


# Water disappearance dynamics in growing-finishing pig production

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**ABSTRACT** - The objective of this study was to measure the water disappearance in the drinker and the pattern of daily water intake and estimate the amount of water wasted in pig production. The study will also generate information about the daily behaviour of water intake of pigs in the growing and finishing phases. Sixty male pigs with an average initial weight of 44.43 kg subjected to immunocastration were used. Animals received feed and water *ad libitum*. The animal-performance data, temperature and humidity, and feed and water intake behaviour were collected in real time during the entire experimental period, while water volume consumed was measured daily. The average water disappearance (WD) was 7.98 L, which increased during the studied period, and 29.07% of this corresponds to the estimated water wasted. The daily WD behaviour revealed an increasing pattern throughout the day for growing and finishing periods, with the registered peak at 16:00 and 15:00 h and intake of 6.24 and 9.48 L, respectively. The time spent drinking (TSD) and number of drinker visits (NDV) also showed a peak in the afternoon: 13:00 and 17:00 h for growing and finishing phases, respectively. The TSD was 282.73 and 268.36 s, and the NDV values were 16.13 and 13.84 for growing and finishing phases, respectively. The results demonstrated an increasing pattern during the animal housing period in WD that is proportional to dry matter intake and body weight, and the water wasted represents a significant portion of WD. The daily pattern of WD, TSD, and NDV increase during the total and growing periods, presenting peak activity at 13:00 h. During the finishing phase, TSD and NDV present a pattern similar to the growing phase, but the peak occurs in the last hour of the day.

**Keywords:** drinker visits, pigs, time spent drinking, water disappearance, water wasted

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## Introduction

Water use in agricultural production corresponds to a significant portion of the water consumed in the world (Hoekstra and Mekonnen, 2012). In addition, fast population growth leads to a need for the production of more animal protein in a smaller area, which tends to further increase water use. Intensive production of pigs in growing and finishing phases follows the same trend, since together these phases represent about 75% of the total water used to feed the herd, when considering a full farm lifecycle.

Most of the water used is designated for animal watering and for cleaning activities that surround the growing-finishing pig production unit; this results in strong economic (generate more production costs) and environmental impact (generate more waste volume) when there is no conscientious use of

this resource. It is hard to predict the intake of water by the pigs because there are several factors that interfere in the total volume ingested, such as the amount of wasted water; live weight and productive phase of the animal (Mroz et al., 1995; Brumm, 2006); diet quality and quantity – protein, salt, and fibre content (Vermeer et al., 2009; Ramonet et al., 2017); climatic factors – relative humidity and installation temperature (Seddon et al., 2011); sanitary status of the animals (Brumm, 2006); and housing systems (Wei et al., 2019).

Although there are studies that have evaluated the water intake of growing-finishing pigs (Li et al., 2005; Andersen et al., 2014; Tavares et al., 2014; Maselyne et al., 2016), the interaction of water disappearance with environmental variables and nutrient intake in natural conditions has still not been adequately explored. The objective of this study was to measure the disappearance and pattern of water intake, estimate water wasted, and generate information about the daily behaviour of water intake of pigs in the growing and finishing phases.

## Material and Methods

The study was carried out in Santa Maria, Rio Grande do Sul, Brazil (Latitude: 29°41'29" S, longitude: 53°48'3" W, elevation: 139 m). The procedures adopted to conduct this experiment were in accordance with the provisions of Federal Law No. 11,794 of October 08, 2008, and Decree No. 6,899 of July 15, 2009, under case no. 8688070716 of the local Ethics Committee of Animal Use (CEUA).

Sixty male pigs (Agroceres × Danbred) were housed, with an initial live weight of 44.43 kg and final weight of 124.82 kg (growing – 24.00 to 70.00 kg; finishing – 71.00 to 140.00 kg), distributed in five pens sized 2.80×5.30 m with capacity for 12 animals each, in a total period of 12 weeks. The animals were allocated in a building with a solid concrete floor and a waste collection channel at the back of the pens. The animals started the experimental period from the 10th week of age (week 1 of the experiment). During this period, they were subjected to a feed programme of four pelletised diets, formulated according to the nutritional requirements of the National Research Council (NRC, 2012) and provided *ad libitum* (Table 1). The feeding programme was defined by the animal weight: grower 1 (24.00 to 50.00 kg), grower 2 (50.00 to 70.00 kg), finisher 1 (70.00 to 100.00 kg), and finisher 2 (100.00 to 140.00 kg).

The pen was equipped with a single feed station named *Feed Intake Recording Equipment* (Fire<sup>®</sup>, Osborne) with feeder capacity of one pig each time and two nipple drinkers in the end of the pen. The temperature regulation system was performed through side curtains to keep the temperature of the environment as close as possible to the thermoneutral comfort zone for each category. The pigs were immunocastrated according to the vaccination protocol of Vivax<sup>®</sup> (Zoetis, Brazil). Each animal received two doses of the vaccine (2.00 mL subcutaneously) containing 200 µg of GnRH in conjugate protein per milliliter, and applications were performed by the company staff. The first and second dose applications of Vivax<sup>®</sup> were performed at the 16th and 23rd weeks of age (5th and 10th experimental weeks), respectively. Cleaning of the facilities was performed twice daily, between 08:00 and 09:00 h and between 16:00 and 17:00 h. The waste was removed with the aid of shovels to the collecting channel at the back of each pen.

The experimental design was completely randomised. Each pig received an identification eartag in the left ear and a radiofrequency device in the right ear. The raw data regarding body weight (BW) and feed intake (FI) were collected in real time through Fire<sup>®</sup>. The automated feeder had a weighing platform, informing the BW in real time, and a weighing scale in the feeding dish, which monitored the FI – both values were updated every time the animal ate, by reading the earring signal.

A precision volumetric hydrometer of Sappel brand (3/4" QN 1,5 M3/H) was fitted to the hydraulic system of each pen to measure the volume of water disappeared in each pair of nipple drinker, defined as water disappearance (WD). The WD data was recorded twice a day, at 08:00 and at 18:00 h, then the value at 08:00 h was subtracted from the value at 08:00 h of the previous day and divided by the number of animals in the pen to find the average water volume used per pig. To monitor the daily WD pattern, the data collection of the total housing period was divided into seven observations, each one

lasting three days, in which the hourly values of the hydrometers were recorded between 08:00 and 18:00 h. The height adjustments of drinkers were made according to the recommendations of Gonyou (1996), aiming to provide access for all the animals in the pen and to avoid waste. The equipment flow rate was checked weekly and the values found were in accordance with the recommendations of Piva and Gonçalves (2014), who stated that, for animals weighing more than 25.00 kg of live weight, it should be more than 1 L/min.

The water amount drained by the nipple drinker represents the water ingested plus the water wasted by the animal. In an attempt to estimate water waste, the model proposed by Rigolot et al. (2010) and

**Table 1 - Composition and nutritional values of growing-finishing pig diets**

Ingredient (g kg <sup>-1</sup> dry matter)	Diet <sup>1</sup>			
	G1	G2	F1	F2
Maize	300.00	300.00	453.50	483.40
Maize germ 10%	-	-	142.90	-
Wheat meal	-	-	99.90	-
Broken rice	247.60	262.20	-	-
Wheat bran	77.20	96.80	29.00	-
Rice bran 15%	150.00	150.00	150.00	300.00
Rice with peel	-	-	-	24.70
Soy 46%	168.10	140.10	77.40	114.70
Meat meal 55%	25.80	25.50	23.20	-
Meat meal 52.50%	-	-	-	56.20
Limestone 30.80%	12.50	11.40	11.70	12.80
Salt	3.00	2.70	2.60	3.10
Betaine 95%	0.40	0.40	0.20	-
DL-methionine 99%	0.80	0.70	0.40	-
L-lysine 99%	4.90	4.60	3.90	1.70
L-threonine 98%	1.60	0.50	1.00	0.40
L-tryptophan 98%	0.01	0.02	0.10	-
Calcium propionate 98%	1.00	1.00	1.00	-
Ethoxyquin 66%	0.10	0.10	0.10	0.10
Adsorbent	2.00	2.00	2.00	-
Copper sulfate 35%	0.40	0.40	-	-
Choline of chloride 60%	0.40	0.30	0.30	-
Zinc bacitracin 15%	0.30	0.30	-	0.40
Phytase	0.10	0.10	0.10	-
Kaolin	-	-	-	1.40
Vitamin premix	0.30	0.30	0.20	0.30
Ferrous sulfate premix 1.40%	3.00	-	-	-
Mineral premix 0.05%	0.50	0.50	0.40	0.50
Nutritional composition				
Metabolisable energy (kcal kg <sup>-1</sup> )	3250	3250	3250	3100
Crude protein (g kg <sup>-1</sup> dry matter)	171.30	161.40	140.80	160.00
Ca (g kg <sup>-1</sup> dry matter)	7.40	7.00	6.70	10.00
P (g kg <sup>-1</sup> dry matter)	6.40	6.40	6.70	9.20
Ca:P	1.85	1.75	1.00	-
Lysine (g kg <sup>-1</sup> dry matter)	12.10	11.20	9.30	9.00
Methionine (g kg <sup>-1</sup> dry matter)	4.00	3.70	3.00	2.60
Methionine + cystine (g kg <sup>-1</sup> dry matter)	7.00	6.60	5.50	5.40
Threonine (g kg <sup>-1</sup> dry matter)	7.70	6.30	6.00	6.20
Tryptophan (g kg <sup>-1</sup> dry matter)	2.10	2.00	1.60	1.70

<sup>1</sup>The nutritional requirements were calculated according to the NRC (2012).

G1 = grower diet 1 (24.00 to 50.00 kg); G2 = grower diet 2 (50.00 to 70.00 kg); F1 = finisher diet 1 (70.00 to 100.00 kg); F2 = finisher diet 2 (100.00 to 140.00 kg).

Schiavon et al. (2009) was used, which calculates the water amount required to maintain animal water balance. Water ingested or produced by the animal was considered as inputs and the water excretion or retention (body retention), as outputs. The inputs are represented by the water amount collected at the drinker (hydrometer value), water from the food (in these pelleted diets, it represents 10% of the natural matter – NM), and metabolic water originated from the food oxidation (Rigolot et al., 2010). Outputs, however, are represented by the water amount accumulated for growth (Rigolot et al., 2010), water volume that is excreted as urine (Schiavon et al., 2009), amount eliminated in faeces (Schiavon et al., 2009), and amount eliminated through body surface evaporation and respiratory tract processes (Rigolot et al., 2010).

The animals were monitored in real time with the help of video monitoring cameras installed at the top of each pen. The video storage was done daily on an external hard disk, for later analysis of the time spent drinking (TSD) and the number of drinker visits (NDV). Information on ambient temperature (AT) and relative humidity (RH) were collected through a data logger Bside brand, BTH01 LCD model, and registering the information every minute, installed in the central part of the shed, and the files were backed up weekly. The Temperature and Humidity Index (THI) was calculated from the equation  $THI = (0.8 \times AT) + RH \times (AT - 14.4) + 46.4$  (Hahn et al., 2009), using the AT and RH values stored in the datalogger.

The TSD and NDV were obtained by observing the videos recorded during the experimental period, with moments of handling, pen washing, and human interference being excluded for the data collection. To count TSD and NDV, we used ten observations per pen of eight minutes each, for seven days, distributed between 08:00 and 18:00 h of the second day of the hydrometer hourly readings. The beginning of the drinker visit was considered as the moment the mouth of the animal came into contact with the drinker. When the same animal visited the water fountain two or more times in an interval of less than 30 s, it was considered as a single visit (Rydmer et al., 2010). To optimise the statistical analyses, the TSD and NDV values were evaluated separately in the growing (24.00 to 70.00 kg) and finishing (70.00 to 140.00 kg) periods.

The data obtained in this experiment was analysed using the statistical software SAS® Studio (2017). The data was subjected to descriptive statistics analysis, and then to the variance analysis through the Mixed procedure, with different covariance structures tested for each dependent variable. The best covariance structure was chosen based on the lowest AIC (Akaike information criterium) value. The experimental unit used was PEN with 12 animals. The mathematical model used was:

$$Y_{ijk} = \mu + CAT_i + WEEK_j + (CAT \times WEEK)_{ij} + PEN_k(CAT)_i + \beta(RH_{ijk} - \bar{RH}) + \beta(AT_{ijk} - \bar{AT}) + \varepsilon_{ijk},$$

in which Y = dependent variable;  $\mu$  = general average;  $CAT_i$  = category index i (1 = light, 2 = medium, 3 = heavy);  $WEEK_j$  = week index j (1 = week 1, ..., 12 = week 12);  $PEN_k(CAT)_i$  = error a;  $\beta(RH_{ijk} - \bar{RH})$  = effect of relative humidity covariable;  $\beta(AT_{ijk} - \bar{AT})$  = effect of dry bulb temperature covariant in degrees Celsius; and  $\varepsilon_{ijk}$  = error b. For the category effect, when significant at 5%, the average was compared by the Tukey test ( $P < 0.05$ ). For the effects of week and category  $\times$  week interaction, simple and polynomial linear regression equations of the second and third order were adjusted ( $P < 0.05$ ).

The mathematical model used for the analysis of variance of the TSD and NDV was:

$$Y_{ijk} = \mu + PHASE_i + HOUR_j + (PHASE \times HOUR)_{ij} + PEN_k(PHASE)_i + \beta(RH_{ijk} - \bar{RH}) + \beta(AT_{ijk} - \bar{AT}) + \varepsilon_{ijk},$$

in which Y = dependent variable;  $\mu$  = general average;  $PHASE_i$  = category index i (1 = growing, 2 = finishing);  $HOUR_j$  = hour index j (1 = hour 8, ..., 10 = hour 17);  $PEN_k(PHASE)_i$  = error a;  $\beta(RH_{ijk} - \bar{RH})$  = effect of relative humidity covariable;  $\beta(AT_{ijk} - \bar{AT})$  = effect of dry bulb temperature covariant, in degrees Celsius; and  $\varepsilon_{ijk}$  = error b.

## Results

The average BW of the animals during the study period was 83.60 kg (44.43 to 124.82 kg), with an average FI of 2.58 kg/day and dry matter intake (DMI) of 2.32 kg (Table 2). The ambient temperature recorded was 19.69 °C and the relative humidity was 74.37%, with a variation of 14.41 to 25.22 °C and 61.06 to 87.20%, respectively. The temperature and humidity index presented an average value

of 66.25%, minimum of 57.94% and a maximum of 78.39%. The WD was 7.98 L/pig (Table 2) and represents more than 90% of the total of the estimated inputs (Table 3). The water amount needed for an animal with an 83.60 kg body weight to maintain an adequate water balance was 6.30 L/pig, and the volume of water waste represented about 29.07% of the total water flow (2.32 L/pig), resulting in 5.66 L/pig of water that is actually ingested by the animal.

The regression equations (Figures 1 and 2) are represented by first and third order polynomial equations, in which they demonstrate the relationship between WD versus DMI and WD versus BW, in which WD is represented by the abscissas axis and the other variables by the ordinate axis. The relationship between WD and DMI observed was 2.9:1 (Figure 1) and was linear throughout the housing period of the animals, represented by the function  $Y = 1.254 + 2.902x$  ( $P < 0.0001$ ). When WD is associated with BW (Figure 2), the cubic polynomial equation that best describes the relationship is  $Y = -4.62133 + 0.40517x - 0.00452x^2 + 0.00002x^3$  ( $P < 0.0001$ ).

The total volume of water disappeared in the period from 08:00 to 18:00 h was 6.24 (growing) and 9.48 L (finishing) (Figure 3). The WD pattern increased over the period and peaked at 16:00 h (0.91 L) and at 15:00 h (1.72 L) for the growing and finishing phases, respectively. A small decline in the WD value was also observed at 13:00 h in both periods. The total TSD was 282.73 and 268.36 s in the

**Table 2** - Descriptive statistics for variables involved in daily water disappearance of pigs in the growing-finishing period

Studied variable	Mean	SD	Minimum	Maximum
Body weight (kg)	83.60	26.38	44.43	124.82
Feed intake (kg/day)	2.58	0.41	1.82	3.10
Dry matter intake (kg/day)	2.32	0.37	1.60	2.79
Ambient temperature (°C)	19.70	2.64	14.41	25.22
Relative humidity (%)	74.37	5.16	61.06	87.20
Temperature and humidity index (%)	66.25	5.16	57.94	78.39
Water disappearance (L/pig)	7.98	1.11	5.92	9.85

SD - standard deviation.

**Table 3** - Estimated water balance of pigs during the growing-finishing period

	Litre	%
<b>Input</b>		
Water disappearance (wasted + ingested water)	7.98	92.57
Food water <sup>1</sup>	0.26	3.02
Water of oxidation <sup>2</sup>	0.38	4.41
Total input	8.62	100.00
<b>Output</b>		
Body retention <sup>2</sup>	0.65	10.32
Evaporated <sup>2</sup>	1.47	23.33
Feces <sup>3</sup>	0.85	13.49
Urine <sup>3</sup>	3.33	52.86
Total output	6.30	100.00
Wasted water (total output – total input)	2.32	29.07
Ingested water (water consumption – wasted water)	5.66	70.93
Real input (total input – wasted water)	6.30	100.00

Assumptions: growing-finishing pigs with 83.60 kg body weight, daily gain 1.047 kg/day, protein deposition rate of 0.161 kg/day, and eating 2.580 kg/day, fed a commercial diet.

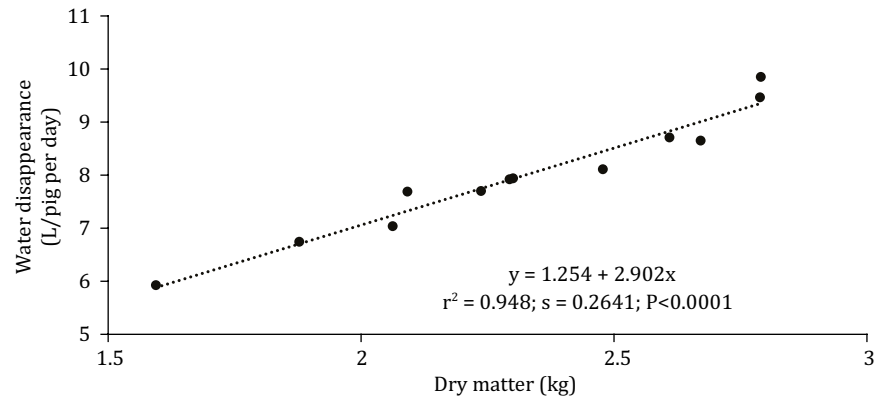
<sup>1</sup> Assumes feed contains 10% of humidity.

<sup>2</sup> Calculated according to Rigolot et al. (2010).

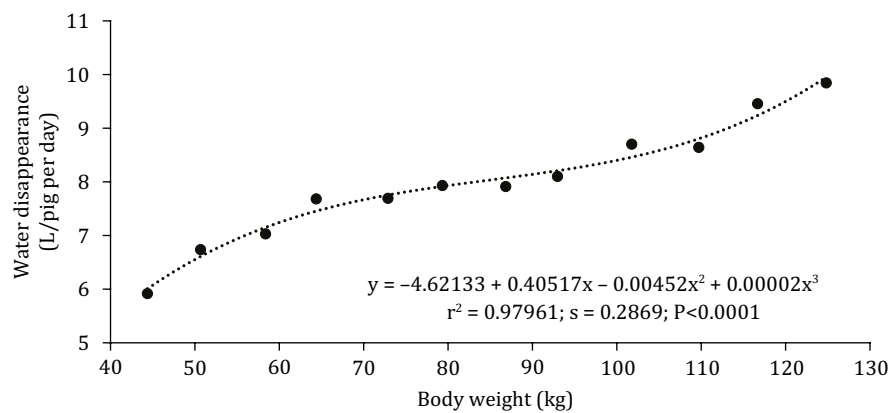
<sup>3</sup> Calculated according to Schiavon et al. (2009).

growing and finishing periods, respectively. The TSD did not exceed 30 s until 13:00 h, but after 14:00 h, the contact period was between 30 and 60 s for each animal (Figure 4). The NDV was 16.13 and 13.84 for the growing and finishing periods, respectively. The observed pattern was that, until 13:00 h, the number of visits did not exceed 1.50 visits per hour, but after 14:00 h, the number of visits was between 1.50 and 3.52 (Figure 5).

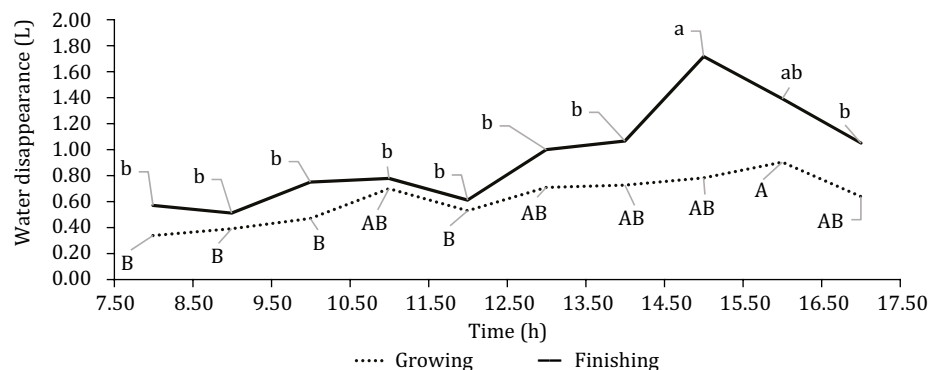
The amount of water required to maintain the homeostatic balance (outputs), the water waste, and water disappearance (input + waste) increased during the 12 weeks of experiment (Figure 6). From



**Figure 1** - Water disappearance and dry matter intake regression of pigs in the growing-finishing period over twelve weeks ( $P < 0.05$ ).



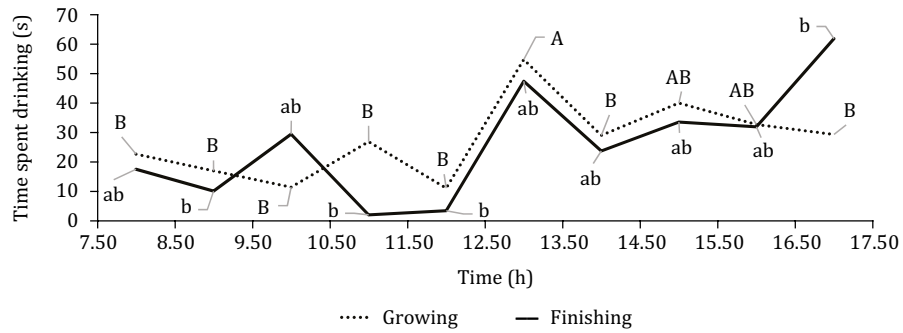
**Figure 2** - Average water disappearance and body weight regression of pigs in the growing-finishing period over twelve weeks ( $P < 0.05$ ).



Same letters =  $P > 0.05$ ; different letters =  $P < 0.05$ ; uppercase = growing phase; lowercase = finishing phase.

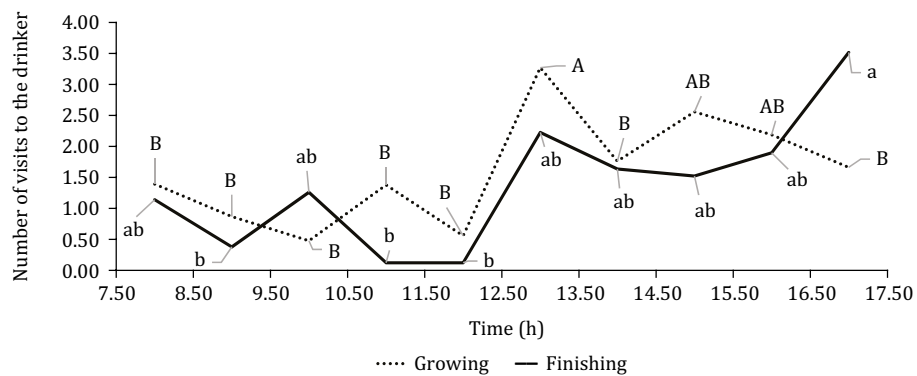
**Figure 3** - Water disappearance pattern of pigs in the growing-finishing period from 08:00 to 18:00 h.

week 1 through week 4, the animals showed a tendency to increase the WD (from 6.022 to 8.369 L, respectively). Concomitantly, the amount of water required for maintenance and water waste also increased. The WD between week 4 and week 10 remained increasing (8.369 and 9.415 L, respectively); however, the variation for water used was lower than in the first weeks. From week 10 to the end of the experiment, there was an increase in WD, reaching 11.514 L in the last week. It was observed that the amount of water required to maintain the adequate body water balance in this period was 5.354 L, which implies in a wasted volume of 6.164 L.



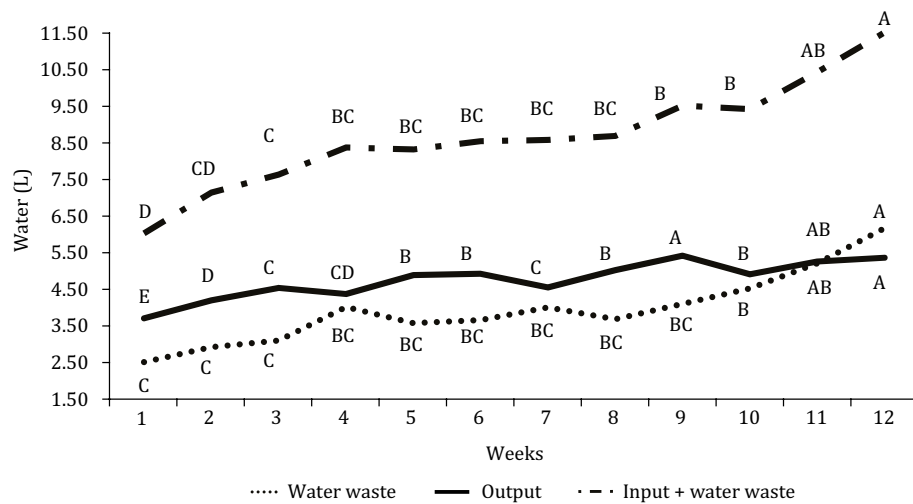
Same letters = P>0.05; different letters = P<0.05; uppercase = growing; lowercase = finishing.

Figure 4 - Pattern of time spent at the drinker of pigs the growing-finishing period from 08:00 to 18:00 h.



Same letters = P>0.05; different letters = P<0.05; uppercase = growing; lowercase = finishing.

Figure 5 - Patter of number of drinker visits of pigs in the growing-finishing period from 08:00 to 18:00 h.



Same letters = P>0.05; different letters = P<0.05.

Figure 6 - Pattern of water output, input, and waste of pigs during growing-finishing period.



## Discussion

The temperature values considered critical by Sampaio (2004) (max. 27 °C and min. 4 °C) were not observed during the experimental period (Table 2). However, the maximum AT recorded, 25.22 °C, exceeded the values considered normal for thermal comfort according to Whittemore et al. (2001). The RH records followed the same trend as AT, presenting values out of the neutral thermal comfort zone for animals, but did not reach values considered critical (Sampaio, 2004). The THI remained close to the thermal comfort value for the category (Hahn et al., 2009); although the maximum value (Table 2) was above the thermal comfort range (THI greater than 75%), it did not exceed values considered critical (THI>84%), which could cause some type of alteration in the behaviour of water intake of animals (Hahn et al., 2009).

Water disappearance (Table 2) only considers the water disappeared at the drinker level and does not distinguish what was ingested from what was wasted. The results measured for this variable are consistent with those found by Li et al. (2005), Tavares et al. (2014), and Rivest et al. (2015) (7.31, 7.72, and 8.30 L/animal respectively), who also evaluated WD in pigs in the growing and finishing phases. The average ratio between WD and DMI was 3.43, which demonstrates the existence of the interaction between these variables. According to Brooks and Carpenter (1993), water intake is given by the amount of feed intake and often this intake of water may not be enough to maximise the adequate biological performance of animals.

The estimated percentage of water wastage (Table 3) was lower than that reported by Andersen et al. (2014), who verified an approximate value of 34.60% of the total WD value. However, Li et al. (2005) demonstrated that the waste can vary from 25 to 30% of the total WD, which corroborates the results estimated in this study. The same authors suggested that the main factors that cause waste are poor regulation and lack of equipment maintenance (Li et al., 2005). In the present study, it is believed that these influences were minimised by constant inspection of the correct equipment operation.

When consuming water, the main objective of the pig is to maintain adequate water balance without compromising animal sanity (Whittemore, 2006). The route of water acquisition is through ingestion (representing the largest proportion) of water contained in the feed and of metabolic water (Table 3). On the other hand, the most representative part of the water eliminated from the organism is the water present in urine (Shaw et al., 2006), followed by evapotranspiration, water contained in faeces, and water retained in the body (Brooks and Carpenter, 1993). In this sense, water intake is related to several factors, such as assisting the degradation processes of proteins and dissolution of salts that are ingested through the diet. In extreme cases of thermal stress, water intake can be used as a tool to aid the heat loss of the animal (Kiefer et al., 2009).

The relationship between WD and DMI observed in this study resembles those found by Smolders and Hoofs (2000) and Li et al. (2005), which were 2.9:1 and 2.88:1 (L/kg), respectively. However, our data differ from those reported by Brumm et al. (2000), who reported values of 1.5:1 (L/kg). The variation between this ratio can be attributed to the type of feed supplied, since it is known, for example, that dry feed generates an increase in the absolute value of WD. Whittemore (2006), for example, stated that there is no specific relationship for water and feed intake in growing-finishing pigs, with values as high as 5:1 (L/kg) found for animals receiving dry feed.

During animal development, the need for nutrients from the diet gradually increases (Nyachoti et al., 2004). Swine tend to increase feed and water intake to meet daily needs up to a limit determined by morphological and physiological factors. The increase in the amount of WD is related to the increase in DMI and in BW (Figures 1 and 2), that is, as the pig develops and increases in weight and DMI, the WD value also accompanies them. Consequently, the capacity of nutrient intake, digestion, and metabolism follow the same trend, being directly related to age, individual genotype, and morphological and physiological factors.

The results of WD found by Madsen and Kristensen (2005), when studying animals from 4 to 11 weeks, revealed that pigs exhibited peak intake between 16:00 and 18:00 h and had a very stable pattern



throughout the day, similar to that observed in this study. In the same way, Brumm (2006) and Vermeer et al. (2009), who compared the amount of water consumed over the same period during summer and autumn, found that the largest periods of water intake activity were concentrated in the afternoon independent of season. Furthermore, the WD standards found were also similar to those found by Rivest et al. (2015), who studied pigs between 55.00 and 81.00 kg BW for 24 h. The results only differed in the WD peak time (Figure 3), which in this study occurred between 15:00 and 16:00 h, whereas Rivest et al. (2015) observed it just after noon (13:00 h). For Brumm (2006), the peak WD was mainly associated with the FI behaviour and the comfort zone the animals were in.

The average TSD (Figure 4) was 27.55 (s/h) and resembled the 24.75 and 27.00 s/h described by Andersen et al. (2014) and Rivest et al. (2015), respectively. Andersen et al. (2014) also showed that TSD was 13.60 s per visit, about 25.92% less than that obtained in this study (18.39 s per visit). Li et al. (2005), when evaluating animals under similar conditions to this experiment, during a 6-h observation, obtained an average contact period per visit of approximately 20.00 s. The TSD in the growing period generally increased in the first few hours of the day. Kashiha et al. (2013) reported similar patterns to this study when studying animals in the growing phase, differing only with regards to the maximum point found for the duration of visits (15:30 h). Meiszberg et al. (2009) observed that the maximum point occurred at 12:00 h, which approximates the time found in this study (13:00 h). During the finishing phase, the TSD peak occurred during the last record time, and differed from the patterns described previously (Meiszberg et al., 2009; Kashiha et al., 2013).

The total NDV in the period from 08:00 to 18:00 h was 14.98 (Figure 5), which is lower than that described by Rivest et al. (2015), a total of 25.40 visits. These authors still stated that the total number of visits in a period of 24 h can vary between 16.00 and 38.00 in about 90% of the cases. However, Andersen et al. (2014) also analysed a period of 24 h and found daily values of 44.00 visits, about 1.83 visits per hour, corroborating the average of 1.50 visit observed in this study. The NDV values in the growing phase followed the same pattern found by Meiszberg et al. (2009), who verified the peak at 12:00 h. The finishing phase was characterised by an increasing number of visits until the last record, with the maximum point at 17:00 h (3.52 hourly visits). Andersen et al. (2014) showed that NDV increased during the afternoon, mainly after 16:00 h, which is similar to the pattern verified in this study; this may justify the higher NDV in the last record time. Although WD, TSD, and NDV are in accordance with what has been described in the literature (Brumm, 2006; Vermeer et al., 2009; Andersen et al., 2014; Rivest et al., 2015), at 13:00 h, increases occurred in TSD and NDV, which was antagonistic to WD. This fact possibly indicates that the highest amount of daily water waste occurred during these times, since the time and number of visits increased in relation to the registered WD volume.

## Conclusions

Water disappearance presented an increasing pattern during the animal housing period, which is proportional to dry matter intake and body weight. Water waste calculated represents a significant portion of water disappearance and shows the importance of developing further studies in this area, since the water that is wasted by the animals interferes with the amount of waste produced and impacts the sustainability of pig production systems. The daily patterns of water disappearance, time spent drinking, and number of drinker visits increase during the growing and finishing phases, and the period of greatest activity is after 13:00 h. However, the drinking activity during the finishing phase, although it presents a pattern similar to that in the growing phase, peaked in the last hour of the observation period.

## References

Andersen, H. M. L.; Dybkjær, L. and Herskin, M. S. 2014. Growing pig's drinking behavior: number of visits, duration, water intake and diurnal variation. *Animal* 8:1881-1888. <https://doi.org/10.1017/S175173111400192X>

- Brooks, P. H. and Carpenter, J. L. 1993. The water requirement of growing-finishing pigs – Theoretical and practical considerations. p.179-200. In: Recent developments in pig nutrition. 2nd ed. Coles, D. J.; Haresign, W. and Garnsworthy, P. C., eds. Nottingham University Press, Loughborough.
- Brumm, M. C. 2006. Patterns of drinking water use in pork production facilities. p.10-13. In: Proceedings of the 2006 Nebraska Swine Report. University of Nebraska, Lincoln.
- Brumm, M. C.; Dahlquist, J. M. and Heernstra, J. M. 2000. Impact of feeders and drinker device on pig performance, water use, and manure volume. *Journal of Swine Health and Production* 8:51-57.
- Gonyou, H. W. 1996. Water use and drinker management: a review. Annual Research Report, Prairie Swine Centre Inc. Saskatchewan, Canada.
- Hahn, G. L.; Gaughan, J. B.; Mader, T. L. and Eigenberg, R. A. 2009. Thermal Indices and their applications for livestock environments. p.113-130. In: Livestock energetics and thermal environmental management. DeShazer, J. A., ed. ASABI Publishing, St. Joseph.
- Hoekstra, A. and Mekonnen, M. 2012. The water footprint of humanity. *Proceedings of the National Academy of Sciences* 109:3232-3237.
- Kashiha, M.; Bahr, C.; Haredasht, S. A.; Ott, S.; Moons, C. P. H.; Niewold, T. A.; Ödberg, F. O. and Berckmans, D. 2013. The automatic monitoring of pigs water use by cameras. *Computers and Electronics in Agriculture* 90:164-169. <https://doi.org/10.1016/j.compag.2012.09.015>
- Kiefer, C.; Meignen, B. C. G.; Sanches, J. F. and Carrijo A. S. 2009. Resposta de suínos em crescimento mantidos em diferentes temperaturas. *Archivos de Zootecnia* 58:55-64.
- Li, Y. Z.; Chenard, L.; Lemay, S. P. and Gonyou, H. W. 2005. Water intake and wastage at nipple drinkers by growing-finishing pigs. *Journal of Animal Science* 83:1413-1422. <https://doi.org/10.2527/2005.8361413x>
- Madsen, T. N. and Kristensen, A. R. 2005. A model for monitoring the condition of young pigs by their drinking behaviour. *Computers and Electronics in Agriculture* 48:138-154. <https://doi.org/10.1016/j.compag.2005.02.014>
- Maselyne, J.; Adriaens, I.; Huybrechts, T.; De Ketelaere, B.; Millet, S.; Vangeyte, J.; Van Nuffel, A. and Saeys, W. 2016. Measuring the drinking behaviour of individual pigs housed in group using radio frequency identification (RFID). *Animal* 10:1557-1566. <https://doi.org/10.1017/S1751731115000774>
- Meiszberg, A. M.; Johnson, A. K.; Sadler, L. J.; Carroll, J. A.; Dailey, J. W. and Krebs, N. 2009. Drinking behavior in nurse piglets: Determining the accuracy between an automatic water meter versus human observers. *Journal of Animal Science* 87:4173-4180. <https://doi.org/10.2527/jas.2008-1737>
- Mroz, Z.; Jongbloed, A. W.; Lenis, N. P. and Vreman, K. 1995. Water in pig nutrition: physiology, allowances and environmental implications. *Nutrition Research Reviews* 8:137-164. <https://doi.org/10.1079/NRR19950010>
- NRC - National Research Council. 2012. Nutrient requirements of swine. 11th ed. National Academy Press, Washington, DC.
- Nyachoti, C. M.; Zijlstra, R. T.; de Lange, C. F. M. and Patience, J. F. 2004. Voluntary feed intake in growing-finishing pigs: a review of the main determining factors and potential approaches for accurate predictions. *Canadian Journal of Animal Science* 84:549-66. <https://doi.org/10.4141/A04-001>
- Piva, J. H. and Gonçalves, M. D. 2014. O Sistema wean-to-finish. p.111-120. In: Produção de suínos: teoria e prática. Associação Brasileira de Criadores de Suínos, Brasília.
- Ramonet, Y.; Chiron, J.; Eto, F.; Fabre, A.; Laval, A.; Nielsen, B.; Pol, F.; Prunier, A. and Meunier-Salaün, M. 2017. Abreuvement des porcs: état des connaissances et conséquences sur le bien-être des animaux et la gestion des effluents chez des porcs alimentés en soupe. *Journées Recherche Porcine* 49:139-150.
- Rigolot, C.; Espagnol, S.; Pomar, C. and Dourmad, J. Y. 2010. Modelling of manure production by pigs and NH<sub>3</sub>, N<sub>2</sub>O and CH<sub>4</sub> emissions. Part I: animal excretion and enteric CH<sub>4</sub>, effect of feeding and performance. *Animal* 8:1401-1412. <https://doi.org/10.1017/S1751731110000492>
- Rivest, J.; Labrecque, J.; Roy, M.; Ricard, M. and Fortin, F. 2015. Le système de mesure de la consommation d'eau individuelle pour les porcs à l'engraissement de la Station d'évaluation des porcs de Deschambault. *Journées Recherche Porcine* 47:149-50.
- Rydmer, L.; Lundström, K. and Andersson, K. 2010. Immunocastration reduces aggressive and sexual behaviour in male pigs. *Animal* 4:965-972. <https://doi.org/10.1017/S175173111000011X>
- Sampaio, C. A. P. 2004. Caracterização dos sistemas térmicos e acústicos em sistemas de suínos na fase de creche e terminação. Thesis (D.Sc.). Universidade Estadual de Campinas, Campinas, SP, Brazil.
- SAS® University Edition. 2017. Statistical Analyses System SAS/University Edition, © SAS Institute Inc.
- Schiavon, S.; Maso, M. D.; Cattani, M. and Tagliapietra, F. 2009. A simplified approach to calculate slurry production of growing pigs at farm level. *Italian Journal of Animal Science* 8:431-455. <https://doi.org/10.4081/ijas.2009.431>

- Seddon, Y. M.; Farrow, M.; Guy, J. H. and Edwards, S. A. 2011. Can monitoring water consumption at pen level detect changes in health and welfare in small groups of pigs? p.13. In: Proceedings of the 5th International Conference on the Assessment of Animal Welfare at Farm and Group Level. University of Guelph, Guelph.
- Shaw, M. I.; Beaulieu, A. D. and Patience, J. F. 2006. Effect of diet composition on water consumption in growing pigs. *Journal of Animal Science* 84:3123-3132. <https://doi.org/10.2527/jas.2005-690>
- Smolders, M. A. H. H. and Hoofs, A. I. J. 2000. Unrestricted drinking water supply for finish pigs on liquid feed with by-products. Research Institute for Pig Husbandry; Report No.:P4.45. Amsterdam.
- Tavares, J. M. R.; Belli Filho P; Coldebella, A. and Oliveira, P. A. V. 2014. The water disappearance and manure production at commercial growing-finishing pig farms. *Livestock Science* 169:146-154. <https://doi.org/10.1016/j.livsci.2014.09.006>
- Vermeer, H. M.; Kuijken, N. and Spoolder, H. A. M. 2009. Motivation for additional water use of growing-finishing pigs. *Livestock Science* 124:112-118. <https://doi.org/10.1016/j.livsci.2009.01.009>
- Wei, S.; Guo, Y. and Yan, P. 2019. Comparison of two housing systems on behaviour and performance of fattening pigs. *Journal of Applied Animal Research* 47:41-45. <https://doi.org/10.1080/09712119.2018.1561372>
- Whittemore, C. T. 2006. Requirements for water, minerals and vitamins. p.404-416. In: Whittemore's science and practice of pig production. 3rd ed. Whittemore, C. T. and Kyriazakis, H., eds. Blackwell Publishing, Oxford.
- Whittemore, E. C.; Kyriazakis, I.; Emmans, G. C. and Tolkamp, B. J. 2001. Tests of two theories of food intake using growing pigs 1. The effect of ambient temperature on the intake of foods of differing bulk content. *Animal Science* 72:351-360.