Drinking Water Considerations on Dry Lot Dairies

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INTRODUCTION

Dairy cows require large amounts of water daily. Sources of water for the dairy cow include:

1) Drinking or free water,
2) Water (moisture) in feed, and
3) Metabolic water.

An average of 83 % (range: 7 to 97 %) of total water consumed by cattle is from drinking water. Metabolic water is insignificant compared with water ingested freely or contained within feeds. Some major factors affecting water intake by dairy cattle are: dry matter intake (**DMI**), milk production, dry matter (**DM**) content of the diet, temperature and environment, and sodium (**Na**) intake (NRC, 2001).

A small limitation in water intake may decrease DMI by 1 to 2.2 lb/d, which may limit peak milk production by 2 to 5 lb/d. Lactating dairy cows require total water intakes of 4.4 to 5 lb of water/1 lb of milk produced. The total daily water intake comes from both drinking and moisture (water) in the consumed ration. Cows have peak water intake during the hours when feed intake is greatest.

RELATIONSHIP BETWEEN WATER AND FEED

Kume et al. (2010) studied the impact of feed water intake and free water intake (**FWI**). The average total water requirement was 26.0 gal/d (**gpd**)/cow with approximately 5.5 gal (20 %) obtained from the feed source and the balance from drinking water. The ratio of FWI to milk was 2.6 and ratio of FWI to DMI was 3.74.

Appuhamy et al. (2016) reviewed multiple research studies involving FWI of dairy cows. They reported average water consumption of all of the studies was 19.9 ± 6.4 gpd/cow. The range of the full data set was from 2.9 to 32.3 gpd. The average ratio of FWI to DMI was 4.1 and average ratio of FWI to milk production was 2.67. Dry cow water consumption was reported as 9.3 gpd/cow with a ratio of FWI to DMI of 3.1.

Dry matter content of the diet has been shown to affect the FWI. Holter and Urban (1992) showed a decrease of ration DM from 50 to 30 % decreased FWI by 8.75 gpd. Ration DM percent can have a negative impact when considering total water intake. When ration DM percent increases, FWI per cow increases; but total water intake decreases. Murphy (1992) suggests this happens because of the need to excrete more nitrogen (**N**) and potassium (**K**) in urine when feeding wet diets. Holter and Urban (1992) concluded that this is only relevant to cows on high protein pasture or succulent silage.

Dewhurst et al. (1998) performed an experiment to examine the effects of silage characteristics on water intakes. In this study, 16 silages were used with DM ranging from 15.9 to 28.0 %. Free water intake per cow ranged from 5.3 to 23.8 gpd, total water intakes from 12.8 to 32.8 gpd, and milk production from 36 to 85 lb/d. They found that FWI increased with increasing silage DM concentration. It also confirmed other reports suggesting that FWI replaces silage water at a rate less than 1:1.

Winchester and Morris (1956) found water intake per unit of DMI remained constant from 10 to 40 °F. From 10 to 40 °F, cows consumed about 0.16 gal (1.36 lb) of water/lb of DMI. At the peak of 90 °F cows consumed 0.38 gal (3.18 lb) of water/lb of DMI. These water to feed ratios may be different with today's genetics in the dairy industry.

Murphy et al. (1983), Holter and Urban (1992), Little and Shaw (1978), Stockdale and King (1983), Castle and Thomas (1975), and Dahlborn et al. (1998) have published formulas for predicting water consumption. The Murphy et al. (1983) formula is as follows:

$$FWI = 15.99 + 1.58 \times DMI + 0.90 \times MY + 0.05 \times SI + 1.20 \times Temp_{min}$$

Where:

FWI is free water intake in kg/d,
DMI is dry matter intake (kg/d),
MY is milk yield (kg/d),
SI is sodium intake (g/d) and
$Temp_{min}$ is minimum temperature (°C).

The 2001 NRC recommendations used the formula developed by Murphy et al. (1983) to estimate FWI. The Murphy et al. (1983) formula shows that drinking water changes 1.58 kg for every 1 kg change in DMI, 0.90 kg for every 1 kg in milk yield, 0.05 kg for each 1 g change in Na intake, and 1.20 kg for every 1 °C change. This shows that DMI, minimum temperature, and milk yield have more influence than Na intake on drinking water intake. Potts (2012) developed a meta-analysis using data from 50 individual studies recording water intake by dairy cattle. Ration water intake (**RWI**) was calculated from the DMI and DM percent reported. Table 3 reports the actual FWI from the data set and what the prediction equations estimate for FWI using the meta-analysis data points. Using the 116 data points, the ratio of FWI to milk yield averaged 2.82. Figure 1 shows the relationship between daily milk production and FWI based on the 2.82 ratio. Daily water requirements are proportional to increased milk production.

Table 1. Comparison of four prediction equations of free water intake (FWI) to prediction equations of actual water intakes and milk efficiency from all data points (116) from scientific papers where dry mater intake, ration water intake, and milk yield were reported.

Data Source	Estimated Free Water Intake (gal/cow/day)	Predicted Milk Efficiency (lb water/lb milk)
Actual	21.4	2.82
Little and Shaw (1978)	20.1	2.64
Stockdale and King (1983)	10.2	1.35
Potts et al. (2012)	21.4	2.82
Castle and Thomas (1975)	22.6	2.92
Dahlborn et al. (1998)	18.7	2.46

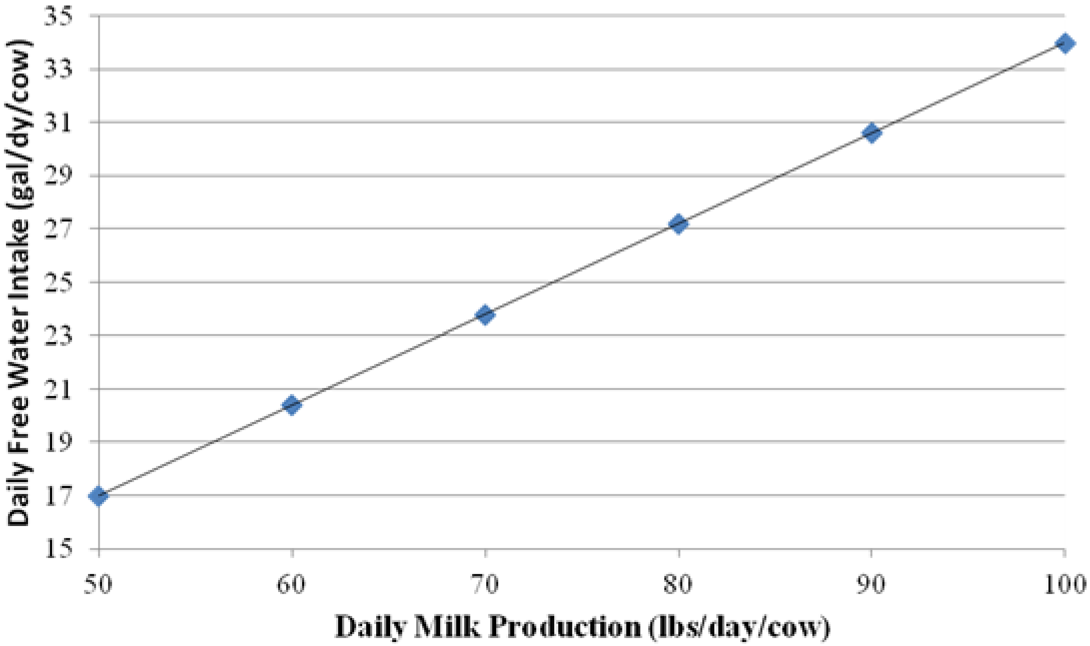

Figure 1. Relationship between daily milk production and free water intake assuming a water intake to milk ratio of 2.82 based on scientific data (Potts, 2012).

DRINKING WATER REQUIREMENTS OF DAIRY COWS

Total water consumption of lactating milk cows is between 30 and 50 gpd/cow. Brugger and Dorsey (2008) compiled total dairy farm water usage from January 1, 2005 to December 31, 2006. This study was conducted on a 1,000 cow dairy farm in northwest Ohio where the average high temperature was 60 ˚F and the average low temperature was 39 ˚F. Over the 2 y period the total farm water usage averaged 29.6 gpd/cow. The total water usage included the milk center and drinking water usage but there was minimum cow cooling. Free water intake by the dairy cows was lowest during the month of December 2005 at 11.6 gpd/cow and the highest was in July 2005 at 33.8 gpd/cow. The cows alone consumed an average of 23.3 gpd/cow of FWI over the entire study period. No information on milk yield, DMI, or ration moisture content was provided.

Zuagg (1989) summarized the daily water usage on 5 dairies in Arizona. Early lactating cows drank between 29 and 35 gpd/cow, while late lactating cows drank 25 to 28 gpd/cow. This was a function of milk production and feed intake. Water consumption was less than 20 gpd/cow during the dry period on all of the farms.

Impact of Water Restriction

Severe water restriction can have a profound impact on productivity and feeding behavior of cattle. Steiger Burgos et al. (2001) evaluated the impact of 50 and 75 % restriction in water intake for 8 d. The 50 % water restriction resulted in a 21.3 % decrease in 24-h feed intake, a 57.4 % reduction in size of first meal, and a 41 % increase in number of meals/24 h. The 75 % reduction in water intake resulted in an 11.3 % decrease in 24-h feed intake, a

53 % reduction in the size of the first meal every day, and a 31 % increase in the number of meals/24 h. A reduction in size of the first meal each day of greater than 50 % accounted for most of the suppression in feed intake.

Andersson et al. (1984) looked at the effect of water flow rates in water cups on the consumption of water by tied up dairy cows. Using flow rates of 0.5, 1.8, and 3 gal/min they reported that Swedish Red and White breed cows drank 2.5 and 3.3 gpd more water with the increased flow rates. The time spent drinking by each group of cows also decreased from 37 min/d on the low flow rate to 7 min/d on the high flow rate. The cows also spent more times per day drinking with low flow rates (40 times/d) than the high flow rate (30 times/d). No data was provided on the impact of flow rate on water wastage. While the cows spent more time drinking, the flow rates did not affect milk production or DMI. However, at the high flow rates there was a tendency for increased milk production. These results indicate that cows will adapt to slower flow rates by changing their drinking behavior (Andersson et al., 1984).

Andersson and Lindgren (1987) studied the consumption of water by cows by restricting access to water during feeding. The treatments were a control where cows had free access to drinking water, no drinking water for 1 h after feedings, and no drinking water for 2 h after feeding. They reported that cows prefer to have water available during feeding. However, cows will consume 60 to 80 % of total water consumption within a few hours after feeding. There were no differences in water intakes between treatments once water was made available. However, the cows with free access to drinking water drank within 15 min after eating (Andersson and Lindgren, 1987).

Dairy Cow Drinking Behaviors

Data collected during the study comparing the impact of dietary fiber (Dado and Allen, 1995) indicates a cow will drink about 1.5 gal of water/trip to a watering trough at a rate of 1.27 gpm. They also found a cow will spend about 12 to 16 min/d drinking water. Their measured FWI were lower than most studies. However, using this data, a cow makes about 18 trips/d if she drinks 28 gpd and consumes 1.5 gal/visit. Assuming a 12-ft watering trough and 6 cows present, the minimum water flow rate would be 8 gpm. A single cow will spend approximately 25 min/d at watering troughs. Even though cows spend only about 2.5 % of their time at the water trough, adequate water space recommendations per cow are to provide 2 ft of tank perimeter or 1 watering space/15 to 20 cows (MWPS, 1997).

Cardot et al. (2008) evaluated water intake on dairy cows housed in freestall housing. Milk production was 58.3 lb ± 13.0 lb/cow/d and FWI was 22.1 ± 4.5 gpd/cow. Cows went to the water troughs an average of 7.3 ± 2.8 times/d. During each visit average water consumption was 3.4 ±1.3 gal/cow/drinking bout. Almost 75 % of the water was consumed between 6:00 and 19:00 and 75 % of the cows visited a water trough within 2 h after the evening milking (2X/d milking). Cardot et al. (2008) estimated 25 % of the daily water consumption occurred within 2 h of milking or feeding. In this study the average FWI to DMI ratio was 4.0. The FWI to milk ratio was 3.15. The 22.1 gpd FWI reported by Cardot et al. (2008) was similar to 22.17 gpd of FWI reported by Meyer et al. (2004) and

21.7 gpd reported by Melin et al. (2005). Drinking bouts per day ranged from 5.2 (Jago et al., 2005) to 9.4 (Huzzey et al., 2005) and average water intake was very similar. Cardot et al. (2008) also reported between 6:00 and 19:00 that 20 and 55 % of the cows hourly visited a water trough. During the 20:00 to 5:00 time period less than 10 % of the dairy cows visited a water trough. This study also examined the effect of overstocking and found that FWI/cow/d did not vary as stocking density per water bowl was increased from 11 to 40 %, but volume of water drank per visit increased while drinking bouts (visit to a water bowl) decreased. The study demonstrated overstocking a pen changes the drinking behavior of dairy cows.

Gavojdian et al. (2010) evaluated the seasonal effect on drinking behavior of dairy cows. The average number of drinking bouts was 8.15 during the winter, but 16.10 during the summer. The actual time spent drinking was 0.82 min in the winter and 0.84 min in the summer. During the winter 85.9 % of the water was consumed between the hours of 7:00 and 21:00, however during the summer only 65.5 % was consumed during that same time period. Water consumption was equally distributed during the three 8-h time periods during the summer months. Gavojdian et al. (2010) found cows visited a water trough within 63.4 ± 7.89 min following milking during the 7:00 to 14:00 period. During the 14:00 to 21:00 time period, cows visited a water trough within 33.4 ± 7.99 min. In the winter time, the time between milking and first drink of water almost doubled as compared to the summer months. They found during the summer months cows consumed water within 6.5 min after finishing ration consumption.

IMPACT OF WATER TROUGH DESIGN

Filho et al. (2004) found grazing dairy cows prefer larger water troughs. They found dairy cows prefer water troughs that are 24 in high compared to 12 in. Water consumption, drinking time, and number of sips all increased with the higher water trough. Drinking time was 27.26 ± 6.22 sec and consumption was 2.45 ± 0.60 gal/visit from the higher water trough.

Brouk et al. (2001) studied the difference in water consumption based on the location of the water trough in a freestall building during summer months. More water was consumed at the center cross alleys than end cross alleys (Table 2). McFarland et al. (1998) reported similar results in an earlier study. Brouk et al. (2001) found cows consumed about 8 % of their daily water needs at watering troughs located near the parlor exit. In addition, daily refilling water troughs after tipping was equal to 10 to 15 % of the daily drinking water requirements. They reported average water disappearance per cow in the housing area ranged from 34.5 to 36.5 gpd/cow in the 4-row freestall pens. They estimated 85 % of the water disappearance was due to drinking and 15 % from tipping / cleaning water troughs daily. The ratio of water disappearance per pound of milk production ranged from 3.6 to 5.4 lb of water/lb of milk, while average milk production per pen ranged from 56 to 98 lb/cow/d. Water consumption ranged from 24.2 to 28.1 gpd/cow in the 2-row freestall, excluding water drank at the parlor exit. The water to milk ratio ranged from 2.6 to 3.5. These values do not include the water drank at the milk parlor exit. Approximately 9 % of the drinking water requirements were met from the 2 additional water troughs located along the back alley of the freestall barn. On a third dairy, water consumption ranged from 28.8 to 30.3 gpd/cow with milk production ranging from 64.3 to 85.6 lb/cow/d. The water to milk ratio ranged from 2.9 to 3.8, while the water to feed ratio averaged 4.2 on this dairy. Water usage tended to decrease as milk production increased. The FWI to milk ratio generally ranged from 3 to 4 lb of water/lb of milk.

WATER TROUGH DESIGN CONSIDERATIONS FOR DRY LOT DAIRIES

Typically, the water trough recommendation is based on 2 to 3 in/cow. This recommendation is based on dairy cows in freestall housing systems, where water troughs are 100 to 140 ft apart. In a freestall housing system a cow is generally within 60 to 80 ft of a water trough. Data shows cows will drink at the nearest water troughs. Dry lot facilities often have 2 or 3 water troughs distributed along the length of the feedline with spacing 200 to 300 ft apart. Occasionally owners opt to place the water troughs at the back of the pen or midway along the fence line increasing the walking time between the feed line and water trough. It is important to have adequate space for all of the cows to be able to reach water in a timely manner following milking and feeding. One research study showed during summer months cows were drinking water within 6.5 min of leaving the feed line. Research shows at least 75 % of the cows will obtain a drink within 2 h following one of these events. Additionally, cows locked in headlocks for extended periods will quickly seek water upon release, particularly during hot weather. While the normal recommendation is 2 to 3 in of water space/cow, owners may want to consider 3 to 4 in of water space for water troughs not shaded (i.e., outside a building). If adequate water space is available upon exiting the milk center, then 3 in/cow should be adequate in a pen. If water is only available in the pen, then 4 in of water trough/cow should be considered. Cows may tend to surge more to a water trough in open lots due to the summer heat, particularly in late afternoon when temperatures drop. As a general guideline, there should be a water trough within 250 - 300 ft of all feed spaces. Water space should be provided for 10 to 12.5 % of the feeding spaces or assuming 150 cows/300 ft of feed space (24 in/feed space or head lock) or a minimum of 15 to 20 cows should be able to

Table 2. Percentage of drinking water utilization at different locations within pens from a dairy where there were 2 water troughs in each cross-over alley (Brouk et al., 2001).

Location of Water Trough	Location in Cross-over	Percentage of Total Utilization	Percentage of Location within Cross-over	Percentage of Total Water Utilization by Cross-over
Pen exit cross-over	Feedlane	12.0	62.2	19.3
	Stall	7.3	37.8	
Cross-over between exit and middle	Feedlane	16.1	62.2	25.9
	Stall	9.8	37.8	
Middle cross-over	Feedlane	15.9	58.2	27.3
	Stall	11.4	41.8	
Cross-over between middle and end of pen	Feedlane	10.9	62.3	17.5
	Stall	6.6	37.7	
Pen end cross-over	Feedlane	5.5	55.0	10.0

drink at once. This recommendation is based on 5 min/cow/drinking event (includes time standing or blocking water trough and drinking time) and assumes all cows will drink within a 40 - 60 min period following milking and/or feeding. Using 3 in of watering space/feed space, it is recommended having 40 ft of trough/150 feeding spaces in the pen and then appropriate watering space along the return lane from the parlor. It is important to remember, the water trough design is not based on average; but on the 2 h period immediately following the afternoon milking when at least 75 % or more of the cows will obtain a drink of water upon exiting the parlor. If we assume 15 min return time from parlor to the pen and 45 min for feeding. Basically, the design has to be based on 75 % of the cows being able to drink within a 60 min period.

Some producers opt to use round or wider tanks to allow cows to drink anywhere around the perimeter of the water trough. Rectangular water troughs where cows drink from both sides should be at least 3 ft wide. Cows should be able to drink without interference from a cow on the opposite side of the water trough. A 10 - 12 ft concrete apron around all sides of a water trough accessible by cows is necessary to provide firm footing. Concrete aprons, if possible, should be sloped towards the feed apron to prevent water/mud holes within the pen.

IMPACT OF WALKING SPEED

Research has shown that cow's walking speed in alleys is 2.5 to 5 ft/sec (**fps**). Chapinal et al. (2009) estimated walking speed of cows with different gait scores. Regardless of hoof health, cows walking speed was 4.9 ± 0.20 fps. Walker et al. (2010) reported walking speeds of 1.7 to 4.5 fps in a study on ground reaction forces. Flower et al. (2006) also evaluated gait speed for cows with and without sole ulcers before and after milking. All cows after milking had a longer stride 4 vs 4.4 ft and walked faster 2.8 vs 3.2 fps. They reported cows without sole ulcers had before and after milking walking speeds of 3.5 vs 2.9 fps. Anon (2018) suggested average herd walking speed was 2.5 fps, but dependent upon many design factors. Telezhenko and Bergsten (2005) reported walking speeds varied from 3.2 to 3.7 fps and stride length ranged from 4.4 to 5.2 ft, depending on floor surface (concrete, rubber, sand, etc.).

Cow walking speed should be considered when calculating the time between the feed line and water trough. The 300 ft maximum distance recommendation between feed line and water trough suggests cows should be able to reach a water trough in 2 min or less based on a walking speed of 3 fps. In freestall housing systems the time interval is less than ½ min, but there are impedances to cow movement in the alleys. Cows seek water within 6.5 min after feeding during the summer months. However, there are other natural activities such as:

- Backing away from the feed line,
- Approaching a water trough occupied by other cows, or
- Distractions

that must be factored into any time allowance.

WATER AVAILABILITY EXITING THE MILKING PARLOR

Brouk et al. (2001) found cows will consume 8 - 10 % of their daily water intake if water is available at the end of exit lanes. A reasonable goal is for all of the cows exiting the milking platform within a 5 min time period to be able to drink simultaneously. For parallel or herringbone style parlors, the rule of thumb to determine water trough length is number of milking units per one side of parlor x 2 ft. For example, the exiting water trough from a double 40 parlor should be at least 80 ft (40 units x 2 ft/unit) long. Table 3 shows the minimum recommended water trough length for the exit of a parallel or herringbone parlor. Table 4 shows the minimum recommended water trough length for rotary parlors based on stall entry time. Regardless of parlor type or sorting technologies, cows should be able to obtain a drink of water within 5 min of exiting the milking unit or stall. Water troughs located along the outside walls of parallel parlors provide access to water immediately; however, cows tend to bunch and may interfere with the next group being released. Another option is to locate parlor exit water troughs along the transfer lane back from the parlor. This also allows cows to pass through foot baths and sorting technologies before drinking. Water troughs should be located within 300 ft of the milk platform. Dairies not able to install water troughs within 300 ft of the milking platform should consider adding an extra water trough near the pen entrance. Often the first water trough is 200 to 300 ft from the pen entrance/exit gate to the milk parlor.

Table 3. Recommendations on water trough length for parallel or herringbone parlors

Parallel or Herringbone Parlor	Minimum Length of Water Trough
Double 20	40 ft
Double 30	60 ft
Double 40	80 ft
Double 50	100 ft

The 300 ft distance should enable cows to drink within 5 min of exiting the milking platform, assuming normal walking speeds and some distractions. Assuming cows drink 1.5 gal/milking prior to returning to their pen, the refill rate of the water trough should be designed based on 0.5 gpm/cow drinking space. If the water trough is designed for 50 cows, the water system should be able to supply 25 gpm (50 cows x 0.5 gpm/cow). If the water demand is not met, the subsequent groups coming to drink may not have adequate water available.

Table 4. Recommendations on water trough length for rotary parlors

Rotary Parlor Stall Entry Time	Equivalent Parallel Parlor	Minimum Length of Water Trough
8 sec	D40	80 ft
7 sec	D44	88 ft
6 sec	D50	100 ft
5 sec	D60	120 ft

WATER AVAILABILITY WHILE MILKING

Water access during milking has been minimally documented; therefore it is uncertain whether the cost of installing water access in the parlor is economically viable given the complexities of implementation and unknown returns. Some dairies with parallel parlors provide water at the milking units, but the water troughs have to be cleaned frequently. Cows may still want to congregate around a water trough after leaving the parlor anyway. With rotary parlors, challenges that must be addressed include: meeting water demands, flushing or cleaning the water trough, and water splash on to electronic components. Currently water troughs are not available to be attached to the inside of the rotary, making water availability during the approximate 6 min rotation time an issue. However, water cups (similar to those used in a tie stall facility) might be an option. In addition, the parlor manufacturer must be contacted to determine if the rotary parlor can handle the extra weight, which is estimated to be 1,200 to 2,000 lb for a 100-stall rotary parlor.

SUMMARY

Research on water consumption in dry lot dairies is not readily available, but ratios of FWI to milk or DMI are consistent. Therefore, dairies should be able to estimate daily free water consumption based on DMI or milk yield. As a starting point, water intakes can be estimated by 0.4 gal/lb of milk (ratio of 3.3 water intake to milk yield) or 0.5 gal/lb of DMI (ratio of 4.2 water intake to DMI). This is average water consumption and some studies suggest cows will drink 25 to 50 % more water during the summer months as compared to winter months. Since water consumption data is not available on dry lot dairies, which tend to be located in hotter/drier regions, the estimates above should be considered as minimum water consumption design recommendations.

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