SOME EFFECTS OF WATER CONTAINING SULPHATES, CHLORIDES AND NITRATES ON THE PERFORMANCE OF YOUNG PIGS

by

Derek Martin Anderson

A thesis submitted to the
Faculty of Graduate Studies and Research in
partial fulfilment of the requirements for the degree of
Master of Science

Department of Animal Science
Faculty of Agriculture
University of Manitoba
Winnipeg

December 1972

ABSTRACT

Water treatments high in chlorides, sulphates or nitrate-nitrogen, having a total solids concentration of approximately 6000 ppm and a control water treatment having a total solids concentration of 125 ppm were supplied to weanling pigs between 3 and 4 weeks of age initially weighing 4 to 6 kg. A total of 189 pigs were allotted, 9 per treatment, and provided with feed and water 'ad libitum' for 5 to 6 weeks (Experiments I, II, III and V). Pigs in Experiment IV were on test for 3 weeks. One experiment was conducted with 22 sows receiving either control water or a natural well water having a total solids content of 4500 ppm from a minimum of 1 week pre-farrowing to 3 week weaning of the piglets. Sows were confined to farrowing crates for the entire experimental period. In conjunction with Experiment III, 8 pigs, 2 per treatment, initially weighing 5 kg were housed in wire mesh cages for separation, collection and analysis of urine and feces.

No significant differences in average daily gain occurred between treatments in either the weanling pig experiments or the sow-nursing litter experiment. No differences in average daily feed consumption or feed efficiency occurred between treatments in the weanling pig experiments. Neither liver vitamin A stores nor blood methemoglobin levels were significantly different between treatments. Kidney weights as a percent of warm carcass weight did not significantly differ among treatments and kidney histological sections did not reveal changes due to treatment. Water consumption by pigs receiving saline waters was considerably higher than control pigs with the differences diminishing with time on experiment. Blood levels of sodium and

and potassium, and hematocrit values were uniform among treatments.

While there were no significant differences among treatments for urine volumes and urinary excretion of potassium, urinary excretion of sodium for the saline water treatments was significantly higher ($P < .01$) than the control treatment. Fecal percent dry matter, percent ash, sodium excretion and potassium excretion did not differ among treatments. Scouring was not an important condition in either the weanling pig experiments or the sow-nursing litter experiment. Deaths during the experiments were not related to water treatment.

Aside from increased water consumption and urinary sodium excretion no major differences occurred among the water treatments. The increased water consumption and urinary sodium excretion had no effect on the performance of weanling or nursing pigs.

TABLE OF CONTENTS

Page

ACKNOWLEDGEMENTS

The author wishes to thank Dr. E.W. Stringam, Professor and Head of the Department of Animal Science for allowing the use of the Department facilities for this research program.

Sincere appreciation is expressed to Dr. S.C. Stothers, for the opportunity to further my education under his guidance and supervision. I am thankful for his patience and understanding throughout the course of the experiments.

Thanks is also expressed to Dr. N.E. Stanger and Dr. L.D. Campbell for their constructive criticism during the writing and presentation of this manuscript.

Acknowledgement is given to Mr. John Baptist and Mr. Cho Yat Pang for their assistance when needed.

Financial support of this project was made possible by grants from Feedrite Mills (1962) Limited and The Manitoba Pool Elevators.

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

INTRODUCTION

Earliest research on saline waters was carried out in North America about 40 years ago. Since then various workers have delved into the problems of saline water for livestock from several points of view. About ten years ago at the University of Manitoba, research with growing and finishing pigs, initially weighing 20 kg, studied the effects of sulphates and chlorides in water at levels ranging from approximately 10,000 parts per million (ppm) to as high as 23,000 ppm total solids.

Research has been done regarding the effects of nitrates on a nitrate-nitrogen basis on pigs of various ages with conflicting conclusions to those expressed by some field surveys of similar situations. Recently in Manitoba, some extension workers have complained of water quality problems with young growing pigs with nitrate-nitrogen considered a possible factor. Because of the documented fact that levels of 10 ppm nitrate N can cause methemoglobinemia in infants, the assumption has been made in some cases that a similar situation was true of young pigs. Further research reported from the University of Manitoba, Roy and Boylan (1964), involved a natural well water high in chlorides with a total solids content of approximately 4500 ppm fed to sows and nursing litters, weanling pigs and finishing pigs. No adverse effects were noted. At the time of the above mentioned experiment the accepted procedure was a six weeks weanling of piglets. Later with the advent of early weaning (3 weeks) younger, smaller, pigs became exposed to saline waters as their only source of water. Recently at the University of Manitoba, Stothers (1970), three week old weaned pigs were supplied with a sulphate water containing approximately 2000 ppm total solids with no adverse effects.

The research reported here was to take a closer, detailed look at the effects of saline waters, including nitrate-nitrogen, sulphate and chloride, on the performance of newly weaned pigs with initial weights of 4 to 6 kg. A smaller study was initiated to up date information on the effects of saline water on nursing sows and their litters housed in a total confinement unit. Whereas work with the weaned pigs involved levels of 6000 ppm total solids from a synthetic mixture; sows and nursing litters received a natural well water containing 4500 ppm total solids in chlorides as their only source of water for the nursing period.

LITERATURE REVIEW

A. WATER QUALITY FOR VARIOUS CLASSES OF LIVESTOCK

Early publications deal with a generalized tolerance to salinity based on acceptability to all livestock. Embry et al (1959) classified water in the following manner for all livestock:

Table 1

SALINITY AS RELATED TO THE QUALITY OF LIVESTOCK WATER

Total Salts (Solids) Content of Water (ppm)		Quality
0	999	Excellent
1,000	3,999	Good
4,000	6,999	Satisfactory
7,000 and over		Unsatisfactory

The Laboratory for Water Analysis at the University of Saskatchewan (1965) indicated a classification of water for drinking by different classes of livestock on the basis of dissolved solids as follows:

Table 2

WATER QUALITY FOR VARIOUS CLASSES OF LIVESTOCK

Dissolved Solids (ppm)

Species	Good	Fair	Poor (Usable)	Very Poor (Questionable)	Limit (Not Advised)
Humans	0- 800	800-1600	1600-2500	2500- 4000	5000
Horses					
Working	0-1000	1000-2000	2000-3000	3000- 5000	6000
Others	0-1200	1200-2500	2500-4000	4000- 6000	10,000
Cattle	0-1200	1200-2500	2500-4000	4000- 6000	10,000
Sheep	0-1500	1500-3000	3000-6000	6000-10,000	15,000
Poultry					
Full Grown	0-1500	1500-3000	3000-6000	6000-10,000	15,000
Chicks	0-1000	1000-2000	2000-3000	3000- 5000	6000
Swine	Young pigs and market pigs tolerate less than Cattle				

The rest of this section will deal with detailed research on the effects of saline water on various classes of livestock excluding swine.

CATTLE

Seddon (1931) noted a 110-150 kg calf could tolerate water with 10,000 ppm sodium chloride without ill effects. Heller (1933) stated 15,000 ppm sodium chloride as the maximum concentration safe for maintenance of dry cows. Lactating cows would tolerate less. He commented that calcium chloride was more toxic than sodium chloride since water with 10,000 ppm calcium chloride was not tolerated.

Work done by Embry and co-workers (1959) used sodium sulphate at levels of 4000 ppm, 7000 ppm, or 10,000 ppm in the water causing reduced feed consumption and rate of gain, scouring, with weight loss and a reduced water intake with fattening heifers at the highest concentrations. Using 10,000 ppm sodium chloride or 10,000 ppm mixed salts failed to show the dramatic reduction in feed consumption or rate of gain associated with similar levels of sodium sulphate. No effect in rate of gain or feed consumption occurred at 7000 ppm total solids. Apparently toxic levels for fattening cattle must lie somewhere between 7000 ppm and 10,000 ppm depending on the salts present, according to the authors. Salt was available free choice.

Weeth et al (1960) found water containing 10,000 ppm sodium chloride to increase water consumption and decrease blood urea in heifers whereas water containing 20,000 ppm sodium chloride caused severe anorexia, weight loss and anhydremia. Weeth and Hunter (1971) using 5000 ppm sodium sulphate in water found a weight loss in heifers over a 30 day period.

SHEEP

Heller (1933) using groups of five sheep for a period of six weeks found sheep could exist on levels of 25,000 ppm sodium chloride, 20,000 ppm magnesium sulphate, or 25,000 ppm calcium chloride but suggested 15,000 ppm total solids as the upper limit for maintenance. Pierce (1957a) stated that sheep receiving 10,000 ppm sodium chloride for 15 months performed as well as control sheep receiving rain water. Sheep receiving 15,000 ppm sodium chloride performed poorly so this level was considered toxic. Pierce (1957a) supplied sheep with a water containing 13,000 ppm total solids made up with various concentrations of 200 ppm to 5000 ppm magnesium chloride with the remaining salt being sodium chloride. He concluded that up to 1000 ppm magnesium chloride combined with 12,000 ppm sodium chloride was the upper limit of magnesium chloride acceptable to sheep since higher concentrations of magnesium chloride caused toxicity. Further work by Pierce (1959, 1960, 1962 and 1963) comparing various salts in combination with sodium chloride showed that, for the most part, combinations up to 13,000 ppm total solids were tolerated by sheep. Pierce (1966) found that wethers receiving a saline water of 5000 ppm bicarbonate had a significantly reduced wool production but with no adverse effects on general health, feed consumption or weight increase. According to Pierce (1968), ewes and their lambs tolerated either a high bicarbonate (5000 ppm) or high chloride (13,000 ppm) water.

POULTRY

According to Selye (1943) water containing 9000 ppm sodium chloride caused heavy mortality in young chicks. Kare and Biely (1948) observed mortality of less magnitude than did Selye (1943) when day old chicks were supplied with 9000 ppm sodium chloride in drinking water and 1800 ppm sodium chloride in the diet. Using the same dietary level of sodium chloride and 3000 ppm sodium chloride in water, Kare and Biely found no effects due to salinity. Edema but not mortality occurred in day old chicks receiving 5000 ppm sodium chloride in water and a dietary level of 10,000 ppm sodium chloride in experiments conducted by Doll, Hull and Insko (1946).

Krista (1961) studied the effects of saline water on chicks, laying hens, poults and ducklings. Chicks were supplied with water containing 4000 ppm, 7000 ppm, 10,000 ppm and 12,000 ppm sodium chloride added to a water analysed at 530 ppm total solids. Significant increases in mortality occurred at 7000 ppm while at 4000 ppm sodium chloride chicks exhibited watery feces, increased water consumption and loss of appetite. Laying hens receiving sodium chloride at levels of 0 ppm, 4000 ppm, 7000 ppm and 10,000 ppm, magnesium sulphate at levels of 10,000 ppm and sodium sulphate at levels of 10,000 ppm and 12,000 ppm, exhibited significant decreases in egg production at 10,000 ppm sodium chloride, 12,000 ppm sodium sulphate and which approached significance at 10,000 ppm magnesium sulphate. Body weight was unaffected by any level of saline water studied. Poults receiving levels similar to those reported for chicks demonstrated significant increases in mortality at 4000 ppm sodium chloride Poults and ducklings receiving 4000 ppm sodium chloride exhibited retarded growth, watery feces, increased water consumption and billing of feed by the ducks.

Losses in young poults from ascites and edema occurred when using a basal ration containing 4600 ppm sodium chloride in combination with water containing 6000 ppm total solids from mixed salts in experiments reported by Robblee and Clandinin (1961).

Sibbald et al (1962) found increased mortality at 7500 ppm sodium chloride in drinking water regardless of the amount of sodium chloride available in diet up to 5000 ppm (.5%) with chicks 0 to 4 weeks of age.

O'Neil (1963) summarizes the effect of various salts with relationship to their individual toxicities. Chicks 0 to 4 weeks of age were used. Feces became more watery with increasing levels of mineral. Water to feed ratios increased with increasing mineral level in water. As the ratio of water to gain approached 8: 1 body weight was significantly depressed. Mortality occurred at higher ratios.

Table 3

INDIVIDUAL TOXICITY LEVELS OF VARIOUS SALTS ON CHICKS

0 - 4 WEEKS OF AGE

SALT	SATISFACTORY LEVEL	TOXIC LEVEL
Sodium Carbonate	2400- 3200 ppm	6400 ppm
Sodium Chloride	4800 ppm	6400 ppm
Sodium Nitrate	6400 ppm	8000 ppm
Sodium Bicarbonate	6400 ppm	9600 ppm
Calcium Nitrate	8000 ppm	9600 ppm
Sodium Sulphate	12,000 ppm	12,800 ppm
Magnesium Sulphate	12,000 ppm	-

RATS

Heller and Larwood (1930) showed that levels of 15,000 ppm of salts lowered growth rate while 10,000 ppm affected reproductive performance in rats.

Muhrer et al (1956) indicated that rats fed 140 ppm or 280 ppm nitrate-nitrogen produced fewer litters than did control rats. Reproductive performance was affected to the point where 9 of 12 female rats receiving 140 ppm nitrate-nitrogen incorporated in their diets and 2 of 8 female rats receiving 280 ppm nitrate-nitrogen incorporated in their diets produced litters as compared to 12 of 12 control female rats producing litters. Of the 8 female rats fed 280 ppm nitrate nitrogen, four produced placental tissue but not litters indicating abortion or absorbed fetuses.

Work done with rats was reported by Embry (1959). Sprague-Dawley male albino rats initially weighing 68 gms were allowed feed and water ad libitum. Using various levels of sodium chloride, sodium sulphate, magnesium chloride, magnesium sulphate, and calcium chloride dissolved in water indicated that levels below 4000 ppm total solids reflected no change in the rats' performance whereas 10,000 ppm usually did.

O'dell et al (1960) used vitamin A depleted rats to study the effect of nitrite (potassium nitrite) on the vitamin A and vitamin E status of rats. Rats receiving potassium nitrite showed dystrophy typical of vitamin E deficiency as well as a more rapid depletion of vitamin A stores. Growth was depressed by addition of potassium nitrite to the ration.

Emerick and Olson's (1962) work with vitamin A deficient rats fed either 420 ppm nitrate-nitrogen or 70 ppm nitrite-nitrogen indicated differences in final weights generally associated with nitrate and especially nitrite fed rats. Both nitrate and nitrite treatments affected liver weights. Nitrite feeding resulted in reduced amounts of vitamin A stored in the liver when vitamin A was administered orally but not when vitamin A was administered by subcutaneous injection.

B. WATER REQUIREMENTS OF WEANLING PIGS

According to the National Research Council requirements, (1968) weanling pigs will consume 20 kg of water daily per 100 kg of body weight. The daily water consumption of a 5 kg pig would be 1 liter.

Herrick, (1971) stated the daily requirements for swine weighing from 9 kg and 18 kg to be 1.1 liters to 2.3 liters respectively.

The ARC publication on Nutrient Requirements of Pigs (1967) states similar recommendations with respect to water consumption as to those recommended by the NRC requirements of 1968.

Friend and Cunningham (1966) found water consumption (excluding milk) of .084 l total during the first week of life with piglets initially weighing 1.26 kg. During the seventh week water consumption was .55 liters per day for sucling pigs weighing 13.8 kg at the end of the seventh week. In this work water was available ad libitum for a nine hour period each day.

C. EFFECTS OF NITRATE-NITROGEN ON THE PERFORMANCE OF SWINE

Due to the fact that initially various publications reported using different forms of nitrate in experiments, here all nitrate levels are expressed as nitrate-nitrogen or nitrite-nitrogen regardless of the source of the nitrogen. Conversions were completed using the table described by Mitchell.[1]

Emerick <u>et al</u> (1965) found that healthy one week old pigs were no more susceptible to nitrite induced methemoglobinemia than the same pigs when older. Data pertaining to methemoglobin formation and reduction were obtained in vitro and in vivo at approximately 1 week, three months, and five and a half months of age at which time average body weights were 1.9 kg, 30.8 kg and 94.1 kg respectively. With respect to the in vivo study, pigs given intravenous injections of

[1] Checking water supplies for Nitrates, National Hog Farmer, Swine Information Service, Bull. D22 p1

3 ppm (0.03 grm $NaNO_2$/kg body wt) developed a lower degree of methemoglobinemia when treated at one week of age than the same pigs at 3 months or 5½ months of age. Percent methemoglobin obtained in vitro was the same for all pigs of all ages although a slower rate of methemoglobin reduction was observed for 5½ month old pigs.

Seerley et al (1965) administered nitrate or nitrite continuously in the drinking water of growing-finishing swine. There were no significant differences in average daily gain, feed efficiency, water consumption and liver vitamin A levels with sodium nitrate at levels up to 300 ppm nitrate N. Gilts fed 300 ppm nitrate N over two farrowings showed no adverse effects on daily gain, feed efficiency or thriftiness. Birth weights, average daily gain, litter size at weaning, blood and liver vitamin A content of piglets from nitrate treated dams were not adversely affected by treatment. Adding 100 ppm nitrite N to drinking water of bred gilts and growing and finishing pigs gave measurable but small increases in methemoglobin without obvious detrimental effects on performance or liver vitamin A values determined after 105 days on treatment.

Dollahite and Holt (1969) state that functional hemoglobin, that is total hemoglobin minus methemoglobin, is more relevant to the welfare of the animal than the total hemoglobin or percent methemoglobin.

Garrison et al (1966) adminstered nitrate and nitrite to drinking water to observe the effect on carotene utilization by growing and finishing swine. Using potassium nitrate at levels of

105 ppm, 210 ppm and 420 ppm nitrate N, vitamin A stores from either a beta carotene source of a vitamin A palmitate source were reduced in all treatments. At levels of 420 ppm nitrate N with beta carotene as a vitamin A source, vitamin A stores were significantly lower than the control treatment ($P < .05$). Feed efficiency was greatly reduced at the 420 ppm nitrate N levels.

In the same study potassium nitrite was administered at levels of 28 ppm, 56 ppm and 112 ppm nitrite N in the drinking water. Treatments of 28 ppm and 112 ppm nitrite N were significantly different ($P < .01$) from the control treatment with respect to rate of gain. Liver vitamin A levels in swine receiving 56 ppm and 112 ppm nitrite N were significantly different ($P < .05$) from the controls.

Case (1957) stated that any amount of nitrate over 3050 ppm nitrate N of the total feed and water intake is a potential problem. Further work by Case (1963) indicates that water containing more than the recommended maximum level of 10 ppm nitrate N is probably going to cause some herd health problems in swine. Reference is made to levels of 10 ppm to 50 ppm nitrate N as marginal in quality with levels above 50 ppm as hazardous, leaving the animal susceptible to attack by disease organisms. He suggests a multiplication of problems with increasing levels above 50 ppm nitrate N in water.

The University of Saskatchewan (1965) mimeographed supplement to the report on quality of rural water supplies, and the Federal Water Pollution Control Administration (1968) refer to the established maximum allowable level of 10 ppm nitrate N and nitrite N combined in water used for human consumption. Methemoglobinemia in human infants (blue babies) has been attributed to slightly higher levels of nitrate N.

Olson et al (1972) found a relationship between nitrate levels in water and livestock feeds to herd health problems. Subtle adverse effects occur on the physiological function of affected animals. Herd health problems in 15% of operations surveyed were related to excess nitrate intake levels of 24.4 ppm to 164.7 ppm nitrate N in the water and 64 ppm to 2562 ppm nitrate N in the feed source.

D. EFFECTS OF SULPHATES AND CHLORIDES IN DRINKING WATER ON THE PERFORMANCE OF SWINE

Seddon (1931) observed a mature pig to tolerate 25,000 ppm sodium chloride for 40 days with some signs of nervous derangement. Two 55 kg pigs consumed water containing 19,000 ppm sodium chloride for 13 and 22 days respectively with a reduced increase in weight gain. A 13 kg pig consumed water containing 9,000 ppm sodium chloride for 40 days without performance being affected.

Sodium chloride of 15,000 ppm was found toxic for pigs, especially young pigs, resulting in decreased feed consumption in a study conducted by Heller (1933). He reported that all pigs could tolerate 10,000 ppm sodium chloride without ill effects.

Buffagni (1935) found pigs receiving brine mixed with food, where each pig ingested the equivalent of 500-600 ml of a 20% solution of sodium chloride per day for 3 days, demonstrated salt poisoning.

Bohstedt and Grummer (1954) reported pigs receiving a swill containing either 15,000 ppm or 20,000 ppm sodium chloride with no drinking water, developed salt poisoning. These workers found no increase in sodium or chloride ions in the plasma or serum of these pigs.

According to Pierce (1957) symptoms of problems with saline waters included; decreased food consumption, reduced rate of gain, diarrhea and increased excretion of urine. The latter would occur since most of the sodium chloride ingested is excreted via the kidney.

Embry et al (1959) reported on work done using pigs weighing 16.8 kg fed a mixture of salts including sodium chloride, magnesium sulphate and sodium sulphate, in a ratio similar to that found in natural waters. Feed contained 5,000 ppm sodium chloride, while water treatments contained 2100 ppm, 4200 ppm or 6300 ppm total solids. Results showed average daily gain, feed consumption and feed efficiency were slightly better for pigs receiving saline waters. Water consumption increased with increasing salinity. Scouring occurred during the first week on test.

Berg and Bowland (1960) used pure salts of magnesium sulphate, sodium chloride, sodium sulphate or mixtures of magnesium sulphate and sodium chloride added to a natural water containing 140 to 150 ppm total solids. No adverse effects were noted in pigs initially weighing 12 kg with waters containing up to 5000 ppm of any salts, when compared with the natural water source. No sodium chloride was added to the treatment diets.

Stothers (1960) supplied 27 kg pigs with water containing 11,123 ppm total solids, two to three times a day in a trough. Slight effects on rate of gain occurred primarily during the first two weeks on experiment. Notably average daily water consumption for the saline treatments was 6.5 liters as compared to 4.6 liters for the control treatment. Feed efficiency was affected by saline treatments mainly during the growing state, since a subsequent study using finishing pigs initially weighing 57 kg showed no effect on rate of gain and feed efficiency.

Stothers and Palmer (1961) supplied weanling pigs, 11 kg to 22 kg with saline water having a total solids concentration of 11,000 ppm particularly high in the sulphate ion (4880 ppm). Similar to the study by Stothers (1960) a slower growth rate, decreased feed consumption, lower feed efficiency and higher water treatments. As with the previous study by Stothers (1960), pigs from 27 kg to 81 kg body weight showed decreased rates of gain, poorer feed efficiency, and higher water consumption when subjected to saline water treatments containing 11,000 ppm total solids. Growing and finishing pigs receiving either 15,900 ppm, 17,900 ppm or 21,300 ppm total solids exhibited decreased growth rate, poorer feed efficiency and higher water consumption, than control pigs.

The work of Stothers and Palmer (1961) also included a study of the effects of a high chloride ion (4,039 ppm) water containing 10,400 ppm or 14,800 ppm total solids on growing and finishing swine. Pigs receiving 10,400 ppm total solids out performed control pigs in all respects, whereas those receiving 14,800 ppm total solids performed so poorly they were removed from test at 57 kg. Water consumption was higher for all saline treatments.

Roy and Boylan (1964) provided a water containing 4300 ppm total solids to sows with nursing litters, weanling and growing pigs (11 kg to 44 kg), and finishing pigs (57 kg to 91 kg). Aside from increased water consumption, no effects due to saline waters were noted. In this experiment and those by Stothers (1960, 1970) and Stothers and Palmer (1961), sodium chloride was added to the diet at levels of 5000 ppm.

Stothers (1970) used a synthetic water supply containing 2400 ppm total solids and a natural well water containing 2000 ppm total solids to attempt to show a relationship between saline water and poor performance in weanling pigs initially weighing 6.4 kg or 12.3 kg. Although scouring was considered the primary effect on pigs given the saline water treatments, it created no problem in this experiment. No performance differences were noted with pigs initially weighing 12.3 kg, but amongst the 6.4 kg weanling, those receiving the natural well water (2000 ppm) and a commercially prepared diet, showed a decrease in gain and feed efficiency as compared to control pigs.

Herrick (1971) indicated that 1000 ppm sulphates may have a cathartic effect, particularily on young livestock, but that a tolerance is built up to constant dietary or water levels of 2000 ppm to 2500 ppm sulphates over a period of time.

MATERIALS AND METHODS

A. OBJECTIVE

Six experiments were undertaken to determine the effects of saline waters, either high in chlorides, sulphates or nitrate-nitrogen, on the performance of 3 to 4 week old weanling pigs initially weighing 4 to 6 kg. Included was one experiment to determine the effects of saline water on the performance of sows and nursing litters in farrowing crates housed in a total confinement barn. At the same time as Experiment III physiological data were obtained from other weanling pigs housed in metabolic cages.

B. WEANLING PIG EXPERIMENTS

The water treatments used and design of the experiments are tabulated in Table 4. All pigs received feed and water 'ad libitum'. Initially pigs received a commercial pig weaner (18% protein). At an average weight of 7 kg, the ration was changed to a university formulated creep feed (wheat-soybean meal-fish meal) (19% protein). From 15 kg average weight pigs received a balanced starter ration (barley-soybean) (18% protein). Composition of the various feeds is summarized in Appendix Table 1. Initially pigs were allotted to treatment by weight, sex and litter. Pens were checked daily for scouring while pig weights, feed and water consumption were recorded weekly.

Since scouring was reported as a problem associated with the use of saline water, scour days were used as a criteria for measurement. A scour day referred to scouring in a pen regardless of the number of animals involved.

Water treatments (Table 5) used were high in sulphates or

Table 4

THE WATER TREATMENTS USED IN THE VARIOUS EXPERIMENTS

AND THE DESIGN OF THE EXPERIMENT

Experiment No.	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N	Chloride	Chloride plus 300 ppm Nitrate N
I		X	X	X		
II	X	X	X	X		
III	X	X	X	X		
IV	X	X			X	X
V	X				X	X
Metabolism Cage Study	X	X	X	X		

chlorides and varying levels of nitrate-nitrogen (Table 6). Nitrate-nitrogen levels were 0 ppm, 150 ppm or 300 ppm. Total solids concentration of all saline water treatments was approximately 6000 ppm. Water solutions were prepared in 204 liter plastic containers from stock solutions of the various salts and were presented to the pigs in 64 liter painted metal barrels, fitted with a watering bowl as shown (figure 1). Pigs were weighed on a weekly basis until the conclusion of the individual experiments.

EXPERIMENT I

During November 1970, 27 weanling pigs weighing between 4 and 6 kg were kept on experiment for a 5 week period to an average final weight of 24.5 kg.

Blood samples were taken on days 20, 27 and 34 by puncture of the anterior vena cava. Analysis for methemoglobin was carried out on the blood by a modified version of the Method of Evelyn and Malloy (1938), using a Spectronic 20, Bausch and Lomb colorimeter. Upon completion of the experiment, two pigs from each treatment were sacrificed and the livers were frozen and stored at -20°C. for subsequent analysis for vitamin A content by the method of Gallop and Hoefer (1946). In addition kidney weights were recorded and slices preserved for histological examination.

EXPERIMENT II

Commencing in February 1971, 36 weanling pigs, initially weighing between 4 and 5 kg, were kept on experiment for a period of six weeks to a final weight of 20 kg.

Fig. 1. Water resevoirs with attached watering bowls

Table 5

SALT COMPOSITION OF WATER TREATMENTS USED IN

WEANLING PIG EXPERIMENTS AND METABOLIC CAGE STUDY

Salt	Control[1]	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N	Chloride	Chloride plus 300 ppm Nitrate N
Calcium Chloride	-	780	780	780	780	780
Magnesium Sulphate	-	1694	1694	1694	-	-
Sodium Bicarbonate	-	2671	1844	1040	2671	1040
Sodium Nitrate	-	-	910	1818	-	1818
Sodium Sulphate	-	708	708	708	-	-
Sodium Chloride	-	-	-	-	2401	2401
Total Solids[2]	125	5978	6061	6165	6077	6164

[1] Solids or salts given in ppm

[2] Total solid concentration includes that found in control water in addition to added salts.

Table 6

INDIVIDUAL ION CONCENTRATIONS OF THE WATER TREATMENTS USED IN WEANLING PIG EXPERIMENTS AND METABOLIC CAGE STUDY

Ion	Control[1]	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N	Chloride	Chloride plus 300 ppm Nitrate N
Calcium	19.4	303	303	303	303	303
Magnesium	5.6	345	345	345	5.6	5.6
Sodium	1.5	961.5	981.5	964.5	1684.5	1687.5
Sulphate	-	1883	1883	1883	-	-
Chloride	120	616	616	616	2560	2560
Bicarbonate	-	1938	1339	755	1938	755
Nitrate N[2]	Nil	Nil	150	300	Nil	300

[1] Ion cencentration given in ppm

[2] Nitrate in the form of nitrate-N rather than the nitrate ion form

On days 24 and 31 blood samples were taken and immediately analysed for methemoglobin content. At the termination of Experiment II, two pigs per treatment were sacrificed with liver samples, kidney weights and kidney sections obtained and treated as in Experiment I.

EXPERIMENT III

In May 1971, 36 weanling pigs averaging 4 to 5 kg initial weight were subjected to experimental conditions for a six week period to a final weight of 20 kg.

No blood samples were obtained, but upon completion of the experimental period, two pigs per treatment were sacrificed. Liver samples for vitamin A analysis, kidney weights and kidney slices for histological examination were collected.

EXPERIMENT IV

In August 1971, 36 pigs initially weighing between 4 and 5 kg were kept on experiment for a period of three weeks to an average final weight of 9 kg.

EXPERIMENT V

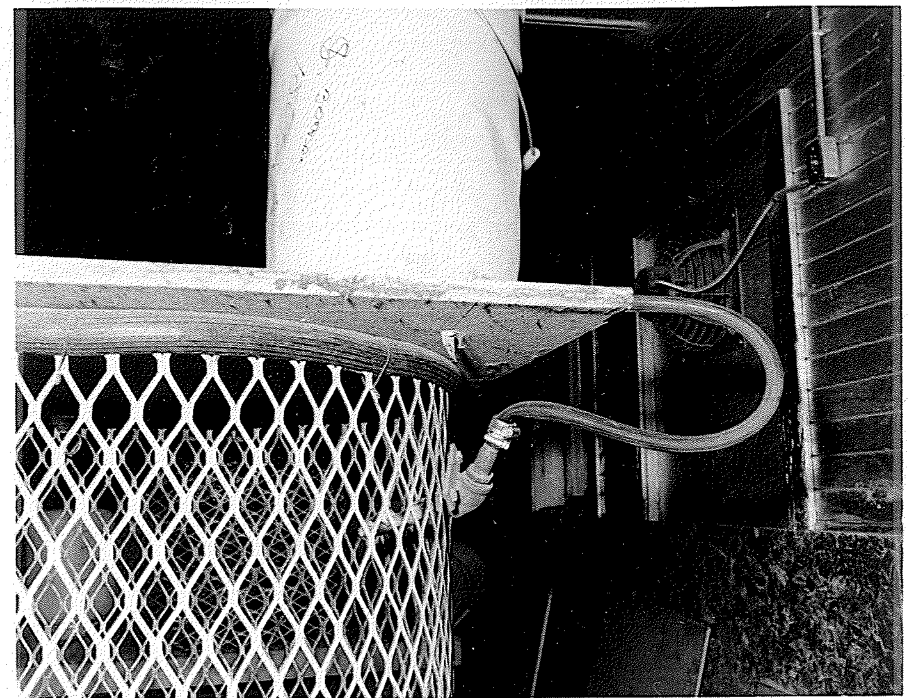
In October 1971, 54 pigs initially weighing 4 to 5 kg, from two sources, were kept on experiment for a six-week period, to an average final weight of 18.9 kg. The 27 pigs from the Glenlea Research Station consisted of 16 pigs having received a chloride water (4500 ppm total solids) before weaning, the remaining 11 pigs received water from the Winnipeg water supply during the three weeks prior to initiation of the experiment. This group of pigs represented one replicate, while the 27 pigs from the campus herd formed the other replicate.

C. METABOLIC CAGE STUDY

Eight barrows from two litters initially weighing an average of 5.2 kg were allotted according to litters to the four water treatments. Over the five-week experimental period, pigs were housed in wire mesh cages, as described by Bell (1948), equipped with bite type waterers (figure 2) for three periods of 1 to 7, 8 to 14 and 29 to 35 days. For the remaining two, days 15 to 21 and 22 to 28, pigs were housed in separate pens, according to treatment.

Average final weights at the end of the experiment period were 16.1 kg. Water was available 'ad libitum' from a 23 liter metal container attached by a rubber hose to the bite waterer. Feed was available 'ad libitum' except when pigs were housed in the wire mesh cages, at which time feed was available twice a day. Performance data were collected as described in the weanling pig experiments. In addition blood was collected on Day 15 and analysed for percent hematocrit, sodium and potassium ion concentrations.

Analysis for sodium and potassium was accomplished using an auto-analyser Technicon II (model AA11 -07) for flame photometry. Daily urine volumes were recorded and a representative aliquot retained and frozen for analysis of sodium and potassium by the method described above. Feces were collected daily with representative amounts frozen and retained for analysis. Samples collected on odd numbered days were analysed for dry matter percent, percent ash, sodium and potassium levels. Dry matter percent was accomplished by freeze



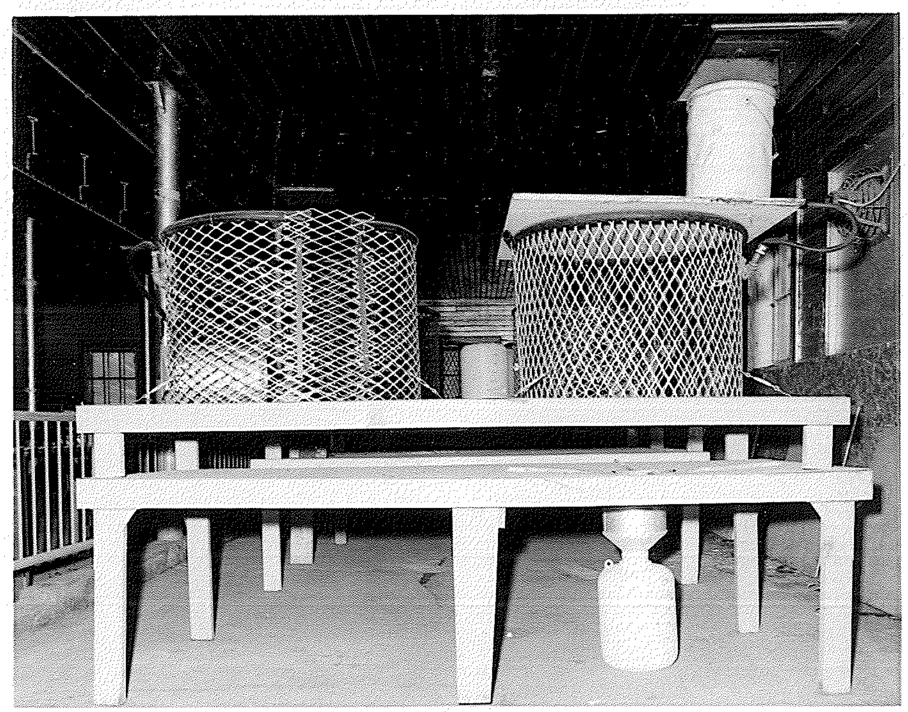


Fig. 2. Metabolic cages with attached bite waterers used in the metabolic cage study

drying the feces in a Virtis Freeze Dryer. Ashing was accomplished in a furnace at 500^{o} degrees C for 15 minutes. Analyses for sodium and potassium were carried out using two methods. To the ashed samples five milliliters of double distilled (demineralized) water were added and the samples shaken for 24 hours. Feces collected on even numbered days were subjected to a Carver Laboratory Press (Model C) (figure 3), from which the expressed juice was collected, diluted and analysed for sodium and potassium.

D. SOWS AND NURSING LITTERS

EXPERIMENT VI(a)

During September 1971, 12 sows were randomly allotted to the two water treatments; control (Winnipeg water supply), or a natural chloride well water (Table 4). Sows were allowed access to water ad libitum from at least one week pre farrowing through a three-week nursing period. Nursing pigs had the same. Data were collected with respect to litter size at birth, birth weight and weaning weight. Sows were fed twice a day but no creep feed was available to piglets. Sows were housed in farrowing crates in a minimum disease, total confinement barn.

EXPERIMENT VI(b)

In January, 1972, ten sows were randomly allowed to one of the two water treatments described in Experiment VIa. Data collected were identical to those reported in Experiment VIa.

E. GENERAL

All statistical analysis was done by the method of Steel and Torrie (1960). All rations for all experiments with weanling pigs

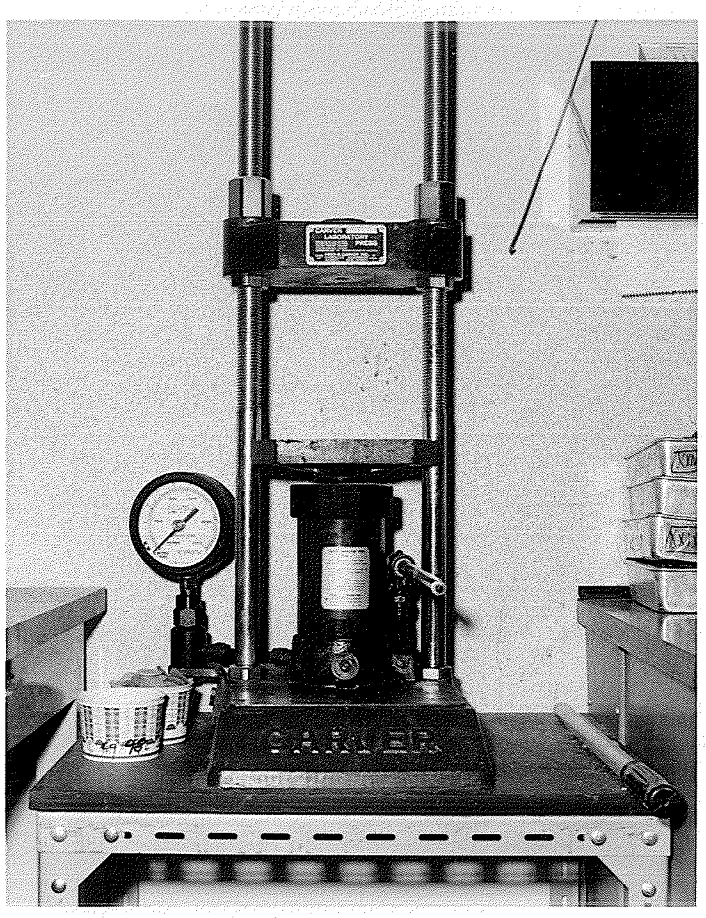


Fig. 3. Carver Laboratory Press used to squeeze feces for analysis of the expressed juice

contained 0.5% trace mineralized salt. Sow rations contained not more than 0.25% trace mineralized salt.

Table 7

WATER ANALYSIS[1] OF THE WATER TREATMENTS USED IN THE SOW NURSING LITTER EXPERIMENTS

Analysis	Glenlea Water	Winnipeg Water
Nitrate	Nil	Nil
Calcium	144	21
Magnesium	63.2	5.8
Sulphate	550	Nil
Sodium	2000	1.5
Bicarbonate	254	107
Total Dissolved Solids	4500	125

[1] Expressed in ppm

RESULTS AND DISCUSSION

A. WEANLING PIG EXPERIMENTS

EXPERIMENT I

No significant differences were observed in rate of gain between treatments (Table 8). Neither feed consumption nor feed efficiency showed apparent adverse effects to sulphate water treatments either alone or in combination with either 150 ppm or 300 ppm nitrate-nitrogen (Table 9 and 10 respectively). Water consumption showed an increase over the period of experimentation in all treatments with a marked difference between the highest level of nitrate and the other two treatments (Table 11). Levels of scouring were four, four, and five scour days for the water treatments sulphate, sulphate plus 150 ppm nitrate-nitrogen, and sulphate plus 300 ppm nitrate-nitrogen respectively. Scouring was limited to the initial week of experiment.

Methemoglobin (%) blood levels are not significantly different among the treatments. No increase in % methemoglobin occurs with increasing time on experiment (Table 12). Liver Vitamin A levels indicate no consistent treatment variation (Table 13) which agrees with results obtained by Seerley et al (1965) using identical levels of nitrate-nitrogen. Similarily kidney weight as a percent of warm carcass weight reflected no change in any of the three saline water treatments (Table 14 (a)). Histologically kidney sections were normal.

Table 8. Average Daily Gain of Pigs on a Weekly Period in kg Per Day

Week	Sulphate	Sulphate plus 150 ppm Nitrate-Nitrogen	Sulphate plus 300 ppm Nitrate-Nitrogen
1	.36	.34	.32
2	.47	.42	.46
3	.60	.59	.50
4	.64	.57	.55
5	.58	.64	.58
overall[1]	.53	.51	.49

[1] Analysis of Variance for overall average daily gain is reported in appendix Table 2.

Table 9. Feed Consumption of Pigs in Experiment I on a Weekly Period in kg Per Day

Week	Sulphate	Sulphate plus 150 ppm Nitrate-Nitrogen	Sulphate plus 300 ppm Nitrate-Nitrogen
1	.46	.47	.50
2	1.16	1.19	1.00
3	1.15	1.33	1.01
4	1.00	.99	.98
5	1.45	1.47	1.33
overall	1.05	1.09	0.95

Table 10. Feed Efficiency of Pigs in Experiment I (kg feed/kg gain)

Week	Sulphate	Sulphate plus 150 ppm Nitrate-Nitrogen	Sulphate plus 300 ppm Nitrate-Nitrogen
1	1.15	1.40	1.60
2	2.60	2.82	2.16
3	1.94	2.28	2.00
4	1.63	1.73	1.60
5	2.50	2.32	2.30
overall	1.99	2.11	1.94

Table 11. Water Consumption of Pigs in Experiment I Reported in Liters Per Day

Week	Sulphate	Sulphate plus 150 ppm Nitrate-Nitrogen	Sulphate plus 300 ppm Nitrate-Nitrogen
1	2.08	2.07	2.24
2	2.06	2.09	2.24
3	2.63	2.61	3.17
4	3.64	3.56	3.96
5	3.27	3.79	4.34
overall	2.78	2.87	3.24

Table 12. Percent Methemoglobin in Pig Blood for Experiment I with Blood Samples Being Drawn on Days 20, 27 and 34.

Day	Sample[1] No	Sulphate	Sulphate plus 150 ppm Nitrate-Nitrogen	Sulphate plus 300 ppm Nitrate-Nitrogen
	1	2.0	2.7	1.8
	2	2.6	2.3	2.3
20	3	2.3	2.3	1.3
	4	1.7	1.8	3.8
	mean	2.15	2.27	2.30
	1	1.2	2.0	3.6
	2	1.0	2.5	2.1
27	3	4.3	2.0	1.7
	4	2.0	1.8	2.3
	mean	2.13	2.08	2.43
	1	0.9	0.6	1.6
	2	1.9	1.0	1.6
34	3	0.2	0	0.8
	4	2.7	2.1	2.3
	mean	1.43	0.93	1.75

[1] Blood was drawn from four pigs per treatment on each day of sampling.

Table 13. Liver Vitamin A Levels (ug Vitamin A/gm Liver) Obtained Upon sacrifice of Pigs in Experiment I

Sample	Sulphate	Sulphate plus 150 ppm Nitrate-Nitrogen	Sulphate plus 300 ppm Nitrate-Nitrogen
1	32.25	31.47	24.57
2	48.82	52.79	50.19

[1]Two pigs per treatment were sacrificed at the end of the Experiment I

Table 14. Kidney Size as a Measure of Effect of Saline Water on Kidney Function, Measured as a Percent of Warm Carcass Weight.

(a) Experiment I

Sample[1] No.	Sulphate	Sulphate plus 150 ppm Nitrate-Nitrogen	Sulphate plus 300 ppm Nitrate-Nitrogen
1	.57	.54	.63
2	.61	.60	.53

(b) Experiment II

Sample No.	Control	Sulphate	Sulphate plus 150 ppm NO3-N	Sulphate plus 300 ppm NO3-N
1	.40	.49	.50	.42
2	.47	.53	.54	.45

(c) Experiment III

1	.40	.54	.48	.48
2	.49	.52	.49	.57

[1] Two pigs per treatment were sacrificed at the end of each of the three experiments I, II, III.

EXPERIMENT II

Scouring was of major importance in Experiment II although virtually all treatments including the control were affected to a similar degree (Table 15). Scouring in this instance was not confined to the initial period, and was of a clinical nature with severe loss of condition among the pigs infected. Scouring here was diagnosed as being due to Esherichia Coli and vibriosis. Scouring during the final 1-week period is reflected in the average daily gain, (Table 16), average daily feed consumption (Table 17) and feed efficiency (Table 18), reported for that period. Although there is a difference in average daily gain during the final period, no significant differences were recorded over the entire experimental period. Water consumption (Table 19) indicates a consistent difference between the control treatment with a lower intake than the saline water treatments.

With respect to liver vitamin A stores (Table 20), there is a tendency for lower values for pigs receiving 300 ppm nitrate-N. This finding is comparable to results obtained by Garrison <u>et al</u> (1966) using much higher levels of nitrate-N. Table 14(b) indicates the relationship between kidney weight and warm carcass weight, and there is no tendency towards higher percent kidney weight with the saline water treatments as compared to the control treatment.

Although there were no significant differences between methemoglobin levels for the control and sulphate treatments compared to the sulphate plus 150 ppm nitrate-nitrogen or 300 ppm nitrate-nitrogen treatments there is a trend toward higher levels in the pigs on the sulphate plus nitrate-nitrogen treatments (Table 21).

Again histological examination of kidney tissue indicated no change in structure due to saline water treatments.

Table 15. Scouring in Pigs on Experiment II in Pig Days

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	7	7	7	7
2	-	-	-	-
3	-	-	-	-
4	-	-	-	-
5	-	-	-	-
6	4	4	3	-

Table 16. Average Daily Gain[1] of Pigs over 1 Week Periods for the Duration of the Experimental Period in kg Per Day

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	.08	0	.02	.04
2	.32	.23	.32	.33
3	.43	.36	.27	.35
4	.53	.44	.38	.46
5	.54	.63	.56	.61
6	.42	.32	.39	.60
overall	.39	.32	.32	.40

[1] Analysis of variance between treatments is reported in appendix Table 3

Table 17. Average Daily Feed Consumption for Pigs in Experiment II (kg Per Day)

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	.22	.22	.12	.22
2	.57	.60	.56	.43
3	.69	.73	.65	.65
4	1.05	.90	.84	.94
5	1.22	1.10	.97	1.09
6	1.07	1.02	1.27	1.12
overall	.80	.75	.71	.74

Table 18. Feed Efficiency of Pigs on Experiment II (kg feed/kg gain)

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	2.7	-	5.60	5.50
2	1.72	2.67	1.73	1.31
3	1.60	2.02	2.39	1.88
4	2.00	2.05	2.22	2.02
5	2.27	1.74	1.73	1.79
6	2.54	3.22	3.25	1.86
overall	2.07	2.33	2.26	1.86

Table 19. Water Consumption in Liters Per Day of Pigs Initially Weighing 4-5 kg in Experiment II

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	.66	.78	.79	.79
2	1.04	1.20	1.06	1.23
3	1.59	1.70	2.07	1.81
4	2.36	2.84	2.86	2.54
5	2.62	2.91	3.21	3.14
6	2.70	2.79	4.36	3.86
overall	1.83	2.01	2.33	2.23

Table 20. Liver Vitamin A Levels of Pigs (ug Vitamin A/gm Liver) in Experiment II

Sample[1] No.	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	59.79	69.22	81.04	48.70
2	75.68	88.41	58.64	49.19

[1] Samples taken from livers of two pigs sacrificed at the termination of Experiment II.

Table 21. Percent Methemoglobin[1] in Blood for Experiment II with Blood Samples Being Drawn on Days 24 and 31

Day	Sample No[2]	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
	1	1.3	1.7	6.6	4.1
24	2	0	0.9	3.1	0
	3	4.3	1.6	10.3	10.9
	mean	1.87	1.30	6.67	5.0
	1	1.4	0	3.9	2.9
31	2	0	1.7	4.3	4.8
	3	5.2	2.1	1.9	7.1
	mean	2.20	1.27	3.37	4.93

[1]Analysis of variance in appendix Table 4

[2]Blood drawn from three pigs per treatment on the sampling days.

EXPERIMENT III

Overall, average daily gain (Table 22) was not significantly different for the four water treatments used. Neither feed consumption (Table 23) nor feed efficiency (Table 24) indicated any differences attributable to saline water treatments. During the initial 3 weeks on experiment control pigs exhibited a trend toward lower water consumption relative to saline water pigs as noted in Experiment II. The opposite was true (Table 25) in the last three weeks. Scouring presented no problem. Initially, the pigs receiving the three sulphate water treatments exhibited a dietary scouring which disappeared once the pigs adapted the water change (Table 26). This looseness of feces is reported on by Herrick (1971) and is explained as an adaptive measure to the laxative effects of the sulphate in the water.

Liver vitamin A levels (Table 27) did not indicate the trend to lower levels with the 300 ppm nitrate-nitrogen treatment which was obvious in Experiment II, this finding being in agreement with Seerley et al (1965). As with Experiment I and II no treatment variation occurred in kidney weight as compared to warm carcass weights (Table 14 (c)). Similarily histological examination of kidney slices showed no differences.

Table 22. Average Daily Gains of Weanling Pigs in Experiment III in kg Per Day

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	.10	.04	.10	.07
2	.20	.17	.25	.17
3	.50	.40	.43	.43
4	.35	.38	.49	.40
5	.69	.48	.47	.47
6	.58	.54	.55	.40
overall[1]	.40	.33	.38	.33

1 Analysis of variance between treatments is reported in appendix Table 5

Table 23. Feed Consumption of Weanling Pigs in Experiment III in kg Per Day

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	.27	.22	.29	.27
2	.38	.40	.37	.36
3	.74	.54	.73	.78
4	.79	.60	.88	.75
5	1.23	1.21	1.25	1.27
6	1.29	1.09	1.23	.99
overall	.78	.67	.79	.73

Table 24. Feed Efficiency of Weanling Pigs in Experiment III

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	2.62	5.45	2.76	3.89
2	1.86	2.39	1.46	2.17
3	1.49	1.33	1.69	1.84
4	2.22	1.60	1.78	1.86
5	1.78	2.51	2.68	2.74
6	2.24	2.02	2.22	2.44
overall	1.94	2.02	2.06	2.20

Table 25. Water Consumption of Weanling Pigs in Experiment III in Liters Per Day

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	0.66	1.29	.91	.93
2	1.09	1.27	1.23	1.29
3	1.80	1.94	1.74	2.01
4	4.08	4.14	3.97	4.24
5	2.75	2.59	2.59	2.33
6	4.00	3.64	3.43	3.17
overall	2.40	2.48	2.31	2.33

Table 26. Scour Days of Pigs in Experiment III

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	0	5	6	6
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0

Table 27. Liver Vitamin A Levels of Pigs (ug Vitamin A/gm Liver) in Experiment III

Sample[1] No.	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	51.37	55.04	36.72	46.01
2	56.07	64.83	72.24	75.95

[1] Samples taken from the two pigs per treatment sacrificed at the end of Experiment III.

EXPERIMENT IV

Experiment IV involves the introduction of a high chloride ion water treatment and a chloride plus 300 ppm nitrate-nitrogen water treatment. The use of these chloride water treatments had no effect on the trend of no statistical differences in average daily gain between the water treatments (Table 28). No increase in average daily feed consumption (Table 29) occurred. This consistancy with no increase in average daily gain is reflected by no real differences in feed efficiency (Table 30). Aside from the initial period, scouring was nonexistent. The increased scouring, (Table 31) associated primarily with the sulphate treatment, was not reflected in poorer gain, feed consumption or feed efficiency and hence represents a looseness of feces without loss of condition of the animals involved. Water consumption (Table 32) for the control group of pigs was lower than that reported for the saline water treatments substantiating the trend previously reported in Experiments II and III.

Table 28. Average Daily Gain[1] of Weanling Pigs in Experiment IV in kg Per Day

Period	Control	Sulphate	Chloride	Chloride plus 300 ppm Nitrate N
1	.07	.07	.11	.07
2	.18	.16	.16	.17
3	.32	.30	.29	.29
overall	.19	.18	.19	.18

1 Analysis of variance between treatments reported in appendix Table 6

Table 29. Average Daily Feed Consumption of Weanling Pigs in Experiment LV in kg Per Day

Period	Control	Sulphate	Chloride	Chloride plus 300 ppm Nitrate N
1	.22	.23	.25	.22
2	.38	.38	.58	.38
3	.75	.66	.53	.61
overall	.45	.42	.45	.40

Table 30. Feed Efficiency of Weanling Pigs in Experiment IV (kg feed/kg gain

Period	Control	Sulphate	Chloride	Chloride plus 300 ppm Nitrate N
1	3.00	3.37	2.19	3.16
2	2.12	2.31	3.58	2.26
3	2.34	2.24	1.85	2.09
overall	2.35	2.41	2.41	2.28

Table 31. Scour Days for Pigs on Experiment IV

Period	Control	Sulphate	Chloride	Chloride plus 300 ppm Nitrate N
1	0	5	1	2
2	0	0	0	0
3	0	0	0	0

Table 32. Water Consumption of Weanling Pigs in Experiment IV in Liters Per Day

Period	Control	Sulphate	Chloride	Chloride plus 300 ppm Nitrate N
1	.63	1.01	1.06	1.01
2	.67	1.08	1.10	.98
3	1.12	1.64	1.49	1.44
overall	.80	1.24	1.21	1.14

EXPERIMENT V

Table 33 represents the average daily gain of pigs on the experimental treatments. No significant differences occurred between treatments. Within the group of pigs from the Glenlea Research Station, 16 pigs were pre-conditioned to saline water by being allowed access to the high chloride natural well water (used in Experiment VI with sows and nursing litters) during the nursing period. As compared to the remaining 11 pigs from the Glenlea Research Station there were no significant differences between average daily gain for the two groups (Table 34). No difference in scouring was observed between the two groups originating from Glenlea Research Station.

On examination of the whole experiment, results indicate no differences in average daily feed consumption (Table 35) and feed efficiency (Table 36). Water consumption (Table 37) generally illustrated the previously mentioned trend toward lower water consumption for the treatment receiving the control water. Scouring (Table 38) occurred during the first week of the experiment but again was not of a clinical nature and could not be attributed to the saline water since both control treatments were involved.

Table 33. Average Daily Gain[1] of Pigs on Control, Chloride, and Chloride plus 300 ppm Nitrate-Nitrogen from either Campus (Winnipeg) or Glenlea Research Station in kg Per Day

Source of Pigs	Control		Chloride		Chloride plus 300 ppm Nitrate N	
	Wpg. Water	Glenlea	Wpg.	Glenlea	Wpg.	Glenlea
Period 1	.09	.003	.14	.05	.14	.10
Period 2	.27	.20	.14	.13	.15	.22
Period 3	.43	.27	.37	.32	.39	.43
Period 4	.43	.34	.36	.29	.26	.36
Period 5	.54	.54	.50	.47	.54	.59
Period 6	.53	.54	.52	.38	.34	.57
overall	.38	.31	.34	.27	.31	.38

[1]Analysis of variance between treatments reported in appendix Table 7(a).

Table 34. Average Daily Gain [1] of Pigs from the Glenlea Research Station divided according to Pre-Treatment while Nursing Sows in kg Per Day

	Control		Chloride		Chloride plus 300 ppm Nitrate N	
	Control[2]	Saline[3]	Control	Saline	Control	Saline
Period 1	0	.043	.049	.045	.07	.065
Period 1	.15	.22	.12	.14	.20	.29
Period 3	.27	.28	.31	.33	.42	.45
Period 4	.27	.36	.32	.28	.31	.37
Period 5	.52	.56	.46	.47	.49	.55
Period 6	.49	.65	.34	.41	.55	.59

[1]Analysis of variance between treatments reported in appendix Table 7 (b)

[2]Control - Refers to same water source (Winnipeg Water Supply) as is used as control for all Experiments.

[3]Saline - Refers to natural well water as described in materials and method for Experiment VI Sow and Nursing Litter Experiment.

Table 35. Feed Consumption of Pigs in Experiment V in kg Per Day

Source of Pigs	Control		Chloride		Chloride plus 300 ppm Nitrate N	
	Wpg. Water	Glenlea	Wpg.	Glenlea	Wpg.	Glenlea
Period 1	.16	.29	.19	.20	.22	.22
Period 2	.46	.38	.40	.37	.39	.40
Period 3	.54	.50	.47	.47	.43	.60
Period 4	1.06	.74	.73	.71	.71	.93
Period 5	1.05	.89	.99	.76	.76	1.03
Period 6	1.20	1.08	1.11	.92	.87	.90
overall	.75	.65	.65	.57	.56	.68

Table 36. Feed Efficiency of Pigs on Experiment V

Source of Pigs	Control		Chloride		Chloride plus 300 ppm Nitrate N	
	Wpg. Water	Glenlea	Wpg.	Glenlea	Wpg.	Glenlea
Period 1	1.76	10.9	.33	4.31	1.54	2.22
Period 2	1.68	1.89	2.95	2.83	2.63	1.80
Period 3	1.25	1.87	1.27	1.46	1.07	1.42
Period 4	2.48	2.22	2.04	2.39	2.76	2.60
Period 5	1.95	1.64	1.99	1.63	1.43	1.74
Period 6	2.26	2.11	2.15	2.42	2.60	1.59
overall	1.95	2.05	1.93	2.09	1.86	1.81

Table 37. Water Consumption of Weanling Pigs in Experiment V in Liters Per Day

Source of Pigs	Control		Chloride		Chloride plus 300 ppm Nitrate N	
	Wpg. Water	Glenlea	Wpg.	Glenlea	Wpg.	Glenlea
Period 1	.61	.56	.74	.69	.83	.74
Period 2	.78	.67	.86	.71	.94	.85
Period 3	1.48	1.13	1.37	1.00	1.65	1.89
Period 4	1.75	1.44	1.51	1.24	1.28	1.92
Period 5	2.13	1.88	2.04	2.10	2.13	2.30
Period 6	2.35	2.29	2.74	2.39	2.50	2.79
overall	1.52	1.33	1.54	1.35	1.56	1.75

Table 38. Scouring in Weanling Pigs on Experiment V in Scour Days

	Control		Chloride		Chloride plus 300 ppm Nitrate N	
	Wpg.	Glenlea	Wpg.	Glenlea	Wpg.	Glenlea
Period 1	1	1	1	-	-	-
Period 2	1	1	1	-	-	-
Period 3	-	-	-	-	-	-
Period 4	-	-	-	-	-	-
Period 5	-	-	-	-	-	-
Period 6	-	-	-	-	-	-

B. METABOLIC CAGE STUDY

With reference to the performance data collected, no significance was found between treatment differences for average daily feed consumption (Table 39) or for average daily gain (Table 40). Like previous observations water consumption (Table 41) showed a slight trend toward lower water consumption for the control group with the differences between treatments not significant. Scouring (Table 42) exhibited the trend toward a dietary looseness among the saline water treatments. Again it appeared a matter of adjustment to treatment since scouring only occurred during the times of maximum stress during the periods spent in the metabobic cages. The difference in scouring was not reflected in a change in feed consumption or average daily gain.

With respect to the blood picture the hematocrit values (Table 43) showed no differences between treatments. The small number of samples and variation within treatments for plasma sodium and plasma potassium values negated some apparent treatment differences.

Urine volumes (Table 44) were not significantly different for treatments. The sodium excretion (Table 44) by the kidney was significantly greater[1] for the saline treatments compared to that excreted by the control, indicating excess sodium was eliminated from the body by means of the kidney. As well as significant increases in urinary sodium excretion between treatments, there was

[1] Differentiation of means using a Duncan's multiple range test. Control water treatments significantly different ($P < .01$) from the saline water treatments.

a significant increase ($P < .01$) in urinary sodium exretion with succeeding periods regardless of treatment. Urinary potassium (Table 44) levels of excretion could not be differentiated with respect to treatment.

No statistical differences occurred in fecal dry matter percent although all saline water treatments had lower percent dry matter than the controls.

Analysis of the feces for percent ash (Table 45), showed no significant differences between treatments. Fecal potassium levels (Table 45) did not vary with treatment. Although two methods were used in obtaining samples for analysis of fecal sodium, statistical analysis of the two methods indicated no significant difference between methods. There was a significant difference between days within methods of sampling but no difference between water treatments. During period 3 the fecal potassium excretion was lower than values obtained for periods 1 and 2. No ready explanantion is available for this observation.

Table 39. Average daily feed[1] consumption of Pigs in Metabolic Cage study (kg Per Day)

	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
Period 1	.23	.25	.20	.26
Period 2	.37	.38	.33	.35
Period 3	.51	.37	.34	.33
Period 4	.45	.50	.36	1.01
Period 5	.86	.86	.83	.84
overall	.48	.47	.41	.56

[1]Analysis of variance between treatments reported in Appendix Table 8

Table 40. Average daily gains[1] of Pigs in Metabolic Cage study on a weekly basis (kg Per Day)

	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
Period 1	.16	.16	.08	.11
Period 2	.21	.23	.18	.26
Period 3	.51	.39	.36	.35
Period 4	.48	.69	.57	.47
Period 5	.29	.21	.20	.31
overall	.33	.34	.28	.30

[1]Analysis of Variance between treatments reported in appendix Table 9

Table 41. Average daily water consumption[1] of Pigs in Metabolic Cage study (liters Per Day)

	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
Period 1	1.13	1.63	1.47	1.10
Period 2	1.33	1.54	1.22	1.25
Period 3	1.60	2.04	1.48	1.41
Period 4	2.26	2.55	2.02	2.40
Period 5	2.23	2.67	4.06	2.60
overall	1.71	2.09	2.05	1.75

[1] Analysis of Variance between treatments reported in appendix table 10

Table 42. Scour days of pigs in Metabolic Cage study

	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
Period 1	1	3	4	2
Period 2	0	6	5	4
Period 3	0	0	0	0
Period 4	0	0	0	0
Period 5	0	0	2	1

Table 43. Analysis of Pig Blood Obtained by Puncture of the Anterior Vena Cava on Day 15 of the Metabolic Cage Study

	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
Hematocrit (Percent)	31.75 ± 0.43	28.63 ± 0.52	31.75 ± 1.01	31.13 ± 1.52
Sodium (serum) (meq/l)	140.05 ± 1.43	140.55 ± 1.50	146.05 ± 2.59	152.05 ± 6.77
Potassium (serum) (meq/l)	4.90 ± 0.37	4.92 ± 0.24	4.13 ± 0.52	4.80 ± 0.34

[1] Blood samples drawn from all pigs in metabolic cage study.

[2] All values are mean values for the two observations per treatment

Table 44. Metabolic Cage Study: Urine Volumes and Urinary Excretion of Sodium and Potassium in meq/Day.

	Period[1]	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
Urine Volumes[2]	1	413.57	385.71	213.57	266.79
	2	369.29	419.64	396.43	466.07
	3	968.57	978.21	1075.71	876.07
	overall	593.17 ± 123.9	594.52 ± 131.6	573.80 ± 174.5	584.60 ± 117.7
Urinary Sodium meq/day[3]	1	7.26	36.65	17.76	25.06
	2	23.84	58.46	74.89	86.27
	3	72.88	128.20	139.19	145.87
	overall	35.33 ± 34.2[A]	85.77 ± 34.2[B]	77.27 ± 34.2[B]	92.12 ± 34.2[B]
Urinary Potassium meq/day[4]	1	50.30	79.19	37.36	63.28
	2	40.07	33.48	49.77	41.91
	3	59.94	56.46	48.85	63.80
	overall	51.71 ± 4.4	56.59 ± 10.6	45.33 ± 5.7	73.93 ± 21.5

[1] Periods 1, 2 and 3 represent the 3 seven day periods pigs were in metabolic cages.

[2] Analysis of variance for urine volumes reported in appendix Table 11

[3] Analysis of variance for urinary sodium reported in appendix Table 12. Saline water treatments significantly greater (P .01) than control water treatment.

[4] Analysis of variance for urinary potassium reported in appendix Table 13

Table 45. Metabolic Cage Study: Analysis of Feces for Percent Dry Matter, Percent Ash and Sodium and Potassium Excretion in meq/day

	Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
Percent Dry Matter[1]	1	27.44	22.33	19.10	26.38
	2	28.43	19.42	19.30	20.57
	3	25.94	25.35	20.69	24.16
	overall	26.22 ± 1.91	22.63 ± 1.40	19.73 ± 1.11	23.99 ± 1.40
Percent Ash[2]	1	12.26	15.76	14.91	14.71
	2	20.42	21.92	18.68	24.15
	3	13.90	13.20	13.51	16.90
	overall	15.08 ± 1.99	16.50 ± 1.83	15.43 ± 1.38	18.09 ± 2.06
Fecal Sodium Percent[3,4] meq/day	1	20.54	62.65	54.44	47.20
	2	28.19	80.00	59.88	65.18
	3	17.59	18.04	15.34	16.69
	overall	21.96 ± 29.61	52.67 ± 29.61	42.81 ± 29.61	42.48 ± 29.61

[1] Analysis of variance reported in appendix Table 14

[2] Analysis of variance reported in appendix Table 15

[3] Analysis of variance reported in appendix Table 16

[4] Fecal sodium and potassium done on the odd numbered days are from the ashed samples whereas those done on the even numbered days are from the expressed juice method of collection

Table 45. (Cont) Metabolic Cage Study: Analysis of Feces for Percent Dry Matter, Percent Ash and Sodium and Potassium Excretion in meq/day

	Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
Fecal Potassium meq/day [5]	1	94.22	112.14	115.01	95.61
	2	85.41	83.31	58.74	74.90
	3	68.02	51.32	52.91	51.54
	overall	82.49 ± 5.8	82.63 ± 11.6	75.96 ± 12.9	73.99 ± 10.9

[5] Analysis of variance reported in appendix Table 17

C. SOW AND NURSING LITTER EXPERIMENTS

Average daily gains for pigs 0 to 3 weeks of age receiving either water from the Winnipeg water supply or the Glenlea well water showed no significant difference due to water treatment in either Experiment VI(a) or Experiment VI(b). Data from Experiment VI(a) and VI(b) (Table 46) indicated that with respect to average weaning weights there were no differences of any magnitude between pigs on either treatment.

Mortality appeared to be an important factor in Experiment VI(a) but the difference between treatments was not supported by the results of Experiment VI(b). Although mortality appeared quite a factor in Experiment VI(a) a closer look at the individual sows indicates no trend toward higher mortality due to saline water treatments since the performance of the sows is consistent with previous litters.

Since young nursing pigs have access to milk it is unlikely that their consumption of saline waters would be very high. According to Barber et al (1964) water consumption normally is extemely low among nursing pigs during the first three weeks of life. Since pigs will normally drink fresh water in preference to saline water (Heller 1933) nursing pigs are apt to rely on milk as their source of water.

Table 46. Data from Sow and Nursing Litter Experiment VI(a) and (b)

	Winnipeg Water	Glenlea Water
Experiment VI(a)		
Number of Litters[1]	5	6
Number of Pigs Born Alive Per Litter	8.60	8.50
Number of Pigs Weaned Per Litter	8.20	7.00
Average Weaning Weight (kg)	6.1	6.4
Average Daily Gain (kg)[2]	0.22	0.19
Mortality	2	9
Total Number of Pigs Born	43	51
Experiment VI(b)		
Number of Litters	4	5
Number of Pigs Born Alive Per Litter	8.5	9.0
Number of Pigs Weaned Per Litter	8.0	8.8
Average Weaning Weight (kg)	5.9	5.8
Average Daily Gain (kg)	0.21	0.21
Mortality	2	1
Total Number of Pigs Born	34	45

[1] Two sows from the Winnipeg water treatments, one from each replicate (a) and (b), failed to produce litters.

[2] Analysis of variance of average daily gain for Experiments VI(a) and (b) are reported in appendix Tables 18 and 19 respectively.

Table 46. Data from Sow and Nursing Litter Experiment VI(a) and (b)

(cont)	Winnipeg Water	Glenlea Water
Overall		
Number of Litters	9	11
Number of Pigs Born Alive Per Litter	8.56	8.73
Number of Pigs Weaned Per Litter	8.11	7.82
Average Weaning Weight (kg)	6.0	6.1
Average Daily Gain (kg)	0.21	0.20
Total Mortality	4	10
Total Number of Pigs Born	77	96

D. OVERALL

Unlike results from research by Stothers (1960) and Stothers and Palmer (1961), who used higher levels (10,000 ppm and up) of total solids on larger pigs, no significant differences in average daily gain occurred. No feed consumption and feed efficiency differences occurred between saline water treated pigs and those receiving control water. No treatment differences in average daily gain, feed consumption and feed efficiency agree with work by Stothers (1970) in which slightly older (3 to 5 weeks) and heavier (6.4 kg) pigs received a sulphate water containing approximately 2000 ppm total solids.

Similar to the Stothers (1970) work, scouring created no serious problem. There was generally an initial period of adaptation during which some of the pigs exhibited a dietary scouring. The dietary scouring is primarily associated with the sulphate water treatments and the cathartic effects of the sulphate ion (Herrick 1971). This scouring does not reflect a change in the performance of the piglet and should not be confused with the clinical situation associated with Experiment II where desease resulted in loss of condition amongst the weanling pigs involved. Dietary scours was at a minimum when waters high in the chloride ion were used.

With respect to water consumption there appears to be an overall trend to higher water consumption by saline water pigs (Table 47). This observation coincides with results obtained by Embry et al (1959), Stothers (1960), Stothers and Palmer (1961), Roy and Boylan (1964) and Stothers (1970) who reported higher water consumption

Table 47. Water Consumption as a Percent of Control Water Treatments in the Five Weanling Pig Experiments

A. Sulphate vs Control: as a percent increase in water consumption of sulphate water treatments over controls

Period	Control	Sulphate	Sulphate plus 150 ppm Nitrate N	Sulphate plus 300 ppm Nitrate N
1	.65[1]	58.5	30.8	32.3
2	.93	51.6	55.9	71.0
3	1.50	63.3	31.3	34.7
4	3.22	-0.6	-0.2	3.1
5	2.69	13.4	16.0	16.7
6	3.35	-3.6	15.2	13.1
overall	2.12	14.2	19.3	22.6

[1] Control treatment values are actual values in liters per day.

Table 47. (Cont) Water Consumption as a Percent of Control Water Treatments in the Five Weanling Pig Experiments

B. Chloride vs Control: percent increase in water consumption of chloride water treatments over controls

Period	Control	Chloride	Chloride plus 300 ppm Nitrate N
1	.60[1]	38.3	43.3
2	.71	25.4	29.6
3	1.24	4.0	33.9
4	1.59	-13.2	0.6
5	2.01	3.0	10.4
6	2.32	10.8	14.2
overall	1.43	1.4	16.1

[1] Control treatment values are actual values in liters per day.

in swine receiving saline waters. The difference between control and saline treatments was greatest during the initial period of the experiment. With respect to sulphates, the difference from the control is large for the first three weekly period but due to an unusually high consumption among the control pigs during the fourth week, the differences virtually disappeared. With the exception of one value, the difference was again realized in the remaining two periods although not as dramatic.

The nitrate levels used by Seerley et al (1965) in their work with older pigs were similar to the levels used in the weanling pig experiments. The results indicating no differences with respect to average daily gain, feed consumption or feed efficiency, regardless of the nitrate levels in the water, compared favourably to their results. Garrison et al (1966) found a marked reduction in rate of gain and feed efficiency in pigs receiving 420 ppm nitrate-nitrogen.

In the same research, a significant ($P < .01$) increase in methemoglobin was shown with nitrite at 112 ppm nitrite-nitrogen but not at levels of 420 ppm nitrate-nitrogen. No explanation was given for the impaired performance of the growing and finishing pigs given 420 ppm nitrate-nitrogen in the water. Seerley et al (1965) found measurable but small increases in methemoglobin when water was drunk containing levels of 100 ppm nitrate-nitrogen. The methemoglobin levels were similar to the higher levels of methemoglobin resulting from sulphate plus 150 ppm and 300 ppm nitrate-nitrogen water treatments in Experiment II but no detrimental effects on performance were noted. Seerley et al (1965) indicated that day old pigs are no more susceptible to nitrate induced methemoglobinemia than the same pigs when older. It appears unlikely that enough nitrite would be formed and consumed in water alone to cause a toxicity in weanling pigs if the initial nitrate-nitrogen content is 300 ppm nitrate-nitrogen or less. This concept is verified by work by Seerley et al (1965) using growing and finishing pigs and gilts through two farrowings.

In contrast Case (1957, 1963 and personal communication) predicted performance changes in pigs receiving more than 10 ppm nitrate-nitrogen with the severity of the subtle physiological changes increasing with increasing levels of nitrate-nitrogen. His assumption was not verified in these experiments as aside from increased sodium excretion in the urine, no dramatic differences were noted between control pigs and any saline water treatment with or without nitrate.

Liver vitamin A stores showed no tendency to change due to treatment.[1] Seerley et al (1965) found similar results with growing and finishing swine. Garrison et al (1966) used growing and finishing pigs receiving levels of nitrate-nitrogen up to 420 ppm and found significant differences ($P < .05$) between liver vitamin A stores of controls and those given the maximum levels of nitrate-nitrogen. Emerick and Olson (1962) stated that vitamin A stores in the liver of rats are affected by dietary nitrite but not by dietary nitrate when vitamin A is administered orally. No effect due to nitrate was reported with subcutaneous administration of vitamin A. It is therefore possible that not enough nitrate was converted to nitrite in the

[1]Analysis of variance for vitamin A stores reported in appendix Table 20.

gastro-intestinal tract to cause a loss of vitamin A. In the latter case, less vitamin A would be available for absorption and hence liver stores reduced.

Analysis of variance for kidney weight[1] indicates no significant differences between treatments. This observation combined with the findings of no histological changes in kidney structure indicates the kidney's ability to handle the excess ions available due to high salinity (6000 ppm total solids) in the water supply.

Bohstedt and Grummer (1954) found no increase in serum sodium. This observation agrees with serum sodium data obtained from the metabolic cage study. Garrison et al (1966) found hematocrit values to be similar throughout their treatments. Hematocrit values in the metabolic cage study indicate a similar result.

The increased dietary sodium intake in a very available form is reflected in the significant differences between urinary sodium levels recorded for control versus the three sulphate waters. Although increased sodium excretion occurred in the feces the major means of removal of the excess sodium ions is via the kidney.

With respect to pig mortality, a condition attributed to the use of saline waters among field workers, no such relationship could be found in either the weanling pig experiments or in the sow-nursing litter experiments. Results of the sow-nursing litter experiments agree with those obtained by Roy and Boylan (1964) using similar water treatments but not using the added stress factor of total

[1]Analysis of variance for kidney weights reported in appendix Table 21.

confinement barns. Since no differences between treatments with respect to average daily gain, general thriftiness of piglets, or sow condition was noted it can be stated that saline waters at 4500 ppm did not cause any deviation in performance of nursing piglets or of their dams.

SUMMARY AND CONCLUSIONS

Saline waters at levels of approximately 6000 ppm total solids, high in either sulphate or chloride ions and containing various levels of nitrate-nitrogen (0 ppm, 150 ppm or 300 ppm) caused no treatment variation in average daily feed, average daily gain or feed efficiency of pigs initially weighing between 4 and 6 kg and 3 to 4 weeks of age.

Water consumption for pigs on saline water treatments was generally higher than that reported for control water treatment pigs. Voluntary water consumptions under normal conditions of non saline water for pigs weighing between 4 and 6 kilograms ranged between .56 and .66 liters per day, while pigs weighing an average of 20 kgs consumed on the average 2.45 liters per day.

Diarrhea created no serious problem with respect to performance of weanling or nursing pigs.

Liver vitamin A stores were not affected by any levels of nitrate N up to the maximum of 300 ppm tested.

Kidney weight and the kidney histological structure were not affected by saline waters at the levels used.

Percent methemoglobin was higher in only Experiment II with high nitrate-nitrogen but the performance of the pigs on treatments receiving nitrate-nitrogen at 150 ppm or 300 ppm was not adversely affected.

Pigs receiving saline waters high in the salts of sodium, exhibited significantly higher concentrations of sodium in the urine, although urine volumes were not significantly affected by treatment. Neither urine potassium nor fecal potassium were affected by saline treatments. Fecal sodium levels reflected the amounts available in the diet with the control level showing a tendency to be lower than the saline water treatments. Hematocrit, blood sodium and blood potassium did not vary with treatment.

Fecal percent ash was unaffected by treatment.

Saline waters of 4500 ppm total solids high in chlorides had no bearing on average daily gain and general good health of nursing pigs between 0 to 3 weeks of age or on the general health of their dams.

BIBLIOGRAPHY

Agriculture Research Council 1967. The Nutrient Requirements of Farm Livestock No. 3. Pigs. Her Majesty's Stationery Office, 40 High Holborn, London WC1.

Barber, R. S., Braude, R., and Mitchell, K. G. 1964. A Note on Formalin-Treated Skim Milk for Suckling Pigs. Animal Production. 6: 369.

Bell, J. M. 1948. An adjustable cylindrical cage for use in metabolic studies with young pigs. J. Nutr. 35: 365-369.

Berg, R. T. and Bowland, J. P. 1960. Salt water tolerance of growing-finishing swine. 39th Ann. Feeders' Day Report. University of Alberta. p14.

Bloomfield, R. A., Hersey, J. R., Welsch, C. W., Garner, G. B., and Muhrer, M. E. 1962. Gastric concentration of nitrate in rats. J. Animal Sci. 21: 1019 (abstr.).

Bohstedt, G., and Grummer, R. H. 1954. J. Animal Science 13: 933.

Bowland, J. P. 1972. Water Quality for Pigs. Rept. Water Quality for Livestock in Alberta. p.8.

Buffagni, V. 1935. Profilassi 8, 53.

Campbell, W. A. B. 1952. Methemoglobinemia due to nitrates in well water. Brit. Med. J. 2: 371.

Case, A. A. 1957. Some aspects of nitrate intoxication in livestock. J. Am. Vet. Med. Assn. 130: 323.

Case, A. A. 1963. The nitrate problem. National Hog Farmer. Swine Information Service. Bull D18: 1.

Case, A. A. 1971. Personal Communications on Effects of Nitrates and Nitrites in Water Supply.

Case, A. A. 1971. Effects of poor water in Livestock Production Feedstuffs. April 3 : 4.

Doll, E. R., Hull, F. E., and Insko, Wm. Jr. 1946. Toxicity of sodium chloride solution for baby chicks. Vet. Med. 41: 361.

Dollahite, J. W., and Holt, E. C. 1969. Nitrate Poisoning. The Southwestern Veterinarian Vol XXIII : 1 : 23.

Embry, L.B., Hoelscher, M.A., Wahlstrom, R.C., Carlson, C.W., Krista, G.F., and Olson, O.E. 1959. Salinity and Livestock Water Quality. S. Dak. Agr. Exp. Sta. Bul 481.

Emerick, R.J., and Olson, O.E. 1962. Effects of nitrate and nitrite on vitamin A storage in the rat. J. of Nutrition. 78 : 1 : 73

Emerick, R.J., Embry, L.B., and Seerley, R.W. 1965. Rate of formation and reduction of nitrite-induced methemoglobin in vitro and in vivo as influenced by diet of sheep and age of swine. J. of Animal Sci. 24 : 1 : 221.

Evelyn, K.A., and Malloy, H.T. 1938. Microdetermination of oxyhemoglobin, methemoglobin and sulphemoglobin in a single sample of blood. J. Biol. Chem. 126: 655.

Federal Water Pollution Control Administration. 1968. Water Quality Criteria. Report of the National Technical Advisory Committee to the Secretary of the Interior. Washington, D.C.

Friend, D.W., and Cunningham, H.M. 1966. The effect of water consumption on the growth, feed intake and carcass composition of suckling piglets. Can. J. Animal Sci. 46: 203.

Gallup, W.D., and Hoefer, J.A. 1946. Determination of Vitamin A in liver. Industr. Eng. Chem. Analytical ed. 18: 285.

Garner, G.B., Cornell, C.N., Moyer, J.H., Muhrer, M.E., and Pfander, W.H. 1960. Nitrate levels in bovine and porcine serum. J. Animal Sci. 19: 1322 (abstr.).

Garrison, G.W., Wood, R.D., Chaney, C.H., and Waddill, D.G. 1966. Effects of nitrate and nitrites in drinking water on the utilization of carotene in swine. University of Kentucky Agriculture Experiment Station Progress Report 164: p. 85.

Hall, R.E. 1972. Nitrate, Sulphate Problems. National Hog Farmer. March: 65.

Heller, V.G., and Larwood, C.H. 1930. Saline Drinking Water. Science 71, 223.

Heller, V.G. 1933. The Effect of Saline and Alkaline Waters on Domestic Animals. Bulletin Oklahoma Agriculture Experimental Station #217.

Herrick, J.B. 1971. Water Quality for Livestock and Poultry Feedstuffs. Feb. 20: 28.

Kare, M.R., and Biely, J. 1948. The toxicity of Sodium Chloride and its relation to water intake in baby chicks. Poultry Sci. 27: 751.

Krista, L.M., Carlson, C.W., and Olson, O.E. 1961. Some effects of of Saline Waters on Chicks, Laying Hens, Poults and Ducklings. Poultry Science. 40: 938.

Mitchell, C. R. Checking Water Supplies for Nitrates. National Hog Farmer, Swine Information Service Bulletin. D22 p.1.

Muhrer, M. E., Garner, G. B., Pfander, W. H., and O'Dell, B. L. 1956. The effect of nitrate on reproduction and lactation. J. Animal Sci. 15: 1291 (Abstr.).

National Academy of Sciences - National Research Council. 1968. Nutrient Requirements of Swine, 6th rev. ed. Publ. 1599. Washington D. C.

O'Dell, B. L., Erek, Z., Flynn, L., Garner, G. B., and Muhrer, M. E. 1960. Effects of nitrate containing rations in producing vitamin A and vitamin E deficiencies in rats. J. Animal Sci. 19: 1280 (Abstr.).

Olson, O. E., Nelson, D. L., and Emerick, R. J. 1963. Effect of nitrate and some of its reduction products on carotene stability. J. Agr. Food Chem. 11: 140.

O'Neil, J. B. 1963. Effects of feeding mineralized waters to chicks. Minutes of the 12th Annual Meeting of the Associate Committee on Animal Nutrition. p. 8.

Pierce, A. W. 1957(a). Studies on Salt Tolerance I, the tolerance of sheep for sodium chloride in the drinking water. Aust. J. Agric. Res. 8: 711.

Pierce, A. W. 1957(b). Saline Content of Drinking Water for Livestock. Vet. Rev. Annot 3: 37.

Pierce, A. W. 1959. II. The tolerance of sheep for mixtures of sodium chloride and magnesium chloride in the drinking water. Aust. J. Agric. Res. 10: 725.

Pierce, A. W. 1960. III. The tolerance of sheep for mixtures of sodium chloride and sodium sulphate in the drinking water. Aust. J. Agric. Res. 11: 548.

Pierce, A. W. 1962. IV. The tolerance of sheep for mixtures of sodium chloride and calcium chloride in the drinking water. Aust. J. Agric. Res. 13: 479.

Pierce, A. W. 1963. V. The tolerance of sheep for mixtures of sodium chloride, sodium carbonate and sodium bicarbonate in the drinking water. Aust. J. Agric. Res. 14: 815.

Pierce, A. W. 1966. VI. The tolerance of wethers in pens for drinking water, of the types obtained from underground sources in Australia. Aust. J. Agric. Res. 17: 209.

Pierce, A. W. 1968. Studies on Salt Tolerance of Sheep. VII. The tolerance of ewes and their lambs in pens for drinking waters of the types obtained from underground sources in Australia. Aust. J. Agric. Res. 19: 577.

Robblee, A. R., and Chandinin, D. R. 1961. The effects of sodium salts in the feed and drinking water on the occurrence of ascites and edema in turkey poults. Can. J. Animal Sci. 41: 161.

Roberts, W. K., and Sell, J. L. 1963. Vitamin A destruction by nitrite in vitro and in vivo. J. Animal Sci. 22: 1081.

Roy, G. L., and Boylan, W. J. 1964. Performance of Swine on High Salt content well water in the Red River Valley. Annual Report on Livestock Research. U. of Manitoba. 14: 19.

Seddon, H. R. 1931. Ann. Rep. Aust. Nat. Res. Coun. Aug p.38.

Seerley, R. W., Emerick, R. J., Embry, L. B., and Olson, O. E., 1963. Effect of Nitrate or nitrite administered continuously in drinking water for swine and sheep. J. of Animal Sci. 24: 4 : 1014.

Selye, H. 1948. Production of nephrosclerosis in fowl by sodium chloride. J. Am. Vet. Med. Assoc. 103: 140.

Sibbald, I. R., Pepper, W. F., and Slinger, S. J. 1962. Sodium chloride in the feed and drinking water of chicks. Poultry Science 41: 541.

Steel, R. G. D., and Torrie, J. H. 1960. Principles and Procedures of Statistics. McGraw - Hill.

Stothers, S. C. 1960. Studies on saline waters. Annual Report on Livestock Research. U. of Manitoba. 10.

Stothers, S. C., and Palmer, W. M. 1961. Further Studies of Saline water for swine. Annual Report on Livestock Res. U. of Manitoba. 11: 6.

Stothers, S. C. 1966. Non-Ruminants (Saline Waters). Manitoba Livestock and Poultry Nutrition Council Proceedings. 8th Annual Conference. p.8.

Stothers, S. C. 1970. Saline water and weanling pigs. Applied Research Papers in Animal Science,Dept. of Animal Sci. U of Manitoba. p.5.

Tollet, J. T., Becker, D. E., Jensen, A. H., and Terrill, S. W. 1960. Effect of dietary nitrate on growth and reproductive performance of swine. J. Animal Sci. 19: 1297 (Abstr.).

University of Saskatchewan. 1965. Supplement to report on quality of rural water supply (mimeo). Laboratory for Water Analysis. Department of Civil Engineering.

Weeth, H. J., Haverland, L. H., and Cassard, D. W. 1960. Consumption of sodium chloride water by heifers. J. Animal Sci. 19: 845.

Weeth, H. J., and Hunter, J. E. 1971. Drinking of sulphate water by cattle. J. Animal Sci. 32: 277.

APPENDIX Table 1. Composition of the various rations used in the experiments with weanling pigs, the metabolic cage study and sow nursing litters experiments

I.	COMMERCIAL CREEP		% of ration
	Crude Protein	(Min %)	18
	Crude Fat	(Min %)	4
	Crude Fiber	(Max %)	3
	Salt	(Actual %)	0.45
	Calcium	(Actual Ca)	0.85
	Phosphorus	(Actual P)	0.70
	Zinc		0.01
	Plus these additives per kilogram		
	Arsanilic Acid		0.099 gm
	Vitamin A (Min)		11,000 IU
	Vitamin D (Min)		2,200 IU
	Chlortetracycline Hydrochloride		0.11 gm
	Sulphamethamine		0.11 gm
	Penicillin (Procaine)		0.06 gm
II.	UNIVERSITY CREEP		% of ration
	Wheat		77.3
	Sugar		5.0
	Soybean Oil Meal		10.4
	Fish Meal		5.2
	Defluorinated Rock Phosphate		0.7
	Limestone (Calcium)		0.9
	Salt		0.5
	Plus these additives per kilogram:		
	Zinc Carbonate		0.2 gm
	Vitamin A (5000 IU per gm)		.44 gm
	Vitamin D (6000 IU per gm)		0.07 gm
	A.S.P. 250		1.98 gm

APPENDIX (Cont) Table 1. Composition of the various rations used in the experiments with weanling pigs, the metabolic cage study and sow nursing litters experiments

III.	UNIVERSITY STARTER	% of ration
	Barley	72.5
	Soybean Oil Meal	25.0
	Defluorinated Rock Phosphate	1.0
	Limestone	1.0
	Salt	0.5
	Minerals and vitamins as additives per kilogram:	
	Vitamin A (5000 IU/gm)	0.44 gm
	Vitamin D (6000 IU/gm)	0.06 gm
	Vitamin B_{12}	0.84 gm
	Zinc Carbonate	0.12 gm
	A.S.P. 250	2.50 gm
IV.	LACTATION RATION	% of ration
	Barley	89.75
	Soybean Meal	8.0
	Limestone	1.25
	Calcium Phosphate	0.5
	Salt	0.25
	Additives per kilogram:	
	Vitamin A (5000 IU/gm)	.66 gm
	Vitamin D (6000 IU/gm)	0.06 gm
	Vitamin B_{12}	0.08 gm

APPENDIX Table 2. Analysis of variance of average daily gain in Experiment I, using a completely randomized design

Source of Variation	df	ss	ms	F
Total	26	1320.41		
Treatment	2	88.91	44.45	0.87
Error	24	1231.50	51.31	

APPENDIX Table 3. Analysis of variance of average daily gain for Experiment II, using a completely randomized design

Source of Variation	df	ss	ms	F
Total	33	2704.38		
Treatment	3	228.75	76.25	0.92
Error	30	2475.63	82.52	

APPENDIX Table 4. Analysis of variance between treatments of percent methemoglobin[1] in blood for weanling pigs in Experiment II

Source of Variation	df	ss	ms	F
Total	23	696.25		
Treatments	3	204.29	68.10	2.39
Days	1	2.96	2.96	0.10
T x D	3	34.58	11.53	0.41
Error	16	454.42	28.40	

[1] Arcsine transformations were performed on the data and analysis of variance as a completely randomized block design

APPENDIX Table 5. Analysis of variance of average daily gain for Experiment III using a completely randomized design

Source of Variation	df	ss	ms	F
Total	34	2756.14		
Treatment	3	250.65	83.55	1.03
Error	31	2505.50	80.82	

APPENDIX Table 6. Analysis of variance of average daily gain in Experiment IV using a completely randomized design

Source of Variation	df	ss	ms	F
Total	35	160.19		
Treatment	3	5.30	1.77	0.37
Error	32	154.89	4.84	

APPENDIX Table 7. (a) Analysis of variance of average gain in Experiment V using a completely randomized design

Source of Variation	df	ss	ms	F
Total	53	1.3019		
Treatment	2	0.0879	0.0439	1.85
Error	51	1.2140	0.0238	

(b) Analysis of variance of average daily gain between pigs in Experiment V receiving saline water previous to experiment and those not receiving saline water previously within the Glenlea born pigs using a completely randomized design

Source of Variation	df	ss	ms	F
Total	26	1248.80		
Treatment	5	396.04	79.21	1.95
Error	21	852.76	40.61	

APPENDIX Table 8. Analysis of variance of average daily feed for pigs in metabolic cage study using a completely randomized design

Source of Variation	df	ss	ms	F
Total	19	1.19		
Treatment	3	0.05	0.018	0.25
Error	16	1.14	0.07	

APPENDIX Table 9. Analysis of variance of average daily gain for pigs in metabolic cage study using a completely randomized design

Source of Variation	df	ss	ms	F
Total	19	.51		
Treatment	3	.01	.004	0.11
Error	16	.50	.03	

APPENDIX Table 10. Analysis of variance of average daily water consumption for pigs in the metabolic cage study using a completely randomized design

Source of Variation	df	ss	ms	F
Total	19	10.03		
Treatment	3	0.58	0.19	0.32
Error	16	9.45	0.59	

APPENDIX Table 11. Analysis of variance of urine volumes for pigs in the metabolic cage study using a completely randomized design

Source of Variation	df	ss	ms	F
Total	7	4.997		
Treatment	3	0.060	0.020	0.02
Error	4	4.937	1.234	

APPENDIX Table 12. Analysis of variance for sodium excretion volumes for pigs in metabolism cage study using a completely randomized block design

Source of variation	df	ss	ms	F
Total	167	673676.8		
Treatment	3	68333.1	22777.7	9.72**
Period	20	315450.9	15772.5	6.73**
T x P	60	93091.0	1551.51	0.66
Error	84	196801.9	2342.9	

Differentiation of means by Duncan's multiple range test indicates controls are significantly different ($P < .01$) from saline water treatments and that with periods there was a significant ($P < .01$) increase with increasing age of pig

APPENDIX Table 13. Analysis of variance of urine concentrations of potassium for pigs in the metabolism cage study using a completely randomized design

Source of Variation	df	ss	ms	F
Total	7	2149.1		
Treatment	3	348.4	116.1	0.26
Error	4	1800.7	450.2	

APPENDIX Table 14. Analysis of variance of percent dry matter in feces using a completely randomized design

Source of Variation	df	ss	ms	F
Total	7	71.02		
Treatment	3	44.11	14.70	2.19
Error	4	26.91	6.73	

APPENDIX Table 15. Analysis of variance of percent ash of feces of pigs in the metabolic cage study using a completely randomized design

Source of Variation	df	ss	ms	F
Total	7	22.07		
Treatment	3	12.86	4.29	1.86
Error	4	9.21	2.30	

APPENDIX Table 16. Analysis of variance between treatments for fecal sodium levels in metabolic cage study

Source of Variation	df	ss	ms	F
Total	159	338471.1		
Methods	1	44.9	44.9	0.008
Between days within methods	18	100243.1	5569.1	3.41**
Between treatments within days within methods	60	97902.43	1631.7	0.93
Within treatments within days within methods (error)	80	140280.7	1753.5	

APPENDIX Table 17. Analysis of variance between treatments for fecal potassium in metabolic cage study

Source of Variation	df	ss	ms	F
Total	7	506.4		
Treatment	3	125.5	41.8	0.44
Error	4	380.9	95.2	

APPENDIX Table 18. Analysis of variance of average daily gain of pigs in Experiment VI(a)

Source of Variation	df	ss	ms	F
Total	83	0.25		
Treatment	1	0.011	0.011	3.87
Error	82	0.24	0.003	

APPENDIX Table 19. Analysis of variance of average daily gain of pigs in Experiment VI(b)

Total	71	0.25		
Treatment	1	.000002	.000002	.0005
Error	70	0.25	0.004	

APPENDIX Table 20. Analysis of variance between treatments for vitamin A content of pigs liver from pigs sacrificed at the termination of Experiments I, II and III

Source of Variation	df	ss	ms	F
Total	21	5842.9		
Treatment	3	461.0	153.7	0.51
Error	18	5381.9	299.0	

APPENDIX Table 21. Analysis of variance of kidney weight as a percent of warm carcass weight in pigs sacrificed at the end of Experiments I, II and III

Source of Variation	df	ss	ms	F
Total	21	0.084		
Treatment	3	0.028	0.009	2.95
Error	18	0.056	0.003	