REVIEW

Water consumption, performance, and health in calves: a review

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Abstract The aim of this review is to summarize the current knowledge of drinking water for dairy calves. Calves receive water from milk or milk replacer (MR), from other feeds, and from free water. Water consumption to weaning is almost low. Opposing opinions are at the beginning of offering drinking water to calves. Some authors recommend providing water from the first day, some since the transition to artificial milk nutrition, or offering after weaning only. The water needed by pre-weaned dairy calves depends on the amount of milk or MR intake. The increased water in MR reduces the need for additional water to be fed as free water. Generally, when calves were fed supplemental water in addition to that provided in MR, they consumed more concentrate mixture and dry matter (DM) as compared with calves not given supplemental water. Water restriction can intensify the stress during heat temperatures period. However, according to recent research, restricting water intake (WI) during milk feeding period did not affect calf feed intake, growth, and health condition. Calves may be able to accumulate water in reserve to be used in periods of reduced water supply. However, we cannot recommend the WI just as part of the MR. We suggest that the water provided by the MR may not be sufficient to satisfy the needs of the animal. Drinking water has to be always at the disposal. Providing ad libitum intake of drinking water is the best approach. Finally, the exactly calves daily water consumptions are listed in a table.

Keywords: dairy calf, environment, growth, water intake

Introduction

Water is the most important nutrient for sustaining life to each animal, it is essential in many biochemical processes in the body (nutrients transport, digestion, and metabolism), the elimination of wastes (respiration, urine, feces), the regulation of body temperature (perspiration) and osmotic pressure, the maintenance of an enough fluids and optimal electrolyte dilution (Houpt 1984; Murphy 1992; Beede 2005; Casamassima et al 2008; Costello 2011; Amaral-Phillips et al 2015). Water availability is important for calf health and does impact feed intake and growth, especially when milk feeding is reduced or the calves are weaned (Davis and Drackley 1998; Chester-Jones 2014).

The amount of water loss from a calf's body is influenced by activity, air temperature, humidity, respiratory rate, water intake, feed consumption, and other factors. Healthy calves lost an amount of water in the feces equal to 5% of water intake, whereas diarrheic, dying calves were losing an amount in the feces equal to 83% of water intake, or 50% of plasma volume (Davis and Drackley 1998). When the calf loses 8-10% of water, the blood is concentrated, the viscosity increases. Further treatment may be needed to keep the calf alive. As water loss continues, acidosis progresses, lowering plasma pH to the point that cell membranes start to depolarize. Potas¬sium begins to leave the cells and its concen¬tration increases in the extracellular fluids (Houpt 1984; Davis and Drackley 1998).

Loss of about 20% of total body water is fatal (Houpt 1984). Blood pressure decreases resulting in circulatory failure and reduced blood flow to the lungs. The heart rate weakens and the calf goes into an irreversible shock. Death results from heart failure (Bianca 1970; Kertz et al 1984; Costello 2011).

Water requirement

During the first weeks of life, calves are functionally monogastric, the milk is the primary source of nutrition. Before weaning, dairy calves are typically fed a restricted amount of milk or milk replacer (MR), with the common daily recommendation being 8 to 10% of live weight at birth (Drackley 2005). Calves receive water from milk or MR, from other feeds, and from free water. Generally, they satisfy their water requirements with three sources of supply: water consumed voluntarily, water contained in the feed, and the metabolic water formed in the organism (Sekine et al 1986; Murphy 1992).

If the calf loses about 4%, the osmoreceptors then cause the calf to drink more water. Houpt (1991) wrote that at least three types of stimuli elicit thirst: an increase in the osmotic pressure of the blood, a decrease in the blood volume, and a dry mouth. The water intake (WI) influence more causes as meteorological conditions, delivery system, water quality, dry matter intake (DMI), age and health (Sekine et al 1994; Davis and Drackley 1998; Quigly et al 1998; Hepola et al 2008; Chester-Jones 2014).

The amount of critical research into the optimum time to apply water to calves has been minimal. There is still a difference of opinion as to the best time to introduce water to calves from the artificial rearing with a MR feeding system. Views differ; some scientists are asking to provide water from the first day, some since the transition to artificial milk nutrition (Wickramasinghe et al 2019). In practice and in some exact trials, there are also sentiments of drinking water offering after weaning only (Atkeson et al 1934, cit. Thickett et al 1981; Willet et al 1969; Thickett et al 1981; Broucek et al 2019). There are suggestions that supplemental water does not seem to be beneficial until the calf is 8 weeks of age. Some dairy producers feel supplemental water causes calves to scour.

However, little information is available on how much water calves fed milk or MR consume during the milk-feeding period. It is probably very important how much milk or MR the calf receives. Calves provided ad libitum milk diets may in fact not consume substantial amounts of water. Considering the feeding practice of calves there are differences in the WI between ad libitum fed and restrictively fed calves. Calves that are restrictively fed with milk may have higher drinking water requirements than calves over-fed with milk (Borderas et al 2009; de Passillé et al 2011).

The amount of liquid contained in the MR and received by the calf also affects the amount of water drunk. Increasing the water content in the milk drink will definitely reduce the feeling of thirst and the amount of drinking water will be reduced (Manthey et al 2011). The calves consumed very little water when they had ad libitum access to MR (Richard et al 1988). Also, calves fed MR at high concentration drink more water (Davis and Drackley 1998). Results indicated that voluntary intakes of water were highest with calves fed on cows' milk and lowest on the MR (Thickett et al 1981). According to Hepola et al (2008), de Passillé et al (2011), and Broucek et al (2019), during the milk-feeding period, the calves drank very little water. Accordingly, it is feasible to suggest that the lower WI intake in the calves could be a reflection of their lower water requirements and capability of budgeting body water. The calves increased WI in rapidly for a few days following weaning on 8 to 9 L per day (Hepola et al 2008).

Daily water consumptions are presented in Table 1. We note, in many professional articles and books only approximate values are given, so we use exact results only from experiments.

Water, feeds and growth

Tradicionally, water intake is also directly related to feed intake, so the more feed the calf consumes, the more water it will consume. Owed to the close association between feed intake and water consumption, any lessening in water accessibility would be accompanied by a decline in feeding activity. Water and dry matter intakes have been shown to be positively related in ruminants (Igbokwe 1997).

According to Cunningham and Albright (1970), Thickett et al (1981), and Amaral-Phillips et al (2015), calves receiving water ad libitum eat more concentrates and gained more body weight than calves not receiving supplemental water. The live body weight gain (LBWG) was reduced by 38% and concentrace mixture intake (CMI) by 31% for calves deprived of water (Kertz et al 1984). Provision of drinking water immediately after birth could improve growth (Wickramasinghe et al 2019). Ad libitum WI increased with increasing DM concentration (Jenny et al 1978).

Concentrate mixture intake is closely related to water intake. Quigley et al (2006) found a high correlation (r=0.85). According to De Passillé et al (2011), WI was positively correlated with CM (r = 0.30), but not with hay intake. According to Beede (2005) is a direct relationship between DMI and WI in cattle. If WI is sub-normal, DMI typically will decrease. However, if WI is normal and sufficient to meet the physiological needs of the animal for maintenance and growth, there is no evidence to suggest that increasing WI beyond normal will result in greater DMI or performance.

Calves need four times more water than DMI (Kertz 2014). The ratios of daily WI to total DMI may be higher for the restrictively-fed than for the ad libitum-fed calves. Wenge et al (2014) found that the ratios of daily water intake to total DMI were 1.6 $L.kg^{-1}$ of total DMI for the restrictively-fed and 0.9 $L.kg^{-1}$ for the ad libitum-fed calves.

Water restriction and performance

Water restriction had no effect on feed intake in the study of Mengistu et al (2004) and suggesting that ruminants are able to accumulate water in reserve to be used in periods of reduced water supply. Water deprivation induces a decrease in body fluid content and an increase in its osmolality.

The objectives of Marai et al (2007) and Ghasemi Nejad et al (2014) studies were to determine the effects of duration of water deprivation on subsequent ruminant's characteristics. Their results indicate that decreased WI could have long-term negative effects on both growth and welfare of dairy calves. Therefore, any limited water supply would inevitably disrupt the productive process in dairy calves.

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Table 1 Water consumption (per animal).

62 female Holstein, hutch, CM and AH *ad lib*, WEAN 30 d; 2 groups, A, water *ad lib* vs. B, water from 31 to 40 d only; from 4 to 40 d: A, WG 2.63 kg more than B, CM (A, 20.21 vs. B, 16.76 kg), AH (A, 1.25 vs. B, 1.00), WI (A, to 30 d 31.43 kg, 1.04 kg.d^{-1}, 4 to 40 d 65.06 kg, 1.63 kg.d^{-1}, B, 31 to 40 d 39.45 kg) (Cunningham and Albright 1970).
54 female Holstein, calf crate, LBW 41.5 kg, MR 1 x daily, dietary treatments from 3 to 23 d, factors: total WI of 6, 8, and 10% LBW (WI 2.33 kg.d^{-1}, 2.10 kg.d^{-1}, 2.75 kg.d^{-1}); DM concentrations 10, 15, and 20% (WI 1.57 kg.d^{-1}, 2.15 kg.d^{-1}, 3.40 kg.d^{-1}) (Jenny et al 1978).
72 male British Friesian, pens, 2.1 m^2.calf^{-1}, 48.6 kg LBW, CM *ad lib*, 6 groups: A, 4 L.d^{-1} milk; B, MR, 100 g fat per kg (100 g.L^{-1}); C, MR, 100 g fat per kg (150 g.L^{-1}); D, MR, 170 g fat per kg (100 g.L^{-1}); E, 170 g fat per kg (150 g.L^{-1}); F, MR 200 g fat per kg (100 g.L^{-1}); WI for 5 weeks: A, 73.08 L (2.08 L.d^{-1}); B, 49.98 L (1.43 L.d^{-1}); C, 64.54 L (1.84 L.d^{-1}); D, 63.42 L (1.81 L.d^{-1}); E, 60.06 L (1.71 L.d^{-1}); F, 62.65 L (1.79 L.d^{-1}) (Thickett et al 1981).
41 Holstein, 4 to 32 d; MR (4 to 25 d 3.78 L.d^{-1}, 26 to 32 d 1.89 L.d^{-1}), CM *ad lib*, WEAN 32 d; 2 groups, A (N 20, water *ad lib*) vs. B (N 21, no water), WI 41.33 kg, 1.48 kg.d^{-1}; A, LBWG 8.45 kg, 0.30 kg.d^{-1} vs. B, 5.26 kg, 0.19 kg.d^{-1}; A, CMI 11.72 kg, 0.42 kg.d^{-1} vs. B, 8.08 kg, 0.29 kg.d^{-1} (Kertz et al 1984).
12 Holstein, individual (2.29 m^2.calf^{-1}) vs. group housing (2.05 m^2.calf^{-1}), WEAN 35 d; cold acidified MR (dry MR 1.20 vs. 1.48 kg.d^{-1}), WI 0.4 kg.d^{-1} vs. 1.27 kg.d^{-1}; CM 0.09 kg.d^{-1} vs. 0.08 kg.d^{-1} (Richard et al 1988).
40 Holstein, hutch, LBW 45.3, MR 454 g.d^{-1} (nipple bottle, 20% CP, 20% fat), CM *ad lib*, No hay, WEAN 28 d; WI to 28 d less 2 L.d^{-1}, after WEAN 4 L.d^{-1}; ADG 0.211 kg.d^{-1} to 28 d (WEAN), 29 to 56 d 0.713 kg.d^{-1}, 0 to 56 d 0.466 kg.d^{-1} (Quigley et al 2006).
9 female Holstein, age 21 to 28 d, individual pen (1.5x1.2 m), LBW 58.7 kg, 3 replicates, 7 d periods, milk 4 L.d^{-1}, water bucket, CM *ad lib*; 3 groups, control, vanilla flavored water, orange flavored water; WI 1.09 L.d^{-1}, 1.00 L.d^{-1}, 0.92 L.d^{-1}, ADG 0.82 kg.d^{-1}, 1.18 kg.d^{-1}, 0.74 kg.d^{-1} (Thomas et al 2007).
24 (20 Ayrshire, 4 Holstein), individually, pen 1.5x1.2 m, 2 groups, bucket water (12, 6 male, 6 female, 7.9 d, LBW 48.2 kg) vs. nipple water (8 male, 4 female, 7.7 d, LBW 48.4 kg); WI to 49 d: 0.36 kg.d^{-1} vs. 0.35 kg.d^{-1}, 50 to 63 d 8.10 kg.d^{-1} vs 8.97 kg.d^{-1}, ADG to 49 d: 1.09 kg.d^{-1} vs. 1.15 kg.d^{-1}, 50 to 63 d: 0.93 vs 0.80 kg.d^{-1} (Hepola et al 2008).
120 male, LBW 50.2 kg, pens (3.0x3.5 m, 5 calves in each, 2.1 m^2.calf^{-1}), open water bowl (depth 80 mm, diameter 220 mm, 2 L capacity, 1 bowl.pen^{-1}); 2 groups, W (warm water, 16 to 18°C, 41 Ayrshire, 19 Holstein) vs. C (cold water, 6 to 8°C, 40 Ayrshire, 20 Holstein); 20 to 75 d (WEAN), MR (7.5 L.d^{-1}), CM, grass silage, AH *ad lib*; 75 to 195 d, grass silage and AH *ad lib*, CM 3 kg.d^{-1}; WI 20 to 75 d: W, 2.8 L.d^{-1} vs. C, 1.9 L.d^{-1}; 76 to 195 d, W, 16.3 L.d^{-1} vs. C, 15.3 L.d^{-1}) (Huuskonen et al 2011).
36 female Holstein, LBW 42.25 kg, age 5.4 d, pens, 3.9 m^2.calf^{-1}, water *ad lib*, WEAN 47 d; 2 groups, 6 L.d^{-1} vs. 12 L.d^{-1}milk, WI 10 to 38 d: 0.178 kg.d^{-1} vs. 0.079 kg.d^{-1} (De Passillé et al 2011).
100 Holsteins (54 male, 46 female), 92 Holstein-Friesian, 8 Holstein-Friesian x Belgian Blue-White, individually, 2 to 21 d, restrictive milk (6 kg, nipple bucket) vs. *ad lib* milk (nipple of automated milk feeder), WI 1.1 L.d^{-1} vs. 0.8 d^{-1}, CM 13 g.d^{-1} vs. 10 g. d^{-1} (Wenge et al (2014).
30 female Holstein, LBW 37.7, individual pens (1.2x1.8 m), milk daily 6 kg to 13 d, 9.6 kg 14 to 42 d, WEAN 49 d, 2 groups: water from birth vs. from 17 d; WI to 16 d 0.75 kg.d^{-1}, 17 to 42 d 0.82 kg.d^{-1} vs. 1.30 kg.d^{-1}, 43 to 49 d 1.88 kg.d^{-1} vs. 2.02 kg.d^{-1}, 50 to 70 d 5.26 kg.d^{-1} vs. 5.32 kg.d^{-1}; ADG to 42 d 0.66 kg vs. 0.61 kg, 43 to 49 d 0.27 kg vs. 0.37 kg, 50 to 70 1.09 kg vs. 1.03 kg (Wickramasinghe et al 2019).
62 Holstein, LBW 42.8 kg, 5–56 d (WEAN), 3 groups (N – sucking water, bucket nipple, B - drinking water, bucket, W - no water), 6 kg MR, CM and AH *ad lib*; WI: N 69.4 kg, 1.33 kg.d^{-1} vs. B 50.7 kg, 0.97 kg.d^{-1} kg, ADG: N 0.46 kg, B 0.43 kg, W 0.43 kg, CM: N 14.4 kg, B 11.3 kg, W 13.3 kg, AH: N 21.3 kg, B 22.3 kg, W 23.6 kg (Broucek et al., 2019).

ADG = average daily gain; *ad lib* = *ad libitum*; AH = alfalfa hay; CM = concentrate mixture; CMI = concentrate mixture intake; CP = crude protein; d = day; DM = dry matter; DMI = dry matter intake; LBW = live body weight; LBWG = live body weight gain or WG = weight gain; MR = milk replacer; WEAN = age at weaning; WI = water intake.

Manthey et al (2011) evaluated the impact of free choice versus restricted WI during the MR feeding period and 2 weeks following weaning on calf performance. Limiting water consumption did not affect calf performance. Similar results showed Broucek et al (2019). They compared calves fed MR with free water offering or without free water. There were no water delivery effects for growth and feed intake. It was probably enough for trial calves to get the water in a 6 kg

MR daily. Also, calves offered drinking water from 17th day had no different growth than calves that drank water from birth (Wickramasinghe et al 2019). However, these authors noted that calves which drank from the birth a significant amount of free water; they could potentially improve growth performance, rumen development, and nutrient utilization efficiency.

Water delivery system

Little information is available on the water delivery systems effects on WI and performance before weaning of calves. The water source did not affect the amount of water consumed, but the calves received water in smaller portions from water nipples than from open buckets (Hepola et al 2008; Huuskonen et al 2011). The drinker (nipple or bucket) had no impact on the water intake in calves to the 56th day (Broucek et al 2019).

On the other hand, study of Pinheiro Machado Filho et al (2004) has shown that drinker design can affect cattle preferences and WI. Also, calves did experience some difficulties in using the water nipples. However, nipple might be a more hygienic water source for young stock, but no information exists about different water sources for older calves in terms of water intake and performance after weaning from milk (Hepola et al 2008).

Water and high temperatures

The amount of water needed by dairy calves depends on the environmental conditions. Water availability is considered to be a critical element for animal production during heat stress (Kay 1997; Alamer 2009; West 2013). Therefore, managing calves during the summer requires attention to a number of factors. Heat stress increases the loss of body fluids due to sweating and panting. During high temperatures season, an increase in water requirements to warrant demand for cooling. Thus, lower water availability during such a condition would complicate the burden on water balance. Water restriction could intensify the effect of heat stress related to nutrient digestibility, decreased performance, and suppress immune system of animals (Marai et al 2007; Ghasemi Nejad et al 2015). Compared to 0°C condition the WI at 30°C increases more than twice. According to Quigley (2001) prediction, at 0°C calves will drink approximately 1.4 L of water per day. At 15°C, calves drink almost 2 L.day^{-1}. By the time the temperature reaches 30°C, intake exceeds 3 L.day^{-1}.

However, ruminants have adaptive mechanisms, which aid in enduring water deprivation during hot and humid weather (Silanikove 1994). In order to maintain thermoregulation during periods of heat stress, calves may sweat and pant, both of which may lead to loss of body water. The main general homeostatic responses to dehydration are reductions in fecal and renal water losses, reductions in metabolism, and protection of plasma volume (Silanikove 1994; Kaliber et al 2016).

Final considerations

According to the Council Directive (2009) calves over 2 weeks of age have to be allowed ad libitum access to water. Prior to this age, they must supply their daily need for fluid through the intake of milk or MR. Nevertheless, the welfare implication of water deprivation in special situations remains unclear.

Although in some attempts water restriction did not result in any obvious effect on feed intake and growth, calves should have water available as soon as possible. We cannot recommend the WI just as part of the MR.

The simplest procedure is from the first, at least from the third day of life. Providing ad libitum intake of drinking water is the best approach. Clean water should be available to calf at all times. However, more research is still needed on the use of water sources for calves.

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