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Major professor

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EFFECT OF WATER FLOW RATES ON PERFORMANCE OF NURSERY PIGS
AND INFLUENCE OF PRESSURE ON FLOW RATE FROM NIPPLE WATERER

By

Jose Enrique Celis

A THESIS

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ABSTRACT

EFFECT OF WATER FLOW RATES ON PERFORMANCE OF NURSERY PIGS
AND INFLUENCE OF PRESSURE ON FLOW RATE FROM NIPPLE WATERER

By

Jose Enrique Celis

The effect of water flow rates on performance of pigs weaned at 28 days of age was studied. In Trial I, ninety six pigs were allocated in eight 1.22 x 2.44 m pens with 2 drinkers per pen. In Trial II, forty eight pigs were allocated in eight 1.22 x 1.22 m pens with one drinker. Pigs in both trials were given access to a water flow rate of 70 and 700 ml/min for 28 days. Results from Trial I demonstrated that rate of gain, feed intake and feed conversion decreased significantly for pigs on the 70 ml/min water flow rate at week 4 after weaning. In Trial II there were not statistically differences on pig performance. For pigs heavier than 16 kg housed at temperatures higher than 26°C, the water flow rate should be increased above 70 ml/min.

The effect of water pressure on the variability of water flow rate was evaluated. The water flow rate was measured for a 35 to 400 KPa range of pressure. It demonstrated that if the water supply system provides pressures in the range of 140 to 400 KPa, the nipple waterer studied will repeatedly supply either 70 or 700 ml/min water flow.

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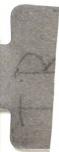
TABLE OF CONTENTS

LIST OF TABLES	v
LIST OF FIGURES	vi
1. INTRODUCTION	1
1.1 Background	1
1.2 Objectives	4
2. LITERATURE REVIEW	5
2.1 Water Function in Animals	5
2.2 Water Requirements of Pigs	7
2.3 Behavioral Response of Early Weaned Pigs	12
2.4 Variability of Flow Rate on Frequent Watering ..	13
3. METHODOLOGY	16
3.1 Experimental Facility and Animals	16
3.2 Trial I	16
3.3 Trial II	19
3.4 Management	19
3.5 Determination of Water Flow Rate and Pressure ..	22
3.6 Statistics	24
4. RESULTS	25
4.1 Trial I	25
4.2 Trial II	29
4.3 Behavioral Response of Nursery Pigs.....	30
4.4 Pressure and Water Flow Rate Variability	33
5. DISCUSSION	37

6. CONCLUSIONS	42
BIBLIOGRAPHY	44
APPENDICES	46
Appendix 1. Repeated measures analysis of variance for weekly growth rate (Trial I)	46
Appendix 2. Repeated measures analysis of variance for average daily gain (Trial I)	46
Appendix 3. Repeated measures analysis of variance for weekly feed intake (Trial I)	46
Appendix 4. Repeated measures analysis of variance for feed:gain ratio (Trial I)	47
Appendix 5. repeated measures analysis of variance for drinker contact (Trial I)	47
Appendix 6. Repeated measures analysis of variance for weekly water intake (Trial I)	47
Appendix 7. Repeated measures analysis of variance for water:feed ratio (Trial I)	48
Appendix 8. Repeated measures analysis of variance for weekly growth rate (Trial II)	48
Appendix 9. Repeated measures analysis of variance for average daily gain (Trial II)	48
Appendix 10. Repeated measures analysis of variance for weekly feed intake (Trial II)	49
Appendix 11. Repeated measures analysis of variance for feed:gain ratio (Trial II)	49
Appendix 12. Repeated measures analysis of variance for drinker contact (Trial II)	49
Appendix 13. Repeated measures analysis of variance for weekly water intake (Trial II)	50
Appendix 14. Repeated measures analysis of variance for water:feed ratio (Trial II)	50
Appendix 15. Individual weights for Trial I	51
Appendix 16. Individual weights for Trial II	54

LIST OF TABLES

3.1 Treatment combinations for Trial I	19
3.2 Treatment combinations for Trial II	21
4.1 Effect of water flow rate on overall performance of nursery pigs (Trial I)	26
4.2 Weekly effect of water flow on mean weight, daily gain, feed intake and feed:gain ratio (Trial I) ..	27
4.3 Weekly effect of water flow rate on drinker contact, water intake, and water:feed ratio (Trial I)	28
4.4 Effect of water flow rate on overall performance of nursery pigs (Trial II)	30
4.5 Weekly effect of water flow on mean weight, daily gain, feed intake and feed:gain ratio (Trial II)..	31
4.6 Weekly effect of water flow rate on drinker contact, water intake and water:feed ratio (Trial II)	32
4.7 Weekly flow rates and pressure for Trial I	34
4.8 Weekly flow rates and pressure for Trial II	36



LIST OF FIGURES

1.1 Type and duration of protective immunity	2
3.1 Floor plan of the nursery room	17
3.2 Distribution of treatments in eight 1.22 x 2.44 m pens for Trial I	18
3.3 Distribution of treatments in eight 1.22 x 1.22 m pens for Trial II	20
3.4 Experimental equipment to measure water flow and pressure	23
4.1 Effect of pressure on water flow rate	35

1 INTRODUCTION

1.1 Background

One of the most crucial periods in swine production occurs after pigs are weaned and moved from farrowing units to nursery facilities at 3 to 5 wks of age. At this age, the pig is unable physiologically and immunologically to survive adequately in a stressful environment. The active antibody production in the young pig begins at approximately three weeks of age (Figure 1.1). During the wk 3 and 4 after birth, the pig is highly susceptible to certain diseases. At this point it is crucial to provide optimal environmental and nutritional conditions that allow the pig to make adjustments as rapidly as possible. Yet environmental and nutritional needs change quickly.

On the other hand, profitability in swine production depends upon maximizing annual production in terms of pigs marketed per sow. In consequence, weaning age becomes a compromise between allowing the pig's own active immunity mechanisms to be completely developed and minimizing the time in the farrowing facility (Leman et al., 1986).

Intensive farming is continually being developed, and a greater number of animals are being housed within artificial environments to satisfy production demands. This may

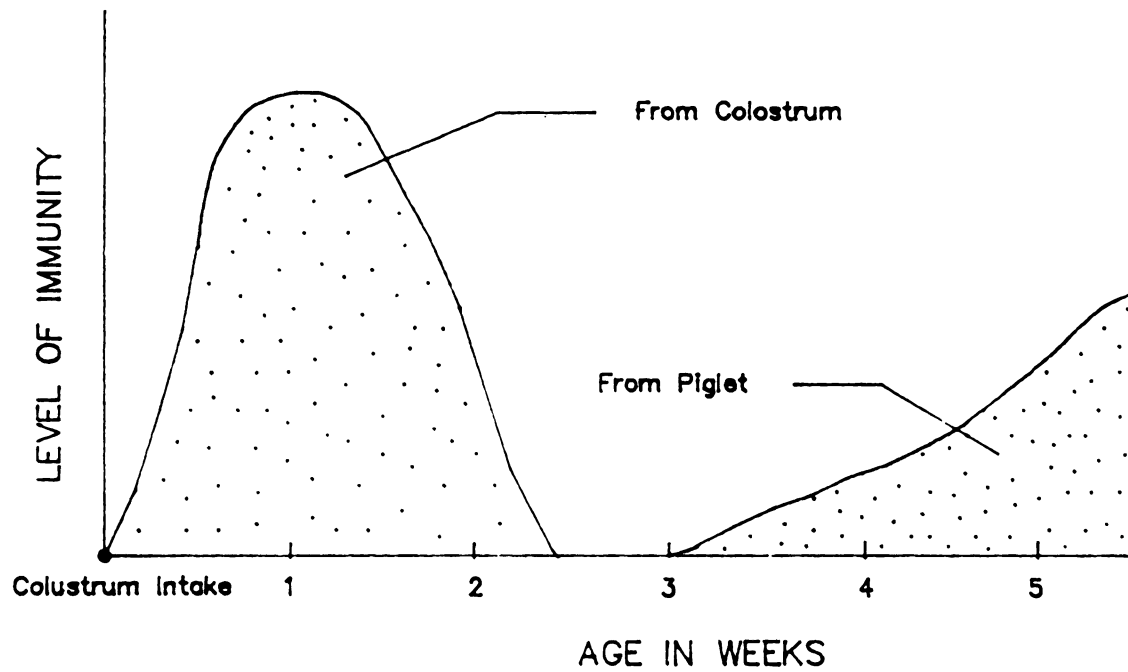


Figure 1.1 Type and duration of protective immunity (Brent et al., 1975).

induce stress on the animal in cases of high stock densities or poor farm layout (Curtis, 1983). Inadequate space in indoor housing, water supply, food provision and trough space could produce animals that develop a dominant behavior at the expense of subordinate animals. The result would be a deterioration of health and general production.

Among the nutrients required by livestock, water is considered to be one of the most important compounds, as it represents 71 to 73 percent of the fat-free body weight (Brent et al., 1975). Water is as important as feed for swine production since a reduction of water consumption may reduce feed intake thus causing a reduction in growth rate and worsening feed conversion. There is a major difference between the water needed for survival and that needed for optimum growth.

The effect that daily water intake, optimal flow rates, number of pigs per drinker, water quality, drinker location and configuration have on performance of nursery-age pigs are not clearly understood. Although, there are studies indicating that pigs tend to adapt to the time they are allowed to spend drinking (Yang et al., 1981; Nienaber and Hahn, 1984). However, water flow rates for optimal production are still unknown.

Blockage, distance from the water pump and loss of pressure have an undesirable effect on water distribution systems by decreasing the water flow rate. On the other hand, too much water results in waste, wet sleeping areas,

increased slurry disposal and raised humidity in rooms. Another important factor to consider when designing a pipeline water distribution system is that high pressure can decrease water consumption. Also, a high head loss decreases the flow rate, so that the pigs do not receive enough water due to exhaustion from extended drinking periods (Olsson and Andersson, 1985). Hence, a well designed water supply system must allow the pigs adequate water supply and must operate at low cost. Although water consumption is important for pigs to produce at an optimum level, this component of pig production is often overlooked and there has been very little research on the subject.

1.2 Objectives

1. To determine the influence of water flow rates provided by nipple valves on performance of pigs weaned at 28 days of age.

2. To study the variability of the flow rates in order to provide design specifications for water distribution systems in nursery facilities.

2 LITERATURE REVIEW

2.1 Water Function in Animals

It is well documented that animals cannot produce to their potential without adequate feed and water intakes (Curtis, 1983). Water is one of the most vital nutrients that animals need to live. They are able to survive longer without feed than water.

Ensminger (1962) stated that because this nutrient exists in abundance and can be provided at low cost, little emphasis has been given to water as compared to other nutrients under normal conditions. The question why not then provide water in abundance can be answered by taking into account some important limiting factors on the pig's performance. First, an excess of water will increase wastage, therefore deteriorate the pen's hygienic conditions. Secondly, an increased water supply would require a larger pump and pipeline distribution system, which is directly related to higher investment costs.

Water is considered to be one of the largest single constituents of the animal body. It ranges from 40 percent in older pigs to 80 percent in newborn pigs. Ensminger (1962) determined that the amount of water in the body of an animal depends on its age and condition. As a rule, the

younger the animal the more water it contains.

An older animal has less water per unit of body weight than a young animal because smaller animals consume less feed per unit of weight, and the water of its body is being replaced by fat. This is why gains in older animals are more costly than equivalent gains in younger animals.

According to Ensminger (1962) and Gillespie (1981), water has many functions in animals and can be summarized as follows:

1. It is vital to the life and condition of every cell of the animal body.

2. It assists with temperature regulation in the body, so that the animal can control its temperature by perspiration in hot environments. But pigs do not regulate their rate of perspiration in response to environmental conditions.

3. It is fundamental for many of the chemical reactions such as digestion and metabolism which take place within the animal's body.

4. It acts as a carrier of the nutrients to different parts of the body and removes waste products from tissues and organs.

5. It helps to dissolve nutrients the animal consumes.

Hence, adequate amounts of fresh, clean water is necessary for animals to grow and produce for the benefit of people.

Curtis (1983) indicates that dehydrated animals are

less heat tolerant than normal animals because dehydration reduces their ability to regulate body temperature by evaporation.

2.2 Water Requirements of Pigs

At present, water is often supplied by automatic drinking systems that can be equipped with heaters to keep the water from freezing when temperatures are extreme.

The most common type of equipment for automatic systems are nipple-type or bite waterers which are low cost, allow free access and provide clean water. They are generally located in the dunging area to maintain the desired dunging pattern and preserve hygienic conditions in the pens.

Another practical system to provide water automatically to pigs is the nose valve. In general nose valves are located above the feeding trough, so when the pig wants to drink, it pushes the valve using its nose. Since the pigs tend to play with nose valves or attempt to cool themselves in warm weather, it could result in the release of more water than needed causing wet feed, wet flooring, reduced manure storage time and increased labor. To control this undesirable situation, watering periods may be restricted only to the feeding periods by a preset timer control (Olsson and Andersson, 1985). Olsson (1983b) found that watering only at feeding times may result in a lower water consumption, which may limit growth rate. He studied the effect of the learning period for a nose valve system on 20



kg pigs. The results showed that the learning period was affected by such factors as the pressure necessary for the pig to release the water, the location of the nose valve in relation to the feeder and the size of the valve button. He concluded that the weight gain performance of the animals was affected by this type of valve because of a low water consumption which was a limiting factor on the growth rate of pigs.

A great number of variables are related to water consumption. Most of them have yet to be determined with precision. Clearly, weight gain of pigs depends on water consumption. Large daily gains will require large amounts of water (Baxter, 1984). According to Gillespie (1981), a continuous supply of water to animals is necessary for rapid growth and efficient production. When animals do not have an adequate water supply, there is inhibition of use of the other nutrients supplied in the feed. However, studies performed on young pigs recently have not clearly supported that point. Carlson and Peo (1982) found that a group of animals that gained less weight consumed 37 percent more water. Another group presented no difference between growth rate and feed conversion from water intakes of 0.6 to 1 l.d⁻¹.pig⁻¹.

The Agricultural Research Council (1981) has summarized the water requirements according to classes of pigs. Typically, growing pigs need between 1.5 to 2 l per day at 15 kg liveweight and 6 l per day at 90 kg liveweight. Non-

pregnant sows require 5 l of water daily, while pregnant sows need 5 to 8 l per day and lactating sows need between 15 to 20 l per day.

Baxter (1984) proposed that the water intake of pigs is a function of their need to maintain an adequate water balance. The pig will adjust the water intake until it equalizes the amount of water stored in body tissue plus the amount lost by the body. It can be denoted as

$$W(\text{intake}) = W(\text{stored}) + W(\text{lost})$$

Water consumption depends on environmental conditions, diet, quality of water, animal size and physiological function (Nienaber and Hahn, 1987). Ensminger (1970) had previously made a similar statement, stating that the higher the temperature the greater the water consumption. At that time he found that water intake of pigs at a high room temperature can be as high as 4 kg of water per kg of dry feed. The amount of water lost by the animal's body is a function of environmental temperatures; therefore, Baxter (1984) indicated that at high room temperatures the water consumption of pigs may be increased by as much as 100 percent. Mount et al. (1971) reported that 21 kg pigs presented no difference in water consumption between 7, 9, 12, 20 and 22°C, but when the temperature was increased to 30 and 33°C the water intake was considerably increased.

According to Curtis (1983), water restrictions of 25 to

50 percent of the requirement may lead to dehydration which is especially notable when animals are growing in a hot environment. In fact, the hotter the environment, the more quickly animals become dehydrated. Also, water restriction appears to decrease productive performance of pigs due to the feed-intake rate decreases with reduced water intake. Church (1984), demonstrated that water restrictions would result in a reduced rate and efficiency of weight gain in pigs and reduced milk production in lactating sows.

Under normal feeding and environmental conditions the water consumption of animals is a function of feed intake. In general, the water requirements of lactating sows and their litters is satisfied by supplying two parts of water to one part of feed (Baxter, 1984). The Agricultural Research Council (1981) showed that early weaned pigs can satisfy their needs at a water to feed ratio of 2:1. Some studies suggest that young pigs can tolerate variances in the water supplied (Carlson and Peo, 1982). Even newly weaned pigs are able to adapt to a wide range of water to feed ratios (Nienaber and Hahn, 1984). Holme and Robinson (1965) evaluated pigs during a 18 and 90 kg liveweight growing period, but found no difference in performance for water to feed ratios of 1.5:1 and 2.5:1. The question is whether adaptation means diversion of resources that could prevent disease (Curtis, 1983).

A study conducted by Yang et al. (1981) with 30 kg growing pigs showed that the pigs consumed more water when

feed was restricted. At 25°C room temperature, pigs drank more water than normally required when they were given a daily limited supply of food of 0.8 kg to 1.5 kg. However, a study conducted by Castle and Castle (1957) showed that as the water to feed ratio varied from 1.5:1 to 3.8:1, it had no effect on overall performance of pigs, and they were still able to maintain the water balance.

Nienaber and Hahn (1984) conducted an experiment in which they measured the effects of water flow restriction and air temperature on nursery pigs. Two trials were conducted to determine the effects of nipple waterer flow rates and environmental factors on the performance of pigs. In the first trial, 42 barrows at 10 weeks of age were housed at 5 or 35°C and fed for 4 wk using flow rates of 100, 600 and 1100 ml/min which were compared to a control group at 20°C and 600 ml/min. When pigs were housed at 35°C, the authors found a linear increase in weight gain from 0.28 kg/d to 0.47 kg/d at 100 ml/min and 1100 ml/min, respectively. On the other hand, pigs fed at 5°C had a decrease in weight gain from 0.86 kg/d to 0.73 kg/d at 100 ml/min and 1100 ml/min, respectively. It is also noted that the weight gain of pigs fed at 5°C and 600 ml/min were similar to that of the control group, averaging 0.76 kg/d.

In a second trial conducted under commercial conditions, they used 120 pigs weaned at 4.5 wk and housed at 30°C for 4 weeks. Water flows were provided at 100, 350, 600, 850 and 1100 ml/min. The results indicated that there

was no effect of water flow rate on body weight gain, feed intake or feed conversion of animals, even though water consumption decreased as water flow rate decreased. On the other hand, time spent drinking at 100 ml/min increased almost four times compared to the rest of the treatments. The study demonstrated that nursery-age pigs are adaptable to restrictions of water supply. Pigs were able to consume a sufficient amount of water by increasing time spent drinking to maintain growth rate.

2.3 Behavioral Response of Early Weaned Pigs

Confinement of animals can result in many behavioral responses of health and performance, some of which are complicated and still not clearly understood. There is an erroneous tendency to assume that if human beings feel comfortable in a certain environment, then pigs would also. Curtis (1983) asserts that pigs may be more or less sensitive when under certain stressors than are humans.

When pigs are penned together after weaning, they develop a dominance order. Animal grouped in high-density situations tend to violate the personal space of other members, and a dominant order will be developed at the beginning. Some animals adopt a dominant behavior and the others a subordinate posture. After grouping, the typical pattern is fighting, manifested by ear biting and head confrontation which results in a social hierarchy (Pond and Maner, 1984; Fritschen, 1981). Curtis (1981) states that the

resulting social stability achieved immediately after grouping has a clear advantage because energy is not further spent in fighting and so damage is minimized. Thus the dominance order tends to decrease social tension in the group to a minimum (Curtis, 1983).

The fights that result have little direct effect on growth. Although they can affect the animal performance indirectly, reducing disease resistance or causing injury that can reduce growth (Curtis, 1983). For that reason, pigs should be mixed in a pen that is new to all; therefore eliminating the possibility that they may become extremely aggressive against intruders on their territory (Curtis, 1981).

2.4 Variability of Flow Rate on Frequent Watering

Water flow through a pipe depends directly on head loss produced between the pump and waterers; therefore the flow rate decreases as the head loss in a pipe is increased. Variability of the flow rate is a function of the pressure difference along the pipe plus the resistance that the valve presents to flow. In systems providing frequent watering, variability of the flow rate is an important factor on assuring a desired water supply.

Olsson and Andersson (1985) conducted a study on growing-finishing pigs and reported that lower flow rates result in water release time becoming too long for the animals; therefore, they tired before they had satisfied their

water requirements. They found that there is always a loss in water pressure from the pump to the waterers, so that the flow rate changes with the water pressure. Their results showed that the valves released about 1.35 and 2.85 l/min at 50 and 230 KPa water pressure, respectively. However, the head losses in the pipeline decreased the flow rate to 0.07 l/min. According to Olsson (1983), the distribution system and nipple should be well designed in order to avoid high head loss in the pipeline that may affect the water capacity of the nipple and the water release time. He reported that water flow rates of nipple waterers varied significantly with design and manufacturer. In addition, partial plugging reduces the flow rate provided to the animals. Partial plugging is often difficult to detect and can result in reduced water consumption, feed intake and weight gain as noted by Nienaber and Hahn (1984). Schulte et al. (1988), testing several nipple waterers commonly used in swine nurseries, found that they vary widely in flow rate and that some designs should have pressure regulators and flow restrictors.

Water flow rate, Q , is a function of the square root of the pressure in the pipeline, P , the square of the nipple diameter, d , and the discharge coefficient, C , which depends upon the nipple's geometry (Schulte et al., 1988).

$$Q = f(C, d^2, P^{0.5}) \dots\dots\dots (1)$$

As the previous function indicates, to meet the water requirements of pigs the water pressure in the distribution pipes needs to be ideal to deliver a sufficient amount of water in a short time (Olsson and Andersson, 1985). As predicted by Equation 1, pressure has a direct effect on flow rates. However, Schulte et al. (1988) reported that various brands of nipple waterers used in swine nurseries operating between 210 to 340 KPa of pressure had little effect on flow rates.

3 METHODOLOGY

3.1 Experimental Facility and Animals

Two studies were conducted at the south nursery at Michigan State University Swine Research Center. The nursery unit consisted of a 17x4x2 m room with a partly slotted floor having one row of fourteen pens (Figure 3.1). Room temperature was maintained by the addition of an electrical heater system controlled by a thermostat to warm the air and a hot water pipeline under the floor. Ventilation was controlled by two variable speed fans in a negative pressure system.

Pigs were weaned at 28 d of age were randomly allotted to treatments based on litter and sex. The variation in initial weight was 8.65 to 8.70 kg for Trial I and 7.85 to 7.92 kg for Trial II. The animals were blocked on weight. In Trial I pigs were tested from September 22 to October 20 of 1987. Trial II was conducted from November 4 to December 2 of 1987. No acclimation period was given to the pigs before trials started.

3.2 Trial I

Eight 1.22 x 2.44 m pens were used (Figure 3.2), with 12 pigs allotted per pen. Pigs were supplied water by means

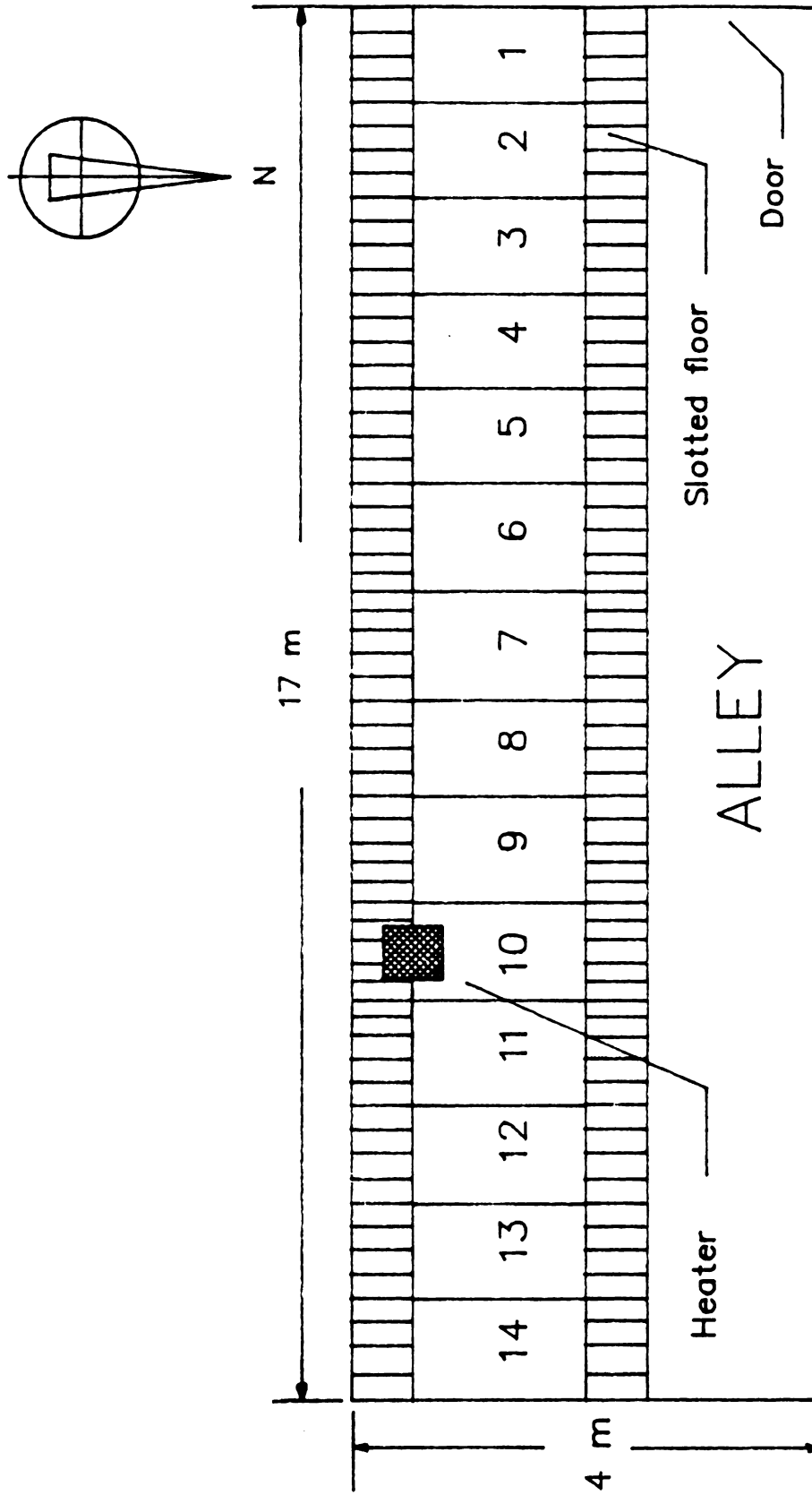


Figure 3.1 Floor plan of the nursery room.

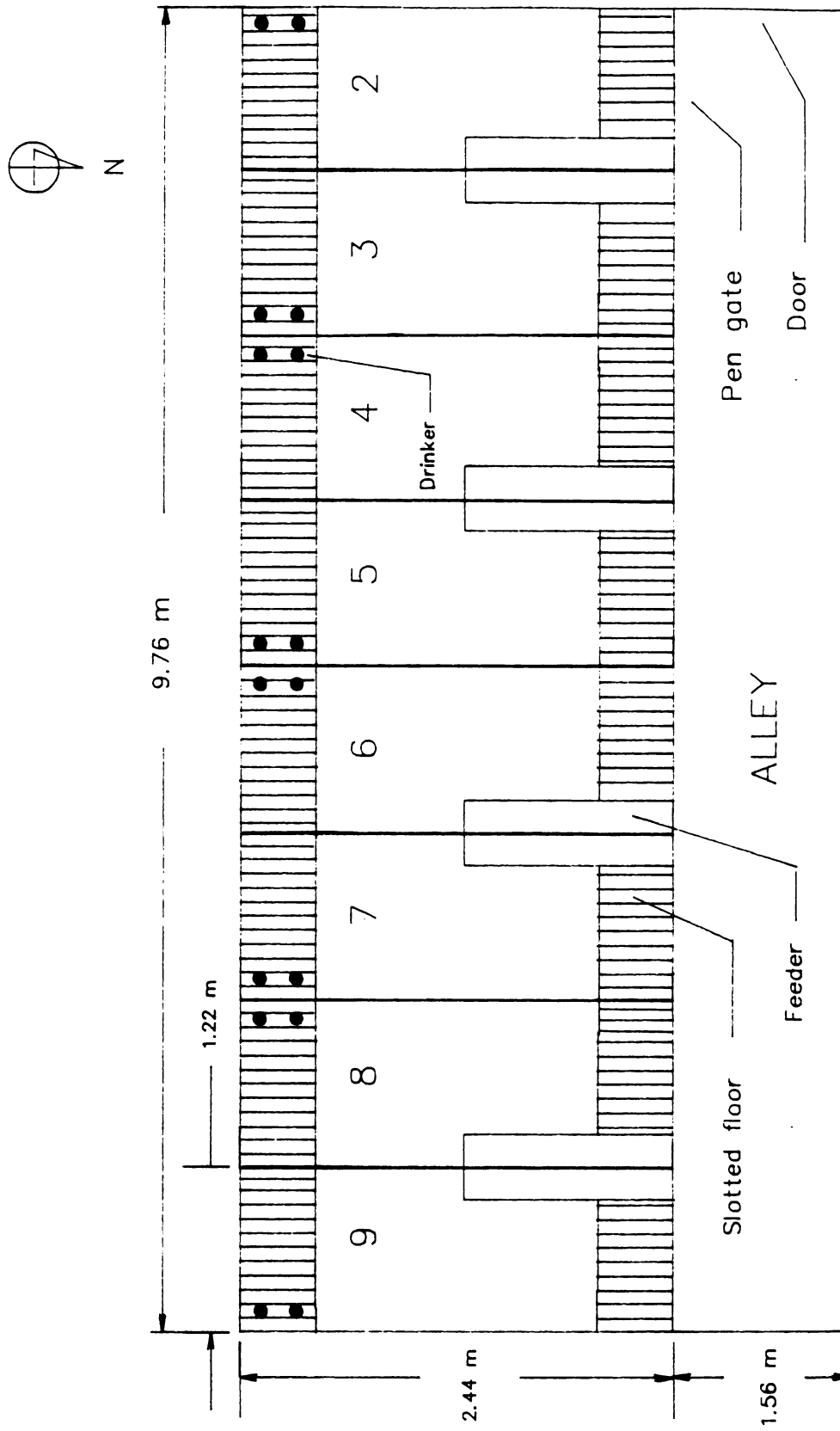


Figure 3.2 Distribution of treatments in eight 1.22x2.44 m pens for Trial I.

of two commercial Edstrom^R 10744 nipple waterers. Because weaned pigs make lunging movements while drinking water from the nipple drinker, the waterers were positioned 30.5 cm apart.

Two water flow treatments combinations were used, as shown in Table 3.1.

Table 3.1 Treatment combinations for Trial I.

Pen Number	Water Flow, ml/min	Weight Class
2 & 4	700	Light
3 & 5	700	Heavy
6 & 8	70	Light
7 & 9	70	Heavy

3.3 Trial II

Six pigs were housed in eight 1.22 x 1.22 m pens. Supply of water was provided by one commercial Edstrom^R 10744 nipple waterer located near the wall. Pens were shortened by moving the gate to the correct position (Figure 3.3).

As in Trial I, two treatments combinations, 70 and 700 ml/min water flow, were evaluated by using two pens per treatment as shown in Table 3.2.

3.4 Management

The experimental diet consisted of a corn-soybean diet containing 15 percent dried whey. It provided 1.15 percent lysine, 0.8 percent calcium, 0.65 percent phosphorus, 0.3

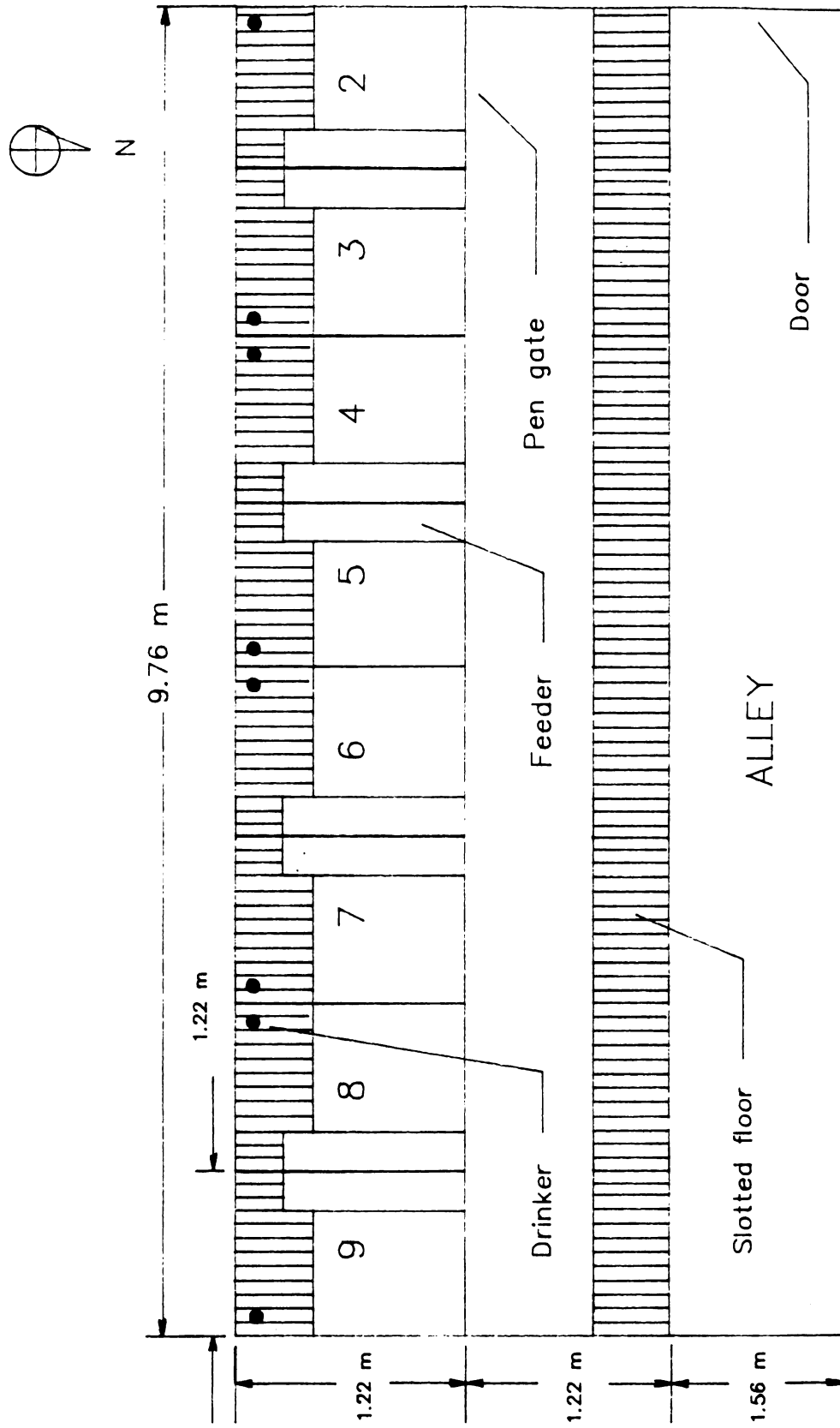


Figure 3.3 Distribution of treatments in eight 1.22x1.22 m pens for Trial II.

Table 3.2 Treatment combinations for Trial II.

Pen Number	Water Flow, ml/min	Weight Class
2 & 4	700	Heavy
3 & 5	700	Light
6 & 8	70	Heavy
7 & 9	70	Light

ppm selenium, 30000 IU/ton vitamin E, 25 percent NaCl and ASP-250 or CSP-250.

At weaning, nipples in all the pens were allowed to drip for four hours in order to familiarize pigs with nipple waterers placement. Nipple drinkers were mounted at 5 cm above the pig's shoulder height and directed at a 45° downward slope from horizontal.

Water flow rates from nipples and pressure were measured weekly using a stopwatch and graduated cylinder. Water flow rate measurements having a variance of greater than 2 percent were repeated and adjusted as necessary to meet the rates specified in the treatments. Water pressure was measured by a water pressure gage installed in the waterline where the water pipe entered the room and at the last pen.

Observation of pigs contacting drinking nipples was conducted weekly on the day prior to weighing the pigs using one pen per treatment combination. Duration of time that pigs made contact with nipple was recorded in minutes simultaneously for all pens under observation. Measurements lasted for four hours and were conducted from 7:00 to 11:00

a.m., when pigs are more actives.

Nursery room temperature was registered daily in the morning and afternoon. Measurements were taken at pig height, 0.5 m above floor, at 3 locations in the room.

Mortality rate of pigs was 2.1 percent in the first trial. One pig died within the first week of the experiment, so it was replaced immediately with a pig of similar size. Another died after the first week, therefore the pen size was decreased by the quantitative amount. On the second trial, mortality was 4.2 percent. Two pigs died in the first week, so they were replaced by others of similar weight.

3.5 Determination of Water Flow Rate and Pressure

In order to determine variability of flow rate as related to pressure in the pipeline, it was necessary to conduct an experiment in the laboratory. It consisted of a tank filled with water which was connected to an air pump. This assured a wide range of constant pressure in the system (Figure 3.4). The flow rate, Q , was measured directly by collecting the volume of water in a cylinder and recording the time elapsed.

According to Equation 1, the water flow rate is proportional to the square of the nipple diameter and the square root of the pressure. A more generalized expression to define Equation 1 is possible by introducing the contracted area of the waterer, A , and the acceleration of gravity, g :

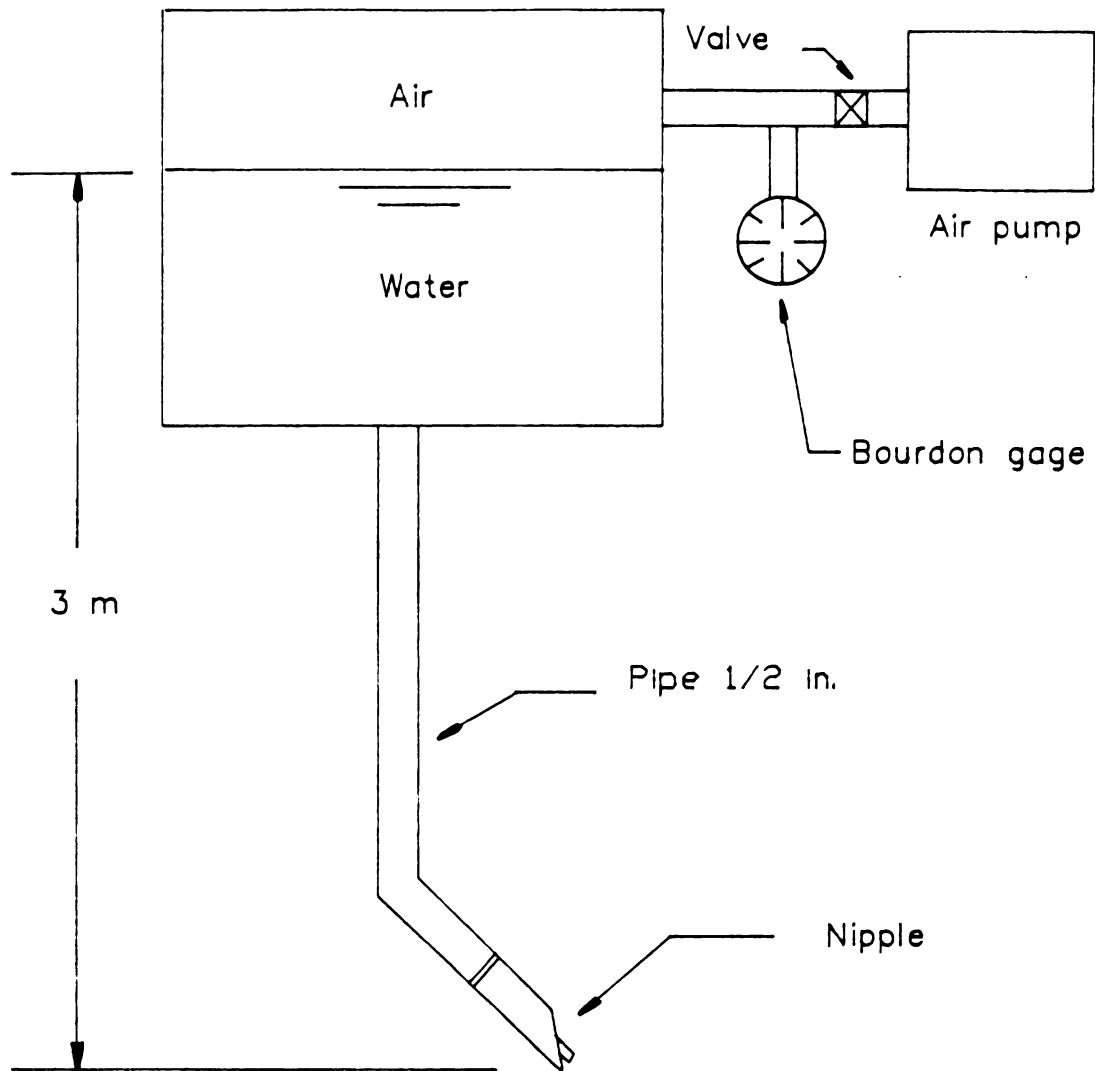


Figure 3.4 Experimental equipment to measure water flow and pressure.

$$Q = C * A * V = C * A * (2g * P)^{0.5} \dots\dots\dots (2)$$

Therefore, the flow rate will depend upon the square root of the pressure, P, and the discharge coefficient, C. In turn, the discharge coefficient will vary with the setting of the nipple's retainer selected.

The flow rate from the nipple was measured at pressure ranging from 34.5 to 400 KPa. Pressure was controlled by manually adjusting a valve located between the air pump and the tank (Figure 3.4). The water level was constant during the experiment. The nipples had a restrictor screw that allowed the water discharge to be adjusted. Three settings were selected which adjusted the water discharge to low, high and intermediate rates.

3.6 Statistics

Results shown in tables and figures are expressed as mean values and standard error. Analysis of variance tables (see Appendices) were calculated using split-plot test with repeated measurements for comparison of treatment means when time was considered (Gill, 1986). The t-test was used to estimate the significance of the difference between two group means. SAS (Statistical Analysis System) computer program was employed to obtain all statistic analysis.

4 RESULTS

4.1 Trial I

During the first trial, the ambient outside air temperature averaged 12°C and fluctuated between 4 and 19°C. The relative humidity of the outside air varied from 49 to 93 percent with an average of 71 percent. The room temperature was maintained between 25 and 27°C.

Performance data for Trial I is summarized in Table 4.1. The means for initial and final weight were not statistically different. For daily gain, feed intake and feed to gain ratio, there was no significant difference between treatments ($P < 0.182$). The total water intake decreased as water flow rate decreased ($P < 0.002$), and there was a decrease in the water to feed ratio at 70 ml/min water flow rate ($P < 0.011$).

Effect of water flow rate on weekly performance of pigs is presented in Table 4.2. Both final and average daily gain were similar for pigs between treatments. Daily feed intake for individual pigs demonstrated no differences between treatments during week 1, 2 and 3 after weaning. Similarly, feed to gain ratio indicated no difference between treatments during week 1, 2 and 3 after weaning. However, daily gain and feed intake significantly decreased

Table 4.1 Effect of water flow rate on overall performance of nursery pigs (Trial I).

Item ^a	Flow Rate, ml/min		SEM ^b	Pr>F
	700	70		
Initial weight, kg/pig	8.70	8.65	0.25	0.998
Final weight, kg/pig	18.11	16.45	0.41	0.081
Avg. Daily gain, kg/pig	0.34	0.28	0.01	0.073
Daily feed intake, kg/pig	0.67	0.61	0.02	0.356
Feed:Gain ratio	1.97	2.18	0.03	0.182
Total water intake, l/pig	80.08	33.18	0.84	0.002
Water:Feed ratio	4.27	1.94	0.35	0.011

^a Data based on average of 2 pens: trial length was 28 d; 12 pigs/pen, 2 drinkers/pen.

^b Standard error of the means.

and feed conversion statistically worsened for those pigs receiving the 70 ml/min water flow rate during wk 4 after weaning.

Effect of water flow rates on drinker contact, water intake per pig and water to feed ratio is presented in Table 4.3. There was a significantly reduced drinker contact at 700 ml/min water flow rate during each week of the experiment. On the other hand, water intake increased at 700 ml/min during in all weeks of the trial. The trend for both treatments was to increase water intake from wk 1 to 3 and then decrease in wk 4. Water to feed ratio was larger for those pigs receiving the 700 ml/min water flow rate, however this ratio was not statistically different during wks 2 and 3. The largest difference occurred in wk 4 after

Table 4.2 Weekly effect of water flow on mean weight, daily gain, feed intake and feed:gain ratio (Trial I).

Item	Treatment, ml/min		Pr>F
	700	70	
Mean Weight, kg/pig			
Wk 0	8.65	8.63	0.989
Wk 1	10.05	9.69	0.489
Wk 2	11.89	11.31	0.484
Wk 3	15.72	14.67	0.221
Wk 4	18.12	16.45	0.081
*SED _T = 0.38			
+SED _W = 0.28			
Avg. Daily Gain, kg/pig			
Wk 1	0.20	0.15	0.307
Wk 2	0.26	0.24	0.423
Wk 3	0.55	0.49	0.250
Wk 4	0.34	0.25	0.037
*SED _T = 0.04			
+SED _W = 0.03			
Avg. Daily Feed Intake, kg/pig			
Wk 1	0.24	0.22	0.841
Wk 2	0.50	0.48	0.729
Wk 3	0.87	0.83	0.640
Wk 4	1.06	0.90	0.037
*SED _T = 0.89			
+SED _W = 0.65			
Feed:Gain Ratio			
Wk 1	1.21	1.46	0.464
Wk 2	1.94	2.09	0.563
Wk 3	1.58	1.75	0.259
Wk 4	3.10	3.68	0.038
*SED _T = 0.31			
+SED _W = 0.26			

*SED_T is the standard error of differences between treatments for the same week.

+SED_W is the standard error of differences between weeks for the same treatment.

Table 4.3 Weekly effect of water flow on drinker contact, water intake and water:feed ratio (Trial I).

	Treatment, ml/min		
Item	700	70	Pr>F
Drinker contact, min/d			
Wk 1	38.40	125.04	0.037
Wk 2	42.96	165.36	0.035
Wk 3	58.56	223.44	0.018
Wk 4	48.24	200.16	0.020
*SED _T = 0.96			
+SED _W = 0.31			
Water intake per pig, l/d			
Wk 1	2.27	0.96	0.003
Wk 2	2.53	1.03	0.002
Wk 3	3.74	1.45	0.001
Wk 4	2.90	1.30	0.002
*SED _T = 0.21			
+SED _W = 0.19			
Water:Feed ratio			
Wk 1	9.46	4.36	0.042
Wk 2	5.06	2.15	0.099
Wk 3	4.29	1.75	0.154
Wk 4	2.74	1.44	0.010
*SED _T = 1.26			
+SED _W = 1.28			

*SED_T is the standard error of differences between treatments for the same week.

+SED_W is the standard error of differences between weeks for the same treatment.

weaning ($P < 0.010$).

Variability analysis of overall daily gain revealed no difference between treatments at 5 percent level of confidence.

4.2 Trial II

In the second trial, the outside temperature averaged 4°C and fluctuated between -7 and 14°C . The relative humidity ranged between 55 and 96 percent, averaging 76 percent. The inside room temperature fluctuated between 26 and 27°C .

Performance of nursery pigs are presented in Table 4.4. There was no effect of water flow rate on final weight, daily gain, daily feed intake or feed to gain ratio ($P < 0.05$). Total water intake per pig decreased by half for pigs receiving 70 ml/min water flow rate ($P < 0.001$). Water to feed ratio also decreased with decreased water flow rate ($P < 0.007$).

Effect of treatments on weekly performance of nursery pigs are shown in Table 4.5. Neither weekly mean weight nor average daily gain presented significant differences between treatments during the 4 wks of the experiment. Average daily feed intake was affected by the lower water flow rate during wk 4 ($P < 0.066$). On the contrary, feed to gain ratio was not affected by reduced water flow rate at any time.

The effect of water flow rate on drinker contact, water

Table 4.4 Effect of water flow rate on overall performance of nursery pigs (Trial II).

Item ^a	Flow Rate, ml/min		SEM ^b	Pr>F
	700	70		
Initial weight, kg/pig	7.85	7.93	0.20	0.998
Final weight, kg/pig	20.99	21.50	0.50	0.784
Avg. Daily gain, kg/pig	0.47	0.49	0.01	0.582
Daily feed intake, kg/pig	0.98	0.95	0.02	0.378
Feed:Gain ratio	2.10	1.94	0.02	0.277
Total water intake, l/pig	62.16	25.20	0.65	0.001
Water:Feed ratio	2.26	0.95	0.11	0.007

^a Data based on average of 2 pens: trial length was 28 d; 6 pigs/pen, 1 drinker/pen.

^b Standard error of the means.

intake per pig and water to feed ratio is presented in Table 4.6. There was a significant increase in drinker contact when water flow rate was reduced ($P<0.004$). Water intake was less at 70 ml/min than at 700 ml/min water flow rate. Finally, water to feed ratio increased ($P<0.024$) at 700 ml/min water flow rate.

4.3 Behavioral Response of Nursery Pigs

After grouping both experiments, visual observations revealed that newly weaned pigs followed the typical tendency to fight which was demonstrated by ear biting during the first 2 days after weaning. Afterward a social stability within pens was achieved quickly.

Table 4.5 Weekly effect of water flow on mean weight, daily gain, feed intake and feed:gain ratio (Trial II).

Item	Treatment, ml/min		Pr>F
	700	70	
Mean Weight, kg/pig			
Wk 0	7.85	7.93	0.995
Wk 1	10.43	10.41	0.997
Wk 2	12.49	12.84	0.816
Wk 3	16.80	17.25	0.795
Wk 4	21.00	21.50	0.784
*SED _T = 0.84			
+SED _W = 0.38			
Avg. Daily Gain, kg/pig			
Wk 1	0.37	0.35	0.921
Wk 2	0.29	0.35	0.440
Wk 3	0.62	0.63	0.924
Wk 4	0.60	0.61	0.983
*SED _T = 0.06			
+SED _W = 0.06			
Avg. Daily Feed Intake, kg/pig			
Wk 1	0.46	0.44	0.886
Wk 2	0.74	0.75	0.998
Wk 3	1.14	1.17	0.709
Wk 4	1.58	1.43	0.066
*SED _T = 0.41			
+SED _W = 0.28			
Feed:Gain Ratio			
Wk 1	1.27	1.25	0.987
Wk 2	2.55	2.16	0.458
Wk 3	1.86	1.86	0.999
Wk 4	2.73	2.37	0.379
*SED _T = 0.32			
+SED _W = 0.36			

*SED_T is the standard error of differences between treatments for the same week.

+SED_W is the standard error of differences between weeks for the same treatment.

Table 4.6 Weekly effect of water flow rate on drinker contact, water intake and water:feed ratio (Trial II).

Item	Treatment, ml/min		Pr>F
	700	70	
Drinker contact, min/d			
Wk 1	16.80	60.48	0.004
Wk 2	21.12	64.08	0.004
Wk 3	17.52	99.84	0.001
Wk 4	19.20	83.28	0.002
*SED _T = 0.27			
+SED _W = 0.19			
Water intake per pig, l/d			
Wk 1	2.13	0.66	0.001
Wk 2	2.70	0.78	0.001
Wk 3	1.77	1.16	0.001
Wk 4	2.28	0.98	0.001
*SED _T = 0.13			
+SED _W = 0.14			
Water:Feed ratio			
Wk 1	4.63	1.50	0.001
Wk 2	3.65	1.04	0.001
Wk 3	1.55	0.99	0.024
Wk 4	1.44	0.87	0.001
*SED _T = 0.05			
+SED _W = 0.05			

*SED_T is the standard error of difference between treatments for the same week.

+SED_w is the standard error of difference between weeks for the same treatment.

No observation of the pigs trying to cool themselves through water wastage or resting grouped was noted, indicating adequate temperature control.

It was observed that in both trials pigs spent more time drinking at the lower water flow rate treatment (70 ml/min). The higher flow rate treatment (700 ml/min) demonstrated that pigs significantly wasted water during drinking, whereas the lower treatment produced insignificant wastage. However, in Trial I the pigs comparatively wasted more water than Trial II. This was due to a higher competition at drinking times. Apparently none of the pigs became tired because of prolonged drinking times, yet heavier pigs possibly became frustrated to the point of affecting performance.

4.4 Pressure and Water Flow Rate Variability

Variability of flow rates and measurements of pressure in the distribution pipeline for Trial I are presented in Table 4.7. Maximum water flow rates occurred during wk 3 after weaning, whereas minimum rates occurred in wk 1. This feature coincided with the fact that pressure in the distribution pipe was maximum in week 3 and minimum in week 1. It showed a direct correlation between water flow rates and hydraulic pressure in the system, which is supported by theory (Streeter and Wylie, 1979).

Based on the square root of pressure as indicated in

Table 4.7 Weekly flow rates and pressure for Trial I.

Week	Treatment, ml/min		Pressure, KPa ^a		P _A -P _B
	700	70	A	B	
1	705	71	207	193	14
2	722	76	276	261	15
3	770	78	283	271	12
4	727	78	252	241	11
Mean	731	76	255	236	13

^a A indicates pressure measured at pipe entering room and B at the last pen location (1 atmosphere = 101.325 KPa).

Equation 2, variability of pressure was determined to be:

$$(283)^{0.5} = 16.8$$

$$(207)^{0.5} = 14.4$$

It indicated that there was a 14.3 percent increase in pressure from 207 to 283 KPa.

Table 4.8 reports variability of water flow rate and pressure for Trial II. Maximum water flow rate and pressure were recorded in wk 2 after weaning, whereas minimum values were measured in wk 3. Based on Equation 2, there was a 20.4 percent increase in pressure from 179 to 283 KPa during the experiment.

The effect of pressure on flow rate from the nipple waterer is illustrated in Figure 4.1, where data was experimentally collected for a range of 35 to 400 KPa. The

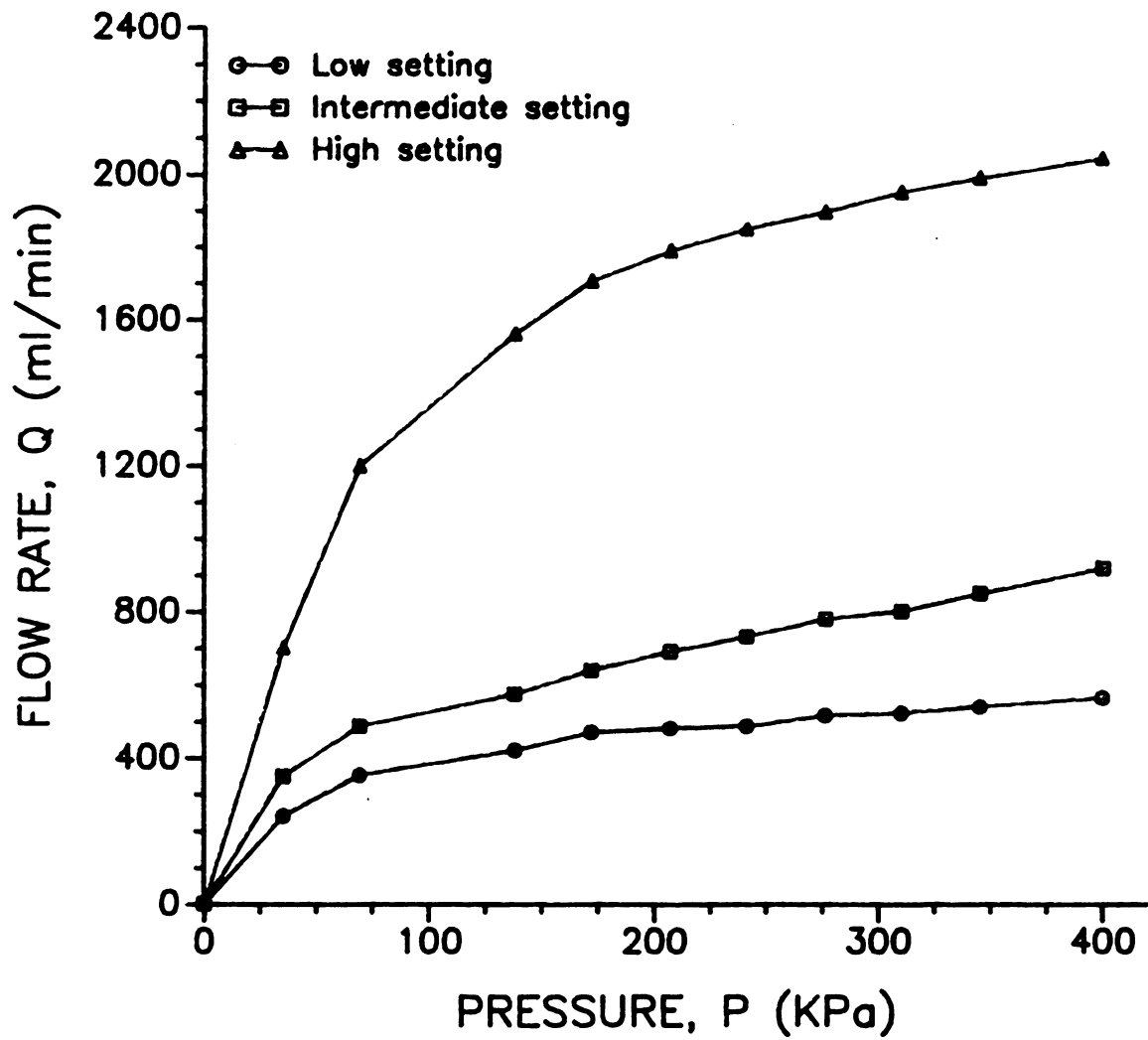


Figure 4.15 Effect of pressure on water flow rate.

Table 4.8 Weekly flow rates and pressure for Trial II.

Week	Treatment, ml/min		Pressure, KPa ^a		$P_A - P_B$
	700	70	A	B	
1	700	70	221	213	8
2	774	73	283	272	11
3	604	70	179	166	13
4	709	70	269	255	14
Mean	697	71	238	226	12

^a A indicates pressure measured at pipe entering room and B at the last pen location (1 atmosphere = 101.325 KPa).

experiment was replicated three times.

In general, pressure had a strong influence on water flow rate in the 35 to 140 KPa but a relatively small effect at pressures higher than 140 KPa. This feature was supported from the values shown in Table 4.7 and 4.8, where there was very good water flow rate control at pressures higher than 140 KPa. At the high setting, changes in the flow rate varied from a minimum of 695 ml/min to a maximum of 2050 ml/min in the 35 to 400 KPa range. At the low setting, flow rate varied from 241 to 564 ml/min in the same range of pressure.

5 DISCUSSION

In Trial I, water flow rate of 70 ml/min indicated a trend for the overall average daily gain to be depressed. Also, weekly performance revealed that average daily gain, average daily feed intake and feed conversion for wk 4 (56 days of age) were significantly affected at 70 ml/min and 25-27°C room temperature with 12 pigs per pen. In Trial II, there were no differences on pig performance, even though the average daily feed intake tended to be lower ($P < 0.066$) during wk 4, while numerically the feed conversion was better. These findings were similar to those of Nienaber and Hahn (1984), who worked with 100, 350, 600, 850 and 1100 ml/min. Moreover, the results for both trials were similar to those found by Carlson and Peo (1982), who found that there was no difference in feed to gain ratio at flow rates higher than 1100 ml/min.

Water intake volumes measured in Trial I and II were lower than the results obtained from a similar experiment conducted by Nienaber and Hahn (1984), who worked with 2 pigs/pen housed at 35°C. This difference may be due to the fact that the pigs were maintained at a lower room temperature and there was a higher density of pigs per pen, as also noted by Nienaber and Hahn (1987). It confirms that

the higher the ambient temperature the higher the water consumption (Baxter, 1984). The results of water intake shown in Table 4.1 and 4.4, probably suggest that nursery pigs usually drink more water than they really need, as previously noted by Yang et al. (1981).

Water to feed ratio of 0.95:1 to 4.27:1 had no effect on final weight and total gain per pig. A similar result was reported by Castle and Castle (1957) and Holme and Robinson (1965), who found that variations from 1.5:1 to 3.75:1 had little effect on overall performance. This difference in the water supplied demonstrated that nursery pigs can tolerate a wide range of water to feed ratios (Carlson and Peo, 1982; Nienaber and Hahn, 1984).

In Trial I, rate of gain decreased at 70 ml/min water flow rate only in wk 4 after weaning, so worsening feed conversion. This is explained by the lower feed intake in that period. A similar tendency was also observed by Brooks et al. (1984) in the first days after weaning. Also, possibly the heavier pigs spent more time drinking during wk 4, yet may have been frustrated to the point of affecting performance.

The importance of the restricted water flow rate is evident when pigs must weight 25 kg liveweight before leaving the nursery unit. In that case, 58 days are required for those pigs receiving 70 ml/min, as compared to 48 days needed for pigs at 700 ml/min water flow rate. The extra 10 days to reach the desired 25 kg for market or movement to

growing facilities will mean crowding of pigs in the nursery units, selling pigs at a lighter weight, or moving those animals into a grower environment that the smaller pigs may not tolerate well.

In Trial I, the decrease in water intake at the 70 ml/min treatment was supported by the fact that the pigs spent four times as much time drinking than at 700 ml/min treatment (Table 4.3). In Trial II significant differences in time spent drinking indicated that pigs also increased their weekly water intake at increased water flow rate (Table 4.6). The time spent drinking in Trial I was double that of Trial II, indicating that there was a greater competition for water in pens with 12 pigs having two drinkers (Trial I) than 6 pigs/pen and one drinker (Trial II). The stronger competition in pens containing 12 pigs was correlated with a higher water wastage when compared to pens containing 6 pigs in Trial II. Although, variability analysis performed for overall daily gain in Trial I revealed no difference between treatments ($P>0.05$). Competition was also evident from the higher growth rate mean values obtained in Trial II as compared to Trial I. The results indicated that smaller groups of pigs have better performance than larger groups, as also noted by Brent et al. (1975), due to less competition for water. A similar pattern was found by Olsson (1983a), who evaluated nipple waterers for fattening pigs.

In both trials water intake decreased as water flow

rate decreased, whereas rate of gain, feed intake and feed conversion remained unaffected. This pattern was also reported by Olsson (1983b) and Nienaber and Hahn (1984). Because of the possibility that nursery pigs do not necessarily have a large water intake and may drink less water than needed without affecting performance, further studies are necessary to measure wastage or even urine output to differentiate between water intake and wastage.

This decrease in water wastage and a longer drinker contact at 70 ml/min for both trials suggests that young pigs are able to adapt to a wide range of water flow rates, a characteristic previously noted by Nienaber and Hahn (1984).

As pigs increase in weight and the temperature rises, water flow rate becomes important (Nienaber and Hahn, 1987). This may explain the differences in growth rate, feed intake and feed to gain ratio in week 4 after weaning, as noted in Trial I (Table 4.2). The 70 ml/min water flow rate for pigs at to 16 kg liveweight and 26°C room temperature tended to be the minimum acceptable water flow rate. This suggests that as temperature rises and pigs are heavier, water flow rate should be increased above 70 ml/min. This indicated that there are limits to the adaptation of nursery pigs to restrictions of water flow rates, as also stated by Nienaber and Hahn (1984).

The higher pig performance results found in Trial II was due to the greater competition in pens containing 12

pigs and 2 drinkers, associated with a visual higher wastage in Trial I. Further studies are recommended to measure water wastage for pigs receiving water flow rate above 70 ml/min. Also, because of the possibility of partial plugging in the nipples, more studies are recommended to study the response of the waterer at low pressures in swine nursery facilities.

As indicated in Table 4.7 and 4.8, there was very good flow rate control. The distribution system was dimensioned so that the 70 and 700 ml/min treatments could be applied very precisely at a water pressure of 179 and 283 KPa. The results were supported with data obtained from the laboratory (Figure 4.1), where the pressure had little effect on water flow rate of the nipple waterer in the 140 to 400 KPa range. Schulte et al. (1988) found a similar response in the range of 200 to 500 KPa. This proved that the nipple waterer could be used widely in swine nurseries without pressure regulators in the pipeline.

6 CONCLUSIONS

1. Providing a water flow rate of 70 ml/min to 12 pigs per pen weaned at 28 days and housed at 26°C room temperature resulted in a reduction in the average daily gain, average daily feed intake and feed conversion during wk 4 after weaning.

2. Overall daily gain tended to be depressed for pigs receiving the lower water flow rate ($P < 0.073$). This depressed tendency has important implications on pig's flow through the nursery, growing and finishing phases.

3. Observation of performance during week 4 revealed that the 70 ml/min water flow rate approaches the minimum requirement for 12 pigs per pen at 16 to 18 kg live weight and 26°C room temperature. This suggested that there are limits to the adaptation of nursery-age pigs to restricted water flow rates. Consequently, as temperature rises and pigs are heavier, water flow rates should be provided above 70 ml/min.

4. The variability of the water flow rate studied demonstrated that if the water supply system provides pressures

at a range of 140 to 400 KPa, the Edstrom^R waterer⁽¹⁾ will repeatedly supply either 70 or 700 ml/min water flow rate without pressure regulators in the pipeline.

(1) It does not imply endorsement nor prejudice for or against this product, or for or against products not mentioned.

APPENDICES

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Appendix A1. Repeated measures analysis of variance for weekly growth rate (Trial I).

Source	df	SS	MS	F	Pr>F
Treatment (T)	1	5.3949	5.3949	5.48	0.0793
Block (B)	1	63.3277	63.3277	64.34	0.0013
T*B	1	0.2641	0.2641	0.27	0.6318
Error 1	4	3.9368	0.9842		
Period (P)	3	421.8967	105.4742	481.23	0.0001
P*T	3	3.2917	0.8229	3.83	0.0227
P*B	3	2.0419	0.5105	2.38	0.0954
P*T*B	3	0.1885	0.0471	0.22	0.9237
Error 2	12	3.4354	0.2147		

Appendix A2. Repeated measures analysis of variance for average daily gain (Trial I).

Source	df	SS	MS	F	Pr>F
Treatment (T)	1	0.0228	0.0228	3.84	0.1217
Block (B)	1	0.0122	0.0122	2.06	0.2244
T*B	1	0.0003	0.0003	0.04	0.8432
Error 1	4	0.0238	0.0059		
Period (P)	3	0.5252	0.1751	111.52	0.0001
P*T	3	0.0033	0.0011	0.70	0.5705
P*B	3	0.0186	0.0062	3.98	0.0352
P*T*B	3	0.0014	0.0005	0.29	0.8302
Error 2	12	0.0187	0.0016		

Appendix A3. Repeated measures analysis of variance for weekly feed intake (Trial I).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	18.868	18.868	1.21	0.3326
Block (B)	1	28.055	28.055	1.96	0.2337
T*B	1	0.248	0.248	0.02	0.9056
Error 1	4	62.234	15.559		
Period (P)	3	1628.149	542.716	156.13	0.0001
P*T	3	18.454	6.151	1.77	0.2064
P*B	3	12.979	4.326	1.24	0.3368
P*T*B	3	1.859	0.620	0.18	0.9090
Error 2	12	41.712	3.476		

Appendix A4. Repeated measures analysis of variance for feed:gain ratio (Trial I).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	0.6641	0.6641	1.83	0.2473
Block (B)	1	0.1365	0.1365	0.38	0.5726
T*B	1	0.0058	0.0058	0.02	0.9056
Error 1	4	1.4498	0.3624		
Period (P)	3	19.5609	6.5203	47.07	0.0001
P*T	3	0.2368	0.0789	0.57	0.6454
P*B	3	0.7810	0.2603	1.88	0.1869
P*T*B	3	0.2092	0.0697	0.50	0.6870
Error 2	12	1.6621	0.1385		

Appendix A5. Repeated measures analysis of variance for drinker contact (Trial I).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	2881.992	2881.992	35.17	0.1063
Block (B)	1	256.344	256.344	3.13	0.3276
Error 1	1	81.936	81.936		
Period (P)	3	326.832	108.936	17.24	0.0214
P*T	3	151.632	50.544	8.00	0.0608
Error 2	6	13.363	2.227		

Appendix A6. Repeated measures analysis of variance for weekly water intake (Trial I).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	22.445	22.445	341.76	0.0001
Block (B)	1	3.125	3.125	47.58	0.0023
T*B	1	0.151	0.151	2.30	0.2037
Error 1	4	0.263	0.066		
Period (P)	3	4.547	1.516	42.46	0.0001
P*T	3	1.095	0.365	10.23	0.0013
P*B	3	0.557	0.186	5.20	0.0157
P*T*B	3	0.447	0.149	4.18	0.0306
Error 2	12	0.428	0.036		

Appendix A7. Repeated measures analysis of variance for water:feed ratio (Trial I).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	1.415	1.415	24.10	0.0081
Block (B)	1	0.009	0.009	0.15	0.7193
T*B	1	0.041	0.041	0.70	0.4492
Error 1	4	0.235	0.059		
Period (P)	3	2.191	0.730	21.25	0.0001
P*T	3	0.272	0.091	2.64	0.0970
P*B	3	0.021	0.007	0.19	0.9007
P*T*B	3	0.007	0.002	0.07	0.9766
Error 2	12	0.412	0.034		

Appendix A8. Repeated measures analysis of variance for weekly growth rate (Trial II).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	0.0020	0.0020	0.00	0.9877
Block (B)	1	39.5723	39.5723	5.30	0.0827
T*B	1	8.4916	8.4916	1.14	0.3463
Error 1	4	29.8602	7.4651		
Period (P)	3	769.4007	192.3501	540.13	0.0001
P*T	3	0.2995	0.0749	0.21	0.9289
P*B	3	3.7086	0.9271	2.60	0.0753
P*T*B	3	2.1955	0.5489	1.54	0.2378
Error 2	12	5.6979	0.3561		

Appendix A9. Repeated measures analysis of variance for average daily gain (Trial II).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	0.0017	0.0017	0.52	0.5106
Block (B)	1	0.0571	0.0571	17.67	0.0137
T*B	1	0.0047	0.0047	1.47	0.2920
Error 1	4	0.0129	0.0032		
Period (P)	3	0.6038	0.2013	24.33	0.0001
P*T	3	0.0050	0.0017	0.20	0.8946
P*B	3	0.0199	0.0066	0.80	0.5172
P*T*B	3	0.0060	0.0020	0.24	0.8662
Error 2	12	0.0993	0.0083		

Appendix A10. Repeated measures analysis of variance for weely feed intake (Trial II).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	2.583	2.583	0.36	0.5823
Block (B)	1	42.950	42.950	5.94	0.0715
T*B	1	1.167	1.167	0.16	0.7084
Error 1	4	28.932	7.233		
Period (P)	3	1501.529	500.510	396.67	0.0001
P*T	3	11.249	3.750	2.97	0.0744
P*B	3	10.115	3.372	2.67	0.0947
P*T*B	3	2.296	0.765	0.61	0.6234
Error 2	12	15.141	1.262		

Appendix A11. Repeated measures analysis of variance for feed:gain ratio (Trial II).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	0.5940	0.5940	13.73	0.0207
Block (B)	1	0.5408	0.5408	12.50	0.0241
T*B	1	0.2775	0.2775	6.42	0.0645
Error 1	4	0.1730	0.0432		
Period (P)	3	9.5584	3.1861	12.35	0.0006
P*T	3	0.7061	0.2354	0.91	0.4640
P*B	3	1.2118	0.4039	1.57	0.2488
P*T*B	3	0.6008	0.2003	0.78	0.5294
Error 2	12	3.0956	0.2579		

Appendix A12. Repeated measures analysis of variance for drinker contact (Trial II).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	563.616	563.616	120.20	0.0579
Block (B)	1	4.553	4.553	0.97	0.5047
Error 1	1	4.689	4.689		
Period (P)	3	40.464	13.488	10.95	0.0400
P*T	3	44.256	14.752	11.97	0.0355
Error 2	6	3.703	0.617		

Appendix A13. Repeated measures analysis of variance for weekly water intake (Trial II).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	14.032	14.032	3023.68	0.0001
Block (B)	1	3.153	3.156	680.15	0.0001
T*B	1	3.032	3.032	653.35	0.0001
Error 1	4	0.019	0.005		
Period (P)	3	0.596	0.199	9.72	0.0016
P*T	3	1.761	0.587	28.72	0.0001
P*B	3	1.691	0.564	27.57	0.0001
P*T*B	3	1.516	0.505	24.73	0.0001
Error 2	12	0.245	0.020		

Appendix A14. Repeated measures analysis of variance for water:feed (Trial II).

Source	df	SS	MS	F	Pr>P
Treatment (T)	1	0.4656	0.4656	156.84	0.0002
Block (B)	1	0.0595	0.0595	20.05	0.0110
T*B	1	0.0882	0.0882	29.71	0.0055
Error 1	4	0.0119	0.0030		
Period (P)	3	0.3937	0.1312	53.71	0.0001
P*T	3	0.1785	0.0595	24.34	0.0001
P*B	3	0.0457	0.0152	6.23	0.0085
P*T*B	3	0.0699	0.0233	9.54	0.0017
Error 2	12	0.0293	0.0024		

Appendix 15. Individual weights for Trial I (pounds).

Weekly weights							
Pen	Pig	Trt	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5
2	122-14	700L	18.50	19.80	21.20	29.00	36.50
2	221-16	700L	17.90	17.80	18.50	19.20	23.10
2	125-2G	700L	17.20	18.30	21.50	27.10	32.00
2	126-10	700L	15.50	17.40	18.80	24.80	28.00
2	126-2G	700L	16.10	19.10	22.30	29.10	25.00
2	225-11	700L	17.90	20.70	26.20	36.90	39.50
2	H5-1G	700L	13.70	16.40	18.50	21.80	24.40
2	127-1G	700L	18.80	21.60	24.00	29.40	37.00
2	228-1G	700L	18.00	22.60	26.70	35.30	41.50
2	228-10	700L	16.30	20.90	24.30	32.60	37.00
2	Y10-1G	700L	17.00	21.30	24.70	34.10	45.00
2	Y10-3G	700L	16.00	20.30	24.40	31.70	37.00
Totals Pen 2			202.90	236.20	271.10	351.00	406.00
3	122-10	700H	24.80	26.40	31.30	43.50	52.00
3	122-1G	700H	23.70	26.20	28.10	38.30	47.60
3	H4-1G	700H	20.30	23.20	25.90	37.50	46.00
3	221-1G	700H	19.90	22.50	25.10	31.10	32.00
3	225-10	700H	19.70	23.40	28.70	37.10	38.00
3	223-13	700H	21.80	25.90	29.70	37.40	38.60
3	223-12	700H	22.00	25.90	32.60	42.20	52.00
3	223-6G	700H	20.90	25.50	33.00	40.00	41.50
3	224-14	700H	20.10	20.00	26.00	36.40	39.50
3	222-12	700H	20.10	22.70	29.30	36.60	44.80
3	227-2G	700H	21.30	23.40	25.70	36.20	41.00
3	227-4G	700H	20.50	25.00	30.60	41.80	45.00
Totals Pen 3			255.10	290.10	346.00	458.10	518.00
4	225-4G	700L	15.10	20.60	25.70	34.50	40.00
4	225-6G	700L	15.00	18.80	23.00	32.70	34.60
4	226-11	700L	17.90	21.40	26.00	35.90	43.00
4	127-14	700L	17.10	21.50	25.10	33.30	38.00
4	127-2G	700L	17.10	21.50	23.40	32.90	39.00
4	223-4G	700L	16.90	20.20	24.00	30.90	36.50
4	223-14	700L	16.30	15.60	26.50	35.20	43.00
4	224-1G	700L	18.30	21.60	24.50	31.30	38.00
4	224-12	700L	13.40	16.70	15.60	20.80	27.00
4	Y10-4G	700L	17.90	19.40	24.00	32.70	38.00
4	124-11	700L	15.90	19.70	21.90	31.20	39.00
4	227-6G	700L	19.20	24.10	27.90	39.50	48.00
Totals Pen 4			200.10	241.10	287.60	390.90	464.10

Appendix 15. (Continued)

Pen	Pig	Trt	Weekly weights				
			Wk 1	Wk 2	Wk 3	Wk 4	Wk 5
5	122-2G	700H	24.50	27.60	31.00	40.40	51.50
5	122-13	700H	20.90	21.00	22.00	30.70	37.00
5	221-2G	700H	21.00	23.00	27.50	34.60	36.50
5	225-1G	700H	20.30	24.60	31.10	37.60	39.00
5	226-10	700H	23.90	28.30	35.70	45.60	52.00
5	226-2G	700H	20.50	23.00	27.90	38.20	45.50
5	127-10	700H	20.00	22.10	28.30	37.30	38.00
5	223-1G	700H	21.60	24.60	28.80	37.90	47.00
5	223-3G	700H	19.90	23.90	28.50	38.20	47.00
5	228-11	700H	19.50	24.70	30.60	40.10	41.00
5	222-13	700H	21.50	26.30	33.20	44.50	54.00
5	227-10	700H	22.80	25.40	28.00	36.30	38.50
Totals Pen 5			256.40	294.50	352.60	461.40	527.00
6	125-4G	70L	14.30	15.00	15.90	18.50	20.50
6	125-3G	70L	17.60	19.20	23.40	30.40	33.50
6	126-11	70L	16.20	18.50	23.60	29.00	29.00
6	126-5G	70L	15.80	18.80	22.20	27.00	30.50
6	225-12	70L	18.20	22.90	26.90	35.70	40.00
6	226-4G	70L	17.00	19.50	22.50	28.30	32.80
6	H6-2G	70L	18.00	17.00	19.80	24.10	29.00
6	127-15	70L	17.70	20.30	22.40	30.60	35.50
6	228-3G	70L	16.10	19.50	23.40	30.70	32.50
6	Y10-2G	70L	18.80	20.40	24.90	33.60	34.00
6	Y9-7B	70L	14.30	16.20	17.30	23.40	29.00
6	221-13	70L	16.80	18.50	20.40	24.20	28.00
Totals Pen 6			200.80	225.80	262.70	335.50	374.30
7	122-3G	70H	22.50	24.50	29.90	37.80	41.50
7	122-11	70H	23.10	26.90	28.30	38.00	45.00
7	225-2G	70H	20.40	22.60	28.50	34.70	39.50
7	226-12	70H	19.90	21.60	25.90	33.00	38.70
7	226-3G	70H	21.20	25.40	30.90	38.60	39.00
7	127-13	70H	18.90	20.50	25.60	32.60	38.00
7	223-10	70H	22.10	26.30	30.30	40.50	47.00
7	223-5G	70H	20.00	21.20	23.50	28.10	33.50
7	224-10	70H	21.50	24.80	27.40	36.40	42.00
7	209-1G	70H	24.50	28.70	31.80	42.00	49.00
7	227-3G	70H	20.80	22.50	25.80	35.30	40.00
7	221-15	70H	20.50	22.00	25.30	29.00	33.50
Totals Pen 7			255.40	287.00	333.20	426.00	486.70

Appendix 15. (Continued)

Pen	Pig	Trt	Weekly weights				
			Wk 1	Wk 2	Wk 3	Wk 4	Wk 5
8	124-10	70L	18.20	22.70	25.60	34.30	36.80
8	225-3G	70L	19.70	25.10	31.00	40.00	44.50
8	H6-3G	70L	14.30	15.00	16.30	17.10	23.50
8	H5-2G	70L	17.70	19.30	22.00	28.00	28.50
8	127-11	70L	17.40	21.20	22.80	29.20	34.00
8	127-3G	70L	15.90	17.20	20.70	27.40	33.50
8	228-12	70L	16.50	18.40	25.40	36.10	39.00
8	224-2G	70L	16.30	19.70	25.60	34.20	39.50
8	224-3G	70L	17.10	20.00	22.60	32.10	41.00
8	124-12	70L	16.10	18.50	20.80	25.20	30.50
8	222-1G	70L	18.10	22.60	28.30	38.80	47.50
8	Y9-6B	70L	13.10	13.60	16.80	23.70	25.20
Totals Pen 8			200.40	233.30	277.90	366.10	423.50
9	125-10	70H	20.70	21.80	26.30	33.60	39.00
9	221-10	70H	19.80	15.20	-	-	-
9	123-4G	70H	25.00	26.60	31.50	39.10	43.00
9	221-11	70H	18.60	19.80	25.20	32.10	32.50
9	126-1G	70H	20.50	22.70	30.50	39.30	39.00
9	226-1G	70H	22.70	25.40	32.40	43.20	40.50
9	223-11	70H	20.80	23.70	26.80	35.40	39.00
9	228-2G	70H	20.30	25.00	30.40	39.10	40.00
9	222-10	70H	22.80	26.20	32.10	45.90	51.50
9	Y11-1G	70H	21.20	21.30	24.90	33.30	38.40
9	122-15	70H	22.90	27.00	36.40	47.50	57.00
9	227-5G	70H	20.80	23.50	25.20	34.50	35.00
Totals Pen 9			256.10	278.20	321.70	423.00	454.90

Appendix 16. Individual weights for Trial II (pounds).

			Weekly weights				
Pen	Pig	Trt	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5
2	Y12-4	700H	18.00	23.20	28.10	36.00	44.50
2	Y14-4	700H	18.20	23.90	30.00	38.00	43.00
2	130-1	700H	20.40	24.30	29.00	40.50	50.50
2	241-13	700H	19.90	19.90	28.00	40.00	50.50
2	249-2	700H	20.60	28.00	36.50	47.50	58.00
2	248-17	700H	17.20	26.40	34.50	47.00	55.00
Totals Pen 2			114.30	145.70	186.10	249.00	301.50
3	253-11	700L	16.70	20.40	26.00	37.50	46.00
3	246-2	700L	16.20	24.10	30.00	40.00	46.50
3	H8-3	700L	15.50	20.70	24.00	36.00	39.00
3	249-12	700L	15.20	19.30	24.90	37.00	44.50
3	253-12	700L	14.70	21.60	21.60	31.00	36.50
3	251-5	700L	14.40	18.70	22.00	31.00	39.00
Totals Pen 3			92.70	124.80	148.50	212.50	251.50
4	Y14-3	700H	21.10	26.80	33.00	40.00	54.00
4	249-14	700H	20.90	26.50	34.00	40.00	53.00
4	Y12-1	700H	19.20	26.30	31.00	42.00	54.00
4	249-11	700H	18.30	24.90	29.00	40.00	50.00
4	241-12	700H	17.10	24.40	29.00	37.00	50.00
4	249-1	700H	18.40	28.60	35.00	45.00	55.00
Totals Pen 4			115.00	157.50	191.00	244.00	316.00
5	Y13-1	700L	16.50	20.20	22.00	28.50	38.00
5	241-15	700L	16.20	23.50	27.00	36.00	49.00
5	Y12-3	700L	15.80	18.90	19.20	28.00	36.00
5	Y14-1	700L	15.00	19.70	21.00	27.00	35.00
5	241-14	700L	14.90	21.30	24.00	32.00	43.00
5	253-14	700L	14.50	19.90	21.40	31.00	40.00
Totals Pen 5			92.90	123.50	134.60	182.50	241.00
6	248-15	70H	19.70	26.60	31.00	40.00	52.00
6	246-1	70H	19.10	25.70	30.00	40.00	49.00
6	243-2	70H	18.50	21.30	27.00	35.00	45.00
6	251-10	70H	17.00	22.90	27.00	36.00	46.00
6	249-10	70H	20.90	28.30	36.00	45.00	55.00
6	248-1	70H	21.90	24.50	30.00	38.00	50.00
Totals Pen 6			117.10	149.30	181.00	234.00	297.00

Appendix 16. (Continued)

			Weekly weights				
Pen	Pig	Trt	Wk 1	Wk 2	Wk 3	Wk 4	Wk 5
7	Y13-2	70L	16.10	21.30	25.60	35.00	43.00
7	241-11	70L	16.80	22.60	29.00	39.00	47.00
7	251-3	70L	15.50	22.10	28.50	38.00	47.00
7	246-10	70L	15.40	19.60	26.00	35.50	43.00
7	130-3	70L	14.60	20.00	25.50	33.00	41.00
7	249-11	70L	14.80	22.20	28.00	36.00	46.00
Totals Pen 7			93.20	127.80	162.60	216.50	267.00
8	248-10	70H	20.80	29.40	36.50	49.50	60.00
8	249-2	70H	21.20	27.90	34.50	46.00	55.00
8	243-10	70H	18.80	23.50	28.00	38.00	48.00
8	241-1	70H	19.50	27.20	26.50	45.00	56.00
8	243-3	70H	18.20	23.30	31.00	41.00	50.00
8	252-1	70H	17.10	19.80	34.00	38.00	47.50
Totals Pen 8			115.60	151.10	190.50	257.50	316.50
9	251-12	70L	14.50	20.40	25.50	35.50	45.00
9	242-3	70L	16.30	20.40	24.50	34.50	42.00
9	130-11	70L	16.70	22.40	27.00	36.00	44.00
9	Y14-6	70L	15.80	19.50	22.50	30.00	39.00
9	Y13-6	70L	15.10	20.20	23.50	37.00	45.00
9	252-2	70L	15.00	19.10	21.50	31.00	41.00
Totals Pen 9			93.40	122.00	144.50	204.00	256.00

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