

WATER INTAKE AND FACTORS AFFECTING WATER INTAKE OF GROWING BEEF  
CATTLE IN NORTH FLORIDA

By

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To my sweetest son, Riley Joshua Brew. You are my sunshine.

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Abstract of Thesis Presented to the Graduate School  
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CATTLE IN NORTH FLORIDA

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An experiment was conducted at the North Florida Research and Education Center, Marianna, Florida, to evaluate water intake in growing beef cattle. Objectives of the study were to measure water intake in growing beef cattle, to determine what factors influence, and are influenced by, water consumption, and to compare observed values to predicted values. Growing bulls, steers, and heifers (n=146; average starting weight of  $276 \pm 67$ kg) were housed at the Feed Efficiency Barn at the NFREC in Marianna for a period of 13 weeks from September 2006 through December 2006. Feed and water intake data was continually monitored by GrowSafe hardware and software and later collected, compiled, and analyzed. Cattle were weighed weekly to measure weight gain and growth.

Mean water intake was 29.98 L/head/day. On a metabolic BW basis cattle drank an average of 0.05 L/kg metabolic BW. Cattle of Brahman and Romosinuano breeding tended to consume less water than British and Continental influenced cattle at the same metabolic BW ( $p < 0.05$ ). There was no difference among bulls, steers, and heifers in terms of either gross water intake or water intake per kg of metabolic BW. The mean daily temperature remained within the thermal neutral zone (5 to 20 C) throughout the study and had no influence on water intake.

Water intake was correlated ( $p > 0.05$ ) with feed intake and gain with heavier feeders tending to consume more water and gain more weight. There was no relationship between water intake and gain to feed ratio.

Two common prediction equations, the Murphy and Hicks equations, were used to predict expected daily water intake. These predicted values were compared with observed values and were found to be statistically higher than observed values. The Murphy equation overestimated water intake by an average of 20.20 L/head/day ( $p < 0.05$ ) while the Hicks equation overestimated water intake by an average of 8.36L/head/day ( $p < 0.05$ )

## CHAPTER 1 GENERAL INTRODUCTION

Water has been traditionally considered an inexpensive, readily available, and renewable natural resource. However, as human populations continue to soar, and major cities continue to grow at nearly exponential rates, this may not always be the case. Current and future legislation will enforce stricter guidelines for water use in residential, industrial, and agricultural realms. In the future ranchers may expect to be held more accountable for water use. Understanding how much water various types of cattle normally consume, and understanding the relationships that exist between water intake and performance is the first step to better water stewardship on behalf of Florida ranchers.

Tropically adapted cattle, such as the Brahman and Romosinuano breeds, are phenotypically better adapted to living in the hot and humid conditions that are common to Florida. Their loose skin, long ears, and pendulous briskets and underlines combine to increase body surface area which in turn allows for greater evaporative cooling of the animal. Numerous studies have demonstrated that tropically adapted cattle are better able to cope with heat stress and are more likely to survive and even thrive in hot and humid conditions. The Brahman and Romosinuano cattle on this study drank significantly less water when compared to the Continental and British influenced breeds. Admittedly, they gained numerically less per day but did so with equal efficiency. Incorporating tropically adapted genetics into Florida beef herds may be one of the most cost effective ways to reduce water consumption.

Water is too vital a nutrient to be withheld from any class of animal. Restricting water intake decreases performance quicker and more drastically than any other deficiency. Water intake is influenced by a number of factors including breed type, production state, size of the

animal, external temperature and dry matter intake. Water intake in turn may influence a number of production traits including weight gain, average daily gain, feed intake, and feed efficiency.

The environmental temperature remained within the thermoneutral zone for growing cattle for the duration of the study and had no influence on water consumption. This trial should be repeated during other times of the year in order to completely capture the influence of weather on water intake. Additionally, because the cattle were housed in an open sided barn they were not exposed to the same degree of heat or wind that they would have experienced in a pasture setting. It is a valid hypothesis to assume that the artificial shelter provided by the barn may have had an influence on water intake. Pasture trials, where animals have to walk a distance to water, and are regularly exposed to sun, wind, and rain, are the next logical step in water intake research.

Water intake was positively correlated with feed intake. Water intake increased linearly as dry matter intake increased. These results concur with the literature. Water is vital to proper feed digestion and it is no surprise that cattle drink more water when dry matter consumption is increased. Water intake was also positively correlated with average daily gain. Cattle who consumed greater quantities of water tended to gain more weight per day than those who consumed less.

Past research has demonstrated an inverse relationship between water intake and feed efficiency. One theory is that as cattle drink more water they increase the rate of washout from the rumen thus decreasing dry matter retention time and digestibility. This trial found no correlation between water intake and gain to feed ratio. Cattle that drank more water gained weight with the same efficiency as those that drank less water.

As water use issues heat up it will be vital that ranchers be able to forecast the amount of water that their cattle will consume in a given time period. This may be done in one of two ways; direct measurement or estimation using prediction equations. Directly measuring water intake is expensive, time consuming, and labor intensive even in a research setting and is simply not practical in production settings. To combat this, prediction equations were created which estimate water intake based on a number of contributing factors. Two of the most widely used prediction equations are the Murphy equation, which was developed for dairy cattle but can be modified for use with beef cattle, and the Hicks equation which was developed specifically for feedlot steers.

Using actual data generated by this research trial the Murphy and Hicks equations were used to predict water intake. The Murphy equation over predicted water intake by 20.20 L/head/d and the Hicks equation overestimated water intake by 8.36 L/head/d. The creation of new equations, or refinement of existing equations, is needed in order to more accurately and precisely capture water intake in growing beef cattle. However, all of the factors that influence water intake must first be identified, and the weight that their influence carries must be evaluated.

As we move further into the new millennium, issues relating to water use will become more contested. As stewards of the land, Florida ranchers have been charged with the responsibility of understanding the ways in which water is used both on their ranch and by their animals. This study, as well as future research which will follow, will be instrumental in accomplishing this goal.

## CHAPTER 2 LITERATURE REVIEW

### **Introduction**

There has been very little research on beef cattle water intake. Water has historically been viewed as a cheap and renewable resource; however this is changing on local, national, and international levels. An increase in regulations governing water resources increases the need for researchers and producers to appreciate the impact that current and future legislation may have on the beef cattle industry (Morse, 1995).

### **Water as a Resource**

Approximately 1.1 billion people throughout the world have no access to safe drinking water. This is generally not the case in the U.S.; however, conflicts over water rights do exist between and within several states, including Florida. A 2003 report by the *Florida Council of 100* recommended “developing a system which enables water distribution from water-rich to water-poor areas”. This report incited widespread opposition by Floridians, thus setting the stage for potentially prolonged water conflicts within the state (Holt, 2007).

Florida is well known for its natural wetlands and artesian springs, both excellent sources of drinking water. However, enormous population growth in the latter part of the 20<sup>th</sup> century has resulted in the destruction of thousands of acres of wetlands, and threatened the states’ drinking water supply (Florida Department of Environmental Protection, 2007)

Approximately 90% of Florida’s drinking water comes from groundwater with the remaining 10% being derived from surface water. Groundwater withdraws are expected to outstrip demand in the near future. As the population in Florida continues to surge groundwater will be increasingly less able to meet demands. The population in Florida is projected to exceed

22.6 million by 2020 and the demand for potable water is expected to increase to an estimated 34.4 billion l/d (Florida Department of Environmental Protection, 2007).

Rainfall in Florida averages 137 to 139 cm per year. However rainfall is highly variable year to year ranging from 76 to 203 cm annually. Additionally only 30% of rainwater ever finds its way to bodies of water or aquifers (Florida Department of Environmental Protection, 2008). The distribution of rainfall and the demands for potable and recreational water are also highly variable throughout the state. The south, southwest, and central regions of Florida have experienced the greatest population increases relative to water supply. These highly populated regions are geographically water poor and existing groundwater sources are threatened by population growth. The threats to groundwater in heavily populated areas are two fold. First, excessive urban growth results in little open land for rainwater to accumulate, seep, and recharge. Second, excessive groundwater pumping has resulted in saltwater intrusion (Florida Department of Environmental Protection, 2007). The majority of cattle production in Florida takes place south of Interstate 4 (Florida Department of Environmental Protection, 2007), therefore the water demands of beef cattle must also be taken into account when considering the water crisis in this area.

Freshwater uses in Florida can be categorized under six types of users; agricultural irrigation, public supply (households served by water utilities), domestic self supply (households served by personal wells), industrial/commercial, electric generation, and recreation irrigation. Agricultural irrigation includes water withdrawals for crops, livestock, and aquaculture. Agricultural irrigation represents the largest water withdrawal followed by public supply. A percentage of the public supply and domestic self supply may also represent agricultural uses on a small scale.

Table 2-1. Freshwater withdrawal by categories of use in Florida 1975-2000

Category	1975	1980	1985	1990	1995	2000
Total	25,638	25,366	23,897	28,704	27,368	31,010
Public supply	4254	5322	6738	7286	7869	9225
Domesticated self supply	863	920	980	1131	1124	753
Commercial or industrial	3342	2649	2683	2914	2619	2131
Agriculture irrigation	11,091	11,454	10,591	13,230	12,279	14,850
Recreational irrigation	NA	NA	687	1173	1063	1556
Power generation	6086	5019	2574	2967	2411	2494

In millions of l/d

### Water Used for Beef Production

Agricultural withdrawals represent a large percentage of potential drinking water withdrawals in the United States in general, and in Florida specifically. However, the term agriculture encompasses a wide variety of activities from commercial horticulture, to crop irrigation, to animal production. Water used for beef cattle production can be categorized into water that is directly consumed by animals, water that is used to produce and to process feed (including crop irrigation), and water that is used to process cattle into beef (Beckett and Oltejen, 1993) By far the category responsible for the greatest water withdrawals is crop irrigation (Oltejen, 1991).

Several researchers have attempted to calculate the amount of water required to produce beef. Robins (1987) estimated that 20,864 L of water were required for every kg of lean meat. Kreith (1991) found that 20,559 L of water were used for every kg of boneless beef produced. However, these estimates were based on one production scenario and may be artificially higher than actual (Beckett and Oltejen 1993).

Researchers at UC Davis (Beckett and Oltjejen, 1993) developed a static model to examine water use by U.S. beef cattle. Government statistics were used to develop a representative picture of beef production in the US. At the time of the study, U.S. beef herds produced 6.9 billion kg of boneless beef and directly consumed 760.0 billion L of water per year. Irrigation of crops and

production of feedstuff for beef cattle accounted for 12,991 billion L of water with irrigated pasture costing an additional 11,243 billion L. Finally, carcass processing required 79 billion L of water annually. Beckett and Oltjen (1993) model estimated 3,682 L of developed water were withdrawn for every kilogram of boneless beef produced. This estimate was significantly lower than previously suggested (Beckett and Oltejen, 1993) by Robins (1987) and Kreith (1991). Irrigation, of both crops and pasture, accounted for the largest portion of water use by U.S. beef cattle. Intensifying or reducing irrigation may be the most effective way of decreases water use in beef cattle operations. Water is too important a nutrient to be denied to any class of animal, but understanding water intake may allow cattle producers to more accurately predict water needs and to better justify water withdrawals.

### **Future Water Policy**

Water is a commodity, subject to the usual economic pulls of supply and demand, to public policy, and to environmental considerations. The state of Florida is currently investigating ways to shape the pricing structure for water to better represent the real cost of supplying water. Compared to other industrial nations, the U.S. charges a nominal amount for water. Germans pay 1.78 USD per cubic meter of water, the French pay 1.08 USD, the British 1.23 USD, and Americans only .054 USD (OECD, 1999).

To legally withdrawal water from aquifers, lakes or rivers in Florida, users must receive consumptive use permits from Florida's water management districts or the Department of Environmental Protection. Applicants must establish that the proposed use of water meets three requirements: 1) it is a reasonable beneficial use; 2) it will not interfere with any presently existing legal water use; and 3) it is consistent with public interests (Florida Department of Environmental Protection, 2007).

The impending water crisis and renewed interest in protecting water as a resource has profound implications for cattle producers in the state of Florida. In the near future, ranchers may expect to be held accountable for their water usage, up to and including being required to apply for special permits before expanding existing operations. It is absolutely essential that ranchers be able to accurately estimate the amount of water that is used on their operation. Current estimates of beef cattle water intake are based on antiquated data gathered under varying circumstances. The genetics of the beef animal have changed dramatically over the past 50 yr and these established values may no longer be representative of the modern animal. Furthermore, current prediction equations that are used to estimate water intake by beef cattle may or may not be accurate.

### **Water as a Nutrient**

Water is the single most important nutrient for animal health and production (Harris and Van Horn, 1991) Indeed the mature bovine body contains 55 to 65% water. Water makes up 75 to 80% of a calves body (Adams and Sharpe, 1995). Sources of water include water contained in feedstuff as moisture, metabolic water derived from the oxidation of fat and protein in the body, as well as water that is directly consumed. Of these sources, drinking water represents the largest portion (Stockhill, 1991).

### **Biological Functions of Water**

Water has several important functions in the body. Water is required for digestion, metabolism, and transport of nutrients, excretion of waste products, maintenance of proper ion and fluid balance, and for temperature regulation (Beede and Myers, 2000). Water also plays an important role in reproduction, providing a fluid envelope for the developing fetus and later contributing to milk production. From a production standpoint, water is required for growth of tissue and production of milk.

Approximately 66% of water in the body is intracellular with the remaining third being found in extracellular spaces, in connective tissues, and in the digestive tract (Beede, 2005). Water constitutes 98% of all molecules in the body. An ideal solvent for glucose, amino acids, mineral ions, water soluble vitamins and metabolic waste, water is vital for the hydrolysis of nutrients and the regulation of mineral homeostasis (Gerrish and Davis, 1995). Water in the digestive tract, including the rumen, accounts for between 15 to 35% of BW (Odwongo et al. 1985). A molecule of water will remain in the rumen for an hour before being transported elsewhere in the body (Woodford et al. 1984).

Loss of only 20% total body water is fatal (Boyles, 2004). Water loss can occur through production, urinary and fecal excretion, sweating, and respiration. In lactating dairy cattle, daily losses via milk production represented 26 to 34% of total water intake (Holter and Urban, 1992). Between 30 and 35% of total water intake was lost in the feces of lactating dairy cattle, losses in urine represented 15 to 22% of total water consumed (Holter and Urban, 1992; Dahlborn et al. 1998). Fecal water losses increase as DM intake and DM content of the diet increase in dairy cattle (Murphy, 1983). Approximately 18% of total water loss in dairy cattle is associated with sweat, saliva, and respiration (Holter and Urban, 1992). Water losses associated with sweat and respiration are highly dependent on environmental temperature and may be greater when temperatures are above the thermoneutral zone ( McDowell and Weldy, 1967).

Limitations on water intake depress animal performance quicker and more drastically than any other nutrient deficiency (Boyles, 2004).. Domesticated cattle can live for up to 60 d without food but will not survive over a week without water (Boyles, 2004). The onset of dehydration can occur rapidly once water has been restricted or removed. Signs of dehydration include tightening of the skin and loss of associated elasticity, loss of weight, and drying of the

mucous membranes and eyes. Chronic dehydration can cause urinary calculi or water belly. As water flow to the bladder and kidney is reduced and kidney stones are formed. When the stones become too big to pass through the urethra, a condition known as water belly results.

### **Factors Influencing Water Intake**

Combinations of factors are involved in determining the quantity of water that is needed by cattle. These factors include physiological state, age, activity level and size of the animal, environmental air temperature and movement, diet and nutrient composition, and the quality of a particular water source (Murphy, 1983; Holter and Urban, 1992, Hicks et al., 1988). Other factors may include frequency of watering, temperature of the water itself, and behavioral interactions of animals (Beede, 1992). The water requirement of beef cattle is a sum of all water needed for growth, fetal development, lactation, and replacement of body stores lost in urine, feces, sweat and respiration. Anything that impacts these needs or losses will alter the volume of water required.

Body water is lost through excretion from the kidney as urine, from the gastrointestinal tract as feces, from the skin as sweat, and as water vapor from the lungs.

The amount of water that is lost as urine is dependent on a number of factors including water consumption, air temperature, and the activity and production level of the animal. The antidiuretic hormone vasopressin affects urine production by controlling the reabsorption of water from the kidney tubules and ducts. When water intake is restricted, urine can be concentrated thus reducing the water requirement by a small amount. Water requirement will increase when the diet is high in diuretic substances such as protein, salt, and certain minerals (Weeth et al., 1965).

The volume of water that is lost in the feces is determined primarily by the nutrient composition of the feed. Feeds high in minerals cause more water to be excreted in the feces

(Weeth et al., 1965). Water is also lost through sweating and as vapor during exhalation. During periods of high environmental temperature or physical activity, perspiration, and respiration can result in more water loss than urine. Additionally, the oxidation of certain nutrients produce water. High energy feeds produce more metabolic water compared to lower energy feeds. Fasting animals and those fed low protein diets may also form water through the breakdown of body protein and fat (Reid et al., 1955).

### **Effect of Dry Matter Intake on Water Intake**

Water is closely tied to DM intake and DM digestion. There is a direct positive relationship between DMI and water intake in cattle (Beede, 1992). If water intake is depressed, DM intake will also be depressed. Water requirements are met not only by directly consuming water, but also through the moisture content of feed. The DM content of a feed influences how much water an animal must drink to meet the requirement, with DM content being positively correlated to drinking water intake (Paquay et al. 1970; Little, 1978; Murphy et al. 1983; Holter and Urban, 1992).

Consumption of high moisture forage, such as fresh grass, may reduce the drinking water requirement. Conversely, Castle and Thomas (1975) found that dairy cattle water intake was dependent solely on DM content of the concentrate feed and was not related to forage type. Urban (1992) found little difference in terms of water intake between dairy cattle fed diets of 70 and 50% DM. When DM content of the diet was reduced from 50 to 30% (moisture content increased from 50 to 70%) drinking water intake decreased by 42%. Dairy cattle managed on fresh pasture met 62% of their water requirement with the moisture found in grass (Stockdale and King, 1983).

Dry matter content of feed and total water consumption (feed moisture + drinking water) may be negatively correlated. Paquay et al. (1970) and Stockdale and King (1983) found that as

DM intake increased, direct consumption of water also increased but total water intake actually decreased in dairy cattle. Holter and Urban (1992) found that as dietary DM content increased from 30 to 60% total water consumption decreased by 14.97 kg/d in dairy cattle. When DM content was further increased from 60 to 90% total water intake was reduced by an additional 4.99 kg/d in dairy heifers.

Restricting water intake in cattle increases the apparent digestibility of DM, organic matter (OM), and crude fiber (CF) (Larsen et al., 1917; Balch et al. 1955; French, 1956; Phillips, 1961). Water intake and DM intake are highly related, restricting water intake will result in reduced DM intake. As DM intake decreases, DM digestibility will increase (Brown, 1966). This is due to the fact that DM is retained in the rumen for longer periods of time allowing for more complete degradation. Additionally, during periods of water restriction, rumen conditions are more favorable for cellulose degradation (Thorton and Yates, 1968). The increase in apparent digestibility may or may not be offset by a decrease in DM intake and may or may not have an impact on weight gain.

### **Influence of Dietary Nutrients on Water Intake**

As a rule of thumb, cattle will consume between 0.9 and 1.8 kg of water/ kg of DM. Dry matter rations high in protein and salt may increase this ratio (Bahman et al., 1993). Holter and Urban (1992) found that raising the CP content of feed from 12 to 13% resulted in an average increase in water intake of 0.99 kg/head/d in dry dairy cows.

### **Effect of Environment and Temperature on Water Intake**

Environmental temperature plays a significant role in regulating water intake in all classes of cattle. As environmental temperature increases, more water is lost via sweat and respiration. In order to compensate for these losses, water intake must also increase. McDowell and Weldy (1967) found that dairy cows drank twice the volume of water at 32 C weather as they did at 3

to 10 C weather. Water intake was positively related to temperature in several other studies as well (Richards 1985; Holter and Urban 1992). Murphy et al. (1983) and Andersson (1987) found that water intake increases 1.2 kg (1.11 L) per degree (C) increase in barn temperature in dairy cattle. Temperature may be an even bigger determinant of water intake than DM intake.

Ragsdale and colleagues (1949) demonstrated that water intake and DM intake are comparable at temperatures of up to 27 C in dairy cows. However, once environmental temperatures surged above 27.2 C water intake increased independent of DM intake.

Temperature alone is not the only environmental determinant of water intake in cattle. Feedlot steers drink more water (31.02 vs 18.93 L/ d) in the summer months than in the winter months (Hoffman and Self, 1972). Mullick et al. (1952) agreed that water intake was highest in the summer months and comparable in autumn and spring, and lowest during winter. These variations in water intake were likely related to temperature differences but may also have been influenced by weather patterns and the length of daylight. During hot summer months, steers will drink less water when provided with adequate shade (Hoffman and Self, 1972). Shade had no influence on water intake during the cooler months. Shultz (1984) supported Hoffman and Self (1972), finding that dairy cows provided with shade consumed less water. Both studies concluded that shade keeps cattle cooler in warm temperatures which results in reduced sweating, and thus reduces water loss (and the need for compensatory increases in water intake).

### **The Influence of Water Temperature on Water Intake**

The temperature of the water itself may also influence consumption particularly when environmental temperature is outside of the thermoneutral zone. During periods of heat stress, chilled water (27 to 29 C) may lower body temperature for a maximum of 2.2 hr in dairy cattle (Stermer et al. 1986). However this effect was not maintained long enough to make a significant impact on body temperature during heat stress conditions. Research at Texas A&M found that

cooling water from between 20 to 30 degrees C to below 10 degrees C resulted in overall decreased consumption but also reduced incidences of heat stress during the summer months.

Feedlot steers allowed access to cool drinking water will gain 0.13 to 0.18 kg more per day than those drinking warm water (Stermer et al. 1986). A two year study in California found that British cattle consumed more feed and gained more weight when given access to cool water (18.3C) compared to warm water (32.2C). The cattle provided cool water also drank significantly less than those provided warm water. Water temperature did not appear to affect Brahman X British crossbred feedlot cattle in terms of intake or performance (Lofgreen et al., 1975)

Cattle may actually prefer warmer water, even during warm weather. Wilks et al (1990) found that when dairy cows were offered warm and chilled water cafeteria style, they preferred warm water 97% of the time.

### **Influence of Access to Water on Water Intake**

Animals drink primarily to satisfy thirst. Thirst is triggered by an increase in electrolyte concentrations in the body fluids. Constant access to water can improve cattle performance (Landfeld and Bettinger, 2002). This fact has been clearly demonstrated in dairy cattle, with farmers reporting an additional 0.91 to 2.27 kg of milk output when cows have readily accessible water compared to animals whose intake was restricted (Landfeld and Bettinger, 2002). Because DM intake is associated with water intake similar improvements in terms of weight gain may be expected in beef cattle.

The availability of water has an effect both on the behavior of cattle and on their water consumption patterns. Cattle prefer to have water available at the time of feeding (Andersson, 1987). If water is not available at the time of feeding, cattle will seek out a water source and consume 60 to 80% of their total water consumption within a few hours of being fed (Andersson, 1987). Andersson and Lindgren (1987) found that dairy cows given free access to drinking

water drank within 15 min of being fed. When adequate water is not available, competition may occur. In a water availability study with dairy cows, researchers found that dominant cows drink more frequently (29 vs 26 times/d) and consumed more water than submissive cows (Andersson and Lindgren 1987).

### **Effect of Breed Type on Water Intake**

Breed type may influence water requirements and therefore water intake in cattle. Beatty et al, (2006) conducted an experiment to determine what differences existed between the physiological responses of *Bos taurus* and *Bos indicus* cattle to prolonged heat and humidity. Water intake in both types of cattle increased as heat and humidity increased. *Bos taurus* cattle increased their water intake later in the experiment (at a higher temperature) than *Bos indicus*. Maximum water intakes during the hot period at least doubled from the control period with increases being more substantial in *Bos taurus* cattle. *Bos indicus* animals consume more feed during periods of heat stress when compared to *Bos taurus* animals. Significant acid-base and electrolyte imbalances also occurred in both types of cattle as temperature became excessive. *Bos taurus* cattle imbalances were both more extreme and more prolonged. Beatty et al (2006) concluded that *Bos indicus* animals are better equipped to cope with prolonged periods of heat and humidity as changes in feed intake, body temperature, respiratory rate, and blood gas parameters were not as dramatic as in *Bos taurus*.

### **Effect of Water Quality on Water Intake**

Evaluating water intake involves not only quantity, but also quality. Poor quality water can reduce voluntary intake and may be a source for disease. An estimated 40% of livestock in the U.S. are watered from streams, lakes, and ponds (Harris and Van Horn, 1991). These cattle may be susceptible to pollution related diseases. Groundwater may be polluted with manure,

pesticides, and parasites from agriculture runoff. Additionally, high levels of certain dissolved minerals may affect health and reduce consumption.

Water quality may also play a role in determining weight gain. A study from Alberta Canada (Brawl, 2002) indicated that beef cows with access to fresh water gained 0.22 more kg/d than those watered from ponds or streams. Calves whose dams drank clean (vs pond) water gained 9% more weight. Steers drinking clean water gained 16 to 19% more weight than those drinking pond water. Aerating water, a process which reduces contaminants, resulted in a 20% increase in water intake (Brawl, 2002).

Water quality can be measured in several ways. Total dissolved solids (TDS) is a measure of all constituents dissolved in water and includes both inorganic anions and cations. In fresh water salinity and TDS are equivalent. Total dissolved solids may be used to determine the suitability of a particular water source to livestock.

Table 2-2. Tolerable levels of Total Dissolved Solids (TDS) in cattle drinking water

Description	Concentration of TDS	Comment
Fresh Water	0-1000	No problems
Slightly Saline	1,000 – 3,000	Satisfactory
Mod. Saline	3,000 – 5,000	Possible diarrhea
Very Saline	5,000 – 7,000	Avoid
Approaching Brine	7,000 – 10,000	High risk
Brine	> 10,000	Unsafe

TDS expressed in mg/L

In addition to TDS, a number of other compounds including, nitrate, S, and Fe, play a role in determining water quality and subsequent intake. Nitrate threats are generally more prevalent in forages than in water, but drinking water may also serve as a source of toxicity. Upon consumption, nitrates are converted to nitrites. Once in the bloodstream, nitrites convert hemoglobin to methemoglobin which results in reduced O<sub>2</sub> carrying capacity. Symptoms of nitrate poisoning include labored breathing, rapid pulse, convulsions, frothing at the mouth, and

a chocolate brown colored blood. Once the hemoglobin-methamoglobin conversion has reached 70 to 80%, the animal normally dies of asphyxiation (Wolff and Wasserman, 1972). Drinking water associated nitrate toxicity is most likely to occur when animals frequent water sources that have been contaminated by heavily fertilized fields (Weichenthal et al., 1963).

Safe sulfate levels have not been clearly defined at this time but it appears that levels above 500 ppm for calves and 1000 ppm for mature cattle may affect water intake (Longeragan et al., 2001). Common forms of sulfates in water include Ca, Fe, Mg, and Na. All forms of sulfate have a laxative effect, with sodium sulfate being the most potent. Iron sulfate has the most dramatic effect on intake. Cattle will become resistant to the laxative effect of sulfate after several weeks (Longeragan et al., 2001) Longeragan and colleagues (2001) found that increasing water sulfate concentration resulted in linear decreases in ADG and G:F ratio. Additionally, increasing water sulfate concentrations quadratically increased then decreased DMI. A water sulfate concentration of greater than 583mg/L, equivalent to 0.22% of the diet, decreased feedlot performance compared to sulfate free water (Longeragan et al., 2001). Mean daily temperature explained 26% of the observed variations in water intake during this trial. Other factors which the researches determined had an impact on water intake included BW, DMI, water sulfate concentration, barometric pressure, wind speed, and humidity.

Iron in water is found predominantly in the highly soluble ferrous form. Water contaminated with Fe is not only unpalatable (and will therefore lead to a reduction in consumption) but consumption may lead to serious health problems. Excess Fe in water, which is both highly soluble and readily absorbed, can upon consumption interfere with the absorption of Cu (Kegley and Spears, 1994) Additionally, when Fe is found in the body in excessive

quantities, it may lead to oxidative stress and cell membrane damage. Symptoms of iron toxicity include diarrhea, anorexia, and reduced performance (Kegley and Spears, 1994).

### **Water Intake Prediction Equations**

Water intake can be determined through direct measurement or through the use of prediction equations designed to predict water intake. Both methods may be fraught with error. The majority of prediction equations were designed with lactating dairy cattle in mind. Due to the enormous need for water for milk production, the water requirement per unit of BW of the high producing dairy cow is greater than any other land mammal. (Woodford et al. 1985). Therefore equations meant to predict water intake in dairy cows may not be suitable for use with beef cattle of any class.

Prediction equations use a number of variables to predict water intake. However, the exact combinations of variables which determine water intake are unknown and may vary from animal to animal.

Murphy et al. (1983) proposed an equation for predicting water intake in dairy cattle. Factors identified as affecting water intake included DM intake, Na intake, milk production, and environmental temperature. Water intake in lbs/day was predicted from the following:

$$\begin{aligned} \text{Water intake (lb/day)} &= 35.2 + 1.58 \times \text{DM intake (lb/day)} \\ &+ .90 \times \text{milk produced (lb/day)} \\ &+ .11 \times \text{sodium intake (g/day)} \\ &+ 2.64 \times \text{weekly mean minimum temperature (degrees C)} \end{aligned}$$

Thus the Murphy equation predicts that water consumption will vary 0.72 kg for every 0.45 kg change in DM consumed, 0.41 kg for each 0.45 kg of milk produced, 0.05 kg for each gram of Na consumed, and 1.2 kg for each degree C change in weekly mean minimum temperature. While the Murphy equation was designed specifically for dairy cows, it can be

modified for beef animals by multiplying the amount of milk produced by a factor of zero. This author is not aware of any studies that have been performed to investigate the efficacy of using the Murphy equation to predict water intake in beef cattle. Additionally, while the Murphy equation does take into account a number of important factors, it does not consider all the factors which may contribute to water consumption.

Hicks et al. (1988) developed an equation to predict water intake specifically in feedlot steers.

$$\text{Water intake (L/d)} = -18.67 + (0.3937 \times \text{MT}) + (2.432 \times \text{DMI}) - (3.870 \times \text{PP}) - (4.437 \times \text{DS})$$

Where MT is the maximum temperature in degrees fahrenheit, DMI is dry matter intake in kg/d, PP is precipitation in cm/d, and DS is the percent of dietary NaCl. While this equation is more applicable to beef cattle than the Murphy equation, it fails to take all factors, such as production state, gender, and breed of the animal, into account and may be little or no more accurate.

The National Academy of Sciences estimates beef cattle water intake based on estimates from Winchester and Morris (1956). While these estimates may provide a rough estimate of water intake by beef cattle they are based on antiquated data and may not accurately capture water intake by modern beef cattle.

Table 2-3. Approximate Total Daily Water Intake of Beef Cattle

Temp C	4.4	10.0	14.4	21.1	26.6	32.2
Weight Kg						
	<i>Growing heifers, bulls, and steers</i>					
182	15.1	16.3	18.9	22.0	25.4	36.0
273	20.1	22.0	25.0	29.5	33.7	48.1
364	23.0	25.7	29.9	34.8	40.1	56.8
	<i>Finishing Cattle</i>					
273	22.7	24.6	28.0	32.9	37.9	54.1
364	27.6	29.9	34.4	40.5	46.6	65.9
454	32.9	35.6	40.9	47.7	54.9	78.0

Water intake in L/h/d

## Measuring Water Intake

Directly measuring water intake may provide a more accurate account of water use in beef cattle. Unfortunately, direct measurements are not without complication. Water intake may be directly measured by taking the average of a group of animals or by isolating animals and measuring individual intake. Group housing animals allows for natural animal to animal interaction and the manifestation of a full spectrum of social behaviors. However, individual performance cannot be linked to individual intakes. Measuring intake in a pen of animals gives gross estimates in terms of volume of intake only.

Traditionally, individual feed and water intake was measured by housing animals individually. However, studies have shown that animals housed individually significantly alter their performance and behavior when compared to animals housed in production settings (Da Haer and Mercks, 1992; Beatty et al., 2006; Guiroy et al., 2001; Nielsen et al., 1995). Individually measuring water intake allows researchers to link productivity and performance to intake but does so at the cost of real life accuracy. Individually housing animals prohibits social interaction and may result in unnatural feed and water intakes. Additionally, the animal to trough ratio of individually housed animals is not representative of feedlot conditions (Nielsen et al., 2005). De Haer and Merks (1992) found that the feeding behavior of individually housed growing pigs differed significantly from that of group housed animals. In their study, the isolated pigs visited the feed trough more frequently and ate in shorter burst (De Haer and Merks, 1992).

Polydipsia (PD) is an excessive thirst manifested by excessive water intake and may be caused by several physiological or environmental factors. Boredom and isolation may also induce psychogenic PD in animals, causing them to drink more than they would in a normal social situation. For this reason, studies which look at water intake in isolated animals may be skewed (Beatty et al., 2006).

Electronic gate feeders have been used to investigate the individual behaviors of pen housed animals. When the animal enters the feeder gate their individual ID is recorded and the feed or water consumed is recorded as an event. Very little information on feeding or drinking behaviors can be recorded in this manner as the effect of competition is not measured. Additionally, the equipment itself may impact animal feeding and drinking behavior. Even the simplest electronic gate feeders are labor intensive and costly to operate.

### **The Use of the GrowSafe System to Monitor Water Intake**

GrowSafe™, a continuous data acquisition system, bridges the gap between individual and group housed intake studies. By reading multiple transponders in close proximity, GrowSafe™ continually monitors feed and water intake, as well as animal behavior with minimal disruption to typical behaviors.

In the GrowSafe™ system, cattle are equipped with an ISO compliant passive transponder. The transponder resembles an ear tag and is unobtrusive in nature. Each transponder has a unique number which corresponds to an individual animal. A GrowSafe™ mat is affixed in the feed bunks and water troughs. When the animal places its head close to a GrowSafe™ mat, the transponder will emit a signal which identifies that animal. The system reports the distance of the transponder both laterally and in relation to the bunk or trough. This geographic data is accurate to within 6 cm and can be sampled once a second. Weight data is sampled eight times a second in increments of 5 g. A GrowSafe™ panel collects, verifies, processes, and stores the data. The panel then transfers the data to a remote computer using spread spectrum technology. GrowSafe™ software then collects, segments, compiles, and analyzes the millions of data points collected by the system. GrowSafe™ continually and automatically records every data point to a hard drive. This data can later be compiled and used in many ways. The data generated by

GrowSafe™ is flexible and allows researchers to make observations within or between events (GrowSafe Technical Bulletin, 2007).

In addition to accurately measuring the amount water intake, GrowSafe™ also measures duration and frequency of drinking. Though not important to this study, GrowSafe™ also measures: duration of every feeding event, head down duration during the feeding event, feed disappearance, feeding rate, amount of time spent at the bunk without consumption, individual bite size, number of bites within an event, and force applied to the bunker (GrowSafe Technical Bulletin, 2007).

A trial was conducted in Canada to demonstrate the efficacy of GrowSafe™ data in terms of reliability and accuracy. The study demonstrated that the GrowSafe™ equipment caused no negative impacts on either animal performance or behavior (GrowSafe Technical Bulletin, 2007)

### **Conclusion**

The impending water crisis in Florida will force ranchers to reexamine how water is used on their operations. In the future it may be necessary for ranchers to accurately account for water consumption and to justify ground water withdrawals. Research is needed to determine the amount of drinking water that is required for different classes of beef cattle. From a production standpoint, it is important to determine what outside factors influence the water requirement and what effects drinking water intake have on growth and feed conversion.

There is currently no satisfactory equation for determining water intake in growing beef cattle. Directly measuring water intake is complicated by a number of factors. GrowSafe™, a continuous data acquisition system, may provide more accurate insight into drinking water use by growing beef cattle.

CHAPTER 3  
WATER INTAKE AND FACTORS AFFECTING WATER INTAKE OF GROWING BEEF  
CATTLE IN FLORIDA

**Introduction**

Water and feed intake have traditionally been measured either by measuring intake of individual animals housed in individual pens or by taking the average intakes of group housed animals. Neither of these two methods is without error or complication. Individual housing of animals is clearly not representative of either natural or commercial settings as the feeding behavior of isolated animals may differ significantly from the feeding behavior of group housed animals. Maintaining animals in isolation eliminates any social behaviors associated with feed and water intake. Additionally, the animal to bunk space ratio is not realistic of commercial settings. Boredom induced polydipsia, a condition wherein animals drink excessively out of boredom, is another complication of housing animals in confinement. Individually penning animals is not only scientifically inaccurate and non representative of real life scenarios, it is also costly and labor intensive.

Taking the average of group housed animals allows for a more natural scenario but limits the researchers in terms of the number of effects they may study. When the average of a group is used there is no way for the researcher to link individual intakes to individual performances or to any genotypic or phenotypic traits which may effect or be affected by the variables in question.

Electronic feeders, such as Calan Gates (American Calan, Northwood, NH), were an early solution to the aforementioned problems associated with intake studies. Electronic feeders isolate individual animals to individual stalls when feeding but allow them to remain in a group setting between meals. When the animal enters the stall the starting weight of the feed bunker or water trough is recorded, likewise when the animal leaves the stall the final weight is also recorded. The difference between the starting and ending weights equal total feed intake. The

artificial nature of an electronic gate system may have an impact on feeding behavior and subsequent feed and water intake. Additionally, little behavioral information can be recorded and the effects of competition are not accounted for.

GrowSafe™ research technology, the newest generation of feed monitoring technology, continuously measures individual consumption of feed and water under commercial feeding conditions without obstruction of natural feeding behaviors. GrowSafe™ uses radio frequency identification (RFID) technology to link intake data to individuals housed in group pens without the need to isolate them artificially at any point. To date, GrowSafe™, represents the most accurate way of measuring individual feed and water intake in group housed animals.

### **Materials and Methods**

A feed and water intake study was conducted at the North Florida Research and Education Center (NFREC) of the University of Florida located at Marianna in northwest Florida (30.5 N. lat). The study ran from late September through late December of 2006 for a total of 13 weeks.

The Feed Efficiency (FE) barn at the NFREC, Marianna, FL was designed for use with the GrowSafe™ system and was used for this study. Each animal was fitted with an International Standards Organizations (ISO) approved RFID ear tag prior to the beginning of the trial. Each RFID tag emitted a frequency which was unique to each animal. The tag is Computer and Communications Industry Association (CCIA) approved and safe for use with growing animals. The pens at the Feed Efficiency Barn each contain two GrowSafe™ feed bunkers and one GrowSafe™ water trough which had been fitted with GrowSafe™ hardware. Adjustable head gates were strategically placed around the perimeter of the bunkers and troughs to allow only one animal to feed or drink at a time. When an animal inserts its head into the bunker or trough its RFID tag is automatically read by GrowSafe™ hardware. The data acquired is sent wirelessly to

a data acquisition centers located throughout the barn. The data is then compiled and sent using spread spectrum technology to a GrowSafe™ software enabled computer in a remote location. The software then automatically analyzes the data and stores it in a readily accessible format.

Growing beef steers (n=61), heifers (n=74), and bull calves (n=11) were housed at the NFREC FE barn for the duration of the trial. Thirteen different breeds and breed composites were used. Sire breeds used included Angus (AN), Brangus (BN), and Charolais (CH). Maternal breeds included BN, AN, Hereford x Angus (HFAN), Romosinuano (RS), Romosinuano x Angus (RA), Brangus x Hereford (BF), Simmental (SM), and Simmental x Angus (SMAN). The resulting composites were; ANBN (n=13), BN (n=58), BNAN (n=13), BNHFAN (n=1), BNRS (n=18), BNRA (n=1), CHAN (n=8), CHBH (n=1), CHBN (n=15), CHRIS (n=15), CHSM (n=1) and CHSMAN (n=2). These breed types are representative of the cattle typically used in commercial herds in Florida ranches. Average starting weight was  $276 \pm 67$  kg.

Cattle were randomly assigned to pens of 15 to 20 head/ pen. The pens measured 7.32 m by 14.63 m. Each pen had poured concrete floors and paneled pen dividers. All pens were under roof and were fully shaded from the sun. Pens were cleaned once a week. During cleaning cattle were removed and either weighed or held in a holding pen until all waste was removed.

Cattle were allowed *ad libitum* access to a total mixed ration (TMR) feed throughout the day with troughs being replenished twice daily at approximately 0800 and 2500. The diet was composed of whole dry corn (38.0 %), soybean hulls (18.1%), cottonseed hulls (13.6%), Beefmaker 60 mineral mix (Flint River Mills, Brainbridge, Ga), (11.6%) corn gluten feed (18.0%), and calcium carbonate (1%). The total CP was 17.33%, NEm was 0.35 mcal/kg, NEg was 0.24 mcal/kg. Water was available *ad libitum*.

Following a two week adjustment period all cattle were weighed weekly on Wednesday mornings (n=13). All the cattle in one pen were removed at the same time. The cattle walked through a series of gates and chutes and were weighed individually using a squeeze chute scale. Weights were recorded into an excel spreadsheet. Cattle were returned to their pens as a group once the pens were cleaned.

Ambient temperature and rainfall was recorded by the Florida Automated Weather Network (FAWN) from the substation in Marianna, Fl. The average daily temperature was  $15.0 \pm 3.5$  C and remained within the thermal neutral zone for the duration of the study. Average daily precipitation was 0.35 cm/d.

Data from GrowSafe™ was transposed to Excel spreadsheets. Total weekly feed and water intakes per animal were calculated for each of the 13 wk. Weekly weights for each animal were also recorded. Weekly ADG was calculated by dividing weekly gain by a factor of seven. Gain: Feed ratio was calculated by dividing the weekly weight gain by the kg of feed consumed. Because feed and water intake are expected to vary with BW, with smaller animals consuming less than larger animals, water and feed intake were adjusted by dividing kg of intake by kg of metabolic BW (MBW). Metabolic BWs were calculated by raising each animal's weekly weight by a factor of 0.75 using the following formula;  $MBW = \text{Weight in Kg}^{0.75}$ . A final spreadsheet was developed which included animal ID, sex, breed composite, average total water intake, average total feed intake, weekly gain, ADG for each of the 13 weeks, G:F for each of the 13 wk, feed intake in kg/ kg MBW and water intake in liters/ kg MBW for each of the 13 wk, and average weekly temperature.

Data was analyzed using SAS version 9.0 (SAS Inst, Inc., Cary , NC ). The variables analyzed included total weekly water intake, total weekly feed intake, average total water intake,

average total feed intake, weekly gain, ADG, G:F, feed intake in kg/ kg MBW, water intake in l/kg MBW, and average weekly temperature The experimental unit was individual animal, rather than pen, as GrowSafe™ allows for individual measurements to be recorded. PROC MEANS was used to determine mean water intake, feed intake, water intake/ kg metabolic BW (wmb), feed intake/ kg metabolic BW (fmb), ADG, and G:F for each breed and again for each gender. PROC GLM and tukeys pdiff were then used to separate significantly different means at the alpha= 0.05 level. PROC CORR was used to detect correlations that existed between variables. PROC REG using a repeated measures model where week (time) was the repeated measure was used to detect the linear relationships between variables. Using actual feed, weight, DM intake, DM composition, and weather data gathered during this trial the expected daily water intake for each animal was calculated using the Murphy et al. (1983) and the Hicks et al. equations (1988). These predicted values were then compared to actual values and means were separated statistically using a Student's T Test.

### **Results and Discussion**

The average daily temperature was  $15.02\text{ C} \pm 3.53$  and remained within the thermalneutral zone (5 to 20 C) for the duration of the study. Body mass is a determining factor for intake of both feed and water intake and was controlled for by calculating the kg of feed or L of water that were consumed per kg of metabolic BW. Mean feed intake (FI) was  $9.73\text{ Kg} \pm 2.01$  kg/ head/d. On average study cattle ate 0.16 kg of feed/ kg of metabolic BW. Mean water intake (WI) was  $29.98\text{ L} \pm 8.56\text{ L/ head/d}$ . When adjusted for metabolic BW, cattle drank an average of  $0.05\text{ L} \pm 0.02\text{ L/ kg of metabolic BW}$ . The cattle gained an average of  $1.41\text{ kg} \pm 1.03\text{ kg/head/d}$  at a rate of  $0.14\text{ kg} \pm 0.11\text{kg weight gain/ kg feed intake}$ .

Charolais x Angus (CHAN) cattle drank significantly more ( $p < 0.05$ ) when compared to all other breed composites. The Angus x Brangus (ANBN), Brangus (BN), Charolais x Brangus

(CHBN), and Brangus x Angus (BNAN) cattle, were similar ( $p < 0.05$ ) in terms of gross water intake. These composites consumed less water ( $p < 0.05$ ) when compared to the CHAN cattle and had a greater gross water intake than either of the two Romosinuano influenced composites ( $p < 0.05$ ). The Brangus x Romosinuano (BNRS) cattle drank significantly less than the non Romosinuano influenced composites but drank more than the Charolais x Romosinuano (CHRS) cattle ( $p < 0.05$ ). The CHRS cattle had the lowest gross water intake when compared to all other breed composites ( $p < 0.05$ ). (Table 4-1)

When adjusted for metabolic BW, CHAN cattle drank significantly more than all other breed composites ( $p < 0.05$ ). The BNAN cattle followed in terms of adjusted water intake and drank more water/ kg MBW than all other breeds except CHAN. The CHBN, BN, BNAN, and CHRS were similar in terms of adjusted water intake, drinking less than CHAN and BNAN cattle ( $p < 0.05$ ). The BNRS cattle had the lowest water intake per kg MBW but were statistically similar to CHBN and CHRS cattle ( $p < 0.05$ ). (Table 4-1)

As was expected, tropically adapted cattle drank less when compared to non tropically adapted cattle with the two Romosinuano influenced breeds having the lowest gross water intake overall. When adjusted for body size, the non tropically adapted cattle still drank more water per kg of BW when compared to the tropically adapted cattle. Tropically adapted cattle such as the Brahman and Romosinuano breeds are phenotypically better adapted to living in the hot and humid conditions that are common to Florida. Their loose skin, long ears, and pendulous briskets and underlines combine to increase body surface area which in turn allows for greater evaporative cooling of the animal. Numerous studies have demonstrated that tropically adapted cattle are better able to cope with heat stress and are more likely to survive and even thrive in sub optimal conditions. This adaptation to warmer climates may also decrease their biological

requirement for drinking water and is likely responsible for their lower levels of both gross and adjusted water intake.

Bulls, heifers, and steers were all similar in terms of both gross and adjusted WI ( $p < 0.05$ ). Differences in terms of water requirement would be expected in more mature animals as differences in terms of growth, metabolic rate, and production become more pronounced. Lactating cows would be expected to have the highest water requirement followed by breeding bulls and then by steers. The lack of differences in this study was likely due to the young age and related lack of developed sex character in growing cattle. (Table 4-2)

Dry matter intake is a determining factor of both water intake and weight gain. Brangus cattle had the greatest gross DM intake when compared to all other breed composites except BNAN ( $p < 0.05$ ). Brangus x Angus, CHBN, BNRS, ANBN, and CHAN cattle were similar in terms of gross feed intake ( $p < 0.05$ ). The CHRS cattle had the lowest gross DM intake ( $p < 0.05$ ). When adjusted for metabolic BW, FI was not significantly different between any breed composite. The differences in FI between breeds were likely a factor of metabolic BW. (Table 4-3)

There were no differences between bulls, heifers, or steers in terms of gross DM intake ( $p < 0.05$ ). When adjusted for metabolic BW, bulls consumed more DM than steers but were similar to heifers ( $p < 0.05$ ). Likewise, heifers were similar in terms of adjusted DM intake to steers ( $p < 0.05$ ). (Table 4-4)

Average daily gain is of significant economic importance in the beef cattle industry. By selecting animals that gain more weight per day one can lessen the number of days that animals must be kept on feed prior to slaughter. The CHAN, ANBN, CHBN, BNAN, and CHRS cattle were similar in terms of ADG ( $p < 0.05$ ). Pure BN cattle were similar in terms of ADG to CHAN,

ANBN, CHBN, BNAN, and CHRS but gained significantly more per day when compared to BNRS cattle ( $p < 0.05$ ). Likewise the BNRS were also similar to CHAN, ANBN, CHBN, and BNAN cattle ( $p < 0.05$ ). There were no differences in terms of ADG between animals of different genders ( $p < 0.05$ ). (Table 4-3; Table 4-4)

Perhaps more important than ADG is G:F. This ratio is determined by dividing the kg of feed by kg of gain for a set period of time. A higher G:F ratio indicates that an individual will gain more weight on the same amount of feed thus decreasing feed costs over time. On this trial there was no statistical differences in terms of G:F between either breed composites or genders ( $p < 0.05$ ). All animals, regardless of breed or gender, tended to gain the same amount per unit of DM intake. (Table 4-3; Table 4-4)

As expected from the literature, FI was correlated with WI, with heavier eaters drinking more water than light eaters ( $p < 0.0001$ ). Gross FI was also correlated with ADG and G:F ( $p < 0.0001$ ); table 4-9. Cattle who consumed more feed gained more weight per day, which is to be expected, and were also more efficient, gaining more weight per kg of feed consumed. Likewise, FMB was strongly correlated with WMB, ADG, and G:F ( $p < 0.0001$ ) demonstrating that the relationship between FI and WI, ADG, and FI is not merely a function of body mass. (Table 4-5)

Gross WI was also related to ADG ( $p < 0.0007$ ) but was not correlated with G:F ( $p = 0.5677$ ). Cattle who consumed greater quantities of water showed a tendency ( $p < 0.05$ ) to gain more weight overall, but were not necessarily more or less efficient at doing so than cattle who consumed less water. (Table 4-5)

When adjusted for metabolic BW, water intake was positively correlated with FI ( $p < 0.0001$ ), FMB ( $p < 0.0001$ ), and ADG ( $p = 0.0164$ ). Once again there was no relationship between WMB and G:F ( $p = 0.7556$ ).

When run through a regression equation, ADG was found to be a function of WMB ( $R^2 = 0.0049$ ) with a weak linear relationship. ADG was slightly more linear in relation to gross WI ( $R^2 = 0.009$ ). The strongest linear relationships existed between FI and WI ( $R^2 = 0.13$ ), FMB and WMB ( $R^2 = 0.084$ ), FMB and WI ( $R^2 = 0.055$ ) and Fi and WMB ( $R^2 = 0.014$ ).

Prediction equations are useful when estimating water requirements and intakes of a group of animals. However, given the number of factors that go into determining water intake, prediction equations may not be able to accurately predict actual intake. Predicted water intake was calculated based on the Murphy et al. (1983) and Hicks et al. (1988) prediction equations. These predicted values were then compared with the observed intakes and were used to determine if the prediction equations accurately captured observed values. The cattle on this trial drank an average of 29.98L/head/d. The observed intake was significantly less than that predicted by either equation ( $p > 0.05$ ). The Hicks equation (Hicks et al., 1988) predicted that they would consume 38.34L/head/d while the Murphy equation (Murphy et al., 1983) predicted an intake of 50.08 L/head/d. Thus, these two equations overestimated intake by a factor of 8.36L and 20.10 L respectively. The Murphy equation (Murphy et al., 1983) was designed for use in dairy cattle rather than beef cattle. It was adapted for use in beef cattle by multiplying milk production by zero. Despite this modification, the Murphy equation (Murphy et al., 1983) grossly over estimates water consumption in growing beef cattle. Using this equation to predict water intake in beef cattle is inappropriate and inaccurate. The Hicks equation (Hicks et al., 1988) was designed for use with feedlot cattle but still overestimated water intake in this study.

This may have been due to the differences in management practices that exist between feed lot cattle raised in open dry lots and study cattle housed in an open sided, concrete floored barn. The Hicks equation (Hicks et al., 1988) considers precipitation to be a determining factor of water intake. Precipitation was recorded during this study and used as part of the Hicks equation (Hicks et al., 1988) to predict water intake, however, due to the shielding nature of the barn, precipitation had little to no effect on study cattle.

The NRC (1996) estimates beef cattle water intake using figures from Winchester and Morris (1956) and provided a range of expected water intake based on animal BW and ambient temperature. The water intake observed during this study fell within the range predicted by Winchester and Morris (1956). However, the range predicted by Winchester and Morris (1956) is too broad in scope to allow for precise estimates. This study has allowed for both a more accurate, and a more precise account of water intake in growing cattle. Additionally this study has enabled water intake to be directly linked to various production traits, something that was not possible using information from prediction equations or estimation tables.

Table 4-1. Water intake by breed

Breed	Gross water intake l/d <sup>1,2</sup>	Water intake/kg MBW <sup>1,3</sup>
Charolais x Angus	42.51 <sup>a</sup>	0.09 <sup>a</sup>
Angus x Brangus	32.33 <sup>b</sup>	0.07 <sup>b</sup>
Brangus	30.77 <sup>b</sup>	0.05 <sup>c</sup>
Charolais x Brangus	29.68 <sup>b</sup>	0.06 <sup>c,d</sup>
Brangus x Angus	28.88 <sup>b</sup>	0.05 <sup>c</sup>
Brangus x Romosinuano	24.08 <sup>c</sup>	0.05 <sup>d</sup>
Charolais x Romosinuano	23.73 <sup>d</sup>	0.05 <sup>c,d</sup>

<sup>1</sup>Within a column, means without a common superscript letter differ (p<0.05). <sup>2</sup>Gross water intake expressed in liters per head per day. <sup>3</sup>Water intake/ kg MBW expressed as liters per kg of metabolic BW/head/day

Table 4-2. Water intake by gender

Gender	Gross water intake l/d <sup>1,2</sup>	Water intake/kg MBW <sup>1,3</sup>
Bull	28.13 <sup>a</sup>	0.05 <sup>a</sup>
Steer	30.55 <sup>a</sup>	0.06 <sup>a</sup>
Heifer	29.72 <sup>a</sup>	0.06 <sup>a</sup>

<sup>1</sup> Within a column, means without a common superscript letter differ ( $p < 0.05$ ). <sup>2</sup>Gross water intake expressed in liters per head per day. <sup>3</sup>Water intake/ kg MBW expressed as liters per kg of metabolic BW/head/day.

Table 4-3. Intake, ADG, and G:F by Breed

Breed	Water Intake/kg Metabolic BW <sup>1,2</sup>	Feed Intake/Kg Metabolic BW <sup>1,3</sup>	ADG <sup>1,4</sup>	G:F <sup>1,5</sup>
Brangus	0.05 <sup>c</sup>	0.16 <sup>a</sup>	1.49 <sup>a</sup>	0.14 <sup>a</sup>
Brangus x Angus	0.05 <sup>c</sup>	0.15 <sup>a</sup>	1.44 <sup>a</sup>	0.13 <sup>a</sup>
Charolais x Brangus	0.06 <sup>c,d</sup>	0.16 <sup>a</sup>	1.47 <sup>ab</sup>	0.15 <sup>a</sup>
Brangus x Romosinuano	0.05 <sup>d</sup>	0.15 <sup>a</sup>	1.20 <sup>b</sup>	0.13 <sup>a</sup>
Angus x Brangus	0.07 <sup>b</sup>	0.16 <sup>a</sup>	1.46 <sup>ab</sup>	0.16 <sup>a</sup>
Charolais x Angus	0.09 <sup>a</sup>	0.16 <sup>a</sup>	1.42 <sup>ab</sup>	0.15 <sup>a</sup>
Charolais x Romosinuano	0.05 <sup>c,d</sup>	0.15 <sup>a</sup>	1.21 <sup>ab</sup>	0.15 <sup>a</sup>

<sup>1</sup> Within a column, means without a common superscript letter differ (p<0.05). <sup>2</sup>Water Intake/ Kg Metabolic BW expressed as liters of water consumed/ kg of Metabolic BW/head/d. <sup>3</sup>Feed Intake/ kg Metabolic BW expressed as kg dry matter per kg of Metabolic BW/head/d. <sup>4</sup>ADG expressed as kilograms of weight gain/head/d. <sup>5</sup>G:F expressed as kg of weight gain per kg of dry matter intake/head/d.

Table 4-4. Intake, ADG, and G:F by Gender

Breed	Water Intake/kg MBW <sup>1,2</sup>	Feed Intake/Kg MBW <sup>1,3</sup>	ADG <sup>1,4</sup>	G:F <sup>1,5</sup>
Bull	0.05 <sup>a</sup>	0.15 <sup>a</sup>	1.35 <sup>a</sup>	0.14 <sup>a</sup>
Steer	0.06 <sup>a</sup>	0.16 <sup>b</sup>	1.36 <sup>a</sup>	0.13 <sup>a</sup>
Heifer	0.06 <sup>a</sup>	0.15 <sup>ab</sup>	1.46 <sup>a</sup>	0.14 <sup>a</sup>

<sup>1</sup> Within a column, means without a common superscript letter differ (p<0.05). <sup>2</sup>Water Intake/ Kg MBW expressed as liters of water consumed/ kg of MBW/head/day. <sup>3</sup>Feed intake/ kg MBW expressed as kg dry matter per kg of MBW/head/day. <sup>4</sup>ADG expressed as kilograms of weight gain/head/day. <sup>5</sup>G:F expressed as kg of weight gain per kg of dry matter intake/head/day.

Table 4-5. Correlations between Variables

	FI	FMB	WI	WMB	ADG	GF
FI		<0.0001	<0.0001	<0.0001	<0.0001	0.0271
FMB	<0.0001		<0.0001	<0.0001	<0.0001	0.0004
WI	<0.0001	<0.0001		<0.0001	0.0007	0.5677
WMB	<0.0001	<0.0001	<0.0001		0.0164	0.7556
ADG	<0.0001	<0.0001	0.0007	0.0164		<0.0001
GF	<0.0001	0.0004	0.5677	0.7556	<0.0001	

P values less than or equal to 0.05 are significant

## CHAPTER 4 GENERAL CONCLUSIONS AND SUGGESTIONS FOR FURTHER RESEARCH

A study was conducted at the North Florida Research and Education Center, in Marianna, Florida, to evaluate water intake in growing beef cattle. The objectives of the study were to measure water intake in growing beef cattle, to determine what factors influence, and are influenced by, water intake, and to compare observed values to predicted values. Immature bulls, steers, and heifers ( $n=146$ ;  $276 \pm 67$  kg) were housed at the Feed Efficiency Barn at NFREC, Marianna, FL for a period of 13 wk from late September 2006 through late December 2006. Feed and water intake data was continually monitored by GrowSafe™ and later collected, compiled, and analyzed at the University of Florida's Department of Animal Science. Cattle were weighed weekly to measure weight gain and to compute ADG.

Mean water intake was  $29.98 \text{ L} \pm 8.56 \text{ L/head/d}$ . On a metabolic BW basis cattle drank an average of  $0.05 \text{ L/kg} \pm 0.02 \text{ L/kg}$  of metabolic BW. Cattle with Brahman and Romosinuano breeding tended to consume less water than British and Continental cattle at the same BW ( $p \leq 0.05$ ). There was no difference ( $p \geq 0.05$ ) between bulls, steers, and heifers in terms of either gross water intake or water intake per kg of metabolic BW. The mean daily temperature remained within the thermal neutral zone throughout the study and had no influence on water intake.

Water intake was correlated with feed intake and weight gain ( $p \leq 0.05$ ) with heavier calves tending to consume more water and gain more weight. There was no relationship ( $p \leq 0.05$ ) between water intake and G:F.

Two common prediction equations, the Murphy equation (Murphy et al. 1983) and the Hicks equation (Hicks et al. 1988) were used to predict expected daily water intake using data from the actual cattle on the trial. These predicted values were compared with observed values

and were found to be statistically higher ( $p \leq 0.05$ ). The Murphy equation overestimated water intake by an average of 20.20 L/head/d while the Hicks equation overestimated water intake by an average of 8.36L/head/d.

Further research is needed to determine the influence of temperature on water intake during other seasons, and to determine water intake in different classes of cattle. This study also demonstrates a clear need for more accurate prediction equations for use with growing beef cattle in Florida.

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## BIOGRAPHICAL SKETCH

A Florida Gator from the time of birth, Megan Noël Brew was born January 18, 1981 in Gainesville, Florida. Megan spent her early years exploring the woods and pastures of Lake City, Florida before returning to Gainesville for school. As a high school student Meg excelled in History, English, Art, and the Sciences, earning multiple advanced placement credits toward college in each subject. Upon graduation Megan enrolled at the University of Florida as an anthropology major. Quickly discovering that she preferred hard science over social science, Megan transferred into the Department of Animal Science as a sophomore. She obtained her Bachelor of Science in Animal Science with a concentration in the equine industry in 2004.

Meg spent a year at New Mexico State University where she served as the coach for the collegiate horse judging team and worked as a graduate assistant in the lab of Dr. Timothy Ross. Meg relocated to Florida shortly after the birth of her son, Riley Joshua. In January 2006, she was admitted as a graduate student at the Department of Animal Sciences, University of Florida. Since that time she has been working on her master's degree in preparation for a career in extension education.

An avid equestrian from a young age, Meg has logged many hours on horseback. When not writing for graduate school, Meg enjoys spending as much time as possible in the barn, surrounded by horses and cattle.