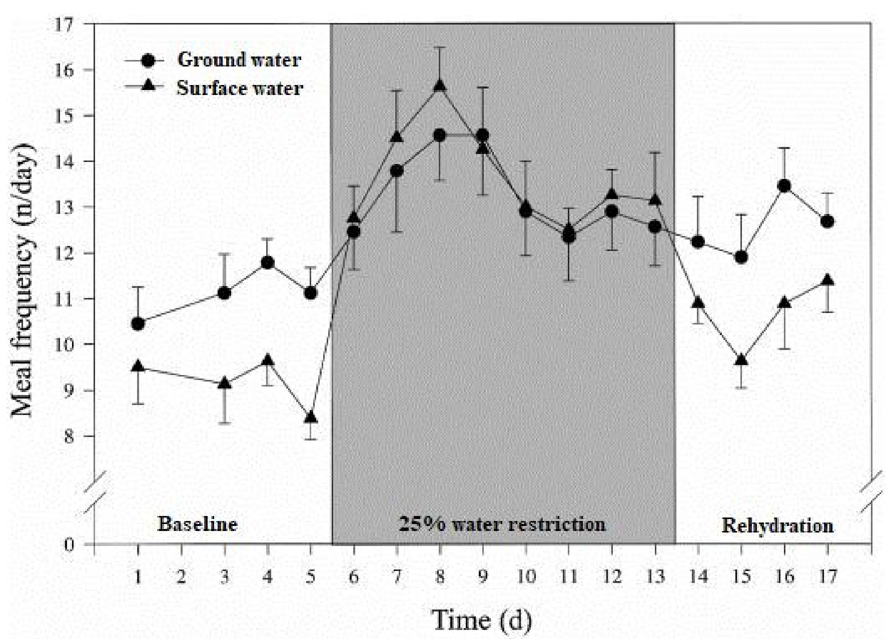

Fig3: Mean effect of quality ground water and fresh water diet on the meal frequency behavior of dairy cattle over time.(Source: Gustafson & Kessel, 2019)

There has been reports that water restriction subsequently subjected to 25% drinking water restriction, body weight decreased in cows(Chang,et. al., 2011). On rehydration, the body weight immediately increased above the baseline level and was higher (P, 0.05) than during baseline on all rehydration days (Fig-4)(Smithet. al., 2008; Gustafson & Kessel, 2019).

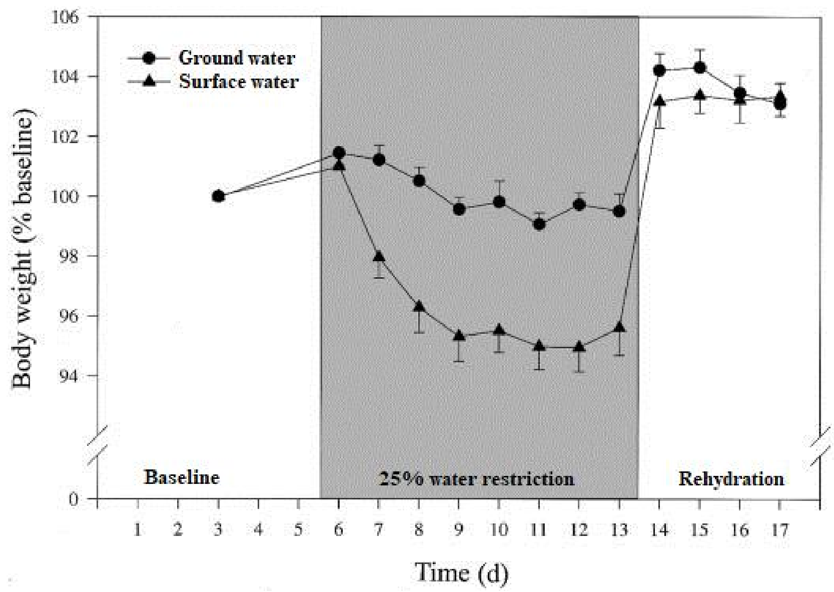

Fig4: Mean effect of quality ground water and fresh water diet on the body weight of dairy cattle over time. (Source: Gustafson & Kessel, 2019)

3.6 Effect of Water Quality on Blood Composition of Dairy cattle

The main reason due to water restriction mediated behavioral changes in dairy cattle can be described by its blood constitutional change at its anatomical level that expresses the phenomenon of dropping down of the effective translocation and absorption of essential nutrients(Haynes & Williams, 2013). In a detailed study of blood constitutions of a 25% water restrained dairy cattle it has been found that the plasma concentrations of urea and sodium as well as the hematocrit were higher (P, 0.05) during the water restriction than during the Control period (Table 6)(Sowlatet. al., 2011).

Plasma concentrations of lactate, BHB, and chloride, as well as plasma osmolality, tended to be higher during the water restriction period; plasma glucose, FFA, and glycerol tended to be lower (Table 6)(Sowlatet. al., 2011),but all these differences did not reach significance(Beede, 2015). Plasma concentrations of insulin, cortisol, glucagon, triglycerides, protein, and potassium, did not change during water restriction (Table 6)(Davies-Colley & Smith, 2011; Chang,et. al., 2011). The plasma concentrations of some metabolic hormones and metabolites showed great individual variations due to one animal that was in estrus during the baseline period(Sowlatet. al., 2011).

Table 6: Composition of the blood plasma of 6 lactating dairy cows with access to water (control) and with 50% water restriction

Blood attributes	**Control**	**50% water restriction**
Insulin, mU/ml	8.9±0.6	8.5 ±0.6*
Cortisol, nmol/l	21.5±3.2	17.3±2.1*
Glucagon, pg/ml	126.5±11.7	128.8±11.6*
Glucose, mmol/l	3.47±0.23	3.17±0.14*
Lactate, mmol/l	0.58±0.04	0.61±0.02*
BHB, mmol/l	0.73±0.06	1.11±0.17*
Triglycerides, mmol/l	0.20±0.01	0.20±0.01*
FFA, mmol/l	0.12±0.05	0.05±0.00*
Glycerol, mmol/l	19.3±1.2	18.5±1.1*
Proteins, g/l	75.3±2.2	75.3±2.3
Urea, mmol/l	3.0±0.1	5.5 ±0.1*
Na, mmol/l	135.2±0.5	139.3±0.7
K, mmol/l	4.0±0.1	4.0 ±0.1
Cl, mmol/l	99.5±2.0	103.0±1.8*
Hematocrit	29.6±0.8	31.5±0.6*

Values means of 6 cows. * Significantly (P, 0.05) different from control (DMRT). (Source: Sowlatet. al., 2011)

3.7 Effect of Water Quality on Physiological Behavior of Dairy cattle

Apart from the fact of its cellular physiology dairy cattle under water stressed condition may exhibit abnormality on several other biological processes intensively related to the day to day physiological processes(Sapkotaet. al., 2007; Chau,2016). Several researchershave confirmed this case on a various number of studies that due to lack of water intake cattle drastically drops their metabolic activity which is expressed by low amount of O_2 consumption and CO_2 production(Dawson & Haslam, 2013). On the basis of the reduced (P, 0.05) gaseous exchange during the restriction period, absolute heat production decreased (P, 0.05) by 21.7% (Table 7).

Table 7: Gaseous exchange, heat production, and body fat balance of 6 lactating dairy cows with access to water (control) and with 50% water restriction

Attributes	Control	50% water restriction
O_2 consumption, l/day	5,212 ±174	4,125 ± 120*
CO_2 production, l/day	5,758 ± 214	4,375 ± 132*
CH_4 production, l/day	640 ± 27	488 ± 20*
Heat production, MJ/day	111.5 ± 3.8	87.3 ±2.5*
Extra heat for milk production(k_L= 0.6)	40.8 ± 1.5	29.2 ± 1.4*
Heat spent for maintenance	70.7 ± 2.4	58.1 ± 1.7*
Body fat balance, kg	20.62 ± 0.09	20.08 ± 0.17

Values means of 6 cows. * Significantly (P, 0.05) different from control (DMRT). k_L,efficiency of utilization ofdietary metabolizable energy for milk production. (Source:Drewry, et. al., 2010)

Heatproductioncanbedividedintoheatrelatedtomilkproduction[calculatedwithk_L=0.6]andheatrelatedtomaintenanceneeds(Di&Cameron,2012).Undertheassumptionofanunchangedefficiencyofutilizationofmetabolizableenergy(kl),heatproductionformaintenancewasreduced(P,0.05)by17.8%duringtherestrictionperiod(Table3)(Drewry,et.al.,2010).Inlinewiththetrendobservedinenergybalance,thecowsmobilizedless(P,0.05)fatduringwaterrestrictionthancontrol(Table3)(Drewry,et.al.,2010).

Moreover, the decrease in physiological processes in cattle can also be evident by the amount of nitrogen intake in urine and milk of a water stressed cattle(Haynes & Williams, 2013). The nitrogen balance becomes negative during thewater restriction period (P, 0.05, Fig. 5). Expressed aspercent of nitrogen intake, the proportion of nitrogenexcreted with milk and especially with urine waslower (P, 0.05) during the restriction than duringthe control period(Fig. 5)(Ocampo-Duqueet. al., 2006). Therefore, nitrogen utilization was less efficient during water restriction thanduring the control period (0.53 vs. 0.65), and the cowshad less nitrogen available for productionthan the control (P, 0.05,Fig. 5)(Liouet. al., 2013; Ocampo-Duqueet. al., 2006).

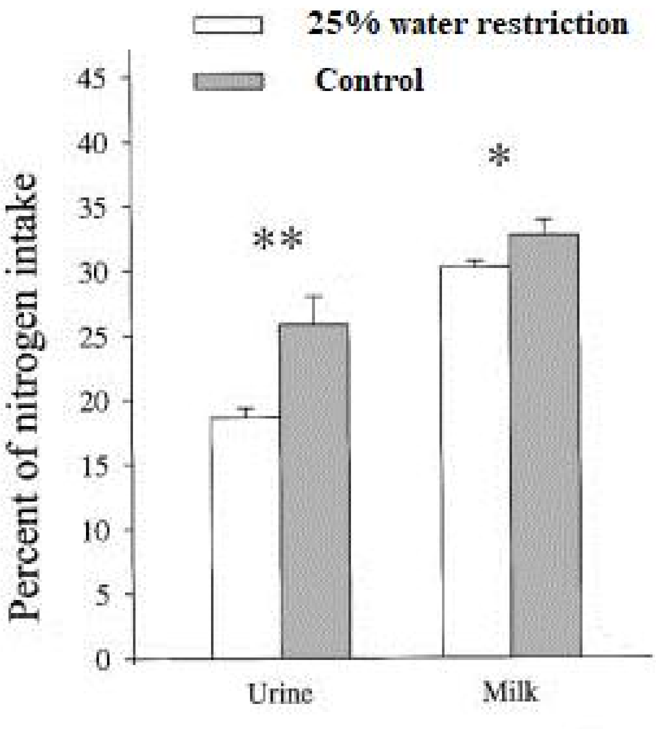

Fig5: Mean effect of 25% water restriction diet on the milk and urinenitrogen content of dairy cattle over control. '**' indicates 99% level of significance and '*' indicates 95% level of significance. Source Ocampo-Duqueet. al., 2006

3.8 Effect of Water Quality on Milk production of Dairy cattle

Apart from all the downregulations in physical and physiological behavior of lactating cattle the final result that becomes evident is lowering the milk production due to less amount of water intake(Caruso, 2010). It is beyond mentioning that water is the major part that makes up the milk(Keller & Hunt, 2015). So, by a simple equation it is easily understandable that less amount of water intake will reduce the liquidity, amount and quality of milk. It has been reported by many a scientist that milk yield was lower with 25% water restriction (effect of day: P, 0.05) than during baseline (Fig-6). Some also reported that milk yield also recovered with a 1-day delay during the subsequent rehydration period (Fig-6)(Gustafson & Kessel, 2019).

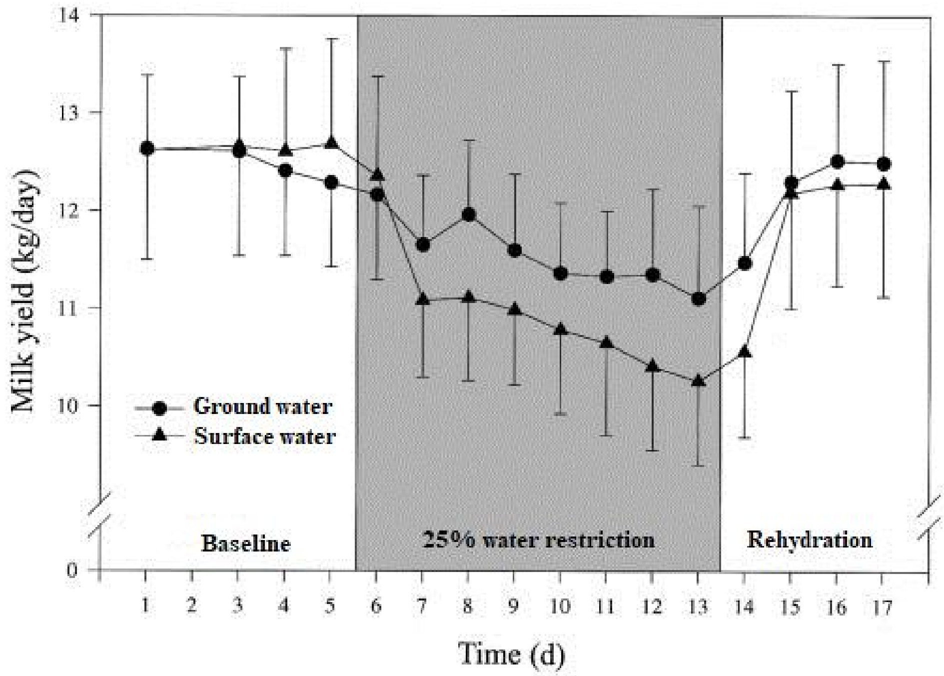

Fig6: Mean effect of quality ground water and fresh water diet on the milk yield of dairy cattle over time. (Source: Gustafson & Kessel, 2019)

Not only the milk yield is affected by the water quality parameters but also the milk quality and its constitutions are also affected(Sapkotaet. al., 2007; Jones & Richardson, 2014). In a report by Cooper & Thomsen, (2018) it has been found that with the increase of water quality parameters towards the optimum level milk quality parameters increases along with it (Fig-7)(Krameret. al., 2018; Murphy, 2012). Major milk quality parameters were assed for the effect of quality water on dairy cattle milk production and the results suggested that with the increase of water quality regarding the amount of water intake as constant milk protein content (Fig-7a), lactose content (Fig-7b), total soluble solid content (Fig-7c) and water content (Fig-7d) increased significantly(Hecky&Kilham, 2018; Krameret. al.,

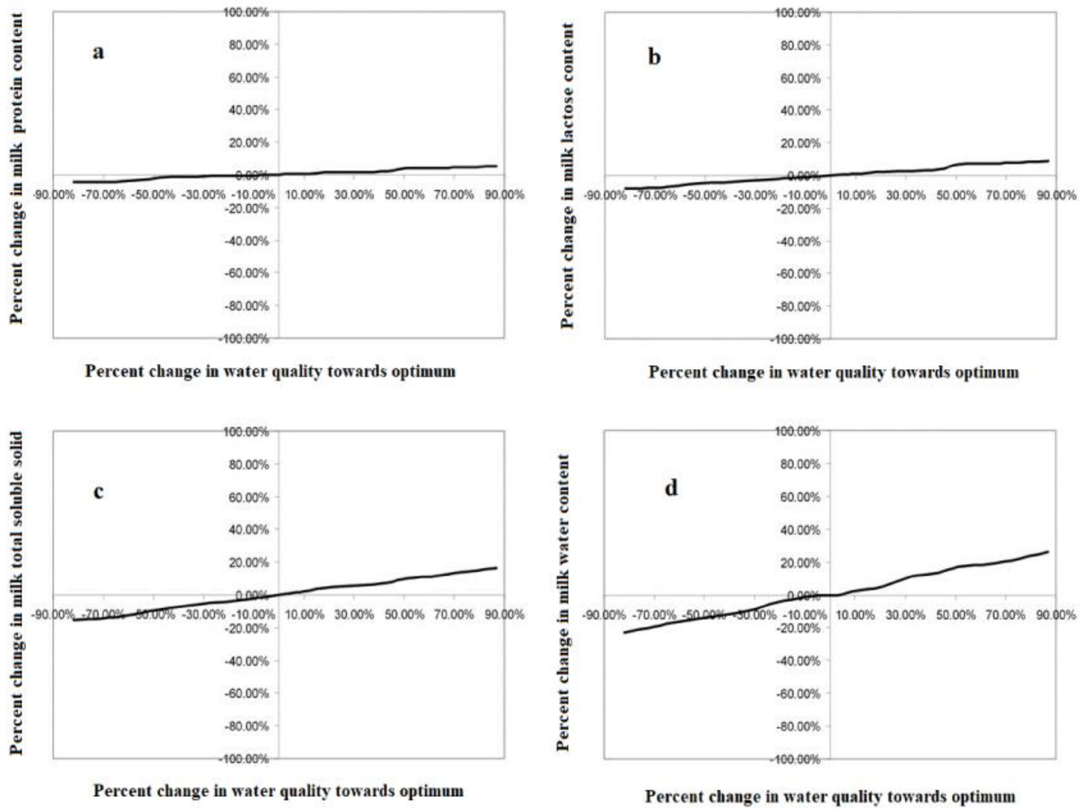

Fig7:A sensitivity analysis indicating the effect of percent changes in the water quality parameters towards optimum on mean milk (a) protein content, (b) lactose content, (c)total soluble solid content and (d)total water content. Source: Krameret. al., 2018

CHAPTER 4

CONCLUSIONS

Mostoftheresearchworkon various type of water have showedthatphysicochemical,microbial, heavymetals and minerals levels arehigherthanthe normal limitsthroughouttheworld. The causalfactors ofwaterqualityeffectsoncattlehealthincluding highbacterialload, excessminerallevel, and highlevelofheavymetals.

The good qualityofdrinkingwaterwould increase thedairycattlehealthandproduction. Waterqualityisgettingdeterioratetremendously,whichmayaffectthereproductionandmilkpro ductionofdairycattle.Therefore,itistheearliesttimetoprovide good quality ofwater to the lactating dairy cattle sothatcattleherdhealthandtheproductivitymaybe increased.

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