Effect of Anolyte on Broiler Performance

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I, the undersigned, hereby declare that the work contained in this assignment is my own original work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature:.. Date: ..13th ....Feb....2003

Abstract: Effect of Anolyte on Broiler Performance

Holcroft, Joanna.

A farm in Zimbabwe (Farm A) obtains its water for the poultry operations from the Makavusi River that is heavily contaminated with bacteria and performance results are thereby reduced. Anolyte is a Russian invention that claims to have bactericidal effects that could be beneficial to broilers. The aim of this research is to investigate the effect of Anolyte on production profits of broilers given water of poor quality by carrying out a number of trials. Trials that were conducted are basic in vitro tests on Anolyte within the laboratory, water analysis on water supply to the broiler section (both chemical and bacteriological), and a detailed trial within an experimental trial site comparing broiler performance results with different chemical water treatments and different dilutions of Anolyte. Broiler chicks from different hatcheries (Hatchery A and Hatchery B) were also compared. Performance results were based on growth rate, mortality, feed conversion ratios (FCR), performance efficiency factors (PEF) and profit margin comparisons.

Results showed that in the laboratory, Anolyte had an antibacterial activity. In the broiler performance trial on Hatchery B broilers, the live weights at forty two days of age in broilers given 15% Anolyte differed from other treatments ($P<0.05$) other than 10% Anolyte ($P > 0.05$). However, the FCR and mortalities did not differ ($P > 0.05$) between treatments.

In the trial on Hatchery A broilers to 42 days of age, growth rates in broilers given 15% Anolyte differed from the control, Chematron and 20% Anolyte ($P < 0.05$). However, the FCR and mortalities did not differ between ($P>0.05$) treatments.

In comparing chicks from different hatcheries, Hatchery B broilers differed ($P < 0.05$) from Hatchery A broilers in live weights at 42 days on 10% Anolyte, 15% Anolyte and on Chematron treatments. However, the cumulative mortalities and FCR did not differ ($P > 0.05$) between the Hatchery B and Hatchery A on any treatment.

When comparing profitability, the treatment that had the greatest margin in comparison to the control (untreated drinking water) was 15% Anolyte for both the Hatchery B and Hatchery A trials.

Uittreksel: Die invloed van Anolyte op Braaikuiken Prestasie.

Holcroft, Joanna

'n Plaas in Zimbabwe, (Plaas A) verkry water, vir hul pluimvee bedryf vannuit die Makavusi rivier. Die rivier is swaar besmet met bakterië en as gevolg daarvan verhoed dit dat hulle hul volle opbrengs potential bereik.

Anolyte is 'n Russiese uitvindsel wat aanspraak maak daarop dat dit bakteriëdodende effekte besit wat tot die bevordering van slaghoenders kan lei. Die doel van die navorsing is om Anolyte op proef te stel aangaande produksie profyt op slaghoenders waaraan swak kwaliteit water verskaf is. Verskeie toetse is uitgevoer nl. 'n basiese 'in vitro' toets in samewerking met die laboratorium, water ontleding op water wat aan die slaghoender seksies verskaf is (beide chemikalies and bakteriëologies) asook 'n intensiewe proefnemeing waarin die verskeie obrengs resultate, van chemikaliese behandelde water en verskillende verdunnings van Anolyte, met mekaar vergely is, in 'n experimetele navorsings eenheid.

Slaghoender kuikens van twee verskillende broeihuise (nl. Broeihuis A en Broeihuis B) is ook met mekaar vergelyk. Dié resultate is gabasseer op groei tempo, sterftes, voer omsettings verhouding, opbrengs geskikthied faktore asook vergelykings op wins.

Laboratorium navorsing het bevestig dat Anolyte wel antibakteriese aktiviteit getoon het. Terwyl in die proefneming op Broeihuis B slaghoenders, het die lewende gewig van hoenders, op 42 dae van ouderdom, waaraan 15% Annolyte verskaf is, verskil van ander behandelings ($P<0.05$) met die uitsondering van 10% Anolyte ($P>0.05$). Alhoewel die voer omsetting verhoudings en sterftes nie in die verskillende behandelings verskil het nie.

In die proefnemeing op Broeihuis A slaghoenders tot 42 dae van ouderdom, het die ontwikkeling van slaghoenders, waaraan 15% Anolyte verskaf is, verskil van die kontiole, Chematron en 20% Anolyte. Die voer omsettings verhoudings en sterftes het egter geen verskil getoon tussen die verskeie behandelings nie.

Resultate van die vergelyking tussen die kuikens uit die twee verskillende broeihuise, het getoon dat die Broeihuis A en Broeihuis B lewensgewigte, op 42 dae van ouderdom, wel met mekaar verskil het met 10% Anolyte, 15% Anolyte sowel as die Chematron behandelings. Daar was egter geen verskil, ($P>0.05$) tussen die twee tipes aangaande elke tipe se saamgestelde sterftes en die voer omsettings verhoudings, in welke behandeling nie.

Die vergelykings op wins het getoon dat die behandeling met die grootste brulo marge, die was van 15% Anolyte in vergelyking met die kontiole (onbehandelde drinkwater) vir beide die Broeihuis A en die Broeihuis B proefnemings.

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Please note that the use of trade names does not imply endorsement of the products nor criticism of similar products not mentioned.

Table of Contents

Introduction

Water is 60% of the diet of poultry and is 70% of the total body weight and thus any superior management and nutritional programme that is implemented can be offset when poor water quality is used for poultry consumption. In order to optimise feed conversions, weights gains and egg performances, good water quality is essential to compliment nutritional and management systems. The goal of any water treatment is cash flow enhancement and thus any water treatment programme should improve profitability not just for the farmer but also for the integrator. In broiler production systems where there are water quality issues, water treatments should be implemented to increase the weight of the bird for processing at a decreased production cost per weight slaughtered.

Water is vital in producing optimum results within poultry production systems. It has many important functions within the body which include moving feed through the digestive system, digestion and absorption of the nutrients, as a major constituent of the blood it is important in the transfer of nutrients to different organs, it is involved in may chemical reactions within the body, it is essential in the removal of toxic substances through the kidney, it is necessary in the lubrication of joints and its role is vital in order to maintain body temperature (Keshavarz, 1987). Due to the fact that water is a solvent, it may carry dissolved minerals, gases, pathogens and chemicals that when ingested may interfere with metabolic processes of the bird and affect production.

The bird obtains its water by drinking, by eating and by catabolism of body tissues, which is a normal part of growth and development (Leeson and Summers, 1997). Water obtained via the feed is a small part as feed contains approximately 10% water but this is not usually considered in calculating water balance. Water is created in the body as a by-product of general metabolism; on average 0.14g of water is produced for each kcal of energy metabolised so that feed and metabolic water together account for 20% of total water needs (Leeson and Summers, 1997). However, the largest percentage of water requirements is obtained by drinking water.

In any poultry production system, an estimate of the water requirements is essential in order to ascertain that there is sufficient water supply to the production unit. In general, birds consume approximately 1.8 times as much water as feed consumed (1.6 for nipple drinkers) and water requirements increase by approximately 6.5% per degree Centigrade over 21 °C and in tropical areas prolonged high temperatures will double daily water consumption (Ross Breeders, 1999). In order to calculate the increased water intake in hot climates, an average daily temperature (ADT) can be calculated as in Equation 1.

Equation 1 Average daily temperature (Cilliers, 1995)

ADT = t + 2/3 X (t-T)

Where T = average maximum temperature

t = average minimum temperature

Thus, in summer months in Zimbabwe, the maximum temperature could be 32°C and the minimum could be 15°C, thus the ADT will be 26°C. Table 1 shows typical water consumption by Ross broilers (Ross Breeders, 1999). In order to calculate the total water required for a section, knowledge of the estimate of water consumption as well as that required for cleaning of the section is needed. For cleaning of poultry houses, water requirements are approximately 10 litres per square metre per period of five hours (Cilliers, 1995).

Table 1 Typical Water consumption by as-hatched broilers at 21°C in litres/1000 birds/day with bell drinkers. (Cilliers, 1995)

Age (days)	Water consumption litres/1000 birds/day assuming 1.8litres/kg feed
7	59
14	110
21	171
28	238
35	284
42	326
49	351
56	358

Thus, in Zimbabwe, in a broiler section consisting of 110 000 broilers at an average daily temperature of 26°C, the total water required will be as tabulated in Table 2.

If the broilers are housed at 13 birds/m2 (open sided houses), then the total area required for 110 000 broilers will be 8460 metres squared. For washing of the section, ten litres of water is required per square metre and thus a total of 84 600 litres of water will be required to wash the house. Thus, for a section of 110 000 broilers, the total water requirements over the eight weeks (six week grow and two weeks clean out) will be 1 296 580 litres of water. If this amount is divided by the number of days, this will give an average of 23 153 litre per day required. With a borehole pumping for ten hours, this means that the requirements will be for 2 315 litre per hour from the borehole.

Once the quantity of water that is required has been established, the water quality must be checked as it affects three types of norms with reference to poultry production systems (Casey et al, 2001)- poultry health, product quality and watering systems. Water quality issues that affect poultry health can be as a result of direct factors (such as a deficiency or a toxicity of an element within the water that affect the physiological processes of the body resulting in inferior performance, poor health and reduced immunity), or indirect (such as a high concentration of minerals which clog the water system resulting in water deprivation). Product quality issues stem from an accumulation of potentially hazardous constituents of the water within the biological tissues of the poultry product such as eggs or meat. These may impact negatively on the health of the consumer. The watering system is affected when clogging, scaling, encrustation and sedimentation affect the drinking equipment and the water delivery.

Table 2 Total water requirements for a broiler section of 110 000 birds to 42 days of age at 26 degrees

Age (days)	Water consumption per 1000 chickens per day (Ross 1999) at 21 degrees C.	Water consumption per 1000 chickens per day at 26 degrees C (@6.5% per degrees C over 21 degrees C)	Number of broilers	Water consumption per day for the section - litres	Water consumption per week – litres
7	59	78	110 000	8 580	60 060
14	110	146	110 000	16 060	112420
21	171	227	110 000	24 970	174 790
28	238	315	110 000	34 650	242 550
35	284	376	110 000	41 360	289 520
42	326	432	110 000	47 520	332 640
Total					1 211 980

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Before any water is used for poultry, it should be tested for microbiological and chemical content – these are usually undertaken by separate laboratories. Water quality is characterized by its taste, acidity, alkalinity, odour, colour, turbidity, salinity, electrical conductivity, pH, biochemical oxygen demand, hardness, and the presence of anions, cations, herbicides and pesticides.

Taste is mostly due to the presence of salts in the water (ferrous and manganese sulphates will give the water a bitter taste). A rotten egg smell is due to the presence of hydrogen sulphide. The colour should be colourless; iron will give a reddish brown colour and copper will give a bluish tinge to the water. Total dissolved solids (TDS) is a measure of the total cations and anions within the water. Hardness is a measure of the total calcium and magnesium content and high levels cause the formation of crystals and clogs up the watering system. Softening treatments should be used to treat high levels of calcium and magnesium. Here calcium and magnesium are exchanged for sodium. However, it has been suggested that sodium is not the ideal choice for a softening treatment as high levels cause wet droppings (Keshavarz, 1987). PH is an expression of the acidity or alkalinity of the water nitrates and nitrites have an organic origin (due to contamination from fertilizers/manure) or inorganic (dissolving of nitrate containing rocks). Nitrate is converted to nitrite in the intestinal tract, which is very toxic, and when it enters the blood stream it makes the haemoglobin incapable of releasing oxygen (Keshavarz, 1987). Some elements are toxic (lead, selenium and arsenic) and will affect production.

Water quality acceptable measurements have usually been compared to international standards for human health such as World Health Organisation water standards as existing water quality guidelines for poultry watering are contradictory. However, even water quality guidelines that are used in different countries vary. In South Africa, the South African Bureau of Standard SABS) has a document entitled "Specification for Water Domestic Consumption" (Cilliers, 1995) which is used as recommended levels. In America, the Environmental Protection Agency (EPA) is the regulatory agency responsible for setting human drinking eater standards and these standards fall into two categories – primary (based on human considerations and maximum allowable contaminant levels) and secondary (regulate non-health related inclusions) (Zimmermann *et al*, 1993). The primary maximum contamination levels (MCL) of inorganic compounds are set by the EPA and enforced by the State but each state may set and enforce lower MCLs than the EPA requirement. In Zimbabwe, the government laboratories in water quality reports state the World Health Organisation 1996 guidelines. These comparisons are shown in Table 3.

Table 3 Comparisons of human water quality guidelines in South Africa, America and Zimbabwe (these are also used as guidelines for poultry).

Parameter *	Unit	Zimbabwe (WHO 1996)	South Africa SABS	America (EPA MCLs)
PH		6.5 – 9.5	6.0-9.0	6.5-8.5
Colour	T.C.U	15		15
Turbidity	N.T.U	5		
Approximate total dissolved solids	Mg/l	1000		500
Total hardness	Mg/l	500	20-300	
Chloride	Mg/l	250	250	250
Sulphate	Mg/l	250	200	250
Nitrate	Mg/l	50	6	10
Fluoride	Mg/l	1.5	1	4
Sodium	Mg/l	200	100	
Magnesium	Mg/l		70	
Iron	Mg/l	0.3		0.3
Manganese	Mg/l	0.5		0.05
Lead	Mg/l	0.01		0.015
Cadmium	Mg/l	0.003		0.005
Nickel	Mg/l	0.02		0.001

Please note that the parameters shown above may not be all the parameters stipulated in each of the regulatory data – the data above is to show comparative differences in some of the water quality guidelines.

In all of the countries, the standards for bacteriology are similar in that that there should be no Coliforms present.

However, even though human water quality guidelines have been set, the question is are these water quality guidelines suitable for poultry and, if any water quality parameter is sub optimal, what effect will this have on the performance of poultry? The ideal situation would be for a poultry farmer to have his poultry water analysed, parameters compared to a standard and if different, to have a guideline as to the estimated effect of this reduced water quality guideline on his poultry performance.

In the initial studies of the effects of water qualities on poultry performance, most studies were undertaken to study death or at least serious injury. Furthermore, most were conducted with single constituents (Good 1985). Since then there have been numerous studies conducted over the years in order to try and first of all determine the water quality of water available within areas and then try and correlate any water quality parameters that are outside of the standards with any change in poultry performance parameters.

Waggoner (as quoted by Keshavarz, 1987) started to investigate to see if certain parameters of water could be related to poultry performance. After several years of collecting data, it was found that there was no correlation. Good (1985) carried out further studies, this time dividing the study farms (all had good management) into those that operated on above average cost and those that settled below average cost. He concluded that no definite statement could usually be made when considering averages of individual constituents of water. Much more important is what is present and the ratios (Good 1985).

Barton (1996) undertook a study of three hundred broiler farms in Arkansas in the United States. Water was tested and performance criteria collected (body weight, feed conversion, liveability and condemnation). In the overall analysis, nitrate was the only mineral that had any significant effect on performance. Higher nitrate levels had a detrimental effect on performance. Simple correlation coefficients that were significant ($P<0.05$) are shown in Table 4. Here, calcium was negatively correlated with feed conversion which meant that feed conversion improved as calcium increased. Bacterial samples were also collected from 200 of the farms and cultured for *Pseudomonas* and E. *coli.* No differences were found between the top and bottom producers related to bacterial contamination. However, it does not say in the article, how heavily contaminated the water was with the bacteria in terms of most probable numbers.

Table 4 Simple correlation with performance data (Barton, 1996).

Performance data	Positive correlation	Negative correlation
Feed conversion	Magnesium	Calcium
Live weight	Dissolved Oxygen, Bicarbonate, Hardness, Calcium, Magnesium	Nitrate
Liveability		Calcium, Potassium
Condemnation	Calcium, Nitrate	

Zimmermann (1993) carried out a similar study on broiler farms in Washington State in America. A water profile on each farm was obtained and water inclusion data was correlated with broiler performance parameter. The results showed that water having high concentrations of sulphate and copper was associated with poor feed conversion. Water having high levels of potassium, chloride and calcium reduced mortality. Results are tabulated in Table 5.

Table 5 Relationship of water quality and broiler performance in Washington (Zimmermann 1993).

Performance data	Positive correlation	Negative correlation
Feed conversion	Sulphate copper	
Mortality		Potassium, Chloride, Calcium

In this study, it was found that calcium and potassium were negatively correlated with mortality, or positively correlated with liveability. This is in contrast with those results obtained by Barton (1996) where calcium and potassium were negatively correlated with liveability. However, Zimmermann (1993) pointed out that the water inclusion profile in Arkansas varies greatly compared to that in Washington. These results emphasis the differences in water quality between regions and how different water inclusion profiles can affect broiler performance.

A further study by Zimmermann (1998) was conducted on broilers, this time in Delmarva and significant correlation of water inclusions with broiler performance variable is shown in Table 6. This study showed in a rank multi-element statistical model (identified interaction between drinking water inclusions and their cumulative effect on growth performance) there is often an indication that total aerobic bacteria number (TB) has an influence on growth performance parameters, in contrast to single element analysis where TB did not have significant effects.

Table 6 Relationship of water quality and broiler performance in Delmarva (Zimmermann 1998)

Performance data	Positive correlation	Negative correlation
Feed conversion		Potassium, hardness electrical conductivity
Mortality		Magnesium, potassium, hardness, electrical conductivity
Condemnation		Iron, Sodium, hardness, pH, electrical conductivity

Zimmermann (1995) carried out another study in Washington, this time on laying hen facilities. Drinking water samples were again collected and analysed for inclusions and bacteria. Layer hen performance was correlated to water analysis. A negative relationship between hen housed egg production and drinking water conductivity, sodium, chloride and sulphate – increasing levels of these inclusions decreased hen housed egg production. Contrary to expectations, drinking water bacteria populations were positively correlated with weeks of hen day egg production above 90% and peak hen day production.

In studies by Waggoner (as quoted by Keshavarz, 1987), broiler performance was compared in two houses in which one had satisfactory water quality and the other had a high concentration of sodium and was contaminated with too may numbers of bacteria to count. It was found that the birds on the poor quality water had poor performance.

In South Africa, Coetzee *et al* (2000) collected water samples form 35 boreholes at poultry producers in the Western Cape and these were analysed. The objective was to identify constituents in excess of the recommended guidelines (PHCs) and those within 10% of the upper limit (COCs). It was found that a total number of PHCs identified were 14, whilst a total number of 7 COCs were found in some areas. A further study analysed water from five provinces within South Africa (Casey et al, 2001) and the total number of PHCs were identified as 10 and a total number of 3 COCs were found. They found that the range between the minimum and maximum levels of a specific water constituent varied markedly.

In addition to correlation studies to statistically evaluate the effect of water quality constituents on poultry production parameters, there has been research into the effects of specific levels of specific water constituents on poultry production parameters. An example of this is the work carried out by Grizzle et al (1997) to study the effect of water nitrate and bacteria on broiler growth performance. In this he concluded that neither nitrate (5.19mg/l) or bacterial contamination of the water (E. coli and Ent. Cloacae to 100 and 50 CFU/ml) alone affected broiler body weights. However, a combination of E. coli (>100CFO/ml), Ent. Cloacae (>50CFU/ml) and 3.72 or 5.19mg/l nitrate – nitrogen reduce six-week broiler body weights.

Research has indicated that a high bacterial load in the drinking water supplied to young chicks will increase leg problems, especially Femoral Head Necrosis (FHN) and associated *Staphylococcus aureus* infections (Ross Breeders 1999). Keshavarz (1987) also reports that there have been associations between bacterial contamination of water and respiratory diseases. Other research shows that there are numerous effects of microbial contaminants on poultry and these may be summarized as in Table 7 (from Anitox).

Table 7 Effects of Microbial Contaminants on Poultry

Microbial contaminant	E *coli*	*Pseudomonas*	*Salmonella*	*Pasteurella*	*Clostridia*	*Candida albicans*
Disease symptoms	Air sacculitis Pericarditis Septicaemia Diarrhoea Decreased appetite	Diarrhoea Septicaemia Oedema Decreased appetite Death	Diarrhoea Enteritis Listlessness Weak Knees Death	Diarrhoea Pericarditis Septicaemia Decreased feed consumption Lameness Death	Peritonitis Decreased feed efficiency Water droppings Death	Diarrhoea Listlessness Decreased body weight gain Decreased feed efficiency

In terms of the effects of water contaminants on poultry performance, Madeira summarized what he considered the effects of water borne contaminants on poultry (Madeira, 1999):

- Induce excess secretion of water
    - Bacterial toxins
    - Excess organic chlorides: acid diarrhoea, systemic hypochloremia, hypokalemic acidosis
    - Excess sodium
    - Low pH: excess hydrogen ions, acidosis

    - High pH: excess calcium, carbonates, metals favour anaerobic bacterial overgrowth and virus proliferation.
    - Excess manganese
- Reduce water consumption
    - Electrolyte imbalance: excess sulphate, chloride and aluminium
    - Contribute to Tibial Dyschondroplasia
    - Excess sodium relative to potassium
    - Excess chlorides
    - Inorganic fluorides
- Block the absorption and metabolism of proteins and amino acids.
    - Low potassium to sodium ratio
    - Excess chlorides
    - Bacterial toxins
    - Competitive bacteria: Pseudomonas
    - Sodium chlorate/chlorite
    - Excess hydrogen peroxide
    - Low pH: acidosis increases ammonia loss by kidneys, decreasing overall nitrogen balance.
- Block assimilation of minerals and vitamins
    - Imbalance of sodium-potassium-chloride ratio
    - Bacterial overgrowth within the intestine
    - Bacterial toxins
    - Gastritis
- Interfere with carbohydrate assimilation
    - Nitrates
    - Bacterial toxins
    - Sodium chlorate/chlorite
    - Arsenic
    - Excess chlorides
    - Excess hydrogen peroxide
- Foster respiratory alkalosis

  - When sufficient water is not ingested in heat conditions, panting will increase carbon dioxide loss, which causes an electrolyte imbalance and metabolism is then depressed.
  - Cause liver, kidney and pancreas damage
  - Chlorinated organics (trihalomethanes: THMs)
  - Organics: pesticides, petroleum by-products, acrylamides
  - Heavy metals: cadmium, lead, copper, manganese, mercury, iron, thallium
- Interfere with reproduction
  - Chlorinated organics (THMs)
  - Organics: pesticides, petroleum by-products, acrylamides
  - Excess chlorides: interferes with required calcium and carbonate balance
- Promote parasitic infestation
  - Nitrates
- Cause gastro enteric diseases
  - Pathogenic bacteria
  - Parasites
  - Cephalopods
  - Algae
- Contaminate the marketable portions of the animal
  - Pathogenic bacteria
  - Parasites

From above, it can be seen that a large amount of research has been carried out into the effects of water quality on poultry performance, but studies carried out are often contradictory. Casey et al (2001) further investigated the effects on poultry production of the water constituents that were deemed to be of concern from his water analysis study. He investigated the effects on poultry performance by studying literature. An example of some of the existing water quality guidelines for poultry watering are shown in Table 8 (adapted from Casey et al, 2001).

Table 8 Some Existing Water Quality Guideline for poultry watering (adapted from Casey *et al*, 2001).

Water Quality	Maximum acceptable Level	Effects
Bacteria	Total = 100/ml Coliforms = 50/ml	Infection: solve problem with 1mg chloride for 3 minutes and pH 8. Respiratory diseases and bloody droppings.
Cadmium	50mg/l 0.01 mg/l 0.005 mg/l 0.05 mg/l	Excess causes severed health effects, reduced growth, decreased egg production
PH	> 6	Lower performance, lower egg quality, lower effectiveness of vaccines. Solve with mild solutions of NaOH. Acidic water – corrodes pipes

As discussed, it can be seen that there are vast differences in water quality between countries and within regions and that different water inclusion water profiles can affect broiler performance – a mixture of inclusions is perhaps as important to poultry performance as is the absolute concentration of individual inclusions. (Zimmermann 1993). Due to often conflicting standards that have been referenced in water quality issues pertaining to poultry, a Water Quality Guideline Index System (WQGIS) for poultry has been a modelling approach in which the relationship between biological response and their causes are predicted within the relevant site-specific factors that may apply (Casey et al, 2001). The objectives of the model are:

- Identify the main production systems within the poultry production spectrum and the water sources available to them.
- Identify the main influences on the ingestion of these water sources and their effect on poultry production.
- Develop a WQGIS for each production system.
- Provide supporting information to make proper risk assessment with appropriate management and alleviator solutions.

Within the development of the WQGIS, there are two water quality guideline systems: Generic and Specific. The generic application is a static water guideline application level - it makes use of single value comparisons but it also indicates possible effects on poultry at given levels. The water quality constituents are then divided into those that have a High Incidence of occurrence within the poultry aquatic environment, Medium Incidence or Low Incidence. An example of the generic WQGIS is shown in Table 9, which has been adapted from Casey *et al*, 2001.

Table 9 Generic Guidelines for WQGIS in poultry (Casey *et al*, 2001)

Cadmium - Medium Incidence

Concentration mg/l	Effects on poultry
Target Water Quality Range = 0 – 0.005	No adverse effects
0.005 – 0.01	Adverse chronic effects such as reduced growth and decreased egg production may occur but are unlikely of the following interactions are observed: Added dietary ascorbic acid protects against Cd induced anaemia. Added Se and Zn reduce the effects of Cd toxicity. Fe deficiency leads to increased kidney Cd
> 0.01	Adverse acute effects such as nephritis and enteritis may occur. Immature birds are more susceptible than adults are.

Specific WQGIS incorporates site-specific influences on water ingestion in terms of the bird, environment and nutrition (for example feed intake, water intake, body weight, mortality, weight gain and FCR, egg production, beak trimming, housing, ventilation rate, lighting, stocking density, relative humidity, environmental temperature, feeding programme, and additives). A factor is applied to water intake estimates according to variations on specific influences. This water intake is then used to estimate the dose of a potentially hazardous constituent within any water to see if it is in excess of maximum recommended limits.

If water testing shows that the water is heavily contaminated with a range of inorganic, microbiological and organic components and there is no alternative source of water, the water must treated. A number of factors have to be taken into consideration when investigating into water treatment methods. As mentioned earlier, the goal of any treatment must be to improve the bottom line of the enterprise (as well as taking into account any health issues). The steps that can be followed are:

- Carry out full and comprehensive water quality testing – both chemical and bacteriological.

• Establish if there are any water constituents that are outside the recommended concentrations.

• An investigation into any possible performance reduction as a consequence of any high levels of any constituents. If there is no documented data on this, this can be investigated on site by simple water treatment trials

• From the above, there needs to be an evaluation on terms of any economic reduction in margins due to reduced performance.

• Investigate any potential consumer health hazards on terms of water quality (from test results) – they must be within minimum stipulated standards. If they are above, then the cost of treating the water in order to reduce to within standard levels must be investigated.

• Full investigation into water treatments that are available – the costs, effect on performance, pollution and finally the effect on profit margins for the poultry enterprise.

The choice of a specific water treatment is dependant on the goal and there is no simple method of treatment that will serve for a general application in water treatment. Water treatment methods can be either by mechanical or chemical treatment. The majority of chemical treatments involve the oxidation of the water supply. However, this process can be expensive and so mechanical treatments can be put in place to try and remove as much contamination as possible prior to exposing the water to oxidation. Mechanical processes that can be used for the separation of contaminants from water are: sedimentation tanks, particulate filtration, organic filter, reverse osmosis and ion exchange.

Chemical water treatment is the application of a wide range of products for the removal, manipulation and restructuring of the contaminants within water prior to consumption. In addition to the use of chemical treatment to improve water quality in terms of the chemical/bacterial contents of the water itself, the importance of chemical treatment in the role of removing biofilm from water lines cannot be overstated.

One of the considerations that must be taken into account in any poultry operation is that of the removal of the biofilm - this clogs the interstitial space of water line as a result of bacterial activity. The bacteria tend to attach onto surfaces and colonize to form a biofilm and these colonies often become progressively more resistant to biocides. This grows with time and as the water passes over the surface, chemicals are extracted and concentrated within the biofilm. These also provide a "shelter" for the micro-organisms and both can cause the blocking of the drinker lines. In young chicks, the high temperatures and low water flow provide an ideal medium for the growth of bacteria within water supply lines. Polluted lines can reduce water intake by the birds (due to adverse change in the taste of the water), they can also reduce feed intake, efficacy of water additives (such as vaccines) due to reactions with the biofilm itself (Van der Sluis, 2002).

Thus, chemical treatments can be looked at to treat the water as well as to reduce the biofilm contamination within the water supply system. Sometimes a multitude of ingredients are needed in order to address a range of contaminations and are dependant on the pH of the water for their effectiveness. One other factor is the exposure time with which the chemicals can act within on the contaminant.

The main chemical treatments that can be used are chlorine, chlorine dioxide, ozone, and ultra-violet light. The concept of using electro chemically activated water is new and the investigation into its possible use within the poultry production industry (initially broilers) is the main aim of this article.

One of the concerns of the public in recent years has been the effect of chemical water treatment on contamination of ground and surface water sources. Society is demanding that agriculture implements environmentally friendly systems of production that have low chemical usage. Management of pollutants ensures that there will be a safe and healthy drinking water supply for humans and animals. However, there is often a conflict between what is considered to be environmentally acceptable and profitability of agricultural enterprises. In areas where there is intensive poultry farming, it is the actual waste products of the poultry enterprises (manure, mortality and most importantly processing plant waste) that often pollutes the naturally occurring surface and ground water that may then have to be treated for poultry consumption. Thus, it is vital that the whole integrated poultry chain is aware of environmental pollutant issues and looks for cost effective ways in which to reduce the problem. When considering the use of a chemical water treatment, it is imperative that the environmental impact of any excess chemical that is discharged is considered.

This assignment investigates the effect of Anolyte on broiler performance. In the broiler performance trials that are described later, the effect of Anolyte on broiler performance is compared to the effect of two other chemical treatments – a chlorine chemical and a chlorine dioxide chemical. Thus for the purpose of this review on chemical treatments, chlorine and chlorine dioxide will be discussed.

Chlorine has been widely accepted as a disinfectant for many years within all types of industries. Chlorine, at a pH of 4-5, produces hypochlorous acid, which is the desired disinfectant that is active against all micro-organisms. According to Madeira (1999), there are a number of factors that will affect the activity of the chlorine and these include:

- pH must be reduced to 4-5. By adjusting the pH, the bicarbonates become carbonates and cease to scavenge the oxidants.
- Chlorine activity is temperature sensitive. Cold water slows down the activity and thus and requires more chlorine than warmer water.
- Organics will consume the chlorine to form chloramines and trihalomethanes (THM).
- Ammonia and Nitrates will slow down the bacterial kill action of the chlorine, increasing the contact time required for the chlorine to work.

Chlorine is the most frequently used treatment for municipal and many agricultural supplies. It may be relatively cheap, but has long-term residual and downstream effects, which are causing people to question its use. Chlorine is also corrosive in its nature. Another disadvantage of chlorine is the contact time between the chlorine and the bacteria. A contact time of 20 minutes is necessary (Keshavarz, 1987) and thus a storage tank should be large enough to provide this length of time. The chlorine may be added by a proportioner and chlorination levels should be maintained at two to three parts per million at the proportioner site. Any excess chlorine should be removed by a proper filter to prevent the reduction of the palatability of the water.

Murphy *et al* (1987) showed that chlorination of drinking water reduced total bacterial counts, water consumption, litter moisture and caking and condemnation rates whilst improving feed conversion in broilers.

Even if the water supply is low in bacterial contamination, then there may be contamination at the drinker level within the house. Studies have shown that water in bell-type drinkers has high levels of bacteria (Ernst 1989) and that chlorination water treatment is an effective method of controlling it. It was suggested that a level of 1ppm chlorine at the drinker mid-house is sufficiently high enough to control this contamination. These levels can be measured with a pool test kit. The move by commercial growers to nipple drinkers has resulted in a great deal of control over the bacterial contamination at drinker level (Grizzle *et al*, 1997).

Chematron 950 is a halogenated hydantoin biocide based on Chlorine and Bromine with 41% available chlorine and 41% available Bromine (Product Information – Chematron *). Hydantoins are known stabilizers of chlorine and bromine in solution. It differs from straight chlorine in that chlorine in water is in the form of 100% active free available halogen whereas Chematron 950 provides only a portion of its halogen as free but will continue to supply halogen on demand. Free bromine forming chemicals have many advantages over chlorine (Product Information - Chematron):

- Greater kill ratios on slime forming bacteria
- No decrease in biocidal activity in the presence of ammonia
- Reduced corrosion.

Chematron 950 is applied by putting a briquette within the drinking water.

* Chematron, P O Box ST 899, Southerton, Harare, Zimbabwe

Another water treatment chemical is that of chlorine dioxide which acts as a powerful oxidant. Chlorine dioxide gas however is toxic and unstable in aqueous solution. Modern technology has managed to stabilize chlorine dioxide in a concentrated form with low toxicity. It does not have the same properties as chlorine as shown:

- It does not have any pH limitations
- It's disinfection capabilities are minimally diminished by organic matter.
- It is colourless, has a mild odour and low corrosivity to metals.
- It has been accepted as having no environmental impact on disposal. This is because the stabilized chlorine dioxide does not form the highly carcinogenic trihalomethanes, as do hypochlorites in the presence of organic materials.

The chlorine dioxide must be activated before using and this is done by adding a food grade acid such as citric acid to lower the pH in a well-ventilated area to below 4. However, the activated chlorine dioxide has a half-life of approximately 48 hours under standard conditions. This is one area of concern in that the activated solution has to be used very quickly.

A commercial product of chlorine dioxide is Oxine. It is described as Chlorine dioxide and activator solution with a microbial efficacy against most bacteria, viruses, fungi and algae. It is activated by slowly mixing 100 parts of water, 10 parts Oxine WT and 1 part Activator (Oxine WT Data sheet *) In treatment of water for poultry drinking water we were advised to use the activated Oxine at 0.01% solution.

Electro- chemically activated water (ECA) is produced as a result of passing a diluted saline solution through a FEM (Flow-through Electrolyte Module), which generates highly active solutions of Anolyte and catholyte. The FEM consists of the anode, a solid titanium cylinder with a special coating, which fits coaxially inside the cathode, a hollow cylinder also made form titanium with another special coating. A ceramic membrane separates the electrodes. When attached to manifolds, FEMs form different capacity ECA reactors that are incorporated into delivery systems containing hydraulic and electronic components.

* Glenchem Chemical Consultants, P O Box 14920, Bredell 1623, South Africa

Electrochemical activation is a relatively new technology and work started in this in 1972 by an engineer, V.M. Bakhir in Tashkent Scientific Research Institute of Natural Gas, USSR, Ministry of Gas Industry (Bakhir, 1997). Over the years, through a lot of research many USSR certificates of authorship and foreign patents have been set up and the system improved. The FEM modules have been improved and the latest and more sophisticated elements are the FEM-3 elements. From 1995, manufacture of STEL devices for sterilizing solutions began which are based on the REM-3 elements and these are manufactured in Russia. (Leonov, 1997).

The process of electrochemical activation uses initial solutions that are diluted aqua-saline solutions with a low electric conductivity. When this is passed through the FEM-3 element and is activated, two streams of activated water are produced – Anolyte and catholyte.

The Anolyte is a strong oxidizing agent and it is possible to produce acidic, neutral or mildly alkaline Anolyte with a pH range of 3.5 to 8.5 and an oxidation reduction potential (ORP) of +600 to +1200mV. The Anolyte is considered to be a biocidal agent and its properties are reputed to include (according to the ECT home page):

- Sporicidal
- Kill micro organisms in extremely short contact time
- Does not bleach surfaces or material
- Solutions can be applied for multiple purposes and in different forms such as ice, liquid or fog.
- It is non-toxic and its residual by-products are also non-toxic.
- It reverts over time to its original state, a weak saline solution.
- It can be generated on site. This can be of economic importance due to the saving in transport and handling of other potentially toxic chemicals.

The catholyte, in comparison, has a pH of 12 to 13 and an ORP of about –900mV. It has reducing properties and is an antioxidant.

According to Cloete (2002) and Bakhir (1997), during the process of electrochemical activation three classes of product are produced:

- The acids (in the Anolyte) and bases (in the catholyte) that are stable and influence the pH of each solution. Their concentration is proportional to the water mineralization and electricity consumption within the process.
- Free radical and other active ions that are unstable and they gradually pass to a stable stage as a result of spontaneous structural and chemical conversion. These radicals enhance the oxidation-reduction potentials of the solutions.

- Quasi-stable structures which are formed near the electrode surface. They are complexes of hydrated membranes around ions, molecules and radicals. They represent a very electrically and chemically active component of the ECA.

There has been some research carried out on the biocidal properties of ECA. The Anolyte and catholyte were tested for their effect on the growth of Streptomyces spp (Hotta *et al*, 1994). It was found that when spores were exposed to the acidic solution (pH 2.5-2.6 and ORP 1170) for one minute, the colony formation was totally inhibited. The alkaline solution only had a marked inhibition when the exposure time was increased to ten minutes. Further tests concluded that that it was unlikely that it was the low pH that contributed to the antimicrobial activity of the Anolyte (Hotta *et al*, 1994). In further trials, the use of Anolyte from electrochemical activation of a sodium sulphate solution (rather than a salt solution) did not result in significant antimicrobial activity. This led to the conclusion that it seemed likely that chlorine played a key role for the antimicrobial activity of the Anolyte (Hotta *et al*, 1994).

However, there has been some debate as to the exact mechanism within the Anolyte that causes its antimicrobial activity. It has been claimed that it is the anions present in the Anolyte that kill the bacteria (Cloete, 2002). The bacterial cell membrane provides the osmotic barrier for the cell and catalyses the active transport of substances into that cell – it also has an electrical charge. Any alterations in transmembrane potential (caused by the action of electron donor or electron acceptor factors such as anions present in the Anolyte) will result in water diffusion against ORP gradients and the bacterial membrane will rupture. Furthermore, bacteria obtain their energy source from outside the cell. These are transported across the membrane via an electro-chemical gradient and if the access to these sources is restricted due to changes in the ORP (due to Anolyte), then the functions of the cell will be affected.

Cloete (2002) also determined the minimum inhibitory concentration of Anolyte using fifteen reference strains of bacteria. It was found that Anolyte gave a 100% kill of all the test isolates at a concentration of 100% and 10%. At a 1:20 dilution, variable kill percentages were obtained ranging from 100% to 31%. Anolyte was more effective against the Gram-positive bacterial strains. Studies on the effects of Anolyte on biofilm revealed that exposure of a biofilm to 1:100 dilutions did not yield any noticeable removal of the biofilm. At 1:10 dilution and neat solution of the Anolyte resulted in the dispersion and removal of the biofilm after a 20-minute exposure.

Work carried out by Li (1995) showed that C. *jejuni* was effectively destroyed in poultry chiller water by the use of pulsed electrical current with either sodium chloride or trisodium phosphate at concentrations from 0.1% to 0.3%. The high salt concentrations accelerated the bacterial destruction. Research at the University of Arkansas documented significant reductions in food pathogens from dipping treatment of fresh-cut vegetables using electrochemically activated water. (Li, 2001).

Research has been carried out by Marais and Brozel (1999) on the use of electro chemically activated water in dental lines - they concluded that it effectively reduces bacterial counts and removes biofilm in dental unit water lines. Trials are currently underway in the Karoo to investigate the use on Anolyte to reduce the biofilm in boreholes (Radical Waters, personal communication). Amongst the variety of trials currently underway world wide as to the practical applications of Anolyte, its use against anthrax in being investigated (Smith, 2001).

Very little research has been carried out to investigate the effects of Anolyte on broiler performance. Zimmermann et al (1991) investigated the effect of different electronic devices on growth performance in broilers. He found that two of the devices increase dissolved oxygen content of the water, reduced conductivity and micro-organism counts. One of these reduced broiler mortality, decreased pH and increased iron and manganese concentration in the water. Neither the third device (the electrostatic water treatment) nor the other devices affected body weight or feed conversion at 49 days of age. However, this trial utilized high quality water – different results may have been observed if lower quality water was used.

One of the practical problems associated with the production of Anolyte is the disposal of the catholyte. It is produced in a volume of approximately one sixth of the volume of the Anolyte.

Radical Waters has the sole rights to the globally patented EAW electrolyte cell technology in Africa and has patented the device used to produce the activated solutions across a diverse array of industry categories (Food Review, 2002).

Farm A is a poultry breeding company that is part of a fully integrated poultry company within Zimbabwe. It has the option to place broilers from its own breeding stock (also on Farm A), which are hatched in an old hatchery on the farm (Hatchery A broilers). It also has the option to purchase broilers from another hatchery producing broilers of the same breed (known as Hatchery B broilers). This has been a preferred option due to poorer quality broiler chicks from the Farm A hatchery. The broiler results at Farm A have been far from satisfactory in that poor growth rates, high mortalities and poor feed conversion ratios have been seen. However, it has been noticed that the performance of the Hatchery A broiler has been worse than that of the Hatchery B broiler in terms of mortalities and FCR, although the growth rates have been similar.

Farm A's water supply is via borehole (which has limited volume and is kept as much as possible for the breeding operations) and an unlimited supply of highly contaminated water from two border rivers which is used mainly within the broiler sites.

Owners of Farm A are willing to spend the money to sort out the water quality but would rather not put in mechanical treatment plants due to the current situation in Zimbabwe and thus chemical treatment

Further laboratory tests were carried out in order to establish the minimum inhibitory concentration (M.I.C) of Anolyte. Here, overnight cultures (eighteen hours) in Nutrient Agar and MaConkey Agar for the following organisms were prepared:

- *Escherichia coli*
- *Salmonella enteridites*
- *Klebsiella pneumoniae*
- *Aspergillus spp*

A standard inoculum was prepared and emulsified in saline. Stock solutions of neat, 20%, 10%, 5%, 2% and 1% of Anolyte were made and 0.1 ml of the cultures were added to the Anolyte and then incubated and the effect of the diluted solutions on the culture observed.

Within the laboratory a total colony count method of testing Anolyte was also done. This is a general count of all organisms present and it indicates the level of contamination of the poultry section water. Water samples were collected from the trial sites and 1ml amounts of trial water were inoculated onto surfaces of agar and incubated for 2 days at 37 C and colonies counted.

Finally, a sample of water supplied to the section was taken and a chemical water analysis performed by the Zimbabwe Government Analyst Laboratory.

The next set of trials were carried out within a broiler trial site at Farm A, and this was to evaluate the effects of water treatments on broiler performance.

As previously discussed, the importance of removing biofilm in poultry production cannot be over stated. The effects of Anolyte on biofilm has already been discussed and thus by removing the biofilm within water systems delivery water to the poultry operations with Anolyte can be considered an important factor. However, the question is if there is a broiler performance benefit in administering Anolyte solely through the drinking water (assuming that there is no biofilm constraint)? There is no documented literature on the effect of Anolyte on broiler performance and thus the trial had to be constructed in such a way as to provide data relating to the:

- Effects of dilution rates of Anolyte on broiler performance. For the purposes of this trial the dilution rates that were used were 10%, 15% and 20% Anolyte solutions and this was administered via manual filling of chick fonts from large 70 litre containers, i.e. not via any water pipes where the presence of biofilm could be a factor.
- Length of time that the Anolyte should be administered. From preliminary trials based in Botswana, it had been established that the Anolyte still had an effect on broiler performance when given for the first 14 days. For this reason, individual live weights were taken for all birds at 14 days. There is a logistical question in giving Anolyte longer than 14 days due to the increase water consumption as the

broilers get older. This would mean that in large broiler units, there is a logistical problem in physically moving the Anolyte.

• Due to the fact that other chemical water treatments (Chematron* and Oxine**) are given for the full length of the trial, one Anolyte treatment (10%) was also given for the full length of the trial.

This was split into two main trials – broilers from Hatchery A and broilers from hatchery B and treated according to Tables 10 and 11 respectively.

Chicks for Experiment 1 and 2 were placed in separate houses within the same poultry section. Chicks within Experiment 1 were all from the same aged parents (aged 44 weeks of age) and chicks within Experiment 2 were all from the same parents at Farm A (aged 45 weeks of age). An average weight of the chicks from each group was measured at day one. The placing of each group within the house was done by randomly drawing the pen number against group number. For each group the management was exactly the same in terms of space given, number of brooders, feeders and drinkers per group. All groups had exactly the same vaccination programme: 2 days HI 20 (Infectious bronchitis), 15 days V877 (Infectious Bursal Disease) and NDW (Newcastle) and 28 days NDW (Newcastle). All were administered via the drinking water with skimmed milk inclusion and all treated water was withdrawn for 24 hours before and after the vaccination.

Table 10 Experiment 1 – broilers from the Hatchery B (hatch date 25th June 2002)

Description	Number of days on treatment	% Anolyte	Number of days on treatment	% Anolyte	Number of groups	Number of birds in group	Total number of birds per treatment
Control	14	0%	26	0%	3	50	150
Oxine	14	0%	26	0%	3	50	150
Chematron	14	0%	26	0%	3	50	150
10% Anolyte	14	10%	26	10%	3	50	150
15% Anolyte	14	15%	26	1%	3	50	150
20% Anolyte	14	20%	26	1%	3	50	150

* Chematron supplied by Vetco, Harare, Zimbabwe; ** Oxine supplied by Vetco, Harare, Zimbabwe

Table 11 Experiment 2 – broilers from the Hatchery A (hatch date 5th July 2002)

Description	Number of days on treatment	% Anolyte	Number of days on treatment	% Anolyte	Number of groups	Number of birds in group (+-1)	Total number of birds per treatment
Control	14	0%	26	0%	2	50	100
Oxine	14	0%	26	0%	2	50	100
Chematron	14	0%	26	0%	2	50	100
10% Anolyte	14	10%	26	10%	2	50	100
15% Anolyte	14	15%	26	1%	2	50	100
20% Anolyte	14	20%	26	1%	2	50	100

All groups were given the same feed from the same batch bought from a local feed company. Broiler starter (crude protein 21%) was given as 1 kg per bird placed and then broiler finisher (crude protein 19%) until the end of the trial. The feed was delivered in bags and these were weighed to ensure that they were 50 kilogram's each. Daily issues were recorded.

Mortalities were recorded on a daily basis and all were sent to a veterinary laboratory for post mortem analysis.

Vetco laboratories manufactured the neutral Anolyte and the pH was tested as 6.9 and ORP as 828 mV. Fresh Anolyte was manufactured on a daily basis to ensure that the Anolyte that was administered was not older than 48 hours. It must be noted that the water used within the laboratory from which the Anolyte was manufactured was borehole water and not bacterially contaminated. For the water treatments, each trial has its own 70 litre bucket of water into which the treatment was administered. The Oxine (at dilution 0.01%), 10% Anolyte, 15% Anolyte and 20% Anolyte were measured into the 70 litre bucket at the correct volumes each time the water had to be replenished. The large Chematron briquettes were weighed at the beginning and put into a porous bag within the 70 litre bucket. At the end of the trial the briquettes were then dried and weighed to calculate the actual weight of Chematron used for the trial. Each group within the treatment was given water from the same 70 litre bucket to rule out differences in dilution rates (i.e. Group 1,6 and 10 - 20% Anolyte were all issued with the treated water from the same bucket). The water was administered to the broilers manually via chick fonts, which were cleaned out daily with the treated water. The total water consumed for each treatment was calculated so that the amount of chemical used per treatment could be calculated.

Weekly measurements were carried out as per Table 12 for each Experiment.

Table 12 Weekly measurements for Experiment 1 and 2.

Age (days)	Live weight	Mortality	Feed consumed	FCR
1	Total to get an average	Cumulative	Total issued minus feed left	Total feed consumed/total live weight
7	Total to get an average	Cumulative	Total issued minus feed left	Total feed consumed/total live weight
14	Individual weights	Cumulative	Total issued minus feed left	Total feed consumed/total live weight
21	Total to get an average	Cumulative	Total issued minus feed left	Total feed consumed/total live weight
28	Total to get an average	Cumulative	Total issued minus feed left	Total feed consumed/total live weight
35	Total to get an average	Cumulative	Total issued minus feed left	Total feed consumed/total live weight
42	Individual weights	Cumulative	Total issued minus feed left	Total feed consumed/total live weight

Measurements at 14 days (live weights only) and 42 days (live weights, FCRs and mortalities) were analysed within each treatment between Hatchery B and Hatchery A as well as between the two different sources of broilers. For each experiment, descriptive statistics (means, median and standard deviations) were computed in SPSS for Windows Version 10. Box plots were produced to compare the different treatments for each experiment at 14 and 42 days of age. Analysis of variance (ANOVA) was used to compare mean weights for the different treatments for each experiment. Multiple comparisons or Pairwise Comparisons were conducted using the Least Significant Difference (LSD) technique. A p- value of less than or equal to 0.05 was considered as significant. Mortalities and FCRs in different groups were compared using the odds ratios and chi square test in Epi Info Version 6. Performance efficiency factors (PEF) were done at 42 days and a comparative costing was also carried out for each trial at this age.

An ANOVA test was done to compare results on the same treatments between the Hatchery B and Hatchery A for the live weights and mortalities.

Results

In the laboratory tests of Anolyte the impregnation method for testing Anolyte efficacy tests was conducted on the neutral and acid Anolyte and results indicate that at a dilution of 10% both acid and neutral Anolyte have antibacterial activity after a contact time of at least one minute. This is shown in Tables 13 and 14.

Table 13 Impregnation method for testing Neutral Anolyte

Time (minutes)	Undiluted	10% diluted neutral Anolyte
1 (Control)	Profuse Growth	
1	0	0
5	0	0
10	0	0
20	0	0
30	0	0

Table 14 Impregnation method for testing Acid Anolyte

Time (minutes)	Undiluted	10% diluted acid Anolyte
1 (Control)	Profuse Growth	
1	0	0
5	0	0
10	0	0
20	0	0
30	0	0

Minimum inhibitory concentration tests of neutral and acid Anolyte revealed that at a minimum concentration of 5% dilution, both acid and neutral Anolyte had an antibacterial activity as shown in Tables 15 and 16.

Table 15 M.I.C method for testing Neutral Anolyte

Concentration (%)	1 minute	5 minutes	10 minutes
0 (Control)	PG	PG	PG
1	PG	PG	PG
2	PG	PG	PG
5	0	0	0
10	0	0	0
20	0	0	0
Neat	0	0	0

Where PG- Profuse Growth

Table 16 M.I.C. method for testing Acid Anolyte

Concentration (%)	1 minute	5 minutes	10 minutes
0 (Control)	PG	PG	PG
1	PG	PG	PG
2	PG	PG	PG
5	0	0	0
10	0	0	0
20	0	0	0
Neat	0	0	0

Where PG - Profuse Growth

However, when the M.I.C. test was carried out on Aspergillus spp, both the acid and neutral Anolyte only inhibited growth when undiluted.

The effect of a 15% Anolyte solution (that was taken from the trial site) was also shown to have a marked effect on the total colony count of the water as shown in Table 17. These results also show that there is an unacceptably high bacterial level in the untreated water that is drunk by the control group of broilers.

Table 17 Total colony count of control water and 15% diluted Anolyte

Bacteria	Control Water	15% Anolyte
Total bacteria	596 000	0
Coliforms	20 000	0
E. *coli*	10 000	0
Staphylococcus	13 000	0
Pseudomonas	3 000	0
Klebsiella	3 000	0

The results of the water sample that was taken to the government laboratory were compared to an analysis that was carried out on water taken from the same river last year. These results are shown in Table 18.

Table 18 Inorganic Water Analysis Report (performed by Zimbabwe Government Analyst Laboratory.)

Parameter	Unit	Results from Zimbabwe Government analyst (2002)	Results from SGS (private laboratory) 2001
PH		5.9	6
Colour	T.C.U	0	
Turbidity	N.T.U	1.3	23.4
Conductivity	MSm^{-1}	24.8	0.152
Approximate Total Dissolved Solids	Mg/l	145.1	106
Lime Hardness	Mg/l	40.7	
Total Hardness	Mg/l	65.1	38.96
Alkalinity	Mg/l	85	50
Chloride	Mg/l	27.5	16
Sulphate	Mg/l	28	1.88
Nitrate	Mg/l	0.9	0
Bicarbonate	Mg/l	103.7	
Fluoride	Mg/l	0.4	
Sodium	Mg/l	44	1.4
Potassium	Mg/l	5	3.3
Magnesium	Mg/l	3.7	5.2
Calcium	Mg/l	16.3	9
Iron	Mg/l	0.2	13.6
Manganese	Mg/l	ND	0.8
Lead	Mg/l	ND	
Cadmium	Mg/l	0.1	
Nickel	Mg/l	ND	

These results show that there is some variation in water quality between 2001 and 2002. The areas of concern are the consistent low pH, and the high levels of cadmium in 2001.

In the experimental trials, the results are divided into those from Hatchery B and those from the Hatchery A.

In terms of the Hatchery B, all the individual live weights per group are shown in Table 19 (in the addendum). For the purpose of the statistical analysis, the lowest three live weights for each treatment were removed. It must be noted that this was also the case in all live weight statistical analyses for Hatchery B and Hatchery A individual weights. However, for comparing FCRs and PEFs, the total weights were used as individual bird FCRs were not measured.

The live weight measurements taken at 14 days of age for the Hatchery B are summarized in Graph 1 where it is shown that the 15% Anolyte treatment had the highest average live weight at 14 days of age. When these results were statistically analysed with the Anova test, it was shown that the live weights of each treatment differed ($P<0.05$) as shown in Table 20.

Graph 1 Box Graph of Mean Live Weights of Hatchery B at 14 days of age.

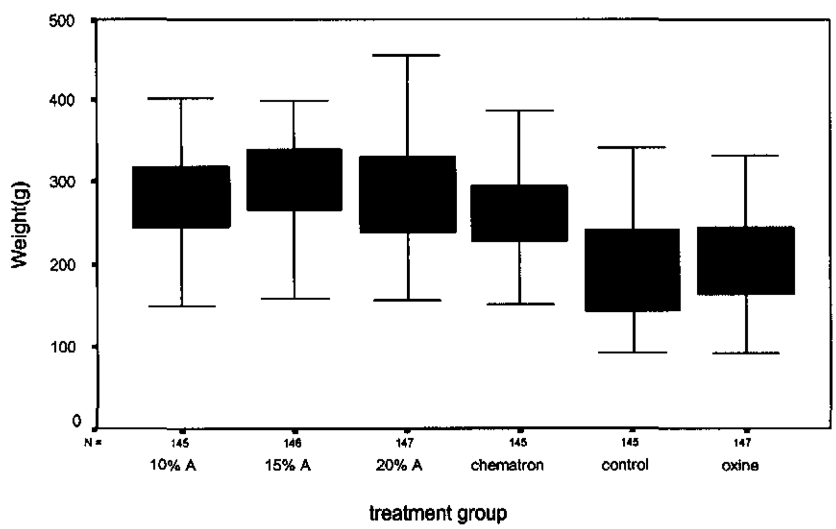


Table 20 Anova test on Hatchery B live weights at 14 days of age

Descriptive

Treatment	Number	Mean	Std deviation	Minimum	Maximum
10% Anolyte	145	281.05	57.95	150	456
15% Anolyte	146	298.19	53.62	159	461
20% Anolyte	147	286.62	61.77	157	454
Chematron	145	262.03	53.20	151	399
Control	145	194.92	58.02	93	341
Oxine	147	202.73	53.14	93	332
Total	875	254.26	69.42	93	461

Anova

	Sum of squares	Df	Mean square	F	Sig
Between groups	1449382	5	289876.483	91.203	0.000
Within groups	2761989	869	3178.353		
Total	4211372	874			

When a least significant difference (LSD) test was conducted on the difference between the treatments for the live weights at 14 days of age, it can be seen that all treatments differed ($P<0.05$) other than those on 10% Anolyte and 20% Anolyte, 15% Anolyte and 20% Anolyte, control and Oxine as shown in Table 21.

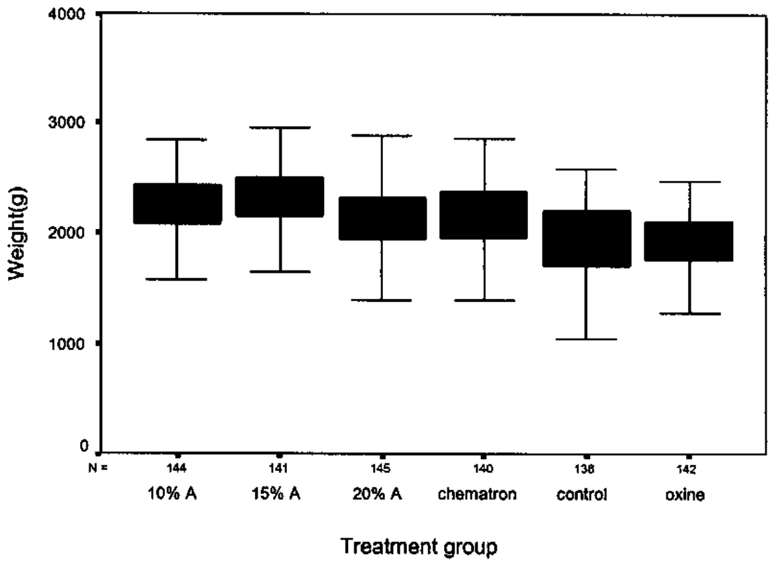
Table 21 LSD - P Values -result on multiple comparisons between tests (Hatchery B at 14 days of age)

Treatment	Control	Chematron	Oxine	10% Anolyte	15% Anolyte	20% Anolyte
Control	-	-	-	-	-	-
Chematron	0.001	-	-	-	-	-
Oxine	0.237	0.001	-	-	-	-
10% Anolyte	0.001	0.004	0.001	-	-	-
15% Anolyte	0.001	0.001	0.001	0.010	-	-
20% Anolyte	0.001	0.001	0.001	0.399	0.079	-

These results show that at 14 days of age, the live weights of Hatchery B broilers on 15% Anolyte differed to all other treatments ($P<0.05$) in that they are heavier - other than when comparing to the 20% Anolyte.

At 42 days of age individual live weights were done (shown in Table 22 in the addendum). The live weights of the different treatments at 42 days of age once again showed that the 15% Anolyte treatment had the higher average live weight as shown in Graph 2.

Graph 2 Box graph of mean live weights of Hatchery B broilers at 42 days of age



Once again, an Anova test showed that the results differed (P<0.05) as shown in Table 23.

Table 23 Anova test on Hatchery B live weights at 42 days of age.

Descriptive

Treatment	Number	Mean	Std deviation	Minimum	Maximum
10% Anolyte	144	2247.36	290.69	1580	3200
15% Anolyte	141	2306.10	314.69	1380	2960
20% Anolyte	145	2136.69	305.00	1340	2880
Chematron	140	2137.14	331.37	1400	2860
Control	138	1924.93	339.07	1040	2580
Oxine	142	1919.30	301.09	800	2640
Total	850	2112.92	345.54	800	3200

Anova

	Sum of squares	Df	Mean square	F	Sig
Between groups	18229365	5	3645873.075	37.011	0.000
Within groups	83139599	844	98506.634		
Total	1.01 E+08	849			

When a least significant difference (LSD) test was conducted on the difference between the treatments for the live weights at 42 days of age, results showed that most treatment differed (P<0.05) other than between 10% Anolyte and 15% Anolyte, 20% Anolyte and Chematron, Control and Oxine. A summary of the results is shown in Table 24.

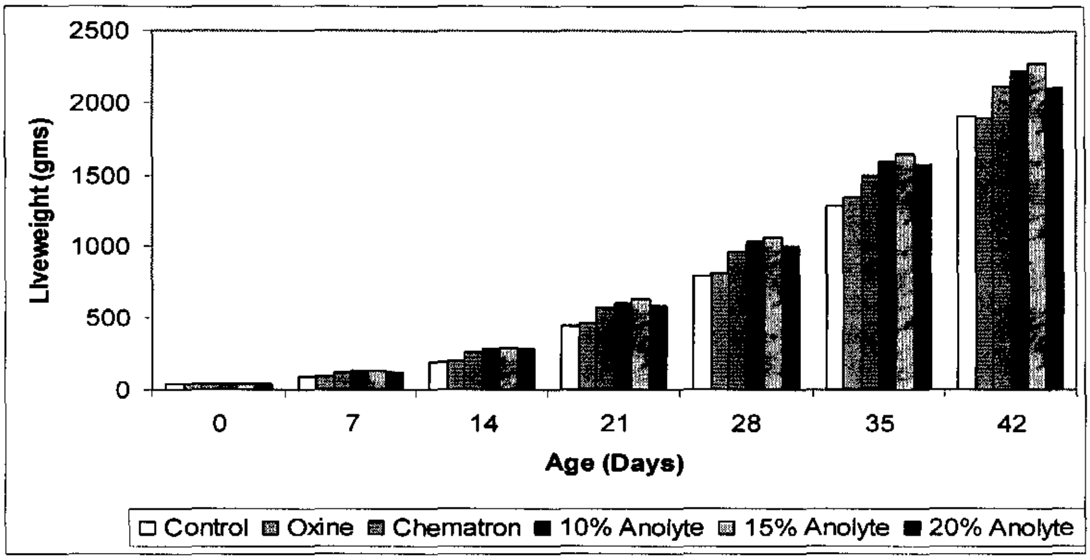
Table 24 LSD - P Values -result on multiple comparisons between tests (Hatchery B at 42 days of age.

Treatment	Control	Chematron	Oxine	10% Anolyte	15% Anolyte	20% Anolyte
Control	-	-	-	-	-	-
Chematron	0.001	-	-	-	-	-
Oxine	0.881	0.001	-	-	-	-
10% Anolyte	0.001	0.003	0.001	-	-	-
15% Anolyte	0.001	0.001	0.001	0.115	-	-
20% Anolyte	0.001	0.990	0.001	0.003	0.001	-

From the above it can be seen that at 42 days of age, once again the 15% Anolyte treatment resulted in the heavier live weights that differed from the other treatments (P<0.05) other than the 10% Anolyte (P>0.05).

Graph 3 shows the change in live weight for age for the different water treatments in comparison to the control on the Hatchery B broilers.

Graph 3 Live weight for age for Hatchery B broilers on different treatments.



It can be seen the highest live weight at 14 days of age (15% anolyte) also has the highest live weight at 42 days of age.

The cumulative mortality records for each group within the treatments are shown in Table 25.

When an odds ration test was done on the mortalities between treatments, it was found that the control group was more likely to die in comparison to all the other treatments other than the Chematron treatment. Only the 20% Anolyte and control differed ($P<0.05$) as shown in Table 26.

Table 25 Mortality (numbers) per week per group (Hatchery B at 42 days of age)

Group	Trial	Birds placed	7 days	14 days	21 days	28 days	35 days	42 days	Cumulative mortality %
5	10% Anolyte	50	1	0	0	0	0	0	2.00%
11	"	50	0	1	0	0	0	1	4.00%
12	"	50	0	0	0	0	0	0	0.00%
3	15% Anolyte	50	0	1	2	1	0	0	8.00%
14	"	50	0	0	0	0	0	2	4.00%
17	"	50	0	0	0	0	0	0	0.00%
1	20% Anolyte	50	0	0	1	0	0	0	2.00%
6	"	50	0	0	0	0	0	0	0.00%
10	"	50	0	0	0	0	1	0	2.00%
4	Chematron	50	0	0	1	0	0	1	4.00%
7	"	50	0	1	1	0	0	0	4.00%
16	"	50		1	1	0	0	1	6.00%
8	Control	50	0	1	0	1	0	0	4.00%
13	"	50	0	0	0	1	0	1	4.00%
15	"	50	1	0	0	1	1	2	10.00%
2	Oxine	50	0	0	1	1	0	0	4.00%
9	"	50	0	0	0	0	2	0	4.00%
18	"	50	0	0	0	0	1	0	2.00%

Table 26 Odds Ratio on mortalities (comparisons done between groups in treatment) – Hatchery B at 42 days of age.

Comparison A group	Comparison B group	Factor by which A group is more likely to die than B group	P value
Control	20% Anolyte	5	0.0300
Control	15% Anolyte	2	0.4267
Control	10% Anolyte	3	0.0700
Control	Oxine	2	0.2735
Control	Chematron	1	0.6073

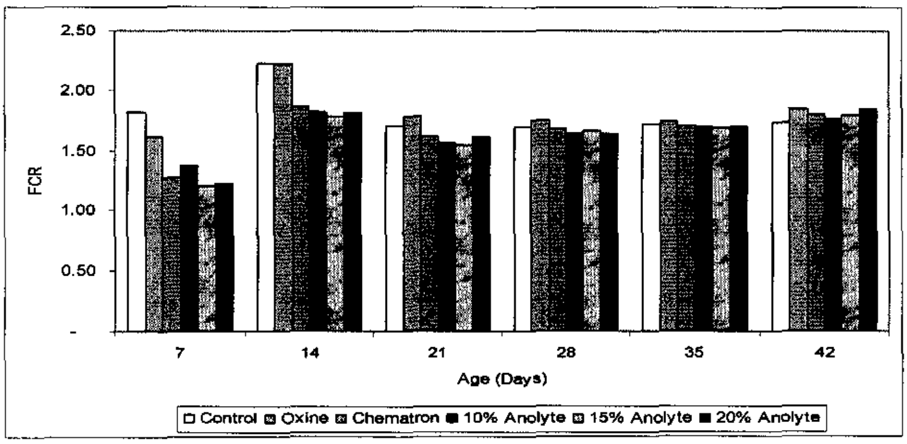
The FCR results for all the treatments were excellent as shown in Table 27 and an Anova test was conducted and none of the treatment differed (P>0.05).

Table 27 FCR at 42 days of age for Hatchery B

Group	Trial	Cumulative feed given to 42 days of age (kgs)	FCR at 42 days of age
5	10% Anolyte	197.9	1.84
11	"	190.1	1.73
12	"	191.1	1.74
3	15% Anolyte	187.7	1.80
14	"	198.0	1.78
17	"	203.4	1.79
1	20% Anolyte	182.0	1.84
6	"	201.5	1.79
10	"	191.9	1.92
4	Chematron	196.6	1.85
7	"	178.0	183
16	"	170.5	1.71
8	Control	143.6	1.73
13	"	162.1	1.71
15	"	160.0	1.77
2	Oxine	170.0	1.87
9	"	157.0	1.79
18	"	180.0	1.87

FCR results for each treatment were calculated on a weekly basis and results are shown in Graph 4.

Graph 4 FCR with age on different water treatments on the Hatchery B broiler



In many broiler enterprises the Performance Efficiency Factor (PEF) is taken as an indicator of broiler performance. It takes the four key areas of performance into an equation to obtain a PEF value that can be used to compare performances of different flocks. The PEF was calculated as in Equation 2.

Equation 2 Calculation of PEF

$$PEF = \frac{\text{Average live weight (kgs) X Flock livability (\%)}}{\text{FCR X Age at slaughter (days)}}$$

The PEF results at 42 days are tabulated in Table 28 and as can be seen, the results of the 10% Anolyte and the 15% Anolyte are very similar although the 10% Anolyte PEF is marginally better.

Table 28 PEF results at 42 days of age for Hatchery B

Treatment	PEF
10% Anolyte	293.95
15% Anolyte	291.30
20% Anolyte	268.19
Chematron	267.38
Control	245.50
Oxine	236.39

The object of the research was to investigate the effects of Anolyte on production profits within an integrated broiler enterprise and thus the final exercise that was carried out on the Hatchery B trial was a costing analysis. This trial was based on completion of a set number of days to slaughter (42 days) i.e. the turn around time within the broiler sites is fixed and cannot be extended to accommodate birds that are too small.

For the purposes of simplification, only the costing parameters that were affected were used in the margin comparisons. For example, the cost of the chicks was the same and thus was not involved in the calculation. The variable costs that were used were the feed costs and disinfectant (water treatment) costs. The feed costs were used due to the fact that different amounts of feed were consumed (due to different FCR) even though the dollar per unit was the same. The disinfectant costs were used as different amounts of the different disinfectants were used that had different dollars per unit cost. All costs were in Zimbabwean dollars at the time of the trial (June 2002 to August 2002).

For the income, the equivalent total dressed weight (taken at 80% of the live weight) was taken and multiplied by the current broiler contractor price that is paid by the abattoir (Suncrest) * to the contractor. The comparative margin (after feed and disinfectant costs) between treatments gives increased dollar per bird placed amount to the broiler grower for each treatment in comparison to the control (untreated water). A detailed schedule is shown in Table 29 within the addendum. Here it can be seen that in the Hatchery B trial to 42 days of age, the most profitable treatment to the broiler grower is that of the 15% Anolyte at Z$176.69 per bird placed which is a Z$21.80 increase on the margin of the control. This is mainly due to the better live weight (and hence dressed weight) of the group.

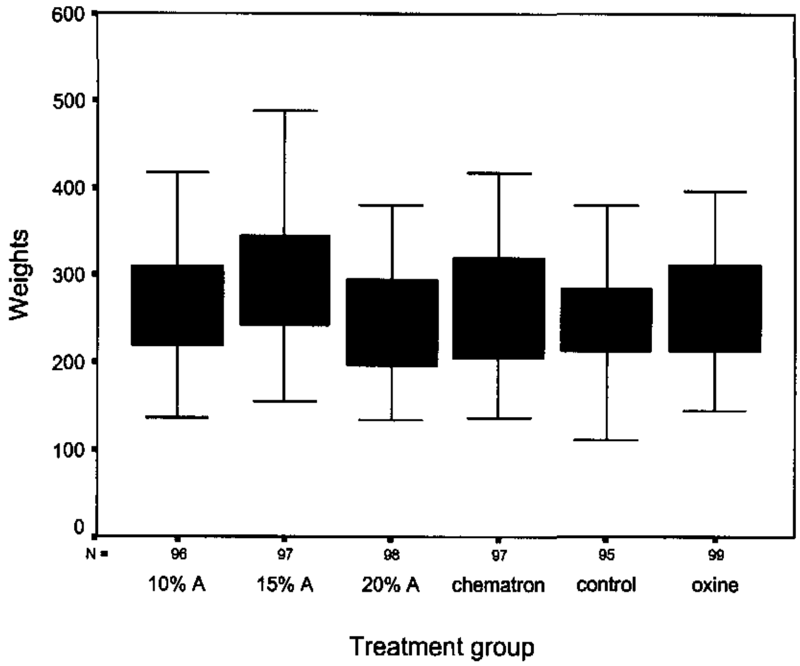
This margin was then extended to an annual basis on the assumption that Farm A places 110 000 broilers per week so that a margin comparative to control per treatment can be obtained. From Table 29, it can be seen that the annual margin on the control group would be estimated at Z$885,818,248 whereas that on the 15% Anolyte would be Z$1,010,532,666 which is a comparative increase of Z$124,714,418 to the broiler section only.

The costing analysis must also be extended to the abattoir, as an increased volume of dressed meat through the abattoir will also lead to an increased profit (assuming that the product can be sold). In Table 29 it can be seen there is a comparative margin of Z$703,422,720 on the 15% Anolyte group in comparison to Z$572,091,520 on the control group which is a Z$131,331,200 increase. Thus, the total possible increase in margin for both the broiler enterprise and the abattoir when the drinking water is treated with 15% Anolyte in comparison to untreated water that is currently being used is Z$256,046,618. In must be born in mind that these margins are assuming that the commercial management condition would be the same as the trial management conditions.

In the next trial, the same treatments were carried out on Hatchery A broilers. Individual live weights at 14 days per group are shown in Table 30 within the addendum. In Graph 5 showing the mean live weights per trial, it can be seen that once again the highest growth rate at 14 days was in the 15% Anolyte treatment.

* Suncrest Chickens PVT Ltd – Amalinda Road, Harare South, Harare, Zimbabwe

Graph 5 Mean Live Weights of Hatchery A broilers at 14 days of age



An Anova test carried out on the 14 day live weights (Table 31) shows that the effects of the treatments differed (P<0.05).

Table 31 Anova test on Hatchery A at 14 days of age (live weights)

Report

Treatment	Mean	Number	Std Deviation	Minimum	Maximum
10% Anolyte	264.27	96	64.12	135	419
15% Anolyte	298.37	97	66.13	155	489
20% Anolyte	250.77	98	63.39	134	381
Chematron	263.44	97	72.22	135	419
Control	250.19	95	60.47	110	404
Oxine	261.12	99	63.22	145	398
Total	264.71	582	66.73	110	489

Anova

	Sum of squared	Df	Mean square	F	Sig
Between groups	150444.1	5	30088.814	7.113	.0001
Within groups	2436533	576	4230.073		
Total	2586966	581			

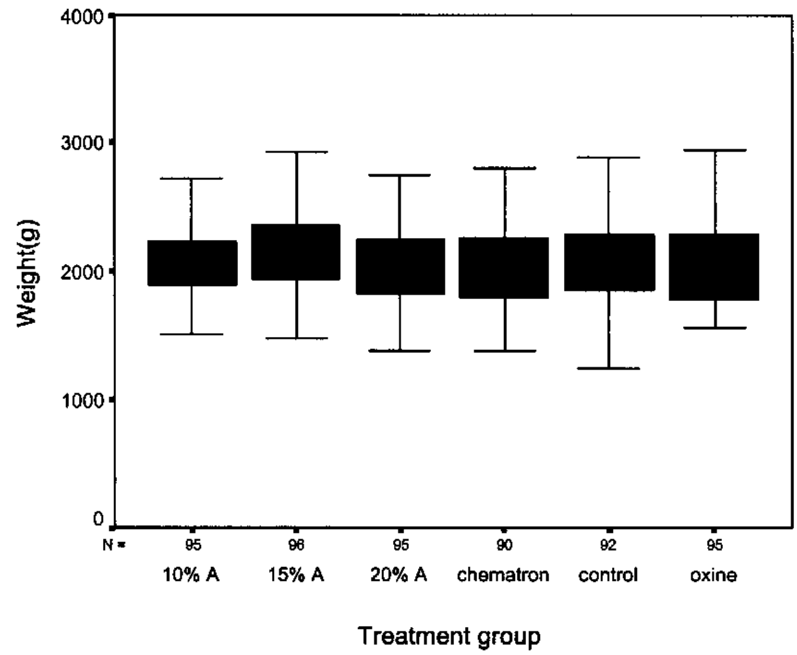
When comparing treatments between the treatments, Table 32 shows that only when comparing 15% Anolyte to the other treatments was there any difference (P<0.05).

Table 32 LSD – P values – result on Multiple Comparisons between tests (Hatchery A at 14 days of age)

Treatment	Control	Chematron	Oxine	10% Anolyte	15% Anolyte	20% Anolyte
Control	-	-	-	-	-	-
Chematron	0.159	-	-	-	-	-
Oxine	0.242	0.803	-	-	-	-
10% Anolyte	0.135	0.930	0.735	-	-	-
15% Anolyte	0.001	0.001	0.001	0.001	-	-
20% Anolyte	0.951	0.174	0.264	0.149	0.001	-

Table 33 (in the addendum) shows the individual live weights of all the groups at 42 days of age. The average live weights of each treatment in shown in Graph 6 and it can be seen that once again the 15% Anolyte has the heaviest average live weight.

Graph 6 - Box graph of mean live weights of Hatchery A broilers at 42 days of age



An Anova test between all the groups showed that there was no difference in the weights at 42 days of live weight (P>0.05) as shown in Table 34. Multiple comparison tests between the treatments showed that only 15% Anolyte and control, 15% Anolyte and 20% Anolyte as well as 15% Anolyte and Chematron differed (P<0.05) this is shown in Table 35.

Table 34 Anova test on difference in Hatchery A live weights between treatments at 42 days of age.

Report

Treatment	Mean	Number	Std Deviation	Minimum	Maximum
10% Anolyte	2083.16	95	325.79	1220	2860
15% Anolyte	2149.17	96	344.02	1480	2920
20% Anolyte	2047.79	95	316.06	1380	2900
Chematron	2020.67	90	328.13	1380	2800
Control	2017.39	92	378.32	1000	2880
Oxine	2070.74	95	322.55	1560	2940
Total	2065.61	563	337.79	1000	2940

Anova

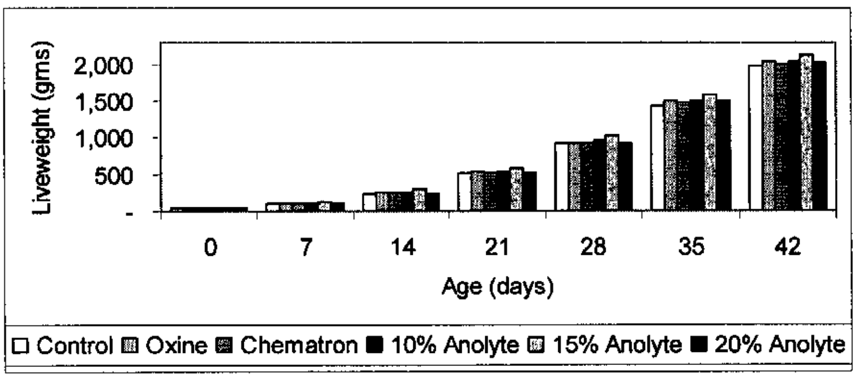
	Sum of squared	Df	Mean square	F	Sig
Between groups	1127859	5	225571.9	1.994	0.078
Within groups	62996804	557	113100.187		
Total	64124664	562			

Table 35 LSD – P values – Result on Multiple Comparisons between tests (Hatchery A at 42 days of age).

Treatment	Control	Chematron	Oxine	10% Anolyte	15% Anolyte	20% Anolyte
Control	-	-	-	-	-	-
Chematron	0.948	-	-	-	-	-
Oxine	0.279	0.312	-	-	-	-
10% Anolyte	0.182	0.207	0.799	-	-	-
15% Anolyte	0.007	0.009	0.108	0.176	-	-
20% Anolyte	0.537	0.584	0.638	0.469	0.038	-

Graph 7 shows the change in live weight for age for the different water treatments in comparison to the control on the Hatchery A broilers. The trend is the same as those of the Hatchery B trial in that those birds with the highest weight at 14 days of age also have the highest live weights on completion of the trial.

Graph 7 Live weight for age for Hatchery A broilers on different treatments



The mortalities per week per treatment to 42 days of age for the Hatchery A are shown in Table 36. An odds ration test shows that the control is more likely to die than all the other treatments even though the mortalities did not differ (P>0.05) as shown in Table 37.

Table 36 Mortality (numbers) per week per group (Hatchery A at 42 days of age)

Group	Trial	Birds placed	7 days	14 days	21 days	28 days	35 days	42 days	Cumulative mortality %
5	10% Anolyte	51	0	1	1	0	0	0	3.92%
13	"	51	1	1	0	0	0	0	3.92%
8	15% Anolyte	50	0	0	0	0	0	0	0.00%
11	"	51	1	0	1	0	0	0	3.92%
3	20% Anolyte	51	0	0	0	0	1	0	1.96%
6	"	51	0	1	0	1	0	1	5.88%
4	Chematron	50	0	0	2	1	0	0	5.88%
9	"	50	0	1	2	0	1	1	10.00%
7	Control	51	0	2	1	0	0	1	8.00%
10	"	51	0	1	0	1	0	0	3.92%
2	Oxine	51	0	0	2	0	0	1	3.92%
12	"	51	0	0	1	0	2	0	3.92%

Table 37 Odds ratio on mortalities (comparisons done between total of groups in treatment) - Hatchery A at 42 days of age.

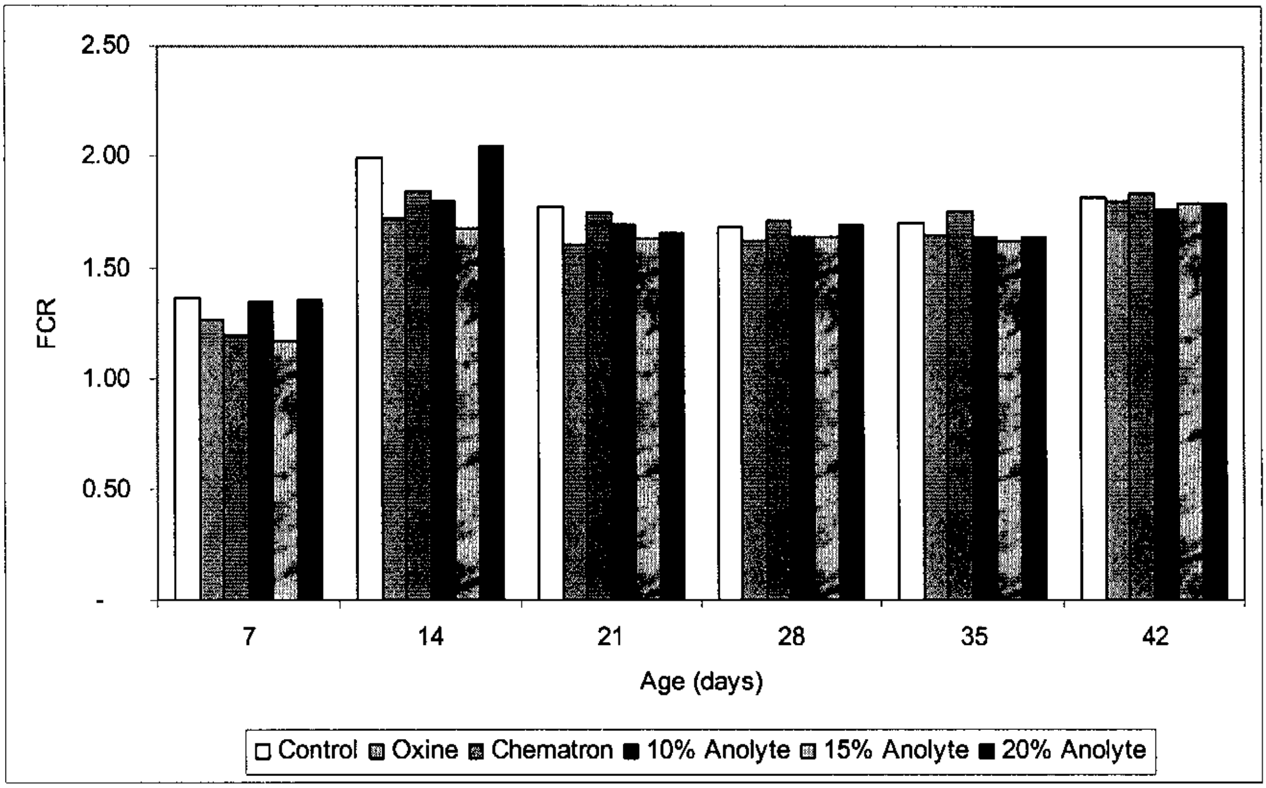
Comparison A group	Comparison B group	Factor by which A group is more likely to die than B group	P value
Control	20% Anolyte	2	0.506
Control	15% Anolyte	3	0.1489
Control	10% Anolyte	2	0.506
Control	Oxine	2	0.506
Control	Chematron	1	0.5795

FCR values were once again of a very high standard as shown in Table 38, however an Anova test carried out showed that the FCR values did not differ between treatments ($P>0.05$). Like the Hatchery B trial, FCRs were calculated on a weekly basis and the results shown in Graph 8.

Table 38 FCR at 42 days of age for Hatchery A

Group	Trial	Cumulative feed given to 42 days of age (kgs)	FCR
5	10% Anolyte	177.9	1.76
13	"	175.8	1.76
8	15% Anolyte	183.1	1.75
11	"	192.0	1.82
3	20% Anolyte	173.3	1.77
6	"	181.4	1.81
4	Chematron	164.3	1.83
9	"	176.6	1.82
7	Control	167.8	1.82
10	"	173.3	1.80
2	Oxine	180.5	1.81
12	"	179.0	1.77

Graph 8 FCR with age on different water treatments on the Hatchery A broiler



PEF values for the Hatchery A at 42 days of age showed that, like the Hatchery B, the 15% Anolyte had the best PEF value as shown in Table 39.

Table 39 PEF results at 42 days for Hatchery A

Treatment	PEF
10% Anolyte	266.79
15% Anolyte	277.58
20% Anolyte	259.2
Chematron	238.67
Control	244.84
Oxine	261.49

Once again a profit margin exercise was carried out on the Hatchery A at 42 days of age in exactly the same way as that done on the Hatchery B. In Table 40 (in the addendum) it can be seen that on the broiler farm, assuming that the limit is the turn around time, at 42 days of age the most profitable treatment is that of the 15% Anolyte which has an increase of Z$ 18.02 per bird over the control group (in the Hatchery B groups, there was an increased comparative margin of Z$21.80 per bird). Assuming 110 000 broiler placed per week, the increased margin when comparing the 15% Anolyte to control on an annual basis for the broiler grower would be Z$103,084,933 (compared to Z$ 124,714,418 on the Hatchery B) and for the abattoir the increase annual margin would be Z$68,385,148 per year to give a total increased annual margin when comparing the 15% Anolyte to control group for the integrated broiler and abattoir of Z$171,470,082 (compared to Z$256,045,618 for the Hatchery B).

Finally, a significance values for differences between the treatments for Hatchery A and Hatchery B at 42 days of age were established and shown as in Table 41.

Table 41 Significant differences in live weights between treatments between Hatchery A and Hatchery B at 42 days of age.

Treatment	Hatchery A		Hatchery B		P value
	Mean	Sd	Mean	Sd	
10% Anolyte	2051.63	367.12	2227.76	320.41	0.0004 ***
15% Anolyte	2122.83	372.00	2283.33	348.78	0.001 **
20% Anolyte	2025.1	336.58	2106.76	367.95	0.087 ns
Chematron	1988.82	368.17	2119.02	350.9	0.01 *
Control	1981.26	423.12	1903.40	366.08	0.134 ns
Oxine	2047.76	343.79	1955.86	736.04	0.250 ns

Where

*- significant difference

'** strong evidence of significant difference

'*** very strong evidence of significant difference

ns not significant

This shows that the Hatchery A and Hatchery B live weights on the 10% Anolyte, 15% Anolyte and Chematron differed ($P<0.05$), whilst those on the 20% Anolyte, control and Oxine did not ($P>0.05$). An Odds Ratio test was carried out between the two broiler types comparing mortalities between the treatments as shown in Table 42. This shows that, in general, the Hatchery A is more likely to die in the Odds Ration test but that the results did not differ ($P>0.05$).

Table 42 Odd Ratio test and p-value on comparing mortalities between treatment between Hatchery A and Hatchery B.

Comparison A group	Comparison B group	Factor by which A group is more likely to die that B group	Fishers exact test – P value
Hatchery A – 10% Anolyte	Hatchery B – 10% Anolyte	2.0	0.4456 ns
Hatchery A – 15% Anolyte	Hatchery B – 15% Anolyte	0.5	0.4806 ns
Hatchery A – 20% Anolyte	Hatchery B – 20% Anolyte	3.0	0.2258 ns
Hatchery A – Chematron	Hatchery B – Chematron	2.0	0.2929 ns
Hatchery A – control	Hatchery B – control	1.0	0.6048 ns
Hatchery A - Oxine	Hatchery B – Oxine	1.0	0.5305 ns

Where – ns = not significant

Discussion

In the introduction, the varying effects of different water quality constituents were discussed. It was also shown that constituent levels that are higher than recommended maximum levels also cause varying effects on the poultry performances and this has lead to perhaps different recommended poultry guidelines for water constituents. The trials undertaken here were done in order to gain a better understanding into the quality of the current drinking water at Farm A, antibacterial activity of a new proposed water treatment, Anolyte, a comparison of performance of broilers under trial conditions between different water treatments and finally a comparison of the performance of different sources of broilers under the same water treatments.

The simple laboratory tests that were carried out on the efficacy of Anolyte against bacterial water contamination showed that it did indeed have antibacterial activity. The impregnation method showed that both the neutral (pH 6.9) and acid (pH 1.8) Anolyte killed any bacterial activity both when undiluted and at 10% dilution in the impregnation test. This supports work by Hotta et al (1994) in that he concluded that it was unlikely that it was the low pH that contributed to the antimicrobial activity of the Anolyte.

The minimum inhibitory concentration test results supported those result found by Cloete (2002) in that the minimum dilution for Anolyte for 100% kill was at least 10% (our dilutions went down to 5% and it was found that there was still 100% kill at this dilution). For the purposes of the broiler performance trial, concentrations of 10%, 15% and 20% inclusion levels of neutral Anolyte were used as we were not sure of the effect on an increased bacterial load level at drinker level would have on the Anolyte. It was interesting to note that the Anolyte had a 100% kill on all the bacteria which included *Salmonella enteridites* which is of importance within the poultry industry.

With regards to *Salmonella enteridites*, a study was undertaken to evaluate the use of disinfectants in the removal of this bacteria from poultry houses (Davison et al, 1996). The study suggested that the inability to remove S. *enteridites* from layer houses might, in part, be associated with the source of the water.

The total colony count done on the control drinking water (untreated river water) confirmed that there was an unacceptably high level of bacteria within the water. A sample of the 15% Anolyte treatment (taken from the trial site administering bucket) had no bacteria, which further confirmed the laboratory results that the Anolyte had antibacterial activity.

The presence of coliforms bacteria is generally related to faecal contamination of drinking water due to runoff to surface or ground water. Unlike most other constituents of water that are not living organisms (i.e. chemical constituents), bacteria (as well as fungi, viruses and algae) have the ability to multiply and exponentially double their numbers. Thus, as the bacteria enters the system in the water supply, they have the capability to increase in numbers as they go through the system from the water supply (in this case the river), to the storage tanks, poultry house lines (biofilm complications as well) and finally within the drinkers themselves. Even water that is clean at the point of entry to the house (i.e. good quality mains water) can become contaminated quickly by exposure to the bacteria within the house environment (Ross Breeders, 1999). In view of this, chemical treatment of drinking water will also reduce the bacterial contamination of the water that is available for the bird to drink. Regular cleaning of the drinkers will also assist.

The likely negative impact of the bacterially contaminated water supply from the river on poultry performance will have negative effect on profitability and thus it is imperative that a chemical treatment be carried out on the drinking water supply. However, from Table 18 it can be seen that there were also other constituents within the water supply that were outside the recommended levels – pH (6 when recommendation are a minimum of 6.5) and cadmium (0.1 mg/l when recommendation are a minimum of 0.003mg/l).

With regards to pH, Good (1985) in his studies found that there was some detriment to performance at levels of 6.0 – 6.3 and that at below 5.9 there were definite adverse effects on broilers performance and on egg quality in layers. He recommended the addition of mild solutions of sodium hydroxide. Casey *et al* (2001) report confirms that pH does have a negative effect on broiler performance. Further more, it was found that it could cause a lowered effectiveness of vaccines. This is important due to the fact that perhaps the broilers on Farm A are more susceptible to disease as their immune system may already be impaired due to the high bacterial contamination of the water. If the low pH of the water decreases the vaccine efficacy, the antibody response may not be as effective, rendering the birds more susceptible to any disease. This may be the cause of a high number of respiratory symptoms that are seen in the older commercial broilers on Farm A (Dr. Chitauro, personal communication).

In relation to pH, Good (1985), found that sodium at 50ppm was found to be detrimental to performance if sulphate at 50ppm or chloride at 14ppm were present (Table 18 shows that our levels are at 44ppm, 28ppm and 27.5ppm). Thus, there may be some detriment to performance as a result of these factors. The other important factor of pH is that it can be unpalatable and corrosive to equipment (Blake and Hess 2001).

The other water constituent that is present in unacceptably high levels is that of cadmium. Casey *et al* (2001) studies reported that recommended levels for cadmium varied according to research done (see Table 8) and that adverse effects could include reduced growth and decreased egg production. Further research carried out by Vodela *et al* (1997) to investigate the effects of drinking water contaminants (arsenic, cadmium, lead, benzene and trichloroethylene) on reproductive performance of breeders concluded that increased levels lower reproductive performance. The river that the poultry drinking water is supplied from does run through a high-density suburb of Harare and also through some industrial sites. Perhaps the levels of cadmium within the water supply are not surprising as urban sewage sludge contain significant amounts of cadmium (Mineral Tolerance of Domestic Animals, 1980). In view of this, it was also expected that levels of other water constituents would be higher due to effluent from the industrial sites. The hypothesis is that due to low river flows and the water hyacinth growth in the river, that the ammonia, nitrates and phosphorous have been taken up in the natural development of the plants (personal communication with consultant engineers).

From the above, it can be seen that the analysis of the drinking water supply reveals that the quality is sub optimum and as a result sub optimal broiler performance can be expected. From the results of the broiler trial, it can be seen that there is indeed poor growth parameters on the birds given no water treatment.

When investigating the growth pattern results (live weight for age Graphs 3 and 7), it is interesting to note that those treatments with the heaviest live weights at 14 days of age also have the heaviest weights at 42 days of age. This is even the case when comparing the 10% Anolyte (which was given through out the 42 days) to the 15% Anolyte (which was only given for 14 days). This indicates that the effect of 15% Anolyte on the live weight to only 14 days of age is still enough to give the highest live weight at 42 days even if the difference is not as great as at 14 days of age (the percentage difference between the 10% Anolyte live weight and 15% Anolyte at 14 days is 6.0% which differs ($P<0.05$), whilst that at 42 days of age is 2.5% which does not differ).

In the Hatchery B, the live weights at 42 days of age on broilers on treatment of 20% Anolyte differed to that of the 15% Anolyte ($P<0.05$)- the Hatchery A was also lower but did not differ ($P>0.05$). This seems to suggest that perhaps the 20% concentration of Anolyte within the drinking water is somehow toxic to the broilers in that it does slow down the growth in comparison to the 15% Anolyte solution. Further research would have to be carried out in order to confirm this hypothesis.

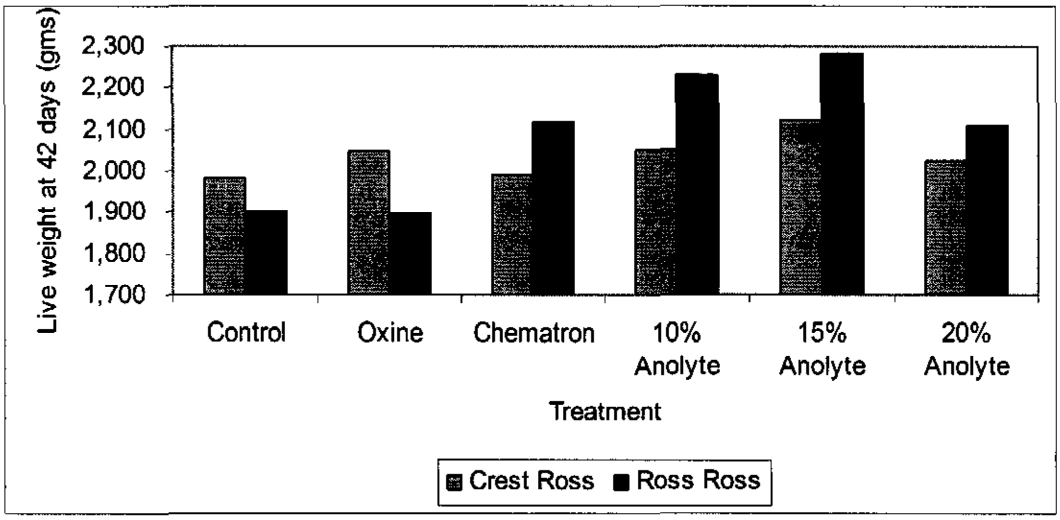
The FCR results for both the Hatchery B and Hatchery A broilers on all the treatments were very good and did not differ ($P>0.05$). This could perhaps be attributed to the fact that the birds were under trial conditions and management conditions were under optimum conditions in that the stocking densities were very low, and there were a low number of birds per drinker and feeder. In view of the high bacterial contamination of the untreated water, it would have been perhaps expected to see the FCR at 42 days of age to differ from the treated water in that they would have been higher (less efficient) – however this was not case at 42 days of age. It can be seen that the trend is for the FCR on both untreated groups to have higher FCR values than any of the treated groups until 14 days of age. There after, the FCR values on all the treatments within the broilers from the same source of parent were similar. Perhaps an explanation for this is that the gut flora of the broiler adapts to the bacterially contamination of the untreated water so that the feed efficiency improves. Further research would have to be carried out to confirm this theory.

Perhaps one of the most interesting comparisons is that of the different responses in terms of live weight at 42 days between the Hatchery B and Hatchery A. This can be seen in Graph 9. This shows that the Hatchery A has a slightly better live weight at 42 days of age on the untreated (control) water in comparison to the Hatchery B even if the results did not differ ($P>0.05$). The fact that the results at 42 days of age did not differ was not as expected as the quality of the chick from Hatchery A is not as good as that from Hatchery B. The cull rate in Hatchery A is at an unacceptable level of over 4%, whilst that at the Hatchery B is below 0.5% (personal communication with respective managing directors).

However, in the water treatments of 10% and 15% Anolyte and the Chematron, the results between the Hatchery B and Hatchery A did differ (P<0.05) in that the Hatchery B broilers had a higher live weight. These findings perhaps mean that the poor water quality is more of a negative influence on the live weight than the chick quality in this case. Another explanation has been put forward is that the parents that are also on poor quality water, may pass on some antibody response to the bacterial contamination that is passed vertically to the chick (Dr. Chitauro, personal communication).

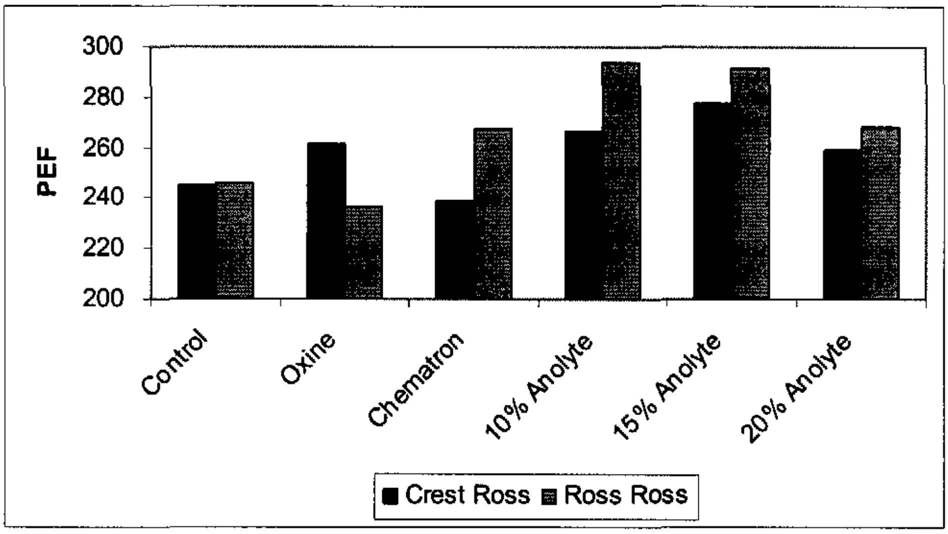
However, with water treatment applied to bacterially contaminated water, the chick quality now becomes an issue in improving weight gain further as can be seen in the Hatchery B live weights at 42 days in comparison to the Hatchery A.

Graph 9 Comparison between Hatchery B and Hatchery A live weights at 42 days between different water treatments.



A further comparison between the Hatchery B and Hatchery A was done for the PEF values – Graph 10. Here is can be seen that once again, the PEF values for the Hatchery B broilers on the Anolyte treatments had higher PEF values and have a higher technical performance and this was mainly due to the higher live weights at this age. It should be noted that although the 15% Anolyte had the highest PEF value for the Hatchery A, on the Hatchery B trial the 10% Anolyte was marginally higher.

Graph 10 Comparison between Hatchery B and Hatchery A PEF values at 42 days between different water treatments.



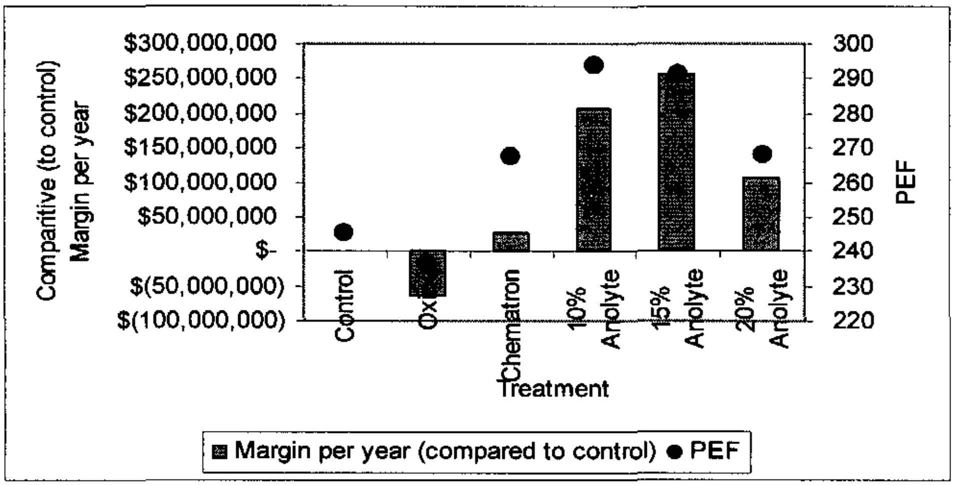
Finally and perhaps the most important factor is the influence of water treatment on the gross margin. There are two main ways in which to increase the margin within a poultry enterprise– either by increasing the income (increased production levels or through selling your product at a higher price) or by reducing your input costs (Kleyn, 2002).

In terms of reducing costs, feed costs contribute the highest percentage of costs within a poultry enterprise. Feed costs have been escalating in South Africa over the last year and this has come about because of two major factors. Firstly last year's maize crop was smaller than anticipated and secondly, the currency has weakened in comparison to those of our major trading partners (Kleyn, 2002) - the same can be said of Zimbabwe. It is unlikely that feed prices or any other input prices are going to come down.

If the input price is not likely to come down, then in order to increase the margins, one has to look at increasing the income of the enterprise. With high levels of inflation and reduced income levels within Zimbabwe, there is likely to be a resistance to price increase of poultry products and thus the only feasible way to increase one margin is to improve the technical efficiencies of the poultry operations. In a broiler operation, this would be to look at live weight, FCR and mortalities, i.e. the factors involved in the PEF equation. Due to the fact that feed is the greatest input cost, then this is the first place to look in terms of improving efficiencies. In a broiler operation, this can be done by introducing phase feeding, use of a post finisher (a diet with no micro ingredients) in the last week or growth control (use of intermittent lighting). However, it is no good having the best-feed programme if it is going to be compromised by some other factor such as water quality. In order to obtain the best possible results possible from a good quality feed, one has to ensure that all other management factors are also of high quality.

From the above, it could be assumed that in comparing PEF factors for different broiler operations will also give an indication to relative margins for those broiler operations. Graph 11 and Graph 12 show the PEF values and margin comparisons for the Hatchery B and Hatchery A trials respectively.

Graph 11 PEF and Comparative annual margin (after feed and disinfection costs) on different water treatments on Hatchery B broilers. Margins were compared to control (untreated water).

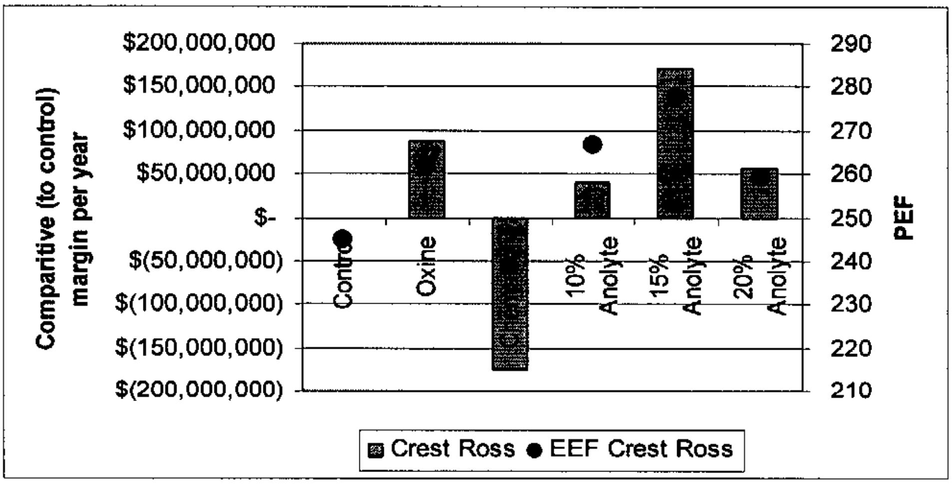


On the Hatchery B treatment (Graph 11), it can be seen that although the PEF value for the 10% Anolyte was marginally better than that of the 15% Anolyte, the cost of achieving this PEF value was greater (due to the fact that the 10% Anolyte was given for the full length of the trial whilst the 15% Anolyte was only given for 14 days) and the annual margin per year was greater in the 15% Anolyte treatment. Thus, we can see from this that the assumption that the best PEF value will give the best economic return is incorrect.

In the Hatchery A trial, the highest PEF value (15% Anolyte) also gave the highest annual margin. In this trial it is interesting to note the very low PEF and margin for the Chematron treatment - it was ranked the lowest of all treatments, including the untreated water. It was noted that the use of Chematron as gm per bird placed in this trial was higher than that of the Hatchery B trial (50gms per chick placed in comparison to 40gms per chick in the Hatchery B). The effect of this may have been two fold: the increase in expenses (Chematron is an expensive treatment which would affect the margin), and a possible negative effect of the higher dose of chlorine on the live weight.

Thus, from the above, it can be seen that it is imperative in these times of reduced margins, that poultry managers assess the operation in terms of financial success. It is no good for a poultry manager to target performance efficiencies as a measurement of success, there has to be some sort of measurement in terms of finances to see if performance improvements are financially viable. It could be that a management strategy to utilize a lower grade feed (which will reduce the technical performance of the broilers, i.e. reduce the PEF value), may give the best economic return. In these times of reduced margins, in order for any business to remain viable, the bottom line of economic return is the most important.

Graph 12 PEF and Comparative annual margin (after feed and disinfection costs) on different water treatments on Hatchery A broilers. Margins were compared to control (untreated water).



Finally, in order to further confirm the economic benefit of Anolyte to increasing broiler performance on bacterially contaminated water a commercial trial would have to be undertaken.

Summary

A number of research trials were carried out to investigate the effect of Anolyte on production profits of broilers. These trials can be divided into laboratory trials and broiler performance trials.

Laboratory trials confirmed that Anolyte at a concentration of 10% killed all the following test organisms: *Escherichia coli, Salmonella enteridites, Staphylococcus aureus, Klebsiella pneumoniae* and *Pseudomonas.* It was also found that a 5% Anolyte solution had a 100% kill against bacterial isolates after a minimum contact time of 5 minutes. A total colony count of the untreated trial water at the poultry site confirmed unacceptably high counts of bacteria. In a sample of the 15% Anolyte solution at the trial site (using the river water as diluent) there had been a 100% kill of bacteria tested.

A broiler performance trial confirmed that broilers on a 15% Anolyte treatment of the bacterially contaminated water had improved live weights in comparison to the control group (untreated river water)

($P<0.05$) for both Hatchery A and Hatchery B broilers. The 15% Anolyte had been given to 14 days of age and thereafter at 1% dilution. Furthermore, under these good trial site management conditions, there was no difference in FCR and mortalities between the groups ($P>0.05$).

When extrapolated results from both the Hatchery A and Hatchery B were used to calculate estimated annual margins on a commercial scale, the 15% Anolyte treatment produced the best margin

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Addenum

Table 19 Individual live weights of Hatchery B broilers at 14 days of age

Gr	8	13	15	2	9	18	4	7	16	5	11	12	3	14	17	1	6	10
Trt	C	C	C	OX	OX	OX	Ch	Ch	Ch	10	10	10	15	15	15	20	20	20
1	201	267	274	332	223	263	287	387	297	333	242	272	387	216	362	221	454	331
2	262	247	261	270	245	214	399	260	200	305	341	310	345	353	340	302	342	373
3	242	265	257	228	161	217	317	328	251	395	341	275	302	344	392	281	280	336
4	166	271	282	135	301	269	295	287	294	403	290	160	350	348	354	227	291	333
5	97	240	253	242	257	105	322	272	212	353	269	195	300	310	270	334	377	279
6	196	284	238	210	108	230	373	333	146	345	269	336	373	298	202	277	405	382
7	101	311	259	211	146	300	355	362	276	246	300	219	327	303	299	276	255	231
8	195	263	213	287	276	204	242	305	301	256	354	313	325	265	331	321	450	226
9	144	218	155	178	249	308	370	257	240	242	285	164	355	333	292	314	399	244
10	164	181	172	189	263	187	302	223	261	316	228	308	306	275	317	287	392	275
11	205	121	135	223	201	275	262	325	198	266	236	456	283	283	255	330	330	154
12	163	239	263	174	227	234	172	176	286	307	292	319	279	271	259	243	370	191
13	130	133	298	226	179	251	276	204	289	297	215	281	375	303	301	306	338	231
14	136	148	268	256	252	183	293	277	269	289	288	199	248	337	378	331	394	272
15	131	255	246	145	244	158	257	289	229	340	334	255	266	241	311	313	318	387
16	217	115	167	103	255	200	324	280	217	229	263	306	259	277	333	255	315	270
17	210	94	190	168	244	214	207	215	261	297	254	287	334	235	376	301	356	331
18	234	257	143	245	131	138	315	209	261	345	253	338	345	361	265	332	374	257
19	298	247	227	175	121	172	238	194	173	345	219	297	336	309	341	261	258	224
20	239	200	132	82	134	141	319	183	214	338	204	265	357	204	247	255	244	308
21	99	189	154	198	146	250	261	272	154	328	353	343	289	282	245	274	341	290
22	227	192	152	73	212	201	189	306	216	260	243	313	293	285	345	254	276	283
23	156	190	214	229	246	187	309	237	258	264	322	205	300	293	322	160	395	267
24	252	341	221	93	181	201	294	293	283	302	266	282	288	343	292	272	359	247
25	240	200	119	199	266	190	348	275	259	339	206	319	245	366	327	298	226	295
26	252	235	216	140	178	291	269	184	244	114	354	307	250	273	328	218	230	251
27	139	132	172	299	267	189	267	291	243	359	268	210	334	399	304	233	300	225
28	245	160	241	206	157	209	294	248	186	293	260	301	370	326	285	254	263	237
29	196	186	230	185	168	216	347	326	289	348	249	259	284	253	269	218	293	256
30	119	93	185	235	192	146	334	151	213	301	268	245	310	206	269	277	329	154
31	186	133	221	191	244	138	270	162	231	265	226	179	309	146	213	294	390	264
32	94	105	192	235	166	227	177	173	244	310	222	282	352	201	123	388	389	249
33	141	158	226	217	220	264	289	345	234	278	295	299	200	350	209	355	334	107
34	221	261	162	213	189	247	240	244	230	317	243	186	287	231	368	269	390	277
35	189	260	177	225	247	291	262	240	248	214	268	276	250	303	312	308	360	157
36	151	115	229	192	151	277	253	373	100	231	210	281	358	243	316	272	365	192
37	218	208	91	184	163	291	303	175	186	281	299	307	275	307	343	278	348	191
38	158	204	231	166	191	126	336	261	246	318	155	157	329	351	321	236	336	188
39	113	241	193	142	143	156	234	253	276	335	141	271	354	336	461	213	401	185
40	188	93	316	227	211	137	281	184	226	384	222	337	280	293	229	247	315	345
41	295	219	260	229	133	119	270	333	267	367	373	319	293	255	279	195	282	311
42	166	181	143	229	200	256	293	128	163	360	298	266	320	306	365	251	365	296
43	272	212	246	112	186	238	300	268	248	341	253	161	174	212	365	213	253	240
44	122	143	209	215	103	292	305	253	184	336	350	137	163	303	344	212	282	211
45	245	136	108	188	212	218	307	300	231	303	301	150	123	211	208	205	179	206
46	126	143	205	253	147	150	280	229	286	371	322	235	281	282	288	262	230	330
47	74	105	130	287	114	180	321	165	275	316	184	151	349	334	288	223	263	210
48	115	134	128	196	138	181	205	182	208	263	317	151	223	221	323	260	349	225
49	295	109	149	230	116	86	308	292	222	205	273	271	159	304	191	239	345	226
50		110		251	99	104	263					221		227	369	215	276	232

Where – Gr – Group placement within the house, Trt – treatment, C – Control, Ox – Oxine, Ch – Chematron, 10 – 10% Anolyte, 15 – 15% Anolyte, 20 – 20% Anolyte.

Table 22 Experiment 1 – Individual Live Weights of Hatchery B broilers at 42 days of age

Gr	8	13	15	2	9	18	4	7	16	5	11	12	3	14	17	1	6	10
Trt	C	C	C	OX	OX	OX	Ch	Ch	Ch	10	10	10	15	15	15	20	20	20
1	880	1300	880	640	640	1160	1380	1400	1140	940	1600	1380	1140	1160	1340	440	1520	1340
2	1040	1380	1340	780	800	1360	1640	1420	1300	1600	1740	1540	1480	1480	1380	660	1760	1400
3	1280	1420	1400	820	1280	1500	1660	1420	1560	1820	1820	1580	1560	1520	1640	1440	1860	1560
4	1280	1440	1420	1200	1440	1500	1740	1480	1580	1820	1820	1680	1660	1780	1780	1580	1880	1580
5	1160	1500	1520	1380	1440	1560	1800	1500	1620	1900	1820	1680	1940	1840	1880	1680	1920	1620
6	1160	1560	1660	1420	1460	1620	1900	1500	1700	1940	1940	1780	1980	1840	1960	1700	1940	1620
7	1220	1580	1700	1520	1520	1700	1900	1560	1800	1940	1940	1820	2000	1980	1960	1720	1960	1740
8	980	1580	1740	1540	1560	1700	1920	1640	1860	1960	2000	1840	2060	2080	2000	1740	1980	1740
9	1420	1660	1740	1540	1600	1740	1940	1680	1860	1960	2020	1840	2080	2100	2000	1780	2040	1780
10	1480	1680	1800	1660	1640	1740	1980	1700	1900	2000	2080	1920	2080	2140	2040	1820	2040	1780
11	1480	1720	1800	1660	1660	1760	1980	1720	1940	2040	2100	1940	2080	2160	2080	1880	2060	1780
12	1500	1740	1840	1680	1680	1800	2000	1780	1960	2040	2100	1940	2100	2160	2120	1880	2060	1800
13	1520	1740	1860	1840	1700	1800	2020	1820	1980	2040	2120	2000	2100	2160	2120	1880	2080	1820
14	1540	1740	1860	1860	1720	1820	2020	1840	2000	2060	2140	2020	2100	2180	2120	1900	2100	1820
15	1580	1760	1940	1860	1760	1860	2040	1900	2000	2080	2140	2020	2120	2180	2160	1940	2120	1860
16	1600	1760	1960	1880	1760	1860	2040	1920	2020	2100	2160	2060	2140	2200	2160	2000	2160	1880
17	1620	1780	1980	1880	1780	1880	2040	1940	2040	2100	2180	2080	2140	2200	2160	2000	2160	1900
18	1620	1800	1980	1900	1780	1900	2040	1940	2040	2100	2200	2100	2180	2260	2160	2020	2160	1920
19	1620	1820	2000	1920	1800	1900	2060	1960	2040	2120	2240	2100	2180	2280	2180	2020	2160	1960
20	1680	1900	2000	1960	1820	1920	2060	1980	2040	2140	2240	2100	2200	2300	2180	2060	2180	1980
21	1680	1900	2000	1960	1840	1940	2080	2000	2080	2140	2240	2120	2200	2300	2220	2080	2180	2000
22	1700	1900	2020	1960	1840	1940	2120	2020	2100	2140	2280	2120	2220	2300	2220	2080	2200	2020
23	1740	1980	2040	1980	1840	1960	2120	2020	2120	2180	2280	2160	2220	2300	2240	2080	2120	2040
24	1740	1980	2100	1980	1860	1960	2140	2020	2160	2180	2300	2160	2240	2320	2240	2100	2120	2080
25	1760	2000	2100	2000	1880	1980	2140	2040	2160	2180	2300	2180	2260	2340	2260	2100	2120	2120
26	1760	2080	2120	2000	1900	1980	2200	2060	2180	2180	2320	2200	2280	2360	2260	2100	2140	2120
27	1760	2100	2140	2020	1920	2000	2220	2060	2180	2180	2340	2200	2300	2380	2280	2120	2140	2120
28	1840	2120	2160	2020	1920	2000	2280	2060	2240	2200	2360	2220	2300	2400	2300	2120	2260	2160
29	1860	2120	2180	2040	1940	2020	2320	2080	2240	2220	2360	2280	2380	2400	2380	2140	2260	2200
30	1880	2120	2200	2060	1940	2020	2320	2100	2260	2220	2360	2280	2400	2440	2400	2140	2280	2200
31	1880	2180	2200	2060	1960	2040	2360	2100	2280	2260	2380	2300	2420	2460	2400	2160	2280	2220
32	1900	2200	2200	2080	1980	2060	2380	2100	2280	2300	2380	2340	2460	2460	2440	2140	2280	2220
33	1920	2240	2240	2080	1980	2080	2400	2100	2280	2300	2400	2360	2480	2460	2440	2200	2320	2220
34	1920	2260	2240	2100	2000	2100	2400	2100	2280	2320	2420	2380	2480	2460	2460	2200	2340	2240
35	1960	2260	2240	2100	2020	2120	2420	2120	2300	2360	2480	2400	2500	2480	2460	2200	2360	2240
36	1980	2280	2260	2120	2060	2120	2420	2160	2300	2360	2480	2420	2520	2500	2460	2220	2360	2280
37	2000	2280	2280	2120	2060	2160	2520	2180	2360	2400	2480	2420	2540	2560	2460	2240	2380	2320
38	2040	2300	2280	2140	2080	2180	2520	2380	2360	2420	2520	2420	2540	2560	2480	2240	2380	2320
39	2040	2300	2300	2140	2080	2240	2520	2420	2360	2420	2520	2420	2560	2580	2500	2240	2420	2320
40	2100	2300	2300	2180	2080	2260	2640	2440	2480	2460	2520	2440	2620	2600	2540	2260	2520	2380
41	2120	2320	2320	2240	2080	2280	2640	2480	2500	2460	2560	2540	2680	2700	2560	2280	2560	2380
42	2140	2340	2360	2260	2120	2320	2680	2480	2520	2480	2600	2580	2700	2800	2560	2320	2580	2400
43	2180	2360	2440	2280	2140	2360	2680	2560	2560	2500	2600	2600	2800	2840	2580	2400	2600	2400
44	2200	2380	2540	2300	2140	2360	2800	2560	2600	2560	2700	2620	2820	2880	2600	2400	2660	2480
45	2260	2440	2580	2300	2160	2360	2820	2640	2600	2580	2720	2640	2840	2900	2620	2440	2680	2500
46	2280	2460		2380	2160	2380	2840	2660	2640	2640	2740	2640	2920	2940	2660	2440	2700	2640
47	2340	2480		2400	2180	2420	2860	2680	2700	2640	2800	2640		2960	2720	2440	2760	2740
48	2440	2500		2640	2380	2460	2020	2780		2700	3000	2660		2480	2740	2520	2780	2880
49						2160				2840		2760			2820	2620	2860	880
50												3200			2920		2860	

See Table 18 - for abbreviation code.

Table 30 Experiment 2 – Individual Live Weights of Hatchery A broilers at 14 days of age

Gr	7	10	2	12	4	9	5	13	8	11	3	6
Trt	C	C	Ox	Ox	Ch	Ch	10	10	15	15	20	20
1	250	275	398	351	181	265	368	318	314	367	353	329
2	345	332	294	293	170	361	393	299	291	366	314	288
3	214	238	288	287	265	355	269	330	409	263	121	355
4	253	163	337	276	342	328	378	252	363	313	209	327
5	269	266	215	298	195	337	206	297	489	213	251	354
6	247	278	237	305	288	333	266	311	393	315	205	326
7	279	136	321	255	300	234	212	381	340	324	188	333
8	251	233	322	303	332	341	313	282	249	237	171	312
9	301	252	191	377	303	258	204	284	341	380	274	298
10	338	306	266	298	223	303	282	258	348	275	187	287
11	353	358	196	358	220	320	204	344	362	343	179	265
12	276	285	334	261	224	293	276	247	213	224	329	293
13	136	240	150	256	260	292	383	259	380	309	224	381
14	353	277	216	315	353	369	419	312	368	390	182	209
15	215	110	324	247	289	340	266	240	330	318	141	265
16	296	338	114	198	242	306	308	295	297	217	335	338
17	261	404	358	260	224	297	306	322	222	277	274	274
18	261	240	273	203	204	332	187	350	196	390	235	285
19	174	331	240	280	109	355	400	299	321	334	235	354
20	85	201	281	374	160	302	269	148	348	342	289	291
21	282	141	163	159	388	332	147	220	312	225	291	353
22	290	316	194	240	219	354	251	337	255	216	253	152
23	216	268	206	341	158	332	166	220	345	304	154	241
24	274	186	325	307	143	369	390	247	295	155	165	235
25	185	259	330	145	316	314	317	267	384	336	96	313
26	285	217	311	345	156	212	253	265	370	325	130	170
27	262	176	270	196	140	296	303	300	324	311	190	196
28	197	257	302	200	102	297	247	295	281	395	149	326
29	266	144	155	285	135	241	285	224	354	304	253	279
30	237	273	224	208	254	258	309	221	303	358	274	140
31	252	272	230	168	357	254	315	227	294	361	160	255
32	203	94	303	320	175	315	277	114	242	199	247	308
33	140	144	187	280	198	404	175	311	217	213	228	185
34	166	230	261	363	213	295	199	186	272	345	285	301
35	208	245	327	180	141	293	149	233	276	322	208	247
36	249	255	212	325	266	92	210	311	244	366	241	218
37	381	255	215	315	250	318	96	345	323	248	331	244
38	316	176	243	260	167	395	135	343	283	215	295	183
39	213	193	226	254	281	193	238	242	185	189	276	163
40	321	288	235	163	374	419	208	220	336	340	134	278
41	215	79	252	254	207	171	181	222	387	240	252	259
42	293	178	322	146	180	224	287	297	94	366	150	145
43	265	213	162	240	311	210	179	217	365	286	256	251
44	270	270	249	278	186	262	228	301	321	145	296	206
45	252	270	148	214	248	224	127	170	179	289	329	317
46	319	202	220	301	173	323	170	233	213	332	150	257
47	254	191	170	355	151	217	230	282	238	273	288	180
48	132	232	260	359	172	153	228	238	173	233	269	236
49		316	105	311	201	246	214	138	271	133	292	161
50		323	242	200	181		230		180	203	256	135
51			128	159	196						230	

Table 33 Experiment 2 – Individual Live Weights of Hatchery A broilers at 42 days of age.

Gr	7	10	2	12	4	9	5	13	8	11	3	6
Trt	C	C	Ox	Ox	Ch	Ch	10	10	15	15	20	20
1	840	1000	1300	1180	1380	1520	1500	1000	1000	1460	1280	1460
2	880	1000	1560	1480	1440	1540	1540	1000	1380	1480	1300	1540
3	900	1120	1580	1600	1480	1580	1580	1160	1480	1560	1340	1560
4	1020	1240	1580	1600	1480	1600	1620	1520	1500	1560	1380	1600
5	1280	1260	1580	1640	1500	1620	1640	1520	1560	1720	1500	1600
6	1460	1340	1600	1640	1560	1680	1700	1620	1560	1740	1520	1720
7	1520	1440	1600	1640	1560	1800	1720	1680	1820	1760	1540	1740
8	1600	1440	1640	1680	1560	1800	1720	1760	1860	1800	1540	1780
9	1760	1620	1640	1680	1580	1860	1740	1800	1700	1860	1580	1800
10	1800	1720	1680	1720	1580	1900	1780	1820	1720	1900	1580	1820
11	1860	1740	1700	1740	1660	1920	1800	1840	1780	1940	1580	1880
12	1880	1740	1700	1760	1740	1920	1800	1880	1800	1940	1660	1940
13	1900	1760	1720	1780	1780	1920	1800	1880	1880	1960	1680	1960
14	1940	1820	1780	1840	1780	1920	1900	1900	1880	1960	1720	1960
15	1960	1820	1800	1860	1780	1940	1920	1920	1880	1960	1740	2000
16	1980	1860	1860	1900	1780	1940	1940	1940	1980	2000	1760	2000
17	2000	1860	1860	1920	1800	1960	1960	1960	1980	2020	1780	2020
18	2000	1880	1920	1940	1840	2020	1980	1980	2020	2040	1820	2020
19	2000	1900	1940	1960	1840	2040	2000	2000	2040	2080	1820	2040
20	2040	1940	1960	1980	1840	2040	2000	2000	2040	2080	1940	2080
21	2040	1980	1980	1980	1880	2060	2040	2020	2060	2080	1940	2140
22	2060	2000	2000	2040	1900	2080	2040	2040	2060	2080	1940	2140
23	2080	2000	2000	2080	1920	2140	2040	2040	2100	2120	1980	2140
24	2080	2040	2040	2100	1940	2140	2060	2080	2120	2120	2000	2160
25	2120	2060	2040	2120	1940	2160	2060	2080	2120	2120	2000	2160
26	2120	2120	2080	2160	1960	2160	2080	2100	2140	2140	2000	2180
27	2120	2120	2080	2180	1980	2160	2080	2100	2160	2160	2040	2200
28	2160	2120	2100	2180	2000	2160	2140	2100	2180	2180	2040	2200
29	2160	2160	2100	2200	2020	2240	2140	2120	2200	2240	2040	2200
30	2200	2180	2180	2200	2040	2260	2160	2120	2220	2240	2040	2220
31	2240	2200	2180	2200	2100	2280	2160	2120	2240	2240	2060	2220
32	2240	2200	2180	2220	2100	2300	2160	2120	2240	2240	2080	2240
33	2260	2200	2200	2240	2100	2340	2200	2160	2260	2260	2100	2240
34	2280	2240	2200	2240	2180	2340	2200	2160	2260	2300	2100	2240
35	2300	2260	2240	2240	2180	2360	2220	2160	2260	2300	2120	2260
36	2300	2260	2240	2280	2180	2360	2240	2180	2280	2300	2160	2260
37	2300	2260	2300	2280	2220	2440	2240	2200	2280	2340	2200	2260
38	2300	2300	2300	2300	2240	2480	2400	2240	2360	2380	2200	2260
39	2320	2300	2320	2360	2260	2480	2440	2240	2400	2380	2220	2300
40	2360	2300	2320	2400	2320	2520	2460	2280	2400	2400	2240	2300
41	2380	2320	2320	2460	2360	2560	2520	2340	2440	2440	2240	2400
42	2400	2320	2320	2480	2360	2600	2560	2360	2520	2560	2280	2700
43	2460	2340	2380	2500	2380	2680	2640	2440	2560	2580	2340	2700
44	2520	2360	2400	2520	2380	2720	2720	2520	2580	2580	2380	2740
45	2720	2420	2480	2540	2620	2800	2740	2540	2540	2660	2440	2900
46	2880	2240	2540	2540	1160		2840	2560	2720	2700	2480	2000
47		2280	2600	2660	840		2860	2660	2760	2820	2480	2020
48		2540	2760	2800	1100		1220	2680	2880	2880	2500	2160
49		2580	2940	1820			2060	2760	2920	2900	2560	
50									1480		2740	

Table 29 Comparison of margins of Hatchery B between treatments at 42 days of age

	Control	Oxine	Chematron	10% Anolyte	15% Anolyte	20% Anolyte
Number of chicks placed	150	150	150	150	150	150
Mortality	9	5	7	3	6	2
Birds slaughtered	141	145	143	147	144	148
Total kgs starter per trial	150	150	150	150	150	150
Cost $/kg starter	$ 79.68	$ 79.68	$ 79.68	$ 79.68	$ 79.68	$ 79.68
Total kgs finisher per trial	315.7	357	395.1	429.1	439.1	425.4
Cost $/kg finisher	$ 77.63	$ 77.63	$ 77.63	$ 77.63	$ 77.63	$ 77.63
Total Feed cost	$ 36,458.21	$ 39,664.13	$ 42,621.64	$ 45,260.89	$ 46,037.14	$ 44,973.68
Total amount of disinfectant	-	0.13	0.60	112.60	29.40	42.00
Cost $/unit	$ -	$ 2,200.00	$ 4,782.61	$ 20.00	$ 20.00	$ 20.00
Total cost of disinfectant	$ -	$ 292.60	$ 2,869.57	$ 2,252.00	$ 588.00	$ 840.00
Total cost	$ 36,458.21	$ 39,956.73	$ 45,491.20	$ 47,512.89	$ 46,625.14	$ 45,813.68
Average cost per bird placed	**$ 243.05**	**$ 266.38**	**$ 303.27**	**$ 316.75**	**$ 310.83**	**$ 305.42**
Total live weight	268.38	274.78	303.02	327.48	328.80	311.80
Total dressed wt (@80% live weight)	214.704	219.82	242.416	261.984	263.04	249.44
Av kg/bird slaughtered	1.523	1.516	1.695	1.782	1.827	1.685
Contractor price per kg (10% GM on control)	$ 278.00	$ 278.00	$ 278.00	$ 278.00	$ 278.00	$ 278.00
Average income per bird slaughtered	**$ 423.32**	**$ 421.46**	**$ 471.27**	**$ 495.45**	**$ 507.81**	**$ 468.54**
Total income	$ 59,687.71	$ 61,111.07	$ 67,391.65	$ 72,831.55	$ 73,125.12	$ 69,344.32
Margin (after feed and disinfection costs)	$ 23,229.50	$ 21,154.35	$ 21,900.45	$ 25,318.66	$ 26,499.98	$ 23,530.65
Margin per bird placed	**$ 154.86**	**$ 141.03**	**$ 146.00**	**$ 168.79**	**$ 176.67**	**$ 156.87**
Bottom line on Crest Farm						
Average number of birds placed per week	110,000	110,000	110,000	110,000	110,000	110,000
Total placed per year	5,720,000	5,720,000	5,720,000	5,720,000	5,720,000	5,720,000
Margin per year	$ 885,818,248	$ 808,685,766	$ 835,136,980	$ 965,485,073	$ 1,010,532,666	$ 897,301,929
Bottom line at Suncrest abattoir						
kg slaughter per bird slaughtered	1.52	1.52	1.70	1.78	1.83	1.69
kg slaughtered per year (after mort)	8,172,736	8,404,587	9,270,213	9,977,968	10,048,896	9,537,909
Margin per kg at abattoir	$ 70.00	$ 70.00	$ 70.00	$ 70.00	$ 70.00	$ 70.00
Margin per year at abattoir	$ 572,091,520	$ 588,321,067	$ 648,914,933	$ 698,457,760	$ 703,422,720	$ 667,653,653
Total increase in Profit for Crest Breeders	**$ -**	**$ (62,902,935)**	**$ 26,142,146**	**$ 206,033,065**	**$ 256,045,618**	**$ 107,045,815**

Table 40 Comparison of margins of Hatchery A between treatments at 42 days of age

	Control	Oxine	Chematron	10% Anolyte	15% Anolyte	20% Anolyte
Number of chicks placed	101	102	101	102	101	102
Mortality	6	4	8	4	2	4
Birds slaughtered	95	98	93	98	99	98
Total kgs starter per trial	101	102	101	102	101	102
Cost $/kg starter	$ 79.68	$ 79.68	$ 79.68	$ 79.68	$ 79.68	$ 79.68
Total kgs finisher per trial	240.1	257.5	236.9	251.7	274.1	252.7
Cost $/kg finisher	$ 77.63	$ 77.63	$ 77.63	$ 77.63	$ 77.63	$ 77.63
Total Feed cost	$ 26,685.44	$ 28,115.80	$ 26,437.04	$ 27,665.57	$ 29,324.69	$ 27,743.20
Total amount of disinfectant	$ -	0.09	0.50	80.40	21.00	25.80
Cost $/unit	$ -	$ 2,200.00	$ 4,782.61	$ 20.00	$ 20.00	$ 20.00
Total cost of disinfectant	$ -	$ 198.00	$ 2,391.30	$ 1,608.00	$ 420.00	$ 516.00
Total cost	$ 26,685.44	$ 28,313.80	$ 28,828.35	$ 29,273.57	$ 29,744.69	$ 28,259.20
Average cost per bird placed	**$ 264.21**	**$ 277.59**	**$ 285.43**	**$ 287.00**	**$ 294.50**	**$ 277.05**
Total live weight	188.22	200.68	184.96	201.06	210.16	198.46
Total dressed wt (@80% live weight)	150.576	160.544	147.968	160.848	168.128	158.768
Average live weight/bird slaughtered	1.98	2.05	1.99	2.05	2.12	2.03
Av kg/bird slaughtered	1.585	1.638	1.591	1.641	1.698	1.62
Contractor price per kg (10% GM on control)	$ 278.00	$ 278.00	$ 278.00	$ 278.00	$ 278.00	$ 278.00
Average income per bird slaughtered	**$ 440.63**	**$ 455.42**	**$ 442.31**	**$ 456.28**	**$ 472.12**	**$ 450.38**
Total income	$ 41,860.13	$ 44,631.23	$ 41,135.10	$ 44,715.74	$ 46,739.58	$ 44,137.50
Margin (after feed and disinfection costs)	$ 15,174.69	$ 16,317.43	$ 12,306.76	$ 15,442.17	$ 16,994.89	$ 15,878.31
Margin per bird placed	**$ 150.24**	**$ 159.97**	**$ 121.85**	**$ 151.39**	**$ 168.27**	**$ 155.67**
Bottom line on Crest Farm					$ 18.02	
Average number of birds placed per week	110,000	110,000	110,000	110,000	110,000	110,000
Total placed per year	5,720,000	5,720,000	5,720,000	5,720,000	5,720,000	5,720,000
Margin per year	$ 859,398,030	$ 915,056,131	$ 696,976,742	$ 865,972,755	$ 962,482,964	$ 890,430,521
Bottom line at Suncrest						
kg slaughter per bird slaughtered	1.59	1.64	1.59	1.64	1.70	1.62
kg slaughtered per year	8,554,515	9,012,925	8,374,420	9,012,925	9,531,446	8,903,012
Margin per kg at abattoir	$ 70.00	$ 70.00	$ 70.00	$ 70.00	$ 70.00	$ 70.00
Margin per year at abattoir	$ 598,816,040	$ 630,904,784	$ 586,209,386	$ 630,904,784	$ 667,201,188	$ 623,210,824
Margin c/f to Control	$ -	$ 32,088,745	$ (12,606,653)	$ 32,088,745	$ 68,385,149	$ 24,394,784
Total increase in Profit for Crest Breeders	**$ -**	**$ 87,746,845**	**$ (175,027,942)**	**$ 38,663,469**	**$ 171,470,082**	**$ 55,427,275**