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Impacts of nipple drinker position on water intake, water wastage and drinking duration of pigs

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Abstract: Water determines the life quality of pigs, however, adequate measures need to be taken in order to reduce wastage while the animals are drinking. The current study hypothesized and examined a suitable position at which to fix the nipple drinker to provide sufficient drinking water to pigs while also limiting water wastage. Additionally, this study describes both the drinking pattern and drinking duration of pigs. The height to place the drinker was calculated based on the neck movement of the pigs (neck movement angle, NMA). According to the NMA, 3 independent treatments were investigated with angles placed at clockwise 30°, 0°, and counter clockwise 30°. These positions will be correspondingly referred to as T1, T2, and T3, respectively. To understand the diurnal drinking pattern and drinking duration, along with each pig's drinking cycle, the number of visits to the drinker was recorded with a camera. The outcome shows that T3 had less water wastage and a higher average daily gain compared to T1 and T2. Further, the number of visits to the drinker and drinking duration were affected by the treatments. The research affirmed that the nipple drinker with a counter clockwise 30° angle at a proper height is the best at reducing water wastage for finishing pigs. Correspondingly, the T3 treatment might create opportunities to drink more water in group housed pigs.

Keywords: Drinking pattern, drinking duration, nipple drinker height, water intake, water wastage

1. Introduction

Water is the most significant requirement for every living thing. In livestock production, it is the most fundamental dietary requirement for the development and enrichment of animals. The total body weight of an animal is made up of almost 70% water and dehydration problems begin to occur if the loss deviates 5% from the standard mean [1,2]. In the case of livestock animals, water consumption is more crucial than feed intake. Further, scarcity of water might result in decreased feed consumption, lessening excretion rates, and medical complications [3,4]. Around 82% of a piglet's body weight is water and this percentage steadily declines to about 50%–55% before it reaches the market weight of 100 Kg [5]. This implies that water contains a substantial part of weight growth during a pig's lifespan. A sufficient water supply plays a vital role in the growth rate of pigs. In addition, water utilization is a key area used to monitor a pig's behaviour. Apart from being the main contributor to the pig's body tissue and metabolic capacities, water is utilized for the regulation of body temperature, mineral homeostasis, and excretion, along with the fulfilment of satiety and social needs [6]. Steady feed intake must be accompanied by higher water consumption as feed intake is strongly correlated with water intake [7]. On average, up to 6.8 L of water a day is the prerequisite for a growing finishing pig in thermo-neutral condition [8].

The choice of feeder and drinker is the initial step to achieve a superior weight in pigs [9]. Previous studies reported that the water intake of pigs using a nipple drinker is comparatively higher than water bowls. Since the water fouled with the feed or faeces, the water intake from the bowl declined when compared to nipple drinkers [10]. Though the water wastage is higher on nipple drinkers than in water bowls, it concluded that pigs prefer to drink from nipple drinkers rather than bowls or troughs [11]. Growing-finishing pigs may waste up to 60% of the water from an ineffectively managed nipple drinker. The amount of water wastage from nipple drinkers can be considerably reduced by adjusting the height of the drinkers [12]. It is tough to place nipple drinkers at a preferable height since the manufacturers consider the shoulder height of the pigs as their total height. The total body height of a pig should include their head and noses since they use their noses

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to access the nipple drinker. A pig can create up to 70° maximum extension angle by using the neck movement angle (NMA). It other words, they can significantly enlarge the access height using the nose length [13]. The movement of the neck (which includes the length from neck to nose) can modify the access height for the pig. Concurrently, to minimize the water wastage and provide adequate water intake without competition, the proper height to place a nipple drinker in a pig barn needs to be carefully considered.

Water intake is not solely determined by the influence of physiological requirements since behavioural mechanisms are also involved [14]. Pigs by nature are greedy water consumers; as well as playful near water, which may reduce the drinking opportunities for other pigs in the group-housed level [15]. Placing a nipple drinker in a comfortable position curtails their mischievous behaviour and competitive nature [16]. An advanced knowledge about drinking patterns grants a constructive grasp on how to provide adequate water at the appropriate time to pigs. Individual drinking patterns and drinking behaviour can accurately map out and predict the number of visits to the drinker, the duration of drinking and water intake in a day [17]. Extensive information about each pig's drinking duration, their number of visits to the drinker, and drinking regularity can give a clear answer to where the location of the drinking facility should be placed so as to avoid any potential problems. These days, cameras are the preferably equipment to employ when observing animals. Top viewed complementary metal-oxide-semiconductor (CMOS) cameras are a capable device for recording videos of all the activities in a pigpen. After taking all these factors in for consideration, the current study hypothesized to examine a suitable position for fixing the nipple drinker to provide adequate drinking water with minimum water wastage for finishing pigs[1]. Furthermore, this study intends to describe the relationship between the number of visits and drinking duration of a pig (along with the hourly drinking pattern).

2. Materials and methods

2.1. Animals and housing

The current research was conducted at the smart farm research centre of Gyeongsang National University. The Institutional Animal Care and Use Committee (IACU) (GNU-150508-R0029) approved the experimental procedure and collection of data. Three model pig barns were utilized to compare the three different heights of the nipple drinkers calculated by NMA. The heat transmission was reduced by nearly 40% in slatted floor barns compared to a concrete floor [18]. Each model pig barn had dimensions of 3.9 m width × 5.1 m length and 0.05 m thick roofs. In addition, each group of pigs was housed in a polypropylene copolymer slatted floor with a total area of 13.26 m^2, giving 2.21 m^2 per pig to decrease heat transmission. The rooms were mechanically ventilated with two ventilation fans in the front and backside of the barns. Each pig barn maintained the same controlled optimal environmental conditions inside; thus, this study used the term "thermo-neutral". Environmental parameters such as room temperature, humidity, and CO_2 were controlled through an automatic network control device to ensure thermo-neutral conditioned model pig barns.

2.2. Feed and water

Each trial building incorporates an automatic infrared sensor based feeder (Robust military automatic feed system, South Korea) integrated with the body weight and body temperature estimation scales. Twice a day (09:00 h and 17:00 h), pigs were offered nutritionally balanced dry feed to meet apparent digestible energy (DE) 3,500 kcal/kg as recommended. The pigs were provided 1.5–3.2 Kg/ day/ pig of dry feed as suggested by the IACU of Gyeongsang national university during the overall experimental time. The dry feed contains the essential supplements such as crude protein 18%; crude fat 4.5%; crude fibre 10%; crude ash 8%; calcium 0.5%; phosphorus 1.2%; lysine 0.9% and digestible crude protein (DCP) 12%. Individual feeding method followed to feed with the guide of feeder along with the infrared (IR) sensors. The feeder has an additional IR sensor which based on pig's movement assisted door close system framework to avoiding the dodge between pigs while entering into the feeder. If the water is excessively acidic (lower than 5), it can make corrosion in water pipelines; then again, pH level (higher than 8.5) can leave layered stores in the pipeline which can be able to reduce the performance of pipelines. Eventually, water pH maintained in the range of 5.5 to 8.5; pH as mentioned earlier range meets the recommended standard of drinking water for pigs.

2.3. Experimental design

Eighteen animals were assigned in total and split into 3 groups of 6 pigs per model pig barn. There were 2 gilts for every pig barn, which aids the social condition of drinking water in gatherings to avoid wastage of water. Without this, there would be an increase in water wastage due to inefficiency [16]. All the animals were cross breeds (American Yorkshire × Duroc) with an average height of 56.4 cm at the start of experiment and were 59.7 cm at the end. The total duration of the experiment was 12 weeks, which included 3 different periods. The research was repeated 4 times with different pig groups. The first 2 weeks of the trial was an adaptation period for the pigs to become accommodated to the new changes and

[1] Finishing pigs: The term is used for pigs weighing between 70 kg and 130 kg of body weight. The average weight of the pigs used for this research is 86.4–142.4 kg. Thus, this literature used the term 'finishing pigs'.

to create a stress free atmosphere within the groups. This period was named the preoperative stage. The next 8 weeks were deemed as the original test period and all the data needed for research was collected within this operative period. The following 2 weeks (postoperative period) was used to clean the pig barns and to examine the collected data. The nipple drinker was mounted in the middle of the wall to give comfortable access to it since pigs have a habit of defecating in the corners of a barn. This would have increased the spoilage rate [19]. Every model pig barn had a separate drinker near to the feeder with standard flow rates. The most notable difference between the 3 pig barns was the height of the nipple drinker. Other parameters, such as feed quantity, water quality, and environmental considerations, were proportionate. To measure water wastage, collection troughs were set under the water drinker in each pig barn. The CMOS cameras (mvBlueCOUGAR-X102eG, Matrix vision, Germany) were located on the rooftop to record top view videos of the whole pig barn. The drinking duration, the number of visits to the drinker, drinking regularity, and behaviour were observed manually from the video files. The practice of providing additional drinking opportunities treated all the pigs with the same importance. This study considers allowing more opportunities to the pigs as a "comfortable zone" in which to study them.

2.4. Angle calculation

As previously discussed, nipple drinkers placed straight out from the wall favour drinking access. Pigs would lift their heads marginally if nipple drinkers were mounted in a descending angle [12]. Nipple drinkers placed perpendicular to the wall that inclined downwards at 45° were based on the NMA. At the initial stage of the experiment, the total body height of the pigs, the shoulder height, and the neck-to-mouth length was recorded to calculate NMA. The lowest pig measurements were considered as the primary measurement of the model in this study to prevent water deficiency for the shorter pigs. An interim drinker sample was set up to find the maximum accessible angles for the pigs during the preoperative stage (first 15 days). Though previous studies have mentioned that pigs could move their heads up to 70°, the interim model observations affirmed that the maximum neck movement angle differs from the maximum drinker access height by the pig nose. From the noted measurements, a right-angled triangle simulated to find the height to fix the nipple drinker. For better understanding, a model diagram was sketched with the same dimensions(Figures 1 and 2). When considering triangles, trigonometry is an essential method to explain the design in terms of simple mathematical expressions. Sine and cosine [sin (θ) and cos (θ)] functions are commonly used to solve the angle and side calculation problems in the trigonometric method. In order to get the height from NMA, 2 angles [sin (θ) and cos (θ)] named θ_1 (angle created by the neck to nipple drinker) and θ_2 (nipple drinker to the neck) introduced to the model diagram. The functions of sin (θ) and cos (θ) expressed as follows:

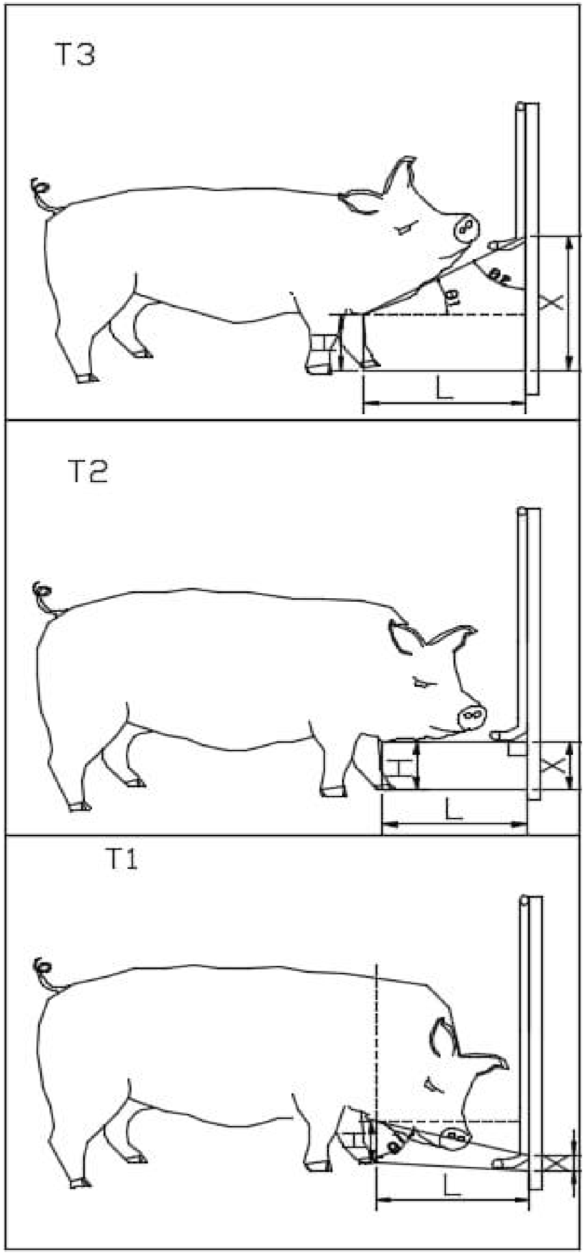

Figure 1. Experimental setup in 3 pig barns; T1 height is 24 cm from floor , T2 height is 46 cm from floor, T3 is 68 cm from floor.

$$\theta_1 = \frac{\text{Opposite side}}{\text{Hypotenuse}}, \ \theta_2 = \frac{\text{Adjacent side}}{\text{Hypotenuse}}$$

The pigs' mouths to neck length and shoulder to nipple height are assumed as sides of the triangle. Mathematically, they were labelled as the adjacent side (Y) and the

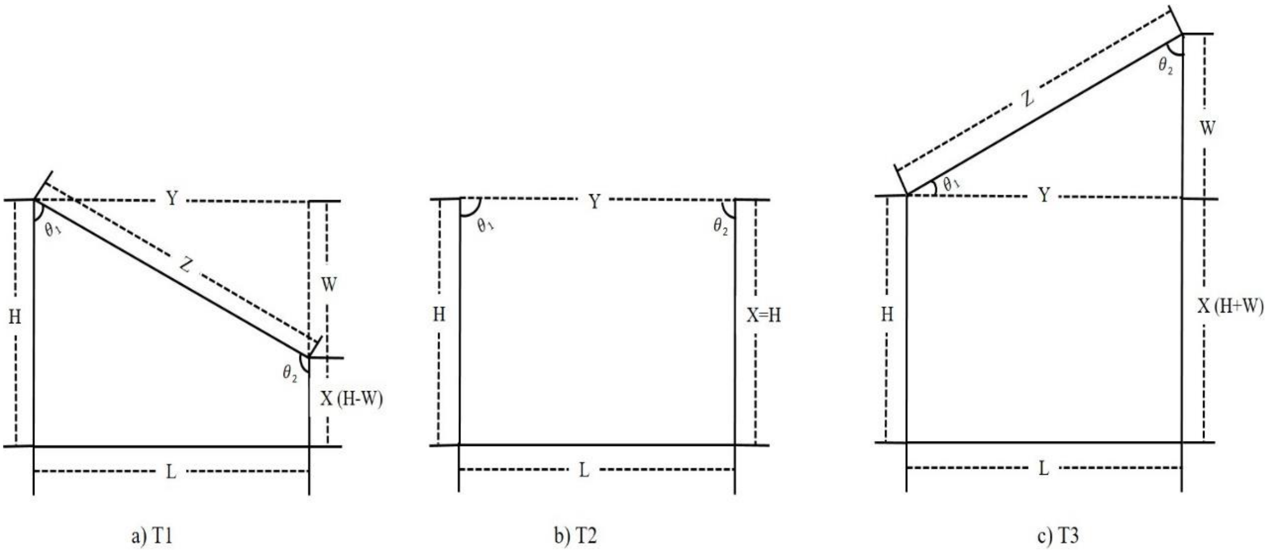

Figure 2. NMA model for fixing the water dispenser, H - Full shoulder height from the slatted floor, L - Measured as the base length, which distances between pigs standing positions, to the pig barn wall, Z - Nose length of the pig from neck, Θ - Angle of neck movement, X - Length found from the angle calculation; T1, T2, T3 considered as the various height positions of the nipple drinkers in 3 pig barns.

hypotenuse (Z). The θ_1 is considered horizontal to the wall of the pig barn, whereas the meeting point of Y and Z can be imagined as the starting point of θ_1. The critical angle for this research is the θ_1 found during the preoperative period; besides, the θ_2 was supporting as supplementary angle of the triangle. Accordingly, the adjacent side (X) was calculated by considering the shoulder height of the pig (H) and the calculated height through NMA (W). The upper angle followed in a counter clockwise direction and is considered positive whereas the lower angle followed in a clockwise direction (negative) from the starting point. Therefore, the W value was added with the height of the shoulder (H) for the higher end and subtracted for the lower end. Three treatments were introduced with their corresponding names, T1, T2, and T3, according to the height of the nipple drinker (Figures 1 and 2).

Treatment 1 (T1) – The lower end X (height of the nipple drinker) was obtained by subtracting W as detected by 30° NMA from H. The X was found to be 24 cm from the slatted floor by the results of the study. The angles according to the pig's NMA and value of X of all the treatments were described below (Table 1). W was subtracted from H since nipple height was inferior to H at the lower end.

Treatment 2 (T2) – The nipple drinker was mounted in the pig barn wall with a height of 46 cm from the slatted floor according to the NMA of 0°. Treatment 2 intended to examine the drinker's performance, which was placed at an equal height to the shoulder height of the pig.

Treatment 3 (T3) – Treatment 3 has the highest angle and height among all pig barns, which was calculated by the maximum angle which a pig can reach. The angle was considered as positive since θ_1 follows the counter clockwise; thus, the W value annexed with H. The nipple drinker was mounted on the pig barn wall with a height of 68 cm from the slatted floor according to NMA (30°).

2.5. Drinker and water measuring system

Providing clean and fresh water, along with uninterrupted access, can enhance the well-being of domesticated pigs. Limited access to drinking water may affect feed intake and weight gain. To avoid such limitations, an ad libitum water supply was offered to the experimental pigs. Since the present investigation depended on the drinking system, selecting an appropriate drinker was a high priority assignment in this experiment. Bite-nipple drinkers were selected for the study because they are especially structured for finishing pigs. Bite-nipple drinkers are wider than other drinkers and come with an easily accessed punched button. They were placed in all the pig barns (LUBING nipple drinker, model no 6131-5, Barnstorf, Germany).

One nipple drinker, with a flow rate range between 250–1000 ml/min, is enough to meet the water needs for 16 to 22 group housed pigs and bolsters satisfactory research results [12]. After considering the available literature, this study fixed the flow rate at 1000 ml/min by utilizing a water pump along with a pressure controller. A water pump with a pressure controller unit was utilized to control the pressure of the nipple drinkers which further ensured an ad libitum water supply (LUBING water supply, Barnstorf, Germany). A flow meter (a combination of a flow sensor and display meter) with an accuracy of ±0.5%

Table 1. Calculated angles and height to place the drinker using NMA.

	T1	T2	T3
θ_1(Angle created by the pig)	–30 °	0°	+30°
θ_2(Angle created from nipple drinker to pig mouth)	–60 °	0°	+60°
Height of the nipple drinker from slatted floor (H ± X) cm	24	46	68

was integrated into the water pipeline (Autoflow, South Korea). A calibration process was carried out by studying the flow meter to minimize device error.

2.6. Data collection and analysis

The water data was collected by utilizing a data logger which was integrated with the water meter. The collected data allowed for the analysis of water usage, hourly water drinking patterns, and peak drinking time calculations. The water intake was determined from the total water usage and water wastage. The water wastage was estimated by measuring the water inside the collection troughs daily. Water evaporation was considered and set at 5 ml for each pig per day and subtracted from the total quantity of water in the waste trough. Since the troughs were placed directly below the drinker, most often the excess does not seem to have fallen straight into the troughs. Therefore, this study excludes the impact of waste in the troughs. Water pump data was observed every day to verify water quality assurance. Furthermore, feed intake and body weight information were collected to calculate the average daily gain (ADG). Videos were examined manually whereas the videos taken at night-time were not examined comprehensively, due to the pigs' diurnal drinking pattern. The 24 h video was split into 3 shifts with one being the night. The afternoon is also a time of inactivity for pigs so, this study decided to focus intensely on the remaining 8 hours of video. Numbers were painted behind every pig to distinguish the pig from the group. This was used to affirm that every pig was drinking. The statistical analyses were performed using the statistical software SAS® software (SAS Inst. Inc., Cary, NC, USA) and SPSS 25.0 (IBM Corp., Armonk, NY, USA). The water usage and water wastage were analysed with a randomized analytical model to test the effect of the treatments. To test the relationships between the treatments, the water intake, water wastage, and water usage were grouped and analysed with a randomized model. Tukey HSD post hoc one way ANOVA analysis was used to find the effects of the treatments and a P-value of $P < 0.05$ was considered as a significance level with the corresponding confidence level being 95%. To find the linearity between the water variable group (water intake, water wastage, and water usage) and the time variables (number of visiting time and drinking duration), both were subjected to a linearity test.

3. Results

After setting up treatments T1, T2, and T3, this research examined the performances of the treatments using various methods of analysis such as water intake, water wastage, ADG, and lower number of visits. Though one of the major intentions of this experiment was to eradicate water wastage during drinking, additionally this experiment affirms that water intake is in terms of water intake measurement and ADG. The analysis between the water utilization variables and activity variables were analysed.

3.1. Analysis of water intake, water wastage and growth rate

During the experiment, the average room temperature was 25.3 °C with variations between 23.2 °C on the 6th week to 29.2 °C on the 5th week. The weekly average data was and reported in these results (Table 2). Likewise, all the pig data used in this part was calculated by averaging the total data. Experimental results clearly describe the effect of the treatments on water wastage and water usage but not on water intake. On average, water usage 17.98 ± 4.31 (mean ± SD), water intake 10.15 ± 0.02, water wastage 8.01 ± 4.43 liters per pig in a day was observed throughout the study. The Figure 3 shows that the maximum water wastage follows a similar pattern with water usage. It seems that water usage and wastage correlated positively in all treatments ($y = 1.0163x - 10.319$; $R^2 = 0.92$). Through observing the graph, the relationship between water usage and wastage showed a clear correlation. The mean difference in water usage between T2 and T1 was 14%, whereas T3 and T1 have an average 39% difference. T3 water usage was 64% less than T1 and 41% less than T2. The general water usage of T1 is higher than T2 and T3. Accordingly, the mean difference in water wastage between T2 and T1 was 27%, while T3 and T1 were 73%. T3 water wastage was 73% less than T1 and 61% less than T2. These results, proved the previous studies, report that 60% of water wastage increase if the nipple drinker height and flow rate are maintained poorly.

Most of T1 had a higher water usage, especially in the 2nd week (36% higher), where it reached the maximum of this study. However, by the end of the experiment, T1 was less than T2. Water intake was almost similar in all treatments and substantial differences between all the

Table 2. Effects of 3 treatmets on water usage parameters and visiting parameters. Significant effects are considered by P ≤ 0.05 based on Tukey's HSD post hoc test.

Trait	Treatment												P- Values
Trail (July-September)	T1				T2				T3				
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	
Water usage l/pig/day	21.87	2.80	19.8	27.9	18.75	1.77	16.3	21.2	13.33	1.46	11.7	16.3	0.000
Water intake l/pig/day	10.12	0.43	9.5	10.9	10.15	0.80	9.4	11.8	10.17	0.48	9.6	11.1	0.986
Water wastage l/pig/day	12.15	2.90	8.6	17	8.57	2.45	5.4	11.8	3.16	1.18	1.2	5.2	0.000
Wastage/usage %	55	-	-	-	45	-	-	-	23	-	-	-	-
Mean air temperature ^{0}C	25.3	2.23	23.2	29.2	25.16	2.13	23.4	28.9	25.25	2.11	23.05	29.1	-
Initial body weight of pigs kg/pig	89.6	1.81	87.2	92.4	90.1	1.9	86.4	92.1	89.2	1.7	86.9	92.1	0.987
Final body weight of pigs kg/pig	138.4	2.39	134.2	140.7	139.5	2.41	135.4	142.4	139.4	2.41	135.2	142.2	0.997
Average daily gain kg/day/pig	0.995	0.579	-	-	1.00	0.75	-	-	1.03	0.76	3.1	-	-
Drinking duration sec/day/pig	712.5	42.62	670	780	681.87	16.56	659	710	562.12	34.28	514	625	0.000
Number of visits time/day/pig	65.25	7.79	54	78	57.62	6.18	53	72	52.25	5.82	46	64	0.003

means was not observed. After calculating the mean difference, the study found that these results displayed very fewer changes among the treatments. Statistically, water intake was not affected by the treatments ($y = 0.0148x + 9.8833$; $R^2 = 0.011$), but a significant difference does exist (P = 0.98, P = 0.99 in T1, and P = 0.99 in T2) concerning the study's treatments effects on water wastage (P = 0.00; P = 0.02 in T1 and P = 0.02 in T2). The water intake data was different for various reasons such as the individuality of the pigs, feed intake, and environmental parameters. Besides, the weekly average gain proves water intake does not affect the growth rate or weight gain of a pig. However, there is no significant difference among the treatments on weekly daily gain (P = 0.97). Still, the results project the gain of T3 is higher than other treatments (T1 = 0.76; T2 = 0.77; T3 = 0.78). Accordingly, the same amount of food and the same amount of water intake lead to stable weight gain in all three treatments. The distinct patterns of the water-based variables with more detailed manner below (Figure 3).

No dramatic changes in growth rate or water intake were observed after the pigs grew to more than 110 kg. Especially in 2nd week, the ADG of the entire week among the treatments was comparably higher than all weeks, (1.71 l) whereas after 4 weeks the ADG follows valid mean values since pigs moved past the grower stage. Moreover, the entire pig barn supports an inconsistent utilization of water between the 3rd and 4th week of experiments along with no evidence of temperature changes observed during the experiment time. Water usage and wastage graphs show that T1 was higher in the first 4 weeks before it moves downwards, whereas T2 follows vice versa. Treatment effects on water intake there was no significance difference found between individual treatments as well as total group (P = 0.996; 0.996; 0.985; 0.986), treatment effects on water intake there was significance difference found between individual treatments as well as total group (P = 0.014; 0.014; 0.000; 0.000) (Figure 4). By analyzing the temperature effects in water intake, a significant difference does exist between the 2 variables other than temperature. Since the outside environment, such as rainfall, solar intensity, and humidity may cause inconsistencies in water intake, that data was not collected during this experiment.

3.2. Drinking pattern of pigs

The water consumption habits of finishing pigs have a distinct daily pattern. The average everyday water intake of an individual pig is explained below (Figure 5). Pigs follow two different distinguished patterns of water intake during the day and night. Due to their diurnal pattern all the activities, such as water intake and the number of visits, are comparatively higher in the daytime. These activities, both water related and behavioural related, are much lower during the night. More specifically, if the feed was consumed, then the water needs of the pigs also increased. In this experiment, dry feed was used to feed pigs, so the maximum water requirement was needed after food consumption. Pigs began drinking water at around 6 am with a peak after feeding. This was followed by a gradual decline for the remainder of the day. During 10:00 h —, 19:00 h, the first and second peak drinking time was observed from data, the peak time of pig's water intake followed by 2.1 and 1.7 L/pig/day (Figure 3). The drinking duration and the number of visits to the drinker vary according to the time of the day.

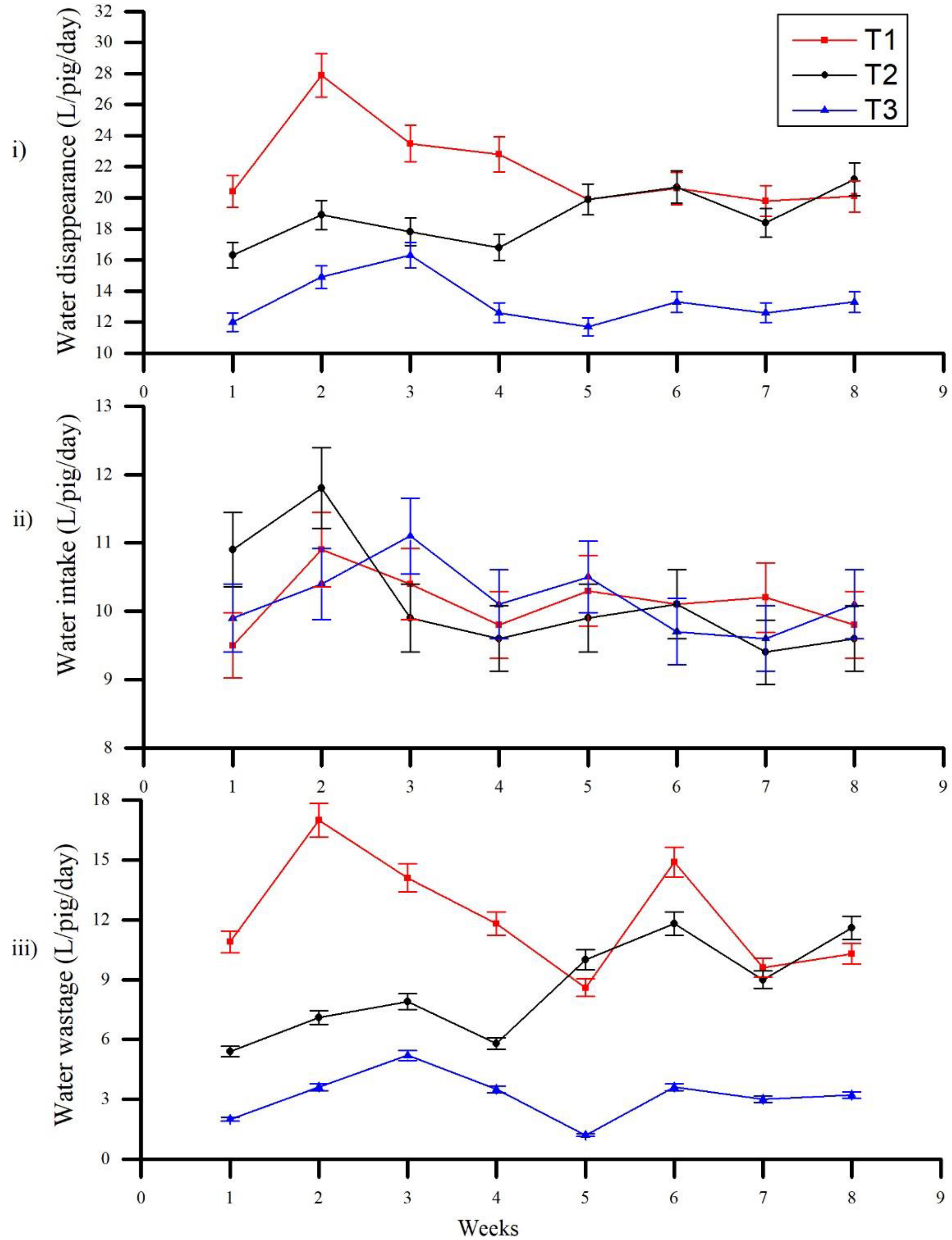

Figure 3. i) Represents the effect of 3 treatments on weekly average water usage (water dissaperance) per pig for 8 weeks , **ii)** Represents the effect of 3 treatments on weekly average water intake per pig for 8 weeks, **iii)** Represents the effect of 3 treatments on weekly average water watsage per pig for 8 weeks. All these error lines showing the standered error (SE) and the weekly average data was calculated from l/pig/day. All of the x-axis represents the weekly data.

Pigs spend more time at the drinker in the day. The number of visits in a day was highest in T1 (65.25 ± 7.79 visits/day) and lowest in T3 (57.62 ± 6.18 visits/day). The water usage and the number of visits were positively correlated (y=5911x + 29.755; R^2 = 0.61). All treatments were not significantly different in the number of visits and the effects of the treatment in T3 were (P = 0.003; P = 0.079 in T1, P = 0.079 in T2 and P = 0.002 in T3). Though T1 and T2 have no significant effects on treatment, it was significant on a group level. The lower number of visits to the drinker may lead to more drinking opportunities for all the pigs, which was considered in previous studies [16].

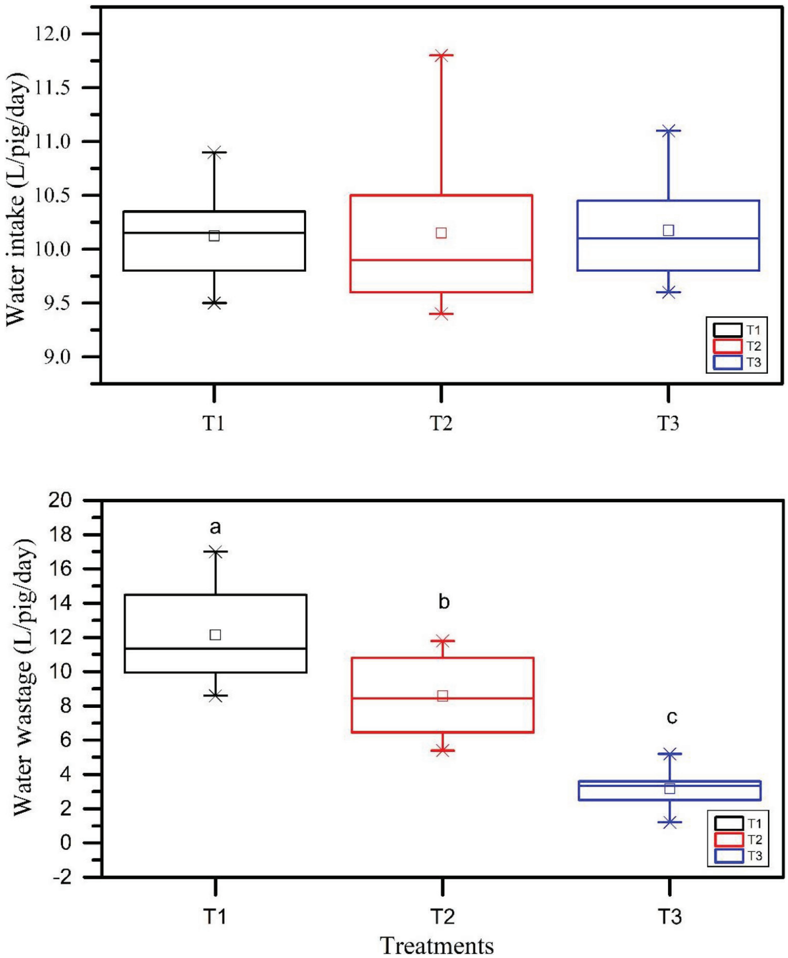

Figure 4. Data represent means and standard deviation (SD) of 3 treatments. Different letters above the bars (SD) denote significant differences among treatments at P ≤ 0.05 based on Tukey's HSD post hoc test. **i)** Treatment effects on water intake there was no signficance difference found between individual treatments as well as total group (P = 0.996, 0.996, 0.985, 0.986), **ii)** Treatment effects on water intake there was signficance difference found between individual treatments as well as total group (P = 0.014, 0.014, 0.000, 0.000).

When comparing all the treatments, T3 has the lowest drinking duration of 9.36 min/pig/day, which is similar to previous literature, whereas T1 and T2 were 11.87 min and 11.36 min (Table 2), accordingly. The average drinking duration from all the treatment was 10.86 ± 1.32 min/pig/day. From the observations, the effect of the treatments was significant on drinking duration between the groups but not between T1 and T2 (P = 0.00; P = 0.17 in T1, P = 0.17 in T2, P = 0.00 in T3). Like water usage and the number of visits, water usage was positively correlated (y = 16.473x + 355.85; R^2 = 0.85). However, the drinking duration increased more than 21% over the 24 h pattern in T1 than in T3 showing that the number of visits and duration of drinking time does not affect water intake of the pig. When considering the 24 h pattern as day and night, the night has no significant effect on visiting length and visiting time. Accordingly, the lowest number of visits to the drinker was found at night for all treatments. However, the overall combined analysis shows that the relationship between drinking duration and water wastage was linear (y = 0.394x - 15.036; R^2 = 0.57). Likewise, number of visiting times and water wastage were also linear (y = 16.473x + 355.85; R^2 = 0.85). The number of visiting times near to the drinker and longer drinking times did not affect intake. However, an increase in visiting times saw the usage and wastage increase. It is worth noting that when exhausted or feeling hot, pigs play with the drinkers, which increased water wastage while leaving intake the same. This is considered a physiological need and not coupled with the intake data [20]. These studies mention that the number of

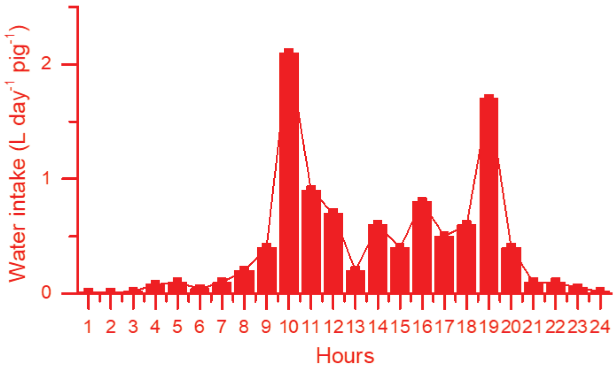

Figure 5. Data represent the hourly water intake by a pig in a day with the two-peak time (10.00 and 19.00 h). These box plots based on the 24-h time interval and the line graphs showing the limit of water intake.

visits did not increase the water intake of pigs more than water usage.

4. Discussion

4.1. Water intake, water wastage and growth rate

Water is the most essential nutrient to support life and yet, it is often taking for granted [6]. An inadequate supply can result in devastating consequences such as overheating, stress, and even death in extreme cases [21]. Providing adequate water with minimal water wastage is a challenge for every livestock producer. Meanwhile, most modern livestock buildings trust nipple drinkers as a preferable watering source thinking they are more efficient. However, several reports reveal that nipple drinkers at a lower height lead to more water wastage since pigs can access them with their noses. There is a higher quantity of water wastage when the drinkers are not at an appropriate height, as recognized by previous research (Table 2)[6]. Additionally, the current study exhibited that the height calculated by neck movement angle (NMA) can substantially reduce water wastage in pig barns. Pigs can adapt their drinking time and drinking speed according to the situation [15]. The suitable height was achieved by placing the nipple with an angle of 30° above the shoulder height of the pig. When the drinker is higher than the measured height by NMA, pigs have difficulty accessing the nipple drinker while younger, so there might be higher wastage. The current research asserts that the T3 with 30° NMA (68 cm from the slatted floor) significantly minimized water wastage along with the usual intake.

The actual water intake of finishing pigs are independent of drinker type, height, and flow rate; meanwhile, water wastage is dependent on those parameters [11,12]. The water spillage increases when the flow rate crosses the threshold level (500–1000 ml/min), regardless of the water intake of the pigs [6,11,12]. The water intake and diurnal drinking patterns were similar in all the treatments since thermo-neutral conditions were maintained in the pig barns (Figure 3). Predicicala and Alvarado, (2014) reported that the water intake of a pig was 8.17 L/day, whereas Chimainski et al. (2019) mentioned 7.981 L/day [22, 23]. The current study results expressed that pigs drink 10.15 L/day, which is higher than the previous studies; moreover, the ADG (1030 g/day) of T3 was slightly higher than Li et al., (2012) study (866 g/day) findings [19]. When the drinker was placed at a lower height (T1), then the wastage is 61% more than in other treatments. Though T3 treatment reduced water wastage, 24% spillage was observed with the flow rate of 1000 ml/min maintained by the water pressure controller.

4.2. Drinking pattern of pigs

In a group house level, water intake pattern of pigs follow a stable diurnal pattern unless affected by disease [24, 25]. Prior stats imply that individual drinking patterns are one of the potential tools for disease monitoring in pigs [15]. Throughout the growing period, pigs consume 75% of their daily water intake before, during, or after feeding. These are considered as the peak time of the drinking pattern [26]. Peak times are inevitable times in the drinking pattern. In addition, personal and intensive care during and after the time of feeding needs to be consider. Two peak times during 24 h (10:00 and 19:00 h) were found during this experiment and special care about the uninterrupted water supply and drinking regularity of the pigs was required.

Proper management of the animal is the first step towards reaching the goal of precision, animal welfare conscious livestock farming [27]. A lower number of visits by one pig might create additional drinking opportunities to other pigs. Increasing the visits may not increase the intake. Instead, it may minimize the drinking opportunities of other pigs, especially in a group-housed environment [28]. The back-numbered marks helped to identify the drinking regularity of each pig. Accordingly, video observation in T3 verified that all the pigs have enough time to drink water since the visits were low (52.25 ± 5.82 visits/day). In the present study, the drinking duration in a 24 h period (average of all treatments) an individual is 10.86 min/pig, which is higher than Turner et al., 1999 report (9.3 min/day)[29]. However, T3 had a 9.3 min/day/pig average, which was comparable to previous literature. The video camera showed that if nipple drinkers are placed at a low height then the visiting time to the drinker increases significantly. In the end, setting up a water supply based on the NMA achieved the expected results, while also reducing the visiting competition, thereby creating a comfortable environment for pigs to drink water. More knowledge is required to become fully aware of how stress can effect a livestock population. These considerations will be researched next in a stress related study.

The nipple drinker placed based on NMA significantly influenced the water wastage and average daily gain of the finishing pigs. However, the nipples at a lower angle led to much higher water wastage. Though water intake looks similar in all the treatments, the water wastage was minimized up to 31% when the drinker was placed at a counter clockwise 30° (T3) compared to T2 and T1 (clockwise 30°). The pattern of drinking, including peak time and the down time, needs to be addressed for the ultimate production of modern pig barns. Extra care during the peak times, which are dependent on the feeding times, will improve production. Consequently, the nipple drinker at a high position has a low number of visits and the lowest drinking duration time. Among the 3 treatments, T3 had the least amount water wastage, the highest average daily gain and provided the most comfortable, behavioural condition for the pigs. This research concluded that the height of the nipple drinker calculated at 30° of NMA has the best performance and creates a comfortable environment for the finishing pigs.

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Conflict of interest

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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