THE EFFECT OF HIGHLY DIGESTIBLE CARBOHYDRATE AND PROTEIN SOURCES INCLUDED IN PRE-STARTER DIETS OF BROILERS ON THEIR PERFORMANCE

by

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DECLARATION

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SUMMARY

In recent years, the aim of the production of broilers became more focused on the increase of the performance of the birds in order to increase profit. To obtain an increased performance with broiler chicks, it is necessary to look at the development of their gastrointestinal tract, the feed requirements and the ability to digest certain nutrients in the period post hatch. Research have shown clear evidence of increased performance of chicks by the inclusion of certain carbohydrate and protein sources in the pre-starter diets, but in contrast to this there are also some research that found no significant effects on the performance of broilers when certain carbohydrate and protein sources were included in the pre-starter diet. Therefore, the purpose of this study was to investigate the effect that a product containing specific carbohydrate and protein sources, included in the pre-starter diets of broiler chicks, would have on their performance. It was believed that the products to be tested would result in increased performance of the chicks in the following growth phases. Special emphasis was placed on the average daily gain (ADG), feed intake, cumulative feed intake, feed conversion ratio (FCR), European production efficiency factor (EPEF) and the protein efficiency ratio.

Different inclusion levels of the different raw materials were investigated in the first trial. Three raw materials and a control were compared using a summit dilution process at 100:0, 66:34, 50:50, 34:66 and 0:100. Specific production parameters such as ADG total live weight gain, feed intake per week, cumulative feed intake, FCR, EPEF and PER were measured and calculated in order to determine if there were any significant differences between the treatments with the different raw material inclusions on the performance of the chicks. No significant differences (P>0.05) were found between the 13 treatments for the ADG, total live weight gain, feed intake per week, cumulative feed intake, FCR, EPEF and PER. The results therefore indicated that there were no significant differences between the different inclusion levels of the different raw materials and no significant differences for the production parameters for animals receiving diets with various levels of the three raw materials. It is thus concluded that these raw materials can be successfully utilised in pre-starter diets of broiler chicks.

The effect of the contribution of sugar to the metabolisable energy (ME) of the raw materials was tested in a commercial grower trial. The three raw materials had inclusion levels leading to supply of either 12% or 18% of the ME in the form of sugar. No significant differences were found between the seven treatments for ADG, total live weight gain, feed intake per week, cumulative feed intake, FCR, EPEF or the PER. It was concluded that the percentage in contribution of sugars between 12 and 18% to the ME of the pre-starter diets had no significant effects on the production parameters tested.

OPSOMMING

Met die produksie van braaikuikens word daar deesdae al hoe meer klem gelê op die verhoging van die produksie van die kuikens om dan dus ‘n verhoging in die wins te bewerkstellig. Om hierdie verhoogde produksie by braaikuikens te kan bereik, is dit nodig om na eienskappe van die kuiken soos die ontwikkeling van die spysvertering stelsel, die nutrient- behoeftes van die kuiken en die vermoë om sekere nutriënte te kan verteer in die periode na uitbroei. Sommige navorsing het gewys dat die insluiting van sekere koolhidraat – en proteïen bronne in die voor-aanvangs diëete van braaikuikens, lei tot ‘n positiewe effek op die produksie van die kuikens, waar ander navorsing geen effek gevind het nie. Daarom was die doel van die huidige navorsing gewees om te toets wat die effek van die insluiting in die voor-aanvangs dieet van braaikuikens ‘n sekere produk met ‘n spesifieke koolhidraat –en proteïen bron samestelling op die produksie van die kuikens sal wees in die daaropvolgende fases. Dit was verwag dat die insluiting van hierdie produkte in die voor-aanvangs diëte van braaikuikens ‘n positiewe effek sou hê op die produksie van die kuikens. Spesiale klem was gelê op die parameters soos gemiddelde daaglikse toename (GDT) voer inname, kumulatiewe voer inname, voeromset verhoudings (VOV) Europese produksie doeltreffendheids- faktor (EPEF) en die proteïen doeltreffendheids faktor (PER).

Verskillende insluitings vlakke van die verskillende produkte wat getoets is, is in die eerste proef ondersoek. Die drie produkte is deur middel van ‘n piek verdunnings proses by verhoudings van 100:0, 66:34, 50:50, 34:66 en 0:100 met mekaar vergelyk. Spesifieke produksie- parameters soos die GDT, lewende massa, weeklikse voer- inname, kumulatiewe voer- inname, VOV, EPEF en die PER is gemeet. Geen betekenisvolle verskille ($P>0.05$) was vir die 13 behandelings verkry nie. Die resultate het derhalwe getoon dat daar geen betekenisvolle verskille tussen die verskillende insluitings vlakke van die onderskeie produkte was nie en dat daar geen betekenisvolle tussen die produksieparameters van die kuikens wat die diëte met die verskillende insluitingspeile van die drie roumateriale ontvand het, was nie. Daarom is tot die slotsom gekom dat hierdie roumateriale suksesvol in die vooraanvangsdieet van braaikuikens aangewend kan word.

Die effek van die bydrae van die suiker tot die metaboliseerbare energie (ME) van die produkte was in ‘n kommersiële groei proef getoets. Die drie rou materiale was by beide 12- en 18% ingesluit. Geen betekenisvolle verskille ($P>0.05$) was vir die sewe behandelings vir GDT, lewende massa, weeklikse voer- inname, kumulatiewe voer- inname, VOV, EPEF en PEF verkry nie.

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LIST OF ABBREVIATIONS

ADG	average daily gain
FCR	feed conversion ratio
EPEF	European production efficiency factor
PER	protein efficiency ratio
LSMean	least squared mean
ANOVA	analysis of variance
ME	metabolisable energy
AME	apparent metabolisable energy
FOS	fructo-oligosaccharides
MOS	mannan-oligosaccarides
TME	true metabolisable energy
NSP	nonstarch polysaccharides

NOTES

The language and style used in this thesis are in accordance with the requirements of the *South African Journal of Animal Science*. This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetition between chapters has been unavoidable.

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CHAPTER 1
GENERAL INTRODUCTION

In recent years, the aim of commercial broiler production became more focused on an increase in the performance of the birds in a shorter time. The increase in the performance of broiler chicks is directly correlated to production parameters such as average daily gain (ADG) feed intake and feed conversion ratio (FCR) (Longo *et al*., 2005a). In order to obtain this increase in performance, it is necessary to determine the nutrient requirements of the bird to obtain optimum growth. For the growth of the bird to be at its optimum, the gastrointestinal tract development also needs to be at its optimum, to ensure adequate digestion and absorption of the nutrients contained in the feed (Noy *et al*., 2001).

Recent research has shown that physiological changes occur in the digestive tract during the first week of life in broiler chicks. Important activities such as digestive enzyme activity, nutrient uptake and nutrient utilization take place and the nutrient utilization increases after the first week post hatch (Garcia *et al*.,2006). The first week of life is a very critical stage in the development of the broiler. It is important for this reason that the birds have to reach market age at an earlier stage. This can be accomplished by giving a pre-starter diet to compensate for the initially immature digestive system. The aim of feeding a pre-starter diet is therefore to provide more digestible ingredients and a higher concentration of nutrients (Garcia *et al*., 2006).

Raw materials included in pre-starter diets must be high in energy and protein. The raw materials should also be highly digestible. Examples of such raw materials are soy protein, gluten meal, glucose- based products, corn glucose solids, simple sugars such as glucose, dextrose (Rutz *et al.*, 2007). The digestion of these carbohydrate compounds is accomplished by the digestive enzymes present in the digestive tract of the bird. The levels of such enzymes are proportional to the concentration of substrate present in the digestive tract (Moran Jr, 1985). The activities of the enzymes digested by the pancreas are increased with the increase in age of the chick (Maiorka *et al*., 2006).

By supplying a pre-starter diet with a high concentration of nutrients with special attention to the quality of energy and protein sources, it is believed to have a positive effect on the production performance of the broiler chicks (Leeson & Zubair, 2004). Some raw materials which contain certain sugar compounds which are included in pre-starter and starter diets are believed to have positive results on broiler performance. Examples of such sugar compounds are dextrose sugar or glucose and these sugar compounds present in raw materials may increase the energy content of the diet and for this reason may result in the increased growth performance of broiler chicks (Batal & Parsons, 2004). The results of (Batal & Parsons, 2004) were consistent with the results found in the study conducted by Longo *et al*. (2007), where different carbohydrate and protein sources were fed in pre-starter diets to broiler chicks and these sources were evaluated to test what effect these raw materials had on broiler performance.

The results showed that the chicks that were fed the sucrose diet had higher body weight gains than chicks that received the maize gluten meal diets. The results obtained by Longo *et al*. (2007) were also consistent with the findings of Longo *et al*. (2005), who included different carbohydrate sources such as glucose, sucrose, corn starch or cassava starch in pre-starter diets of broilers and who reported that the inclusion of sugars led to a significant increase in the performance of the broiler chicks.

It was shown in the study conducted by Awad *et al*. (2008), that some raw materials which contain certain sugar compounds such as mannan- oligosaccharides, may serve as a pre-biotic and can also be an alternative to antibiotics and for this reason had positive effects on broiler performance. These results were consistent with the results obtained by Nollet *et al*. (undated) and Hooge, (2004), where it was found that the inclusion of these mannan-oligosaccharides in diets of broilers resulted in increased broiler performance in terms of ADG, body weight, FCR and the European production efficiency factor (EPEF).

The present study was therefore conducted to determine the effect of the inclusion of certain raw materials in pre-starter diets of broiler chicks on the productive performance of the birds. These raw materials contained highly digestible energy sources such as glucose and its derivatives which were combined with high quality raw materials such as maize gluten meal, soya isolates and concentrates. These products were believed to serve as highly digestible energy and protein supplements. For this reason it was believed that the inclusion of these raw materials in pre-starter diets would exert positive effects on the production performance of the broiler chicks. Increased levels of inclusion of these different raw materials were tested in terms of effect on the production performance of broiler chicks. The contribution of the sugar to the metabolisable energy (ME) of the raw materials was evaluated and what effects it would have on broiler production performance. Production parameters such as ADG, feed intake, FCR, EPEF and protein efficiency ratio (PER) were taken into account to evaluate the production performance of the chicks. A test of hypothesis was done to determine whether the increasing inclusion of test material in the pre-starter diet of broiler chicks had an effect on production performance and whether the contribution of sugar to the Metabolisable energy of the experimental products had any effect on production performance. The H_0 hypothesis was the test where an increasing level of experimental product in pre-starter diets given to broiler chicks had no effect on their production performance and H_1 hypothesis was the test where an increasing level of experimental products in pre-starter diets of broiler chicks had an effect on their production performance. The H_0 hypothesis was the test where the contribution of sugar to the ME of the experimental products in pre-starter diets given to broiler chicks had no effect on their production performance and H_1 hypothesis was the test where the contribution of sugar to the ME of the experimental products in pre-starter diets of broiler chicks had an effect on their production performance.

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CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

The aim of the production of broilers is to increase the performance of the birds in order to increase profit. This increase in performance is directly correlated with production parameters such as feed conversion ratio, weight gain and feed intake. In recent years the objective of the broiler production industry was to obtain an increased performance in the birds in a shorter time (Longo *et al*., 2007). In order to obtain this increase in performance of broilers it is necessary to feed diets that will meet the requirements of the bird more precisely in order to obtain optimum growth. For optimum digestion and absorption of nutrients it is important that the gastrointestinal tract development and growth is optimal (Noy *et al*., 2001).

Research done with young poultry, indicated that physiological changes occur in the gastrointestinal tract during the first week of age. A lot of very important activities therefore take place during this stage such as nutrient uptake, digestive enzyme activity and nutrient utilization. The nutrient utilization is known to increase gradually after the first week post hatch (Garcia *et al*., 2006).

The first week post hatch is a very critical stage of development in the production of modern broilers. The first week post hatch is important for the reason that they have to reach market weight in fewer days (35 to 42 days) (Longo *et al*., 2007). Giving a pre-starter diet during this first critical week post hatch can be a method to compensate for the initially immature digestive system. The goal of feeding the pre-starter diet is for the pre-starter diet to provide either a higher concentration of nutrients or to provide more digestible ingredients (Garcia *et al*., 2006; Rutz *et al*., 2007).

Researchers have become more and more concerned about the use of antibiotic growth promoters in animal feed and the development of antibiotic resistant bacteria. This promoted an increase in research for the improvement of the performance of poultry without the use of antibiotic growth promoters. The focus therefore turned more towards compounds that may have pre-biotic effects to improve the birds' intestinal health (Biggs *et al*., 2007). A combination of pre-and probiotics as synbiotic may positively affect the host by increasing the survival of the healthy micro-organisms in the gastrointestinal tract and this therefore results in greater performance of birds (Awad *et al*., 2009).

Certain sugars such as oligosaccharides can be considered to serve as pre-biotic compounds and may for this reason improve the intestinal health of poultry and may therefore increase the performance of the birds (Biggs *et al*., 2007). Certain oligosaccharides such as mannan-oligosaccharides (MOS) may exert this positive effect in the intestinal tract by inhibiting the adhesion of harmful bacteria to the gut wall and therefore improves the production parameters of broiler chicks. Organic acids such as lactic acid, fumaric acid and propionic acid may also serve as alternatives for antibiotic growth promoters and exert their effects by the inhibition of the adhesion of harmful bacteria to the gut wall and for this reason; organic acids may increase production performance (Ao, 2005).

Different raw materials which consist of highly digestible energy sources such as glucose and glucose derivatives are believed to increase the performance of broiler chicks (Batal & Parsons, 2004a). The same can be said for highly digestible protein sources where the highly digestible protein sources have a high protein density, which are also low in anti-nutritional factors (Rutz *et al*., 2007).

Other nutritional sources such as dietary nucleotides may be examples of such highly digestible energy sources. Nucleotides are essential components of the diet and the body provides mechanisms for the absorption and incorporation of these components into the tissues (Esteve-Garcia *et al*., undated). Nucleotides are intracellular compounds of low molecular weight which consist mainly out of three compounds namely (1) a nitrogenous base, (2) a pentose sugar and (3) one or more phosphate groups (Chiofalo *et al*., undated). The pentose sugar present in these compounds is highly digestible and may therefore exert positive effects on the production performance of broiler chicks (Rutz *et al*., 2007).

2.2 Digestive tract of broiler chicks

In the past few years, the growth of broiler chicks during the first week of life, which consists of 16% of their life span when the target weight of 2 kg is considered best for slaughter, has become very important (Renema *et al*., 2007). This period of growth, consist of the transition of the embryonic absorption of the yolk sac to the utilisation of exogenous feed. This transition is accompanied by many developmental changes in the gastrointestinal tract of the broiler, which include changes in the pattern of growth of the gastrointestinal organs. The main emphasis on developmental changes is from the organs of supply (liver, pancreas, small intestine, heart and lungs) to the tissues of demand (muscle, fat) (Katanbaf *et al*., 1988). It is necessary that there is both an increase in the weight of the digestive organs as well as the secretory activity of the pancreas and digestive organs in order to achieve optimal growth of the chick at an early age (Nitsan *et al*., 1991). It is well known that the first period post hatch is a very critical period for the rearing of broiler chicks. Research have shown that the weight of the first seven days of rearing has a linear relationship with the slaughter weight (Saki, 2005). For this reason, the feeding of the broiler chick post hatch could have an effect on the performance of the broilers (Yang *et al*., 2009). It was shown that including a pre-starter diet as a phase in the nutrition of broiler chicks, had positive effects on the growth performance of the chicks (Saki, 2005; Swennen *et al*., 2007).

The timing and the composition or form of nutrients that are supplied post hatch is very important for enzyme and intestinal development in broiler chicks (Uni *et al*., 1999; Noy *et al*., 2001). Many reports have shown that chicks with early access to feed showed increased initial growth that could be maintained right through to market age (Gomes *et al*., undated; Uni *et al*., 1999; Noy *et al*., 2001). The feed efficiency was not influenced, but the carcass composition of the chicks was altered. Early access to feed therefore increased body weight, the size of the *Musculus pectoralis* and the rate of small intestinal development (Noy *et al*., 2001).

The manipulation of the pre-starter diet can modify the development of the broiler chick (Nir *et al*., 1993). Newly hatched chicks are less efficient in handling the nutrients that are contained in solid feeds, than older birds and this may be due to their immature digestive systems (Batal & Parsons, 2004; Batal & Parsons, 2002). Newly hatched chicks have active satellite cells that are responsible for the accumulation of nuclei in muscle fibres. A few nutritional factors might have an effect on these cells and contribute to modify the size of the muscle fibres and also the proportion of muscle in the chicks (Halevy *et al*., 2000). The manipulation of the starter and pre-starter diets for broilers may therefore modify their growth together with fat accumulation. The energy initially needed, can be met by gluconeogenesis from the corporal tissue. Gluconeogenesis can be avoided by highly digestible and available carbohydrates and proteins contained in pre-starter diets and this may contribute to maintain body reserves (Longo *et al*., 2007).

To meet the energy and protein needs of the chicks in the first ten days of life, a mixture of ingredients with high crude protein content, processed correctly and highly digestible together with high levels of digestible energy must be fed to the birds (Lilburn, 1998). Examples of such highly digestible energy sources are sugars such as glucose or dextrose, sucrose and carbohydrates like starch. The administration of semisolid hydrated nutritional supplements which are based on protein and carbohydrates with no fat added in the diet of broilers have a positive effect on the utilization of the energy of a diet based on maize and soybean meal (Batal & Parsons, 2004a). It was reported that broiler chicks that received a post hatch supplement had greater body weights at 21 days of age than broiler chicks that were fasted for the first 48 hours (Mateos *et al*., 2002).

The development of the immune system starts during the embryonic phase and continues post hatch. During the first week post hatch, there is a rapid increase in leukocytes, together with an increase in size of lymphoid organs (Panda *et al*., 2010). The increases in the number of these cells and organ size are necessary for the development of the acquired immunity. In the newly hatched chick, the yolk sac is important because it transfers passive immunity from the yolk and albumen to the neonatal chick in the form of immunoglobulins, but an early excess or deficiency of nutrients can harm the development of the immune response (Klasing, 1998). For this reason it is very important to feed the chick as soon as possible post hatch and it is also very important not to have an oversupply of nutrients immediately post hatch.

2.2.1 Post hatch development of the small intestine

In newly hatched birds, a major change occurs in the source of nutrients as the yolk is then replaced by an exogenous diet which mainly consists of carbohydrates (Noy & Sklan, 2002). The yolk is the main energy source on day 19 of incubation. The remaining yolk is internalized into the abdominal cavity and continues thereafter to supply energy for a few days post hatch. The intake of exogenous feed will result in the rapid development of the gastrointestinal tract and the associated organs to assimilate the digesta (Uni *et al*., 1998).

The small intestinal development involves the intestinal growth and digestive function development where the enzymes needed for digestion is developed and this is set in action when the exogenous feed is supplied to the chick post hatch. Due to the fact that the duodenum grows faster grows faster than the jejenum and ileum the development of the small intestine is not uniform. The intestines of the broiler chick will be fully developed between day three and eight of age (Dror *et al*., 1977). In the period post hatch the enterocytes and villi are not fully developed, but a few crypts are present (Noy & Sklan, 1997). There are initial rapid increases in the villus size and area in two day old chicks, where after the rate of growth declines and reaches a plateau five to ten days post hatch (Uni *et al*., 1999). The villus size and area in the gastrointestinal tract of broilers are seen to be bigger than that of poults. The mucosal enzyme activity of broilers is also larger. The villus height and crypt depth rapidly increases in the period post hatch and reaches a plateau after six days of age in the duodenal region and ten days in the ileal and jejenal regions (Uni *et al*., 1999). Experiments done on the morphology of the intestine indicated that from four to 21 days of age an increased villus volume and crypt depth may be observed with little change in enterocyte density with age (Uni *et al*., 1998).

Figure 1 shows that the cells per villus in the small intestinal tract which consist of the duodenum, ileum and jejunum increases and develops in the presence of feed in the gastrointestinal tract and with the increase in the age per day of the bird (Uni *et al*., 1998).

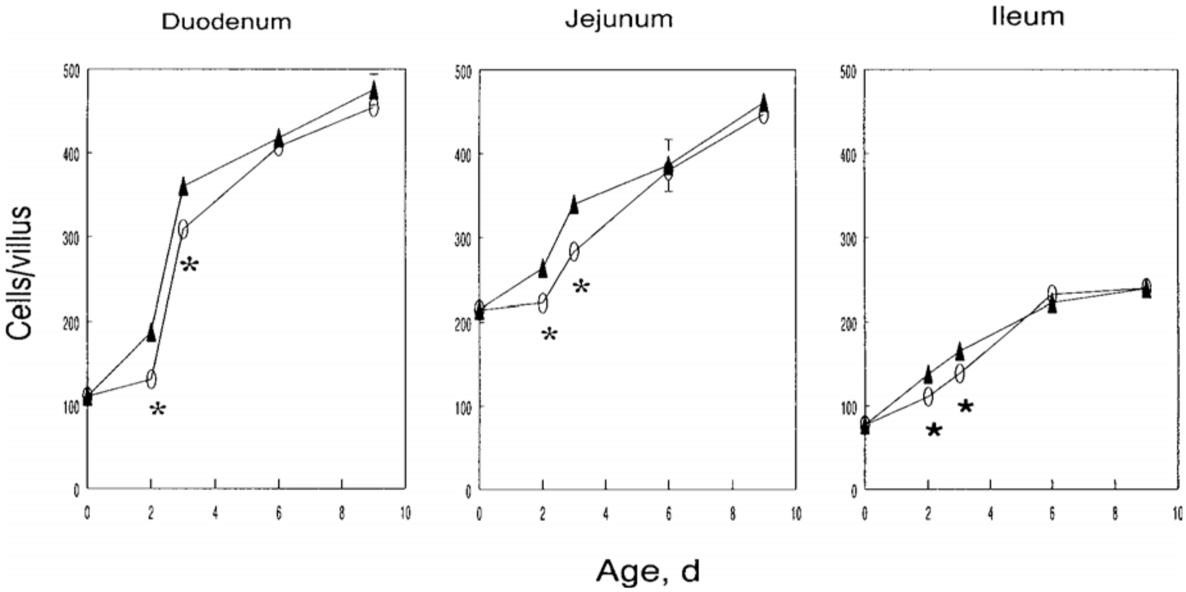

Figure 1 Changes in the number of cells per villus in the small intestine of poults that were either fed (▲) or feed-deprived (O) (*) deviations from the graph (Uni *et al*., 1998)

2.2.2 Post hatch development of digestive enzymes

In the period post hatch the intestinal tract is anatomically complete but still requires physiological and morphological development. The digestive tract of the chick at this stage is therefore still immature, but with the intake of exogenous feed the enzyme activity will start to increase. The physiological development is related to an increase in production and activity of digestive enzymes from the pancreas and the intestinal membrane as mentioned earlier (Uni *et al*., 1999). The enzymes not only perform luminal digestion but also the final stages of hydrolysis of nutrients from the brush border membrane. There are some changes in the secretions of some of the pancreatic enzymes of the intestine from four to 21 days post hatch. After seven days it can be observed that the secretion of the pancreatic enzymes and bile are constant per gram of feed intake (Traber *et al*., 1991). Examples of such enzymes are sacharase-isomaltase, peptidase and phosphatidases (Maiorka *et al*., 2006).

Newly hatched chicks have a reserve of pancreatic enzymes which are produced during the embryonic phase (Nitsan *et al*., 1991). These reserves are not sufficient to hydrolyse the substrate in the intestinal tract with the first exogenous feed present in the tract. Therefore a decrease in the digestive enzymes may be observed in the period just after hatching and this may therefore limit the growth of the birds (Maiorka *et al*., 2006). The activities of the digestive enzymes at the pancreas and the gastrointestinal tract, shows an increase with age (Nir *et al*., 1993). It is shown that chicks that are fed immediately post hatch have higher trypsin, amylase and lipase activities observed in the intestinal mucosa, but the constant intake of feed results in the constant secretion of these enzymes (Sklan & Noy, 2000).

In the newly hatched chicken, the mechanism to digest carbohydrates already exists. Poultry in general are able to digest carbohydrates, such as starch, as soon as the chick is hatched (Maiorka *et al*., 2006). The digestion of a carbohydrate feed source is highly dependent on the presence of the substrate in the gastrointestinal tract. The enzymes that are responsible for the complete digestion of carbohydrates are situated on the surface of the enterocyte brush border. The levels of these enzymes that are secreted are proportional to the substrate concentration present in the intestinal tract (Moran Jr, 1985). The enzyme α-amylase may be observed on the 18^{th} day of incubation and the specific activity of this enzyme is reached at four days post hatch and this enzyme is specifically responsible for the digestion of starch (Marchaim & Kulka, 1967). The maximum values for the enzyme amylase is reached on day eight in the period post hatch (Noy & Sklan, 2002).

The protein digestive system undergoes tremendous changes during the period post hatch and these changes depend on the concentration and composition of nutrients in the diet (Noy & Sklan, 1997). According to Noy & Sklan (1997), the protein digestion taking place in the small intestine increases from 78% at day four to 92% at day 21 post hatch. Austic (1985) stated that amino acid transport may be influenced by the dietary composition. A diet therefore containing a high level of protein increases the amino acid absorption rate in the small intestine, but the degree of absorption ranges according to the amino acid type. The enzyme pepsin is important for the initial digestion of protein in the feed. Pancreatic proteases, peptidases and chymotrypsin contribute to further breakdown of protein of present in feed (Uni *et al*., 1999). It was observed that an increase in the level of protein in the pre-starter diet leads to an increase in the concentrations of trypsin and chymotrypsin (Austic, 1985). Elevated levels of the enzymes trypsin and chymotrypsin may be observed at day 11 (Sklan & Noy, 2000).

Lipids serve as the main source of energy to the embryo during the incubational period. About 80% of the total lipid concentration in the yolk is mobilized and is used during the last week of incubation (Noy & Sklan, 1997). The metabolism of lipids depend on a few factors, such as enzymes like pancreatic lipase, the presence of bile salts and- fatty acid binding protein (Maiorka *et al*., 2006). According to Maiorka *et al*. (2006) the fatty acid digestion increased from 82% at day four to 89% at 21 days of age. The enzyme lipase may be observed on day four post hatch and maximum values of lipase may be observed on day eight in the period post hatch (Noy & Sklan, 1999). The capacity of the bird to digest lipids present in the diet in the period post hatch is limited, due to the limited amount of lipase that is produced. Therefore the amount of lipids that is included in the pre-starter and starter diets should be limited. But as the bird ages, the capacity to digest lipids and fat will increase and lipid content can increase accordingly (Rutz *et al*., 2007).

2.2.3 Enzymatic digestion of sugars in feed

Some enzymatic activity involves the digestion of carbohydrates such as sugar compounds. In the period post hatch chicks have, compared to mammals, a high capability to degrade disaccharides in the mucosa through the sucrose-maltase complex. The disaccharidase activity was observed to be the lowest in the duodenum and the highest in the ileum and jejunum. After two days post hatch, a two- to fourfold increase in the activity of disaccharidase can be observed (Nitsan *et al*., 1991). The dramatic increase in activity may be explained by the ingestion of small amounts of starch or carbohydrate- containing feeds (Uni *et al*., 1998; Maiorka *et al*., 2006).

The enzyme amylase is present in small amounts in the saliva and crop of the bird, but the majority of carbohydrates are degraded and digested to simple sugars in the small intestine and then absorbed from the jejunum (Leeson & Zubair, 2004). The α-amylase found in the duodenum, hydrolyses the starch molecules at the α,1-4 linkages on both sides of the 1-6 branching points (Leeson & Zubair, 2004). Disaccharides such as maltose are then broken down to monosaccharides that can be absorbed. There is a significant increase in the enzyme α-amylase as the chick matures. Other complex sugars or polysaccharides such as cellulose cannot be digested by the enzymes present in the digestive tract of the bird. Other compounds which may serve as ani-nutrients such as pentosans, pectins and β-glucans affect the digestion of carbohydrates in the gut, but these effects may be alleviated by the addition of exogenous enzymes (Annison, 1991; Leeson & Zubair, 2004).

The carbohydrates and sugars that are targeted by the enzyme α-amylase at the mouth area (saliva) are starch dextrin and the end products obtained are dextrin and glucose (Swain, 1992). The enzyme α-amylase is secreted by the pancreas into the duodenum and hydrolyses the α,1-4 linkages of the starch molecules, which then produces mainly maltose and some branched oligosaccharides (isomaltose). The enzyme maltase will then hydrolyse the maltose to produce glucose (Nir, Nitsan & Mahagna 1993). The enzyme oligo- 1,6- glucosidase produced by the intestinal mucosa also hydrolyses the oligosaccharides to produce glucose. The simple sugar sucrose is hydrolysed by sucrase also produced by the pancreas into glucose and fructose and the enzyme lactase converts lactose into glucose and galactose (Swain, 1992). This disaccharide (lactose) can only be partially utilized by the birds, because when the chicks hatch they lack sufficient lactase enzyme (Leeson & Zubair, 2004).

Other complex sugars such as cellulose cannot be digested by the chick due to the fact that the birds do not possess the enzyme cellulase to hydrolyse the β-1, 4 – glucose structure (Jimenez-Moreno *et al*., 2009; Leeson & Zubair, 2004). The polysaccharides that can be found in hemicelluloses found in the cell walls of grains used in the feeding of poultry are pentosans. When xylans are hydrolysed it produces the pentose sugar xylose. Chicks do not possess the enzymes to hydrolyse these pentose sugars (Choct & Annison, 1992b). Pentosans, β-glucans and oligosaccharides such as stachyose and raffinose may have anti-nutritional effects due to the fact that these compounds cause increased viscosity in the gastrointestinal tract and for this reason interferes with the digestion and absorption of carbohydrates, proteins and fats (Chickens *et al*., 1989).

2.3 Sugar compounds present in different raw materials used in broiler feed

2.3.1 Glucose or glucose based ingredients (maize, starch)

Casein is a product which can be better utilized than either fish meal or soybean meal by chicks in the first week post hatch. The energy from maize is also better utilized than the energy from concentrates such as wheat and sorghum but the best source of energy is obtained from various sources of fat such as full fat soya, due to the fact that fat contains the highest concentration of energy and has the lowest heat increment (Mateos *et al*., 2002). In the study conducted by Batal & Parsons (2003) the energy values of maize diets having soybean meal and rapeseed meal as the main protein sources were studied for chicks. With both cases the ME was very low at day two and day four of age but showed an increase as the chicks got older. A greater ME value was observed when dextrose-casein diets were fed to chicks at day two of age, but with no improvements in the ME values afterward. The ME value was calculated as a percentage of the gross energy value and it was observed to be 66% for the corn-soybean meal diet and 88% of the dextrose-casein diet.

Oligosaccharides are compounds that have been shown to alter the intestinal microflora in many animal species by the enrichment of intestinal lactobacilli (Hidaka *et al*., 1991). Studies have indicated that by adding fructo-oligosaccharides (FOS) to the diet of chicks, it may enhance the performance of the birds and it may serve as a substitute for antibiotics (Xu *et al*., 2003; Terada *et al*., 1994). In the study conducted by Xu *et al*. (2003) it was found that by adding different levels (2g/kg, 4g/kg or 8g/kg) of FOS to the diets of broiler chicks, it resulted in different effects on the performance of the chicks. The addition of 4g/kg FOS resulted in increased average daily gain (ADG) the 2g/kg FOS and 4g/kg FOS resulted in decreased feed conversion ratio (FCR). But the addition of 8g/kg FOS did not have any significant effect on the production performance. In the study conducted by Patterson *et al*. (1997) a range of kestose oligosaccharides were produced by pyrolysis of sucrose. The aim was to determine the effects of the dietary inclusion of thermal kestoses on the growth performance and changes in the microbial population in the caecum of broiler chicks. The kestose mixtures consisted of a range of sugars such as kestose, sucrose, glucose and fructose. The results indicated that there was an increase in the lactobacillus populations with the inclusion of 2% kestose in the diet. When feed grade antibiotics were administrated to broiler diets it resulted in a response in the performance of the birds, where oligosaccharides were present.

Sugars such as oligosaccharides present in the diet which are not hydrolysed by the digestive enzymes present in the upper digestive tract of broilers and will enter into the hindgut, where fermentation will take place by the intestinal microflora (Yusrizal & Chen, 2003). Some research indicated that dietary oligosaccharides may be beneficial in terms of the prebiotic effects dietary oligosaccharides has in the intestinal tract of the birds (Spring *et al*., 2000), whereas other research indicated that elevated levels of dietary oligosaccharides lead to increased fluid retention, hydrogen production and diarrhoea, which then affected the utilization of other nutrients (Delcour, 2004). In a study conducted by Kocher *et al*. (2003) it was shown that certain feed stuffs (soybean meal) which contain high amounts (6%) of oligosaccharides and soluble non starch polysaccharides (NSP) exert antinutritive effects by increasing the digesta viscosity. For this reason it is difficult to define dietary oligosaccharides as nutrients or anti-nutrients (Choct & Kocher, 2000). A few studies have shown that supplementing the diet with fermentable carbohydrates such as FOS and MOS resulted in the increase in the villus height (Rehman *et al*., 2007; Iji *et al*., 2001; Kleessen *et al*., 2003). The increase in villus height therefore increased the absorptive area which had a positive effect on the absorption of nutrients and therefore ultimately lead to an increase in the performance of the broilers (Fritts & Waldroup, 2003).

2.3.2 Corn gluten meal

The residual starch fraction and fibre of corn gluten meal yields glucose and glycerol upon hydrolysis along with other sugars such as arabinose, xylose, mannose and galactose (Wu, 1996). These oligosaccharide compounds may serve as nutrients (which are highly digestible) or anti-nutrients, depending on the level in the final feed. The maximum inclusion level of oligosaccharides is approximately 5%. This results in the increased fluid retention, hydrogen production and diarrhoea (Choct & Kocher, 2000). The results in a study done by Longo *et al*. (2007), were consistent with this conclusion, where the chicks fed the corn gluten meal resulted in the decreased feed intake of the birds and therefore decreased weight gain. The feed to gain ratios of the birds that were fed the other carbohydrate and protein diets were better than the feed to gain ratios of the birds that were fed the corn gluten meal. Therefore it could be seen that the addition of corn gluten meal to the diets of broilers may not always exert positive effects on the performance due to the anti-nutritive effects of some of the oligosaccharides present in the diet. The maximum levels at which corn gluten meal should be included in broiler diets are 5 to 10% and are not normally added at higher levels due to the anti-nutritive effects the corn gluten meal would have on the feed intake of broiler chicks (Waldroup *et al*., 2002).

2.3.3 Soybean meal and soy protein concentrates

The typical broiler diet is based on maize and soybean meal and these feedstuffs contain highly digestible nutrients. Soybean meal included in broiler diets results in good growth of the birds in comparison to that of grain legumes (Iji & Tivey, 1998). Soybean meal contains sugars such as oligosaccharides. It was shown that these substances negatively impacted bird health and growth (Iji & Tivey, 1998). An example of two of these oligosaccharides which are from the raffinose family is two α-galactosides (stachyose which consist of fructose, glucose and two galactoses and raffinose which consist of fructose, glucose and galactose) and traces of verbascose. These substances cannot be digested by monogastric animals. These compounds (α-galactosides) may also decrease the fibre digestion and true metabolisable energy (TME) and may also then increase the feed passage rate (Coon *et al*., 1990). It was reported that by supplementing the enzyme α-galactosidase, the feed conversion and liveability of chicks were improved when they were experiencing heat stress, due to the fact that the chicks did not produce the enzyme α-galactosidase (Kidd *et al*., 2001; Leske *et al*., 1995).

These oligosaccharides that are found in soybean meal present a bioavailability problem in chickens due to the fact that these birds do not have the endogenous enzymes in the digestive tract to digest the α-1, 6 linkages of these oligosaccharides (Sathe & Salunkhe, 1981). These oligosaccharide compounds pass through the digestive tract without being digested into the lower gut where the compounds are fermented by gas-producing bacteria. This can result in flatulence, wet droppings and diarrhoea (Wagner *et al*., 1976; Leske *et al*., 1995). Kennedy *et al*. (1985) did a survey on soybean meal and the results (on a dry matter basis) showed contents of sugars such as sucrose (4.0-7.67%) stachyose (2.96-4.14%) and raffinose (0.67-0.94%). Differences that are found in soybean meal when specifically looking at oligosaccharide compounds may be due to the maturity of the bean at harvest, cultivar, or weather damage (Lowell & Kuo, 1989). Research has shown that removing the α-galactosides raffinose and stachyose through ethanol extraction lead to the improvement of the nutritional value of soybean meal for broiler chicks. Nitrogen corrected TME of the soybean meal was improved by 25% while the dry matter, hemicelluloses and cellulose digestibility were also increased (Leske *et al*., 1995).

Soy protein concentrates are raw materials which are processed soybean products which are high in protein. These concentrates are extracted with alcohol and are products that usually contain less soluble carbohydrates and α-galactosides than soybean meal. These soy protein concentrates are used as an alternative low α-galactosides soy protein source (Leske *et al*., 1993; Leske *et al*., 1995). Studies showed that the hydrolysis of stachyose and raffinose by endogenous α-galactosidase in soybeans have occurred *in vitro* under certain conditions (Fleming, 1982; Becker *et al*., 1974; Abdel-Gawad, 1993). In the study conducted by Olson *et al*. (1975), it was found that with the incubation of the ground beans in a sodium acetate buffer solution there were almost complete hydrolysis of raffinose and stachyose to sugars such as galactose and sucrose. Therefore by exploiting of this endogenous enzyme to reduce these compounds present in defatted soy flakes it resulted in the increased availability of energy for the bird to utilize.

2.3.4 Sunflower meal and Canola meal

Sunflower seeds and canola seeds are used in oil production for human consumption (Donald *et al*., 2001). Sunflower meal and canola meal are raw materials that are used mainly as protein sources in rations of monogastric animals, despite their high indigestible carbohydrate content (Kocher *et al*., 2003). These raw materials are not actually incorporated as much in broiler diets in South Africa, due to the cost and availability of these raw materials. An important factor with the feeding of these raw materials which are of concern is the concentration of indigestible oligosaccharides and NSPs present in these raw materials (Simbaya *et al*., 1995). It was shown that canola meal has on average 2.5% α-galacto oligosaccharides and 18% NSPS of which 1.5% is soluble, where sunflower meal has 4.5% soluble and 23% insoluble NSPs (Irish & Balnave, undated). Wheat and barley contains high concentrations of NSPs which raises digesta viscosity and therefore results in reduced starch, protein and lipid digestibility (Choct & Annison, 1992a).

2.3.5 Wheat and Barley

The cell walls of cereal grains consist of nonstarch polysaccharide compounds (NSPs) as mentioned. The main component which is present in the cell walls of wheat is arabinoxylans. These compounds consist of (1-4) - linked β-D-xylopyranose as backbone and α-L-arabinofuranosyl. The major component in barley cell walls is β-glucan or a glucose backbone (Annison, 1991). These compounds cause high viscosity of the digesta and are the way these compounds exert their anti-nutritional effects (Veldman & Vahl, 1994). The addition of enzyme preparations to wheat-and barley based diets may result in the reduction of the NSPs present in these raw materials and may therefore improve the performance of the chicks. The enzymes used mainly target the predominant substrate of wheat-based diets (xylans) and barley- based diets (β-glucans) (Veldman & Vahl, 1994). Pettersson & Åman (1988) showed that by adding xylanase to wheat-based diets that were fed to broilers, the nutritive value of the diet was increased and therefore increased the performance of the broiler chicks (Veldman & Vahl, 1994; Dusel *et al*., 1998).

2.3.6 Lupins

Lupins can be used as a protein source in poultry diets, although it is not commonly used in South Africa. Some research showed that sweet lupin meal could be used in broiler diets up to 400g/kg or may even completely replace soybean meal in broiler diets (Olver & Jonker, 1997). In contrast to this statement, it was argued that the inclusion of high concentrations of lupin meal may have a negative impact on the growth of the chicks. This could be subjected to the fact that lupin seeds contain some anti-nutritional factors such as toxic alkaloids, high concentrations of sugar compounds such as nonstarch polysaccharides (NSPs) and phytates. Already mentioned is the negative effects that the NSPs have in the gastrointestinal tract of the birds and the effects can be alleviated by adding commercial enzyme products (Olkowski *et al*., 2005). When comparing lupin and soybean meal, lupin seed have higher levels of NSPs and it also contains the highest level of cellulose and verbascose and monosugars such as galactose, arabinose and xylose. The main lupin used is the yellow lupin, since it has the highest content of protein with the least NSPs, as well as an amino acid profile very similar to soybeans. For this reason it may also be used as a protein source in broiler diets (Knudsen, 1997; Olkowski *et al*., 2005). The main structural polysaccharides which are found in lupin hulls are cellulose, arabinoxylans and pectic polysaccharides. The endogenous enzymes which are produced by the bird do not have the ability to digest these carbohydrates (Kocher *et al*., 2000). By evaluating all these raw materials for their specific sugar compounds, it can be seen that some of these sugars may exert anti-nutritive effects on the digestion of feed given to broilers. Thus, the inclusion of these raw materials should be done with caution so that these raw materials will not be oversupplied in the period post hatch (pre-starter diet).

2.4 Prestarter as diet for broiler chicks

2.4.1 Pre-starter diet requirements

2.4.1.1 Amino acids

The genetic improvement of broilers goes hand in hand with the optimal nutritional levels which will promote maximum protein accretion and minimal fat deposition (Rostagno *et al*., 2007). Parameters used in the broiler industry are weight gain or live mass and feed intake and it is commonly used to determine broiler nutrient requirements (Schutte & Pack, 1995). Amino acid requirements such as for the amino acids methionine plus cystine and threonine which were determined by the feed intake and weight gain resulted in optimal carcass parameters (Schutte & Pack, 1995). The reduction in the concentration of the protein in the diet also resulted in a linear increase in the abdominal fat deposition, but did not affect the performance or the breast fillet yield, however it resulted in the linear increase of the abdominal fat deposition (Rostagno *et al*., 2007).

It is known that the lysine requirement, as a percentage of the diet, may be influenced by either the age of the chick or the phase of growth the chick is in (starter, grower, finisher) (Narváez-Solarte *et al*., 2005). The increase in weight and the protein and fat deposition rate will have a definite influence on the broiler nutritional requirements. It was observed that the broiler performance in terms of average weight, weight gain and the feed intake were higher with higher levels of lysine in the diet (Araújo *et al*., 2005). The highest results in the weight gain of broilers were observed when a high level of lysine was incorporated in the pre-starter phase (Rostagno *et al*., 2007).

Table 1 Digestible lysine requirements of male broilers with different performances (22 to 33 days of age) as calculated by the equation of Rostagno *et al*. (2007)

Performance	Below Average	Standard	High
Average weight (g)	1250	1330	1438
Weight gain (g/day)	74.1	77.6	82.4
Feed intake (g/day)	130.2	134.5	141.0
Digestible Lysine Requirement., g/day	1.366	1.443	1.550
Digestible Lysine in diet, %	1.049	1.073	1.099

Digestible Lysine (g/day) = $0.1 \times W^{0.75} + (14.28 + 2.0439 \times W) \times G$

W = average body weight (kg) G = weight gain / day (kg)

Digestible Lysine for maintenance = $0.1 \times W^{0.75}$

Table 1 represents daily lysine requirements in g/day for male broilers with different levels of performance for a period of ten days (22 to 33 days). It can therefore be concluded that the higher the performance of the bird the higher the lysine requirement in g/day will be and the higher the total percentage of digestible lysine. The opposite is true for the performance below average where the requirement for digestible lysine is much less than for the birds with higher performance (Rostagno *et al*., 2007).

The requirements for optimal methionine and cystine concentration in the feed of broilers are very important. These amino acids are especially important for the optimal feed conversion ratio and breast meat yield (Schutte & Pack, 1995). A study done by Schutte & Pack (1995) indicated that to obtain the optimal feed conversion ratio and breast meat yield, methionine and cystine levels of 0.88% and a true protein digestibility of 78% had to be included in the diet of broiler chicks. In the study done by Kidd & Kerr (1997), total threonine levels of 0.65, 0.65 and 0.75% for the optimal increase in weight, feed efficiency and the breast fillet weight were obtained respectively. This showed a difference in the requirements for different parameters and the importance of the different concentrations of certain amino acids included in the pre-starter diets of broilers and the interactions of certain amino acids.

Recent recommendations of the ideal protein concept is that the protein level in poultry diets may be reduced, to eliminate an amino acid excess (essential and non-essential amino acids) by supplementing synthetic amino acids, such as lysine, methionine, threonine and tryptophan (Narváez-Solarte *et al*., 2005). In the study conducted by Sterling *et al*. (2002), the effect of decreasing dietary protein was studied, while the essential amino acid levels were maintained. It was also tested what effect decreasing protein had on the breast meat yield and the abdominal fat in broiler chicks. It was found that there was no significant effect on the carcass quality. There existed a linear relationship between the abdominal fat and the dietary protein levels. The carcass fat content linearly decreased as there was an increase in the dietary protein levels. The decrease in the fat deposition in the carcass with an increase in the dietary protein levels could be explained by the fact that the high protein level may have lowered the net energy content. The catabolism of amino acids resulted in a high energy cost and therefore there was a decrease in the total carcass fat in the bird (Macleod, 1997).

In the study conducted by Wertelecki & Jamroz (2006) the influence of different crude protein levels in pre-starter diets, with or without exogenous amino acids supplementation on chemical composition on yolk sac in broiler chicks, were evaluated. In the first five days post hatch, it was observed that a reduction in the protein level of the diet increased the body weight gain independent of exogenous amino acid levels. After day five post hatch, better crude protein absorption from the yolk sac was observed in birds that were fed higher levels of protein mixtures (exogenous amino acids). At the end of the trial, it was concluded that the absorption of exogenous amino acids was diversified by analysed growth phases of chicks and was independent of amino acids supplied to the diet. The same results were obtained in the study conducted by Corzo *et al*. (2005a) where the impact of dietary amino acid density was tested on broiler chicks. Different amino acid densities was tested in a pre-starter and starter period and compared. It was seen that feeding high amino acid density diets (lysine% 1.27, TSSA% 0.95, threonine% 0.82, isoleusine% 0.99) to broiler were only positive when throughout the entire growth period. There were some positive effects on the feed intake, feed conversion and abdominal fat content.

2.4.1.2 Phosphorus and Calcium

Total phosphorus is usually referred to as phosphorus (P) and includes all forms of phosphorus. The available phosphorus (AP) may be defined as the P that is absorbed from the diet of the animal and then absorbed in the cells of the animal animal. It may also be described as the feed P minus the P present in the distal ileum of the animal (Al-Masri, 1995). Retained P may be described as the P that stays in the body which is the feed P minus the P present in the excreta corrected for endogenous P. It is also important to know that non-phytate P (nPP) is the total P minus the phytate P (PP) or the P in the feed that is not bound in the phytic acid molecule (Plumstead *et al*., 2007).

The biological availability of P may be influenced by various dietary factors such as the concentration of other important nutrients such as Calcium (Ca) vitamin D, micro minerals and dietary energy present in the diet. Other environmental factors that may also affect the availability include physiological, management and health factors. Examples of such factors are the feed consumption, growth rate, sex, age and temperature (Angel, 2007).

The AP found in commonly used feedstuffs is normally not sufficient to fulfil the P requirements of chickens (Nelson *et al*., 1971). Therefore, inorganic P sources are usually included in the diet to fulfil the birds' phosphorus requirements (Peeler, 1972; Garcia *et al*., 2006). The enzyme phytase is capable of catalysing the release of phosphorus from phytate. Phytase is not an endogenous enzyme for monogastric animals and therefore they do have the ability to digest the phytate phosphorus. Phytate P therefore should to be included in the diets of broilers (Huff *et al*., 1998). In the study conducted by Huff *et al*. (1998), it was found that the chicks that were fed the diets that were treated with phytase, showed a significant increase in the live weight of the broiler chicks and when the diets were prepared with high available phosphorus maize and supplemented with phytase the dietary addition of total phosphorus could be reduced by 25%, without affecting the performance of the chicks.

The results found by Garcia *et al.* (2006), indicated that the difference in bioavailability of phosphorus between defluorinated tricalcium phosphate (DFP) and dicalcium phosphate (DCP) was not greater than 10% for chicks at the age of 6 or 15 days. This indicated that DFP could be optimally utilized by young chicks during the pre-starter and starter periods.

2.4.1.3 Sodium

It was shown that newly hatched broiler chicks grow very fast and require a high environmental temperature during the first week post hatch (Maiorka *et al*., 2004). Sodium (Na) potassium (K) and chlorine (Cl) are the most important minerals for maintenance of osmotic pressure and the acid-base balance within the body (Moran Jr, 1985). The variation in the acid-base balance leads to changes in the pH values, carbon dioxide concentration as well as base levels in the blood. Therefore the dietary concentration of electrolytes is crucial and will have an indirect effect on growth and feed intake of chicks during the first week of life (Maiorka *et al*., 2004).

It was also shown that if sodium was deficient, it resulted in reduced growth and feed consumption and impaired feed conversion (Burns *et al*., 1953; Ross, 1977). As mentioned above the sodium level also affects the osmotic pressure and the acid-base balance as well as the basal metabolism within the body. Many research studies have shown that there exists a great variation of sodium requirements for broiler chicks (Murakami *et al*., 1997b; Edwards Jr, 1984; Oviedo-Rondón *et al*., 2001). The NRC increased the recommendations for sodium requirements from 0.15 to 0.20% in the last two editions (Vieira *et al*., 2003).

The impact of sodium and chloride on wet litter with broiler chicks increases the awareness of minimizing levels of these elements in broiler diets (Murakami *et al*., 1997a). Wet litter can lead to conditions such as foot pad lesion and breast blisters (Butcher & Miles 2009). In contrast with the study conducted by Vieira & Pophal (2000), the study conducted by Murakami *et al*. (1997a), tested different levels of sodium (0.15, 0.20, 0.25, and 0.30%) and chloride (0.24 to 0.48%) and evaluated what these different levels of the elements had on broiler performance. It was found that the sodium requirement for broiler chicks was no more than 0.20% and sodium that were supplemented at 0.25- and 0.30% resulted in wet litter, which were consistent with the recommendations of the NRC. It was also found that chloride levels above 0.20% were not beneficial. The sodium levels had no positive effects on production performance and it was shown that by maintaining a minimum level of sodium in the diet had positive effects in reducing the problems with the wet litter. The sodium levels had no effect on tibial dyschondroplasia scores. These results were consistent with the findings of Butcher & Miles (2009) and Hooge *et al*. (1999).

In the study conducted by Vieira *et al*. (2003) the effects various levels of sodium in the feed had on the chicks in the first seven days post hatch was investigated. It was concluded that the sodium requirements for broiler chicks in the first seven days post hatch were higher than the requirements given in the NRC for feeds from one to 21 days of age. The estimations of the requirements obtained in this study, based on the body weight gain and feed conversion were found to be between 0.38 to 0.40%. This estimation was substantially higher than the recommendation of the NRC (0.20%). The water consumption also obviously increased due to the increased sodium concentrations in the pre-starter diet. This higher water consumption was then also correlated with an increased feed intake which was beneficial for the growth of the chicks. In over all, increases in performance of the birds were obtained with increases in sodium concentration. On the negative side, it was observed that the mortality rate increased in the first seven days as a result of very high sodium concentrations (0.46%) in the pre-starter feeds.

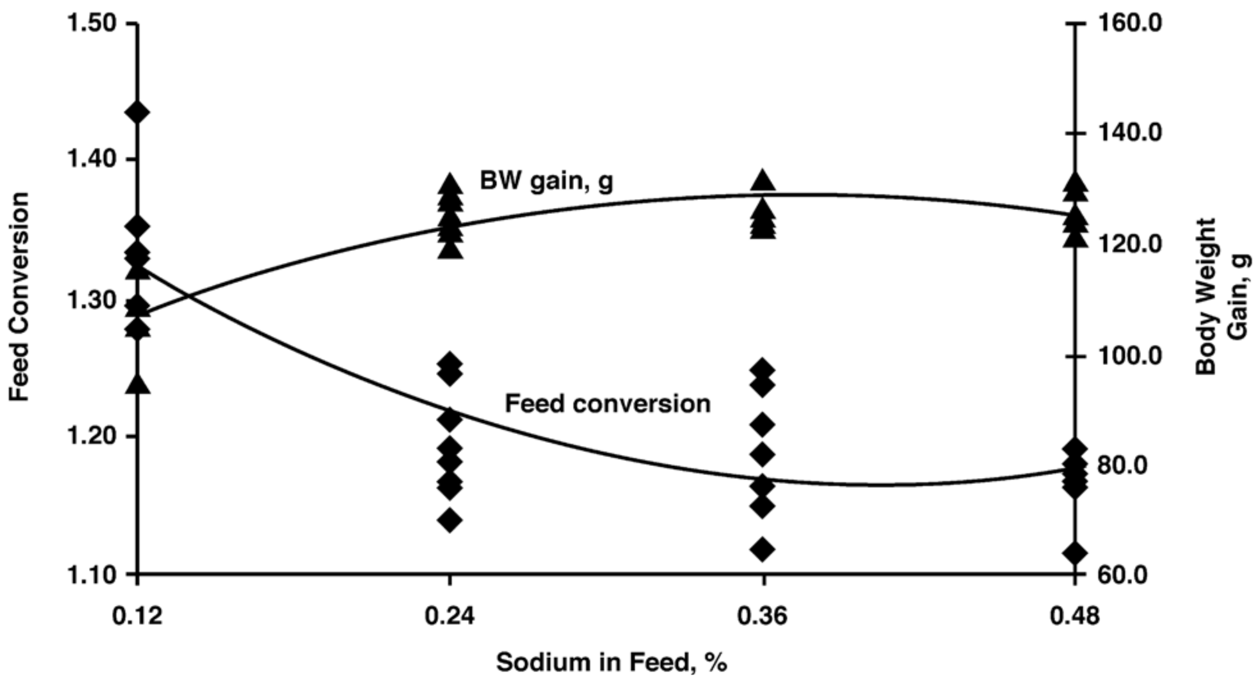

Figure 2 Body weight gains and feed conversions of broilers from day one to seven in relation to sodium levels in the feed (Vieira *et al*., 2003)

In Figure 2 it can be seen that with an increase in the concentration of sodium in the feed of the broilers, there is an increase in the body weight gain up to 0.36% sodium level in the feed. But an increase in the sodium level above this level (0.48% sodium) will result in a slight decrease in the body weight gain. The opposite may be observed for the feed conversion ratio where there is a decrease in the feed conversion with an increase in the sodium level up to 0.36% and a slight increase in the feed conversion if a sodium concentration above this level is given (0.48%).

In the study conducted by (Maiorka *et al*., 2004) they tested the effect of different Na levels and different sodium (Na) potassium (K) and chloride (Cl) Na,K, Cl balances in broiler feeds during the first week post hatch. The results found indicate that approximate values of 0.40% total Na in pre-starter feeds fed to chicks zero to seven days of age increased the feed intake, weight gain and improved the feed conversion ratio. The Na, K, Cl balance therefore affects broiler performance. In the study conducted by Vieira *et al*. (2003) two different dietary electrolyte balances were evaluated (160 or 240 mEq/kg). It was found that increasing the dietary electrolyte balance from 160 to 240mEq/kg, it resulted in positive weight gain and feed conversion ratio, but only limited to the first four days post hatch.

Other studies have shown that broiler performance may be maximized by feeding pre-starter diets which contain sodium levels of 0.39% (Rutz *et al*., 2007). Sodium also participates in the uptake of nutrients from the intestinal tract by a secondary active transport system (McCorry, 2007). This system is not fully developed directly post hatch (Vieira & Pophal, 2000).

It can be concluded that there are various opinions on the percentage of sodium that should be included in pre-starter broiler diets. The NRC of 1994 and Murakami *et al*. (1997a) recommend 0.20% of sodium, where Vieira *et al*. (2003) recommend an inclusion level of 0.38 to 0.40%, Rutz *et al*. (2007) recommend a 0.39% sodium inclusion level and Maiorka *et al*. (2004), recommend an inclusion level of 0.40% sodium in the pre-starter diet. From the results found in these studies done on sodium levels in the pre-starter diets for broiler chicks it can actually then be accepted that a 0.20 to 0.40% level of sodium can be included in the pre-starter diet. From the research done this inclusion level proves to be optimal for broiler performance over all.

2.4.1.4 Energy level of pre-starter diets

The feed intake of chicks is controlled by both the physical satiety and energy intake. The digestive system of the broiler chick does not reach maturity until 14 days post hatch. This delay in the maturation of the digestive system may be directly related to the enzymatic development and nutrient utilization as already mentioned (Rutz *et al*., 2007). Broiler chickens therefore eat to satisfy their energy requirements only after 14 days of age (Araujo *et al*., 2006).

Raw materials such as corn starch consist of approximately 25% amylose and 75% amylopectin. Amylopectin has a higher potential for gelatinization than amylose while amylopectin contains highly branched chains (Rutz *et al*., 2007). It was found that maize with a high amylopectin level has about 2.5% higher metabolisable energy content (Vieira & Pophal, 2000). Maize and soybean meal are both considered to be good feed ingredients for pre-starter diets for broiler chicks. It was observed that these raw materials had lower metabolisable energy together with low amino acid digestibility than was expected for the period the pre-starter was given (Batal & Parsons, 2002).

In the study conducted by Dozier III *et al*. (2007), the dietary metabolisable energy for heavy broilers was evaluated. Dietary treatments consisted of four apparent metabolisable energy (AME) levels (13.28, 13.47, 13.66, and 13.84 MJ/kg). It was found that the increasing levels of AME resulted in decreasing feed consumption and feed conversion, while the growth rate remained the same across the treatments. Feed conversion was decreased by four points for each unit increase of 0.18 MJ/kg. As the dietary AME increased to 13.84 MJ/kg, the feed conversion ratio showed an improvement compared to the other treatments. A similar study was conducted to evaluate the level energy that may be included in pre-starter diets of broiler chicks. In the study conducted by Vieira *et al*. (2006), broiler performance was evaluated in response to increasing levels of feed energy (12.00, 12.55, 12.97 MJ/kg). It was found that an energy level of 12.97 MJ/kg the feed intake of the chicks was decreased, but the feed conversion was improved at 12.55 MJ/kg, as well as the body weight of the chicks.

2.4.1.5 Protein level in pre-starter diets

Pre-starter diets that are highly digestible and contain high protein levels (23% crude protein) sufficient to meet the chick's nutrient requirements in the first week post hatch may be considered an investment and not a cost in the production of poultry (Longo *et al*. 2007; Stringhini *et al*. 2009). The protein requirements of broiler chicks decrease as the chicks get older (Schutte *et al*., 1997). Pre-starter diets for broiler chicks must contain at least 21% crude protein. A high protein concentration is therefore necessary in the pre-starter diet of broiler chicks (Rutz *et al*., 2007). According to Stringhini *et al*. (2009), it was recommended that a level of protein between 22 and 24% in pre-starter rations should be adequate to meet the birds' requirements.

The efficiency of amino acid utilization is at its optimum when the amino acids are slightly below the requirement for protein accretion and maintenance. There can be a minimal loss of nitrogen, by formulating diets that meet but do not exceed the requirements for protein utilization (Kidd *et al*., 2002). Some research have shown that a reduction in the crude protein-amino acid supplemented diets resulted in good growth and feed consumption of broiler chicks (Lipstein & Bornstein, 1975; Deschepper & DeGroote, 1995; Parr & Summers, 1991), but in contrast with this other reports have shown the opposite results where a low level of crude protein and amino acid in the diet resulted in reduced performance in broiler chicks (Edmonds *et al*., 1985; Rezaei *et al*. 2004; Corzo *et al*. 2005b). The findings of Corzo *et al*. (2005a), was consistent with this statement and found that by feeding low crude protein diets or low crude protein diets that were supplemented with individual amino acids, had lower plasma uric acid concentrations than the chicks that were fed the control. The results in this study further indicated that with chicks fed a starter phase diet with reduced crude protein, there will be an additional need for non-essential nitrogen and therefore non-essential amino acids supplemented in the diet of broilers.

In the study conducted by Everaert *et al*. (2009), the aim was to determine the effect of three different levels of dietary protein, supplied in the first five days post hatch, on the growth performance and breast muscle development, in newly hatched chicks. The three levels of dietary proteins that were fed to the chicks were low (LP) (19.6%) medium (MP) (23.1%) and high (HP) (26.7%). A higher body weight was obtained with the chicks fed the high dietary protein levels from day two until day seven compared to the chicks that were fed the low dietary protein levels (Longo *et al*., 2007). Corzo *et al*. (2005a) compared a low amino acid density pre-starter diet (LD) (21.1%) with a high amino acid density pre-starter diet (HD) (22.5%). Beneficial effects were also obtained for the birds fed the high amino acid density diet, but only if they were fed throughout the whole grow-out period. Male birds had higher body weights and lower feed conversion ratios than the female birds, together with higher meat yields. Therefore feeding high nutrient dense diets (high amino acid dense diets) to broilers resulted in the reduction in the cumulative conversion and abdominal fat, but did not have a significant effect on the flock uniformity or other carcass traits. Some authors reported that dietary concentrations of lysine, methionine and threonine, which are above which is required per bird, may improve the body weight gain and meat yield responses in broilers that are grown commercially (Schutte & Pack, 1995; Kidd & Kerr, 1997). In contrast to these findings, some authors found a decrease in meat yields and an increase in the fat deposition when broilers are fed diets containing a low crude protein level (Bartov, 1996; Moran *et al*., 1992).

2.4.1.6 Fat level in pre-starter diets

In newly hatched chicks, the entero-hepatic circulation of bile salts is still not fully developed. There is also low lipase synthesis and secretion at this stage. Therefore newly hatched broiler chicks have a lower capacity to digest fat when compared with older birds (Rutz *et al*., 2007). Adding high levels of fat in the pre-starter diet, might lead to oxidation. This will result in the destruction of fat-soluble vitamins and will also damage the intestinal villi (Wiseman & Salvador, 1991; Mateos *et al.*, 2002).

Certain non-starch polysaccharides (NSP) present in the feed have the ability to bind the bile salts, certain lipids and cholesterol and therefore it further reduces the ability to digest lipids (Vahouny *et al*., 1988). It was reported that in the first three to five days of age, the overall digestibility of lipids was approximately 69% but could be approximately 80% for polyunsaturated fats (Lilburn, 1998). Therefore it was concluded that unsaturated fats may be used in pre-starter diets for broilers and the digestibility would be good (Mateos *et al*., 2002). This was consistent with the findings of Kessler *et al*. (2009), where the diets that contained various levels of free fatty acids, medium chain fatty acids and different n6:n3 ratios had an effect on the crude fat metabolisability, but did not show any significant influence on the performance of broilers one to nine days of age. The diets that contained high concentrations of fat and therefore high ME levels were selected by the broilers at a younger age. It could therefore be concluded that the intake of pre-starter and starter diets which contained high energy levels positively influenced the performance of the broilers when they reached market age.

2.4.1.7 Additives included in pre-starter diets

Additives such as probiotics, mannan oligosaccharides, enzymes, lactic acid, mycotoxin binders, mold inhibitors and antioxidants may be included in the pre-starter diet and are substances which are highly recommended (Leeson, 2008).

The use of sub therapeutic concentrations of antibiotics was a standard practice from the 1940s (Wenk, 2003). The potential hazard of the use of these substances has become more of an awareness in the last few decades. This could be due to the fact that the use of these substances has resulted in multiple drug resistance in humans and therefore an increase in human diseases such as tuberculosis and meningitis, which were illnesses, previously controlled by antibiotics (Mateos *et al*., 2002).

Recent research has indicated that there was a connection in the use of antimicrobials in animal feeds and an increase in the prevalence of antibiotic resistance (Follet, 2001). This could therefore lead to a risk for human health. Due to the increased awareness for antibiotic resistance there is a great urgency to develop alternatives for antibiotic growth promoters. These alternatives would have to provide more economical defences against disease and production stresses (Wenk, 2003). Therefore optimizing the birds' immunity will become more important. The functional role of nutrients is therefore also becoming more important, not only for the nutritional aspect but also the effects on immunity. The concept of feeding dietary nucleotides is an area which lately receives much attention. Nucleotides that are fed to poultry are mainly derived from hydrolysed nucleic acids in yeast (Rutz *et al*., 2007; Wenk, 2003). Dietary nucleotides can serve as an alternative and also have an impact on the immunity (Rutz *et al*., 2007).

Probiotics may be described as a live microbial feed supplement that may have positive effects on the bird by the improvement of the balance of the micro flora present in the bird (Fuller, 1989). Prebiotics may be described as a non-digestible food ingredient that has positive effects on the bird, by selectively stimulating the growth and activity of the bacterial micro flora in the gastrointestinal tract of the bird (Gibson, 1999). Probiotics and prebiotics may be used in combination as synbiotics. This is therefore a mixture of pre- and probiotics which positively affects the bird by the improvement of the survival of live microbial dietary supplements in the gut of the bird. This affects the activation of the metabolism of the health-promoting bacteria which will lead to the improvement of the welfare of the bird (Awad *et al*., 2009). In the findings of Patterson & Burkholder (2003), it was seen that the addition of probiotics to the diet of broiler chicks, lead to an improvement of growth performance and feed efficiency of the birds. Awad *et al*. (2009) tested the effects of a synbiotic and probiotic included in the diet on the broiler performance. It was concluded that the synbiotic had a significant effect on the body weight of the broilers and improved feed conversion ratio. The probiotic was also positive in terms of growth promotion of the chicks, but the effect was lower than for the synbiotics. For this reason these products may be used as good alternatives to antibiotics for the feeding of broiler chicks (Awad *et al*., 2008).

Chicks post hatch, lack complex micro flora and are therefore prone to the colonization of harmful pathogens in the gastrointestinal tract (Milner & Shaffer, 1952). These pathogens work through the attachment to the intestinal surface to establish themselves in the gastrointestinal gut. One way to exclude these harmful cultures is to increase the competitiveness to the attachment sites. This can be done by the addition of mannose or similar sugars in the diet to inhibit the attachment of these pathogens (Spring *et al*., 2000). Oyofo *et al*. (1989) did a study where it was tested what effect different sugars had on the *in vitro* adherence of *Salmonella typhimurium* to the epithelial cells from newly hatched chicks. It was found that the adherence of the salmonella was inhibited by 90% where mannose and methyl-α-D-mannoside sugars were added. Some of these mannose-based carbohydrates could be found in many natural products such as yeast cell walls (Spring *et al*., 2000).

By supplementing organic acids to the diet of broiler chicks, it will acidify the diet and promote the growth of the birds and may therefore serve as substitutes for growth promoters. Organic acids may also be used in poultry diets to inhibit pathogens such as *Salmonella spp*. found in raw materials and processed feeds (Ao, 2005). In the findings of Vogt *et al*. (1979), it was shown that by adding certain organic acids to the diet of broilers such as fumaric acid, propionic acid, sorbic acid and tartic acid, resulted in a positive influence in the production performance of the birds (growth performance and feed conversion ratio). But these findings were not consistent with literature. In the study conducted by Patten & Waldroup (1988), the addition of organic acids to the diet of broilers resulted in increased body weight gain but did not have a significant influence on the feed intake and Skinner *et al*. (1991) found an increase in body weight gain but found no influence on the feed conversion ratio.

Nucleotides are essential elements which are involved in the development of the intestinal tract and repair of it. These elements are also involved in the development of the skeletal muscles, the functioning of the hart and the immune response (Grimble & Westwood, 2000). During periods of fast growth and intensive development in broiler chicks, the nucleotide availability could limit the maturation of fast dividing tissues with low biosynthetic captivity, like the tissues in the gastrointestinal tract (Esteve-Garcia *et al*., undated). In broiler chickens, there are very big changes in the development of the tissues in the small intestinal mucosa after hatching. This includes the enterocyte maturation, intensive cryptogenesis and growth of villi (Geyra *et al*., 2001; Esteve-Garcia *et al*., undated). These occurrences result in development of the intestine which will influence the growth rate (Smith *et al*., 1990).

In the study conducted by Esteve-Garcia *et al*. (undated), the aim was to determine what effect the supplementation of nucleotides had on the productive performance of broiler chickens. The more significant effects, which were observed in the first three weeks of nucleotide supplementation, suggested a greater need for nucleotides during this period of development. Fast cell proliferation occurred during this period, as the intestinal body weight was multiplied by a factor of more than 20. This also suggested that the availability of nucleotides limited the birds' performance during this period. The results in this experiment suggested therefore that nucleotide preparation at 500 mg/kg did significantly improve the performance of the chicks in this experiment. In the findings in the study done by Esteve-Garcia *et al*. (undated), it was found that broiler chicks that were fed diets which contained nucleotides from yeast extracts, showed better performance in terms of higher average body weight, body weight gain as well as better feed conversion ratios from the first to fourth week of age (Leeson & Zubair, 2004).

2.4.2 Effect of feeding pre-starter diets on the performance of chicks

A number of studies were done on the feeding of broiler chicks post hatch to determine what effect this had on the performance of broiler chicks (Gomes *et al*., undated; Saki, 2005; Rutz *et al*., 2007). In the results obtained in the study conducted by Saki (2005) it was found that, by restricting access to feed post hatch it resulted in the reduction in broiler performance. It was also observed that with this restriction in post hatch feeding there was a reduction in growth of the intestinal surface and the absorption of nutrients at the intestinal surface. In the study conducted by Gomes *et al*. (undated), the performance of the broiler chicks were evaluated by feeding a pre-starter diet. The performance of the chicks were evaluated by production parameters such as the body weight, feed intake, weight gain, relative weight gain and feed conversion ratio. In contrast with the study done by Saki (2005), it was found that it was not necessary to feed a pre-starter diet to chicks in order to get good performance. The differences found between the studies could be due to the fact that different raw materials were used. Saki (2005) included wheat, fishmeal and bone meal as well as maize and soybean meal, whereas Gomes *et al*. (undated) only incorporated the usual maize and soybean meal. Therefore it may be concluded that the value of feeding a pre-starter is largely dependent on the raw materials used.

When looking deeper into what is present in the pre-starter diet, different studies can be compared to see what the performance of the chicks was at market age. In the study conducted by Rutz *et al*. (2007), it was found that with the feeding of dietary nucleotides in the pre-starter diet, the body weight gain of the broiler chicks were significantly higher than the controls in the experiment. When looking at the carcass traits, it was also found that the chicks that were fed the dietary nucleotides in the pre-starter had higher carcass yields and yields of drumstick, thigh, wing and breast weights.

It is well known that the ratio of macronutrients (protein, lipids and carbohydrates) in the pre-starter diet of broiler chicks has a great impact on their performance and body composition (Buyse *et al*., 1992; Swennen *et al*., 2007). A change in the concentration of one of the macronutrients in the diet will affect the level of the other macronutrients. This will then make it extremely difficult to ascribe the observed effects to one specific macronutrient (Buyse & Decuypere, 1999). In studies conducted on this specific topic, the results found suggested that changing the level of protein in the diet affected the protein and fat deposition as well as the total energy and protein balance (Swennen *et al*., 2007; Moran *et al*., 1992).

In the study conducted by Swennen *et al*. (2007), the objective of this study was to compare isoenergetic substitution between protein, fat and carbohydrates in pre-starter diets and to investigate the influence of pre-starter diet composition on the performance of the broiler chicks. It was concluded that it was very important to include a pre-starter diet and that the diet was well adapted to the needs of the neonatal broiler chick. It was observed that the newly hatched chicks did not perform as well on the pre-starter diet with low levels of dietary protein compared to the low levels of carbohydrates and lipids. It was also shown that the deficiency of dietary protein could be made up for in the first week post hatch by the use of the yolk sac, but after the depletion of the yolk sac the effects of the low protein pre-starter diet would become evident by a decrease in body weight and a change in the body composition. Therefore it could be observed that the protein concentration in the pre-starter diet should be the main nutrient of concern (Noy & Sklan, 1997).

When looking at the results found in this study compared to the results found in the study done by Gomes *et al*. (undated), it was clear that the concentration of macronutrients in the pre-starter diet did actually influence the production performance of the chicks. The effect of the pre-starter diet did not necessarily give differences in the production performance, but looking at what the pre-starter diet consisted of (different raw materials) and in what ratios the macronutrients (protein, energy and fat) were included showed differences in the performance of the chicks.

In the study conducted by Batal & Parsons (2004a), the aim of the study was to test the use of different carbohydrate sources or high-starch ingredients affected by the age of the birds and also to identify highly digestible carbohydrate sources for chicks in the pre-starter phase. The carbohydrate sources evaluated were dextrose (D-glucose) conventional cornstarch, dextrinized cornstarch, high-amylose starch. The chicks that were given the dextrose-soybean meal diet showed the best performance. They had the highest weight gain and gain:feed ratios at three weeks of age. Chicks that were fed the polycose-soybean diet performed the best at seven days of age. These diets therefore contained rapidly and highly digestible carbohydrates were beneficial for chicks post hatch. The ME value of the dextrose-soybean meal diet was observed to be consistently high until 21 days of age and also significantly higher than the other diets at day zero to day two and three to four days post hatch. Therefore it was concluded that dextrose sugar, which is a highly digestible source of energy, gave very good growth performance together with high dietary ME values and this showed that glucose was well utilised by chicks post hatch. From the studies explained above, it could therefore be concluded that with the addition of the sugar dextrose to the diet of broiler chicks, the performance of the chicks were better compared to chicks that received the maize-soybean based diets only.

2.5 Conclusion

It can be concluded that by feeding pre-starter diets from one to seven days may have significant effects on the performance of the birds depending on the raw materials used and inclusion levels thereof, where as other pre-starter diets may exert no effects on the performance of the birds (soybean meal ≤35%, maize meal ≤60%, gluten meal ≤5%). The positive effects of feeding pre-starter diets may exert their effect on the effective development of the gastrointestinal tract and the digestive enzymes of broiler chicks. It was also necessary to know the requirements of the birds immediately post hatch and what nutrients are needed and at what levels to be included in the pre-starter diet of broiler chicks (Crude protein 22 to 24%, energy 12 to 13 MJ/kg, fat not more than 2%). It can also be concluded that by supplementing a pre-starter diet with highly digestible protein and energy sources such as soybean meal, maize, sugars such as glucose and sucrose, it may exert positive effects on the growth performance of broiler chicks. It was seen that by the inclusion of raw materials which contain various sugars may have effects on the performance of the birds by either acting as growth promoters or pre-biotics whereas other raw materials contain sugar compounds which can have anti-nutritive effects on the bird.

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CHAPTER 3

THE COMPARISON OF PRODUCTION PARAMETERS OF BROILERS FED INCREASING LEVELS OF SUGAR REFINERY BYPRODUCTS

3.1 Abstract

Seven hundred- and fifty day-old Cobb broiler chicks were randomly allocated to 13 treatments each with nine repetitions and five chicks per repetition. Three raw materials containing highly digestible carbohydrate and protein sources and a control were compared using a summit dilution procedure at 100:0, 66:34, 50:50, 34:66 and 0:100. No significant differences (P>0.05) were observed for average daily gain (ADG) live weight, weekly feed intake, cumulative feed intake, feed conversion ratio (FCR) European production efficiency factor (EPEF) or protein efficiency ratio (PER) at 35 days. There were also no significant differences (P>0.05) between the treatments for ADG at seven days. The results of this study has therefore shown that by including these raw materials at different levels had no significant effects on the production parameters of broiler chicks from hatch until slaughter at day 35.

Keywords: pre-starter, soya, glucose, dextrose, sucrose

3.2 Introduction

The products that were tested represented a highly digestible energy source which consisted of mainly glucose and its derivatives combined with high quality raw materials which include maize gluten meal, soya isolates and soya concentrates. These products were believed to serve as energy and protein supplements, which are highly digestible, free flowing, pelletising agents and further improve the palatability of the diets. It was therefore believed that the inclusion of these raw materials in pre-starter diets would be of great value for broilers during the pre-starter phase and that this benefit would carry forward in the subsequent grower and finisher phases (Rutz *et al*., 2007).

Other features and benefits of these products were that the glucose and glucose based ingredients which are polymers of D-glucose, were fast and readily fermentable energy sources with application in post hatchery and transition diets (Batal & Parsons, 2004; Noy *et al*., 2001). It was shown that this product could be used as an energy supplement, in electrolyte formulations, to support animals with impaired gastrointestinal functions (McCorry, 2007), in the support for animals when the animals had to be vaccinated and when faced with any form of stress and the replacement of maize and other cereals in the diet of broilers (Rutz *et al*., 2007).

A benefit of these products as post hatchery supplements in pre-starter diets was that the animal required the minimal gastrointestinal tract function for the digestion and absorption of digesta. It was believed that these products may have served as ideal energy sources for broiler chicks at the pre-initial feeding phase. The products could therefore be optimally digested in low digestive efficient animals such as newly hatched broiler chicks. There was also low fermentation involved in the digestive process due to the high digestibility and therefore less diarrhoea resulted (Vieira & Pophal, 2000). The inclusion of these products in pre-starter diets resulted in lower osmotic pressure and therefore lowered osmotic diarrhoea. These products resulted in the development of lower osmotic pressure compared to sucrose and glucose. The products also consisted of the ability to replace the glycogen stores very fast in the period post hatch and had a sparing effect on amino acids in the sense of when there was a deficiency of glucose; the animal would have used the free amino acids in the amino acid pool and would have deaminated these products and would therefore have used the carbon backbone for glucose metabolism (Macleod, 1997). Some raw materials such as soy protein which contain compounds such as non-starch polysaccharides (NSP) and oligosaccharides such as α-galactosides cannot be digested by the enzymes present in the digestive tracts of poultry, but there are other oligosaccharide groups present in this feed that can be beneficial. For this reason these compounds may result in increased hydrogen production and impaired nutrient utilization, increased osmotic pressure and may lead to diarrhoea (Kocher *et al*., 2000). Therefore the product tested was believed to have beneficial effects on the performance of the broilers.

Other features and benefits of these products were that the Soy protein from High Protein (HP) concentrates and isolates were high in protein density and low in anti-nutrients. These components were readily digested and served as bio-available protein sources (Lemme *et al*., 2004). The products further acted as pelleting agents thereby improving pellet quality and may therefore have served as functional ingredients for the chicks post hatch where it may have been used in paste- and gel formations. The products had a semi-sweet taste which improved palatability. As already mentioned the product was free flowing which made it easy to use and made the handling in mixers and augers better (Thomas *et al.*, 1996).

Carbohydrates present in the raw materials include mannan-oligosaccharides, dextrose, raffinose and stachyose. Mannan-oligosaccharides are indigestible (Awad *et al*., 2008), but serve as a pre-biotic and have been shown to be beneficial for the growth of *Bifidobacterium spp*. (Iji *et al*., 2001) and can thus be utilized as a replacement for antibiotic growth promoters (Patterson & Burkholder, 2003). Dextrose is a readily digestible sugar (Moran, 1990) which increases the energy concentration of the diet (Batal & Parsons, 2004). Raffinose and stachyose, however, have negative effects (Leske *et al*., 1995). These carbohydrates are known to depress feed intake and subsequently weight gain (Leske *et al.*, 1995) due their anti-nutritive action (Carré *et al*., 1990).

Prime gluten was included in the raw materials 0882 and 3040 and the maximum inclusion of this raw material was 7.5% and 15%, respectively. A small fraction or the starch component of corn gluten meal or corn gluten feed mainly consist of glucose and glycerol and also contain other sugar compounds such as arabinose, xylose, mannose and galactose (Wu, 1996). These oligosaccharide compounds present in these products may serve as nutrients or as anti-nutrients. They may serve as anti-nutrients if the oligosaccharides are at elevated levels (more than 5% of the diet (Waldroup *et al*., 2002) and will then result in increased fluid retention, hydrogen production and diarrhoea (Choct & Kocher, 2000). In the study conducted by Longo *et al*. (2007), different carbohydrate and protein sources fed in the pre-starter phase were evaluated and tested what affects these feed sources had on the production performance of broiler chicks. It was found that chicks that were fed the sucrose diet had higher weight gain than chicks that received the corn gluten meal diets. The chicks that were fed the corn gluten meal diet had a detrimental effect on the feed intake of the birds (Longo *et al*., 2003). Therefore, by including the levels of prime gluten above 5% in the diets; may result in the decrease of the productive performance of the broiler chicks.

The aim of this study was therefore to compare production parameters of broilers when fed diets containing increasing amounts of three different test materials.

3.3 Materials and methods

Birds and housing

For the purpose of this trial 585 vaccinated day- old Cobb 500 chicks were sourced from a commercial hatchery and placed in a temperature controlled, mechanically ventilated bioassay unit. The unit consisted of three stacked double sided cage systems, four tiers high and six cages wide per side, a side represented a block. For the purpose of the study five chicks were placed in each of one hundred and seventeen of the pens that were randomly allocated within blocks to 13 different treatments. The trial design allowed for nine repetitions per treatment.

Feed and water were provided *ad libitum* from day old. The temperature and lighting in the house were provided to comply with the recommendations of the primary breeder. The birds were maintained in this unit until 14 days of age. At the end of the 14 day period the chicks were moved to an environmentally controlled house consisting of 117 wire cages, each equipped with a tube feeder and water nipple. Cage allocation was maintained. Chicks were grown in this facility until slaughter at 35 days of age.

Treatment and diets

Treatments were according to diet. Four isonitrogenous and isoenergetic diets were formulated to contain either 0% (control and dilution diet) or 25% of one of the three raw materials (summit diets).

The summit and dilution diets were then blended in a ratio of 100:0; 66:34; 50:50; 34:66 and 0:100 (control diet). The trial diets were supplied for a period of seven days, where after all the birds received the control diet for another seven days. This method allowed for regression analysis and of the data between the 0 and 25% inclusion level.

Table 3.2 Ingredient (%) and nutrient composition of the pre-starter diets

		Broiler Feeds		
	Dilution (Control)	Summit 0882	Summit 1570	Summit 3040
Ingredient (%)	**Ration 1**	**Ration 2**	**Ration 3**	**Ration 4**
Summit 0882		25.00		
Summit 1570			25.00	
Summit 3040				25.00
Vit+min premix	0.15	0.15	0.15	0.15
Maize	61.59	41.04	44.77	52.42
Soybean full fat	16.85	1.94	2.50	9.54
Soybean 46	8.87	18.82	14.86	1.06
Fish meal 65	9.79	9.90	10.00	8.71
L-lysine HCL	0.27	0.30	0.22	0.36
DL methionine	0.27	0.30	0.30	0.26
L-threonine	0.14	0.16	0.16	
Limestone	0.80	1.08	0.81	11.91
Salt			0.02	
Monocalcium phosphate	0.84	0.88	0.81	8.43
Sodium bicarbonate	0.43	0.43	0.40	4.67
Total	100.00	100.00	100.00	100.00
AMEn chick	12.50	12.53	12.50	13.00
Crude Protein%	22.54	21.99	22.54	22.54
Dry Matter%	88.22	90.20	89.93	89.93
Lysine%	1.52	1.51	1.51	1.49
Methionine%	0.69	0.71	0.71	0.69
Crude fat%	6.57	4.21	3.56	5.02
Calcium%	0.90	1.00	0.90	1.00

Avail. Phosphorus%	0.50	0.50	0.50	0.50
Phosphorus%	0.78	0.74	0.74	0.74

Table 3.2 shows the four different pre-starter diets that were supplied to the chicks from 0 to seven days of age. The diets were formulated using Winfeed Version 2 by EFG (software). Feed was supplied in such a manner as to allow an average intake of 300g pre-starter, 600g starter, 1200g grower and 1200g finisher per bird with a total average intake of 3200g per bird which is in compliance with the recommendations of the primary breeder.

Table 3.3 shows the nutritional composition of the three different raw materials that were tested. Recommendations from the supplier states that the main use of the raw material 0882 is in pre-starter and starter diets for broilers. It serves as a protein and energy source. It also contains maize glucose solids, soya protein and prime gluten included at a maximum of 7.5%.

Table 3.3 Product specification: Typical analysis (as is) for the different raw materials (Tongaat Hullet).

Nutrient/ Property	Raw material 0882	Raw material 1570	Raw material 3040
Dry matter, g/kg	948	944	933
ME, MJ/kg	16.31	15.04	14.00
AME, MJ/kg	16.31	15.04	14.00
TME, MJ/kg	16.63	15.45	14.43
Crude protein, g/kg	80	150	313
Lysine, g/kg	3.12	9.37	15.4
Methionine, g/kg	1.46	1.97	5
Crude fat, g/kg	4.06	6.75	15.04
Crude fibre, g/kg	4.13	9.45	17.69
NDF, g/kg	14.93	16.46	56.84
Total ash, g/kg	5.95	18.36	29.84
Carbohydrate, g/kg	854	759	557
Available Lysine, g/kg	2.85	8.61	14.13
Available Methionine g/kg	1.39	1.8	4.67
Available TSAA, g/kg	2.57	3.57	8.87
Available Isoleucine, g/kg	3.23	6.64	13.13
Available Tryptophan, g/kg	0.67	1.8	3.1
Available Threonine, g/kg	2.65	5.19	10.55
Available Arginine, g/kg	3.99	10.49	18.32
Calcium, g/kg	0.2	0.68	1.07
Total Phosphorus, g/kg	0.87	2.16	3.89
Available Phosphorus, g/kg	0.41	1.08	1.88
Sodium, g/kg	0.05	0.11	0.2
Chloride, g/kg	0.03	0	0.07
Potassium, g/kg	1.67	6.21	9.35
Linoleic Acid, g/kg	1.15	1.51	3.89
Lactose equivalent, %	82	70	40
Dextrose equivalent	24	20	13

Table 3.4 shows the relationships to which the test raw materials were formulated.

Table 3.4 Treatments allocated in the pre-starter and relationships to which they were formulated

Treatment	Dilution diet control (%)	Summit diet 0882 (%)	Summit diet 1570 (%)	Summit diet 3040 (%)
1	0	100		
2	0		100	
3	0			100
4	34	66		
5	34		66	
6	34			66
7	50	50		
8	50		50	
9	50			50
10	66	34		
11	66		34	
12	66			34
13	0			

Table 3.5 shows the ingredient and calculated nutrient composition of diets formulated for the different growth phases until slaughter at 35 days. The diets were formulated using Winfeed Version 2 by EFG software. These diets were formulated according to the nutritional specifications given by the primary breeder. After the first seven day period where the test pre-starter diets were fed, the starter diet was given. Each chick was allocated 300g of the pre-starter diet (approximately eight days), 600g of the starter (approximately six days) 1200g grower (approximately 13 days) and 1200g finisher (approximately eight days).

Table 3.5 Ingredient (%) and calculated nutrient composition of experimental diets

	Starter	Grower	Finisher
Ingredients (%)	**Ration 1**	**Ration 2**	**Ration 3**
Maize	61.59	65.76	59.66
Fish meal 65	9.79	10.00	
Soybean full fat	16.85	18.84	36.13
Soybean 46	8.87	3.00	
L-lysine HCL	0.27		0.20
DL methionine	0.27	0.21	0.31
L-threonine	0.14	0.05	0.11
Vit+min premix	0.15	0.15	0.15
Limestone	0.80	1.01	1.58
Salt		0.05	0.25
Monocalcium phosphate	0.84	0.75	1.45
Sodium bicarbonate	0.43	0.17	0.17
Totals	100.00	100.00	100.00
Calculated nutrient composition			
AMEn chick	12.50	12.90	13.00
Crude Protein%	22.54	20.73	18.97
Dry Matter%	88.22	88.03	88.20
Lysine%	1.52	1.21	1.17
Methionine%	0.69	0.62	0.59
Crude fat%	6.57	7.03	8.95
Calcium%	0.90	0.96	0.92
Avail. Phosphorus%	0.50	0.48	0.45

Measurements

The body weight of all the birds per pen were measured at placement (day 0) and every second day thereafter until 14 days of age. After the 14 day period the birds were weighed weekly until they were slaughtered at 35 days of age. The daily feed intake was measured by weighing the initial amount of feed that was offered to the birds and the feed that remained in the feeders every morning at 8:00. Mortalities and morbidities were recorded twice daily.

Feed conversion per raw material pre-treatment was calculated while growth rate up to 35 days of age was compared within initial treatment groups. This will therefore allow for “carry over” effects of the use of the different raw materials in the pre-starter to slaughter day. Cage 6, 17, 89, 104 and 82 were left out of the calculation of the data due to chicks that escaped out of the cages.

ADG was estimated using linear regression and is demonstrated by the following equation:

Equation 1 $y = mx + c$

Where “y” = live weight per chick against the age of the chick

“m” = ADG

“c” = y-intercept

The FCR was obtained by the following equation:

Equation 2 Cumulative feed intake (g)/ total weight gain (g)

The EPEF was calculated by the following equation (Butcher & Nilipour, 2002):

Equation 3 EPEF = Liveability% x Live weight (kg)/ age (days) x FCR x 100

Where: EPEF = European production efficiency factor

FCR = feed conversion ratio (feed per kilogram gain)

Liveability% = percentage of number of birds remaining at the end of the trial

The PER was obtained by the following equation (Buamah & Singsen, 1975):

Equation 4 PER = Live weight gain (g)/ protein intake (g)

Where: Protein intake = feed intake (g) multiplied by protein % in diets. The results so obtained were then submitted for statistical analysis.

Statistical analysis

Data were statistically analysed. Regression analysis was used to determine the influence of the inclusion level and analysis of variance was used to establish differences in this trial. Feed intake per chick was determined on each weigh day in the first two weeks and once a week thereafter until 35 days of age and the cumulative feed intake per chick was also determined. Live weight per chick was determined on each weighing day until day 35. The feed conversion ratios (FCR) were calculated by using the feed intake and live weight gain per chick. The FCR per raw material pre-treatment as well as the average daily gain (ADG) up until 35 days were calculated and compared with initial treatment groups. Therefore if there were any “carry over” effects of the different raw materials in the pre-starter phase, it could be determined. Other production parameters were also estimated such as European production efficiency ratio (EPEF) average daily gain (ADG) liveability (%) and the protein efficiency ratio (PER).

The data were analysed by means of the SAS enterprise Guide 4 program and STATISTICA (data analysis software system), Version 9, by StatSoft Inc. (2009). Statistical analysis of the data required the linear regression models and analysis of variance was used to determine the differences between the treatments by. A test of hypothesis was done to determine whether the increasing inclusion of test material in the pre-starter diet of broiler chicks had an effect on production performance. The H_0 hypothesis was the test where an increasing level of experimental product in pre-starter diets given to broiler chicks had no effect on their production performance and H_1 hypothesis was the test where an increasing level of experimental products in pre-starter diets of broiler chicks had an effect on their production performance.

3.4 Results and discussion

The features and benefits of the product tested is that it can be used as an energy- or protein supplement, it is highly digestible, improves pelletization, is free flowing and may improve palatability of the diet. It is suggested to be included up to 20% into starter feeds (Tongaat Hulett, product specification). The main use of the raw material 1570 is to be used in pre-starter and starter diets for broiler chicks. It may also serve as a protein and energy source. This product also contains corn glucose solids and soy protein, but in contrast to the raw material 0882, this raw material does not contain prime gluten. The features and benefits of this product is the same as for raw material 0882 and may serve as an energy- or protein supplement, it is also highly digestible, free flowing and improves the palatability of the diets of broilers. This product also differs from raw material 0882 and 3040 in the sense that it has good solubility and dispersibility meaning that it is easy to re-hydrate a formula. It is also suggested that this product may be included up to 20% into starter feeds (Tongaat Hulett, product specification). The main uses of raw material 3040 are the same as for the other two products. The ingredients are also the same as for the raw material 1570 except for prime gluten, max 15%. The features and benefits are also the same as well as the suggested inclusion level (Tongaat Hulett, product specification).

ranging from 0.93 to 0.99.

Table 3.6 gives the linear fitted models for the 13 treatments for the ADG. There were no significant differences ($P>0.05$) between the treatments for the ADG for the period of 35 days. The R-Square is the percentage of variation of the y parameter that is explained by the regression function or model. The R-Square for each treatment was calculated to be very near one. The linear models therefore fitted well with R^2 ranging from 0.93 to 0.99.

Table 3.6 ADGs g/day predicted from fitted models (35 days)

Treatment	ADG	Pr > |t|	R^2
1	52.25 [a]	1.0000	0.95
2	54.47 [a]	1.0000	0.98
3	53.30[a]	1.0000	0.95
4	52.78[a]	1.0000	0.98
5	51.60[a]	1.0000	0.93
6	53.17[a]	1.0000	0.95
7	52.99[a]	1.0000	0.98
8	51.32[a]	1.0000	0.99
9	53.40[a]	1.0000	0.99
10	54.37[a]	1.0000	0.96
11	52.64[a]	1.0000	0.99
12	52.41[a]	1.0000	0.98
13	54.55[a]	1.0000	0.97

([a]) Values with same superscripts do not differ significantly ($p>0.05$)

The ADGs for the chicks were calculated for the first seven days where the pre-starter treatment diets were fed to determine if there were any significant differences between the treatments. The following table gives the linear fitted models including p-values and R^2 for the 13 treatments for the ADG for the pre-starter period.

Table 3.7 ADGs g/day predicted from fitted models (seven days)

Treatment	ADG	Pr > |t|	R^2
1	14.84[a]	1.0000	0.90
2	15.57[a]	1.0000	0.92
3	14.05[a]	1.0000	0.89
4	15.49[a]	1.0000	0.94
5	14.71[a]	1.0000	0.87
6	14.78[a]	1.0000	0.90
7	16.02[a]	1.0000	0.94
8	15.43[a]	1.0000	0.95
9	15.27[a]	1.0000	0.95
10	15.13[a]	1.0000	0.92
11	16.29[a]	1.0000	0.95
12	15.54[a]	1.0000	0.94
13	15.70[a]	1.0000	0.93

([a]) Results with same superscripts within columns do not differ significantly (P>0.05)

From

Table 3.7 it could be seen that there were also no significant differences (P>0.05) between the 13 treatments for the ADG for the pre-starter phase. The R-Square for each treatment was calculated to be near one. The average weight at the end of the trial period per bird was 1.8kg. The linear models therefore fitted well with R^2 ranging from 0.93 to 0.99. Similar results were found in the study conducted by Rutz *et al*. (2007), where a dietary nucleotide (which contains a pentose sugar) product which contains some yeast extract (Nupro) was given in the pre-starter diet to test if this product in the pre-starter phase had any significant effect on the performance of the chicks. No significant differences (P>0.05) were found in the weight gain of the broiler chicks.

Also, in the study conducted by Longo *et al*. (2007), similar results could be found, where the performance of chicks from one to seven days (pre-starter) of age was measured. These diets had different protein and carbohydrate sources. The chicks in the pre-starter phase did not show any significant difference (P>0.05) for live weight gain between the alternative pre-starter diets and the control diet. But the difference with the study conducted by Longo et al. (2007) was that the chicks that received the sucrose sugar in the diet showed improved live weights and growth rates in the pre-starter phase (one to seven days) compared to the chicks that were fed maize gluten meal, blood plasma and the maize gluten plus sucrose mixture. The increase in weight gain was suspected to be as a result of greater feed intake and the greater feed intake could have been due to the fact the taste of the feed (palatability) was better due to the sucrose in the diet.

Some of the positive results obtained in the study done by Longo *et al*. (2007), were consistent with the results obtained by a study conducted by Longo *et al*. (2005) where different carbohydrate sources were added such as glucose, and sucrose, corn starch or cassava starch in the pre-starter diet and were found to be beneficial for the growth performance of the chicks during this phase. In contrast with Longo *et al*. (2003) found that substances such as blood plasma, isolated soybean protein, dried whole eggs, or maize gluten meal that were added to pre-starter diets did not show any significant effects on the feed intake but it has been shown to increase live weight gain of the broiler chicks. However, as the chicks went through the different phases through to the finisher (35 days of age) there were no significant differences (P>0.05) between the treatments for live weight gain for the chicks in the trial (Saki, 2005; Leeson, 2008; Moran, 1990).

In the results obtained in the present study, there were no significant differences (P>0.05) found between the 13 treatments for weekly feed intake and cumulative feed intake for the 35 day period. The cumulative feed intake per chick for the growth period was found to be 3000grams or more. Similar results were found in the study conducted by Biggs *et al*., (2007) and Shelton *et al*. (2003).

These results are the opposite of what was found in the results in the study conducted by Rutz *et al*. (2007), where the effect of dietary Nupro which is a dietary nucleotide (containing pentose sugar) was tested on the performance of broiler chicks. It was shown that the birds that were fed the dietary Nupro in the pre-starter phase, had higher feed intake than the control birds which showed that the birds had an improved performance with the dietary Nupro included in the pre-starter phase. Similar results were found in the study conducted by Leeson (2008).

Table 3.8 shows the summary of all the data obtained in the bioassay trial. From this summary it is clear that there were no significant differences (P>0.05) between the treatments for ADG, feed intake, cumulative feed intake, FCR, EPEF and PER.

Table 3.8 Summary of all data obtained at 35 days with means and standard deviations

	ADG g/day	Live weight (g)	Cumulative feed intake (g)	FCR	EPEF	PER
Treatment						
1	52[a] ±2.7	1837.8[a] ±97	3198[a] ±239	1.7[a] ±0.02	314.3[a] ±44	0.22[a] ±0.1
2	53[a] ±2.9	1888[a] ±102	3316[a] ±191	1.7[a] ±0.07	311.8 [a] ±17	0.21[a] ±0.1
3	52[a] ±7.2	1835[a] ±252	3303[a] ±160	1.7[a] ±0.08	298.2[a] ±65	0.21[a] ±0.1
4	52[a] ±6.0	1831[a] ±211	3302[a] ±164	1.7[a] ±0.11	298.3[a] ±75	0.21[a] ±0.1
5	53[a] ±5.4	1862[a] ±192	3210[a] ±390	1.7[a] ±0.17	302.3[a] ±65	0.21[a] ±0.1
6	54[a] ±1.8	1893.7[a] ±66	3319[a] ±128	1.7[a] ±0.03	325.8[a] ±17	0.22[a] ±0.2
7	55[a] ±2.5	1951.9[a] ±89	3249[a] ±82	1.7[a] ±0.02	324.1[a] ±23	0.22[a] ±0.1
8	55[a] ±5.1	1952[a] ±181	3210[a] ±163	1.6[a] ±0.03	329.2[a] ±22	0.21[a] ±0.1
9	52[a] ±3.3	1832[a] ±118	3259[a] ±208	1.7[a] ±0.11	294.1[a] ±51	0.21[a] ±0.1
10	55[a] ±3.6	1932[a] ±128	3344[a] ±150	1.7[a] ±0.02	315.6[a] ±26	0.21[a] ±0.1
11	56[a] ±2.9	1966[a] ±104	3284[a] ±160	1.6[a] ±0.03	326.2[a] ±41	0.23[a] ±0.1
12	55[a] ±2.9	1940[a] ±102	3242[a] ±286	1.7[a] ±0.03	329.5[a] ±20	0.23[a] ±0.1
13	55[a] ±4.0	1927[a] ±142	3330[a] ±110	1.7[a] ±0.15	315.6[a] ±57	0.22[a] ±0.2

([a]) Results within columns with the same superscripts does not differ significantly (P>0.05)

No significant differences (P>0.05) were found between the treatments for the FCR over the 35 day trial period. The average FCR found in this trial was 1.7, which is in range with what could be obtained in commercial broiler production. Similar results were reported by Saki (2005) and Meng & Slominski (2005).

The results obtained in the study conducted by Saki (2005), were consistent with the results obtained in the study conducted by Longo *et al*. (2007), where the effects of different carbohydrate and protein sources and their mixtures, included in the pre-starter diets of broiler chicks were evaluated on the performance of the chicks. Chicks in the pre-starter phase also did not show any significant differences (P>0.05) for the feed: gain ratio between alternative pre-starter diets and the control group, but there were significant differences (P<0.05) between the alternative pre-starter diets in the study of Longo *et al*. (2007). Further, the chicks that were fed the pre-starter in the study of Longo *et al*. (2007) that contained cassava starch had better FCRs than those that received maize gluten meal plus sucrose or blood plasma plus sucrose mixture.

Other production parameters such as the EPEF were determined in this trial. There were no significant differences (p>0.05) between the 13 treatments for the EPEF. As already mentioned this parameter takes the liveability%, age, FCR and live weight into consideration. The EPEF obtained in this study was above 300 and is in range with the normal specifications of commercial broiler production.

In the study conducted by Awad *et al*. (2008), the effect of a certain prebiotic and sugars such as oligosaccharides on the production performance of broiler chicks was tested. The results obtained for the EPEF showed a significant increase in the EPEF for the diets fed to broilers that contained the prebiotic and oligosaccharides in comparison to the control diet. The results of Awad *et al*. (2008) were in contrast to the results obtained in the current study. The results obtained by Awad *et al*. (2008), were consistent with the results obtained by Nollet *et al*. (undated), where the addition of mannan oligosaccharides to starter diets of broiler chicks, resulted in the significant increase of the EPEF.

Analysis of variance was done for this parameter to determine if there were any significant differences between the treatments for the PER. It was found that there were no significant differences (P>0.05) between the treatments for the PER. In contrast to the results obtained, the study conducted by Mohan *et al*. (1996), showed a significant increase in the PER with the addition of pre-biotics supplemented to the diets of broilers.

The fact that there were no significant differences found between the treatments for all the production parameters that were evaluated, could be due to the fact that the experimental units were adequately rested which lowered the pathogenic load of the units and therefore the chicks did not face any challenges. The treatment pre-starter feeds that contained the test products showed the same results for the production parameters as the control treatment. The experimental products did not pose any further beneficial properties other than nutritional values. Therefore it could be concluded that the chicks that were fed the pre-starter treatments that contained the test material performed just as well as the chicks that were fed the control treatment. The diets were balanced so one would expect similar performance between the treatment diets and the control and therefore these products could also be incorporated into broiler diets with the same positive results as the usual pre-starter diet. The H_0 hypothesis can therefore be accepted where the increasing level of experimental products showed no influence on performance.

3.5 Conclusion

No significant differences (P>0.05) were found between the treatments for any of the production parameters evaluated in this trial. There were no significant differences (P>0.05) for the ADG at day seven or day 35 for the 13 treatments. There were also no significant differences (P>0.05) between the treatments for total live weight, weekly feed intake, cumulative feed intake, FCR and EPEF and PER. An average FCR of 1.7 and an average EPEF of more than 300 was obtained in this trial. It could furthermore be concluded that the inclusion of the different raw materials (0882, 1570 and 3040) at increasing levels in the pre-starter diet of broiler chicks, had no significant effects on the production performance of the birds and therefore had no “carry-over” effects of these products to the following growth phases. The fact that the test pre-starter treatments did not differ significantly from the control pre-starter treatment, could be due to the fact that the chicks did not face any challenges. The chicks that received the test treatments performed the same as the chicks that received the control treatment; therefore these products could also be incorporated into broiler diets with the same positive effects on broiler performance as the normal pre-starter diets that are fed to broilers. The H_0 hypothesis of no influence of increasing level of test raw material in pre-starter diets of broiler chicks can therefore be accepted. The H_0 hypothesis is therefore accepted.

3.6 References

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CHAPTER 4

COMMERCIAL BROILER GROWTH TRIAL TO DETERMINE THE EFFECT OF THE CONTRIBUTION OF DIFFERENT SUGARS TO THE ENERGY CONTENT OF PRE-STARTER FEED ON PRODUCTION PARAMETERS OF BROILER CHICKS

4.1 Abstract

Three thousand six hundred day-old Cobb broiler chicks were placed in seven treatments with eight repetitions of 60 chicks per pen. Treatments were according to the contribution of simple sugars to diet metabolisable energy (ME). No significant differences were observed for the average daily gain (ADG) live weight, weekly feed intake, cumulative feed intake, feed conversion ratio (FCR) European production efficiency factor (EPEF) or protein efficiency ratio (PER) at 33 days. There were also no significant differences for the average daily gain (ADG) at seven days of age. The performance of all treatments was according to the guidelines of the primary breeder. The results of this study have therefore shown that the contribution of the sugar to the energy of the different raw materials had no significant effect on the production parameters of the broiler chicks from hatch until slaughter at day 33.

Keywords: pre-starter, soya, sugars, metabolisable energy, dextrose

4.2 Introduction

Three different products (raw material 0882, 1570 and 3040) that were tested were protein and energy sources which may be included in pre-starter and starter diets of broiler chicks. These products contained glucose and glucose derivatives, corn glucose solids, soy protein, and prime gluten. The products served as protein and energy supplements, which were highly digestible and fermentable (Rutz *et al*., 2007). The products also improved pelletization by acting as binders (Thomas *et al.*, 1998); they were also free flowing and improved the palatability due to the semi-sweet taste of the products included (Longo *et al*., 2007). These products contained significant amounts of dextrose and lactose, which contributed to the metabolisable energy (ME) of the products. It was therefore believed that by the inclusion of these products in the pre-starter diets for broiler chicks, it may exert positive effects on the production performance of the birds in the following growth phases.

The features and benefits of these products that were tested were discussed in the previous chapter. The contribution of the sugar of the different products (0882, 1570 and 3040) to the energy of the pre-starter diets was tested in this trial. In the study conducted by Longo *et al*. (2007) the effect of different carbohydrate and protein sources fed in the pre-starter phase on the performance of the chicks were tested. It was shown that the chicks that received the diets which contained sucrose in the pre-starter phase improved live weight gains when compared to chicks that received the other diets. The feed intakes of the chicks were also improved by the inclusion of sucrose in the diet. The same results were obtained in the study conducted by Longo *et al*. (2005), where the addition of sugars such as glucose and sucrose to the pre-starter diets of the birds also resulted in the improved performance of the birds. These results were consistent with the findings of Orban *et al*. (1997), where the effect of feeding sucrose thermal oligosaccharide caramel in broiler diets was tested on the performance of the chicks. It was found that these sugar compounds resulted in increased live weight gains, feed intakes and feed conversions when compared to control diets.

From the bioassay trial, discussed in chapter 3, it was concluded that there were no significant differences (P>0.05) between the treatments allocated in the trial for any of the production parameters. These results therefore indicated that there were no significant differences (P>0.05) between the treatments for the average daily gain (ADG), live weight gain of the chicks, weekly feed intake, cumulative feed intake, feed conversion ratio (FCR) European production efficiency ratio (EPEF) and protein efficiency ratio (PER).

The aim of this experiment was to evaluate the contribution of the sugar to the ME present in the different raw materials tested in a broiler commercial production environment and what effect it had on the production performance.

4.3 Materials and methods

Birds and housing

For the purpose of this trial 3600 vaccinated day old Cobb 500 broiler chicks were bought from a commercial hatchery and placed in a temperature controlled, mechanically ventilated commercial type broiler unit. This unit was subdivided into 64 pens in four rows (16 per row) of which 60 were used each containing 60 chicks. Each row represented a block. The treatments were randomly allocated within blocks. Each pen was equipped with a bell drinker and four tube feeders. There were seven treatments in this trial, which consisted of a control treatment and six test treatments. All the treatments were repeated eight times. Feed and water were provided *ad libitum* from the day of placement. The temperature and lighting program was provided according to the recommendations of the primary breeder. The birds were maintained in this unit until 33 days of age.

Treatments and diets

From the results obtained from the bioassay trial it was concluded that there were no significant differences (p>0.05) between the treatments for any of the production parameters and that inclusion level had no effect on production parameters. It was therefore decided to compare the contribution of sugar to the ME of the raw material products in this commercial grower trial. The amount of sugar that contributed to the apparent metabolisable energy (AME) of the products 0882, 1570 and 3040, were specified to be 89.06%, 81.68% and 55.18%, respectively. Therefore, the total contributions of the various sugars to the AME of the raw materials were 14.53%, 12.28% and 7.73%, respectively. The inclusion levels of 12- and 18% multiplied with the AME contribution of the sugar of the raw materials gave the various inclusion levels of 10.33% and 15.99% (raw material 0882) 12.21% and 18.32% (raw material 1570) and 19.42% and 29.13% (raw material 3040). Treatment 1 served as the control. Treatment 2 and 3 contained the different inclusion levels of raw material 0882. Treatment 4 and 5 contained the different inclusion levels of raw material 1570 and treatments 6 and 7 contained the different inclusion levels of raw material 3040.

The pre-starter test feed were formulated by using the Winfeed program and the pre-starter test feeds were formulated according to the nutritional specifications given by Cobb.

Table 4.9 represents the seven different pre-starter treatments that were given to the chicks until an average consumption of 300g per bird was attained (approximately at day seven). Each chick was allocated 300g of the pre-starter diet (approximately seven days) 600g of the starter diet (approximately 13 days) 1200g grower (approximately 9 days) and approximately 600g finisher (approximately 4 days).

Table 4.9 Ingredient (%) and calculated nutrient composition of the pre-starter diets

	Broiler feeds						
	Control	**0882**		**1570**		**3040**	
		12%	**18%**	**12%**	**18%**	**12%**	**18%**
Ingredient (%)	**Ration 1**	**Ration 2**	**Ration 3**	**Ration 4**	**Ration 5**	**Ration 6**	**Ration 7**
Product 0882		10.33	15.49				
Product 1570				12.21	18.32		
Product 3040						19.42	29.13
Vit+min premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Maize	61.59	53.34	49.22	54.31	50.56	57.52	47.38
Soybean full fat	16.85	10.18	6.85	8.95	5.20	1.78	9.15
Soybean 46	8.87	13.39	15.65	11.62	12.98	8.94	7.65
Fishmeal 65	9.79	9.79	9.79	10.00	10.00	9.48	2.15
L-Lysine HCL	0.27	0.28	0.29	0.26	0.26	0.35	0.45
DLmethionine	0.27	0.28	0.28	0.29	0.30	0.25	0.31
L-threonine	0.14	0.15	0.15	0.16	0.17		
Limestone	0.80	0.81	0.81	0.81	0.82	0.87	1.61
Salt					0.01		0.06
Monocalcium phosphate	0.84	0.86	0.87	0.82	0.82	0.80	1.37
Sodium bicarbonate	0.43	0.43	0.43	0.42	0.42	0.44	0.59
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutrient composition							
AMEnchick MJ/	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Crude Protein %	22.54	22.31	22.19	22.26	22.11	22.47	22.29
Dry Matter %	88.22	89.02	89.42	89.03	89.43	89.00	89.72
Lysine %	1.52	1.51	1.51	1.51	1.51	1.50	1.48
Methionine %	0.69	0.70	0.70	0.70	0.71	0.68	0.68
Crude fat %	6.57	5.51	4.98	4.98	4.20	3.89	5.55
Calcium %	0.90	0.90	0.90	0.90	0.90	0.90	1.00
Avail. Phosphorus%	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Error! Not a valid bookmark self-reference. shows the different rations for the different phases that were given to the chicks from day seven until day 33 (from the second week until the last week of the growth trial). The table gives the formulations for the starter, grower and finisher. The nutrient composition of the different raw materials that were tested was given in the previous chapter. .

Table 4.10 Ingredient (%) and calculated nutrient composition of experimental diets

	Starter	Grower	Finisher
Ingredients (%)	**Ration 1**	**Ration 2**	**Ration 3**
Maize	60.16	50.35	59.66
Fish meal 65	10.00		
Soybean full fat	17.84	42.36	36.13
Soybean 46	9.38	3.00	
L-lysine HCL	0.02		0.20
DL methionine	0.21	0.27	0.31
L-threonine	0.03	0.02	0.11
Vit+min premix	0.15	0.15	0.15
Limestone	1.06	1.59	1.58
Salt	0.04	0.29	0.25
Monocalcium phosphate	0.82	1.56	1.45
Sodium bicarbonate	0.28	0.15	0.17
Totals	100.00	100.00	100.00
Calculated nutrient composition			
AMEn chick	12.50	12.90	13.00
Crude Protein%	22.83	20.73	18.97
Dry Matter%	88.25	88.03	88.20
Lysine%	1.37	1.21	1.17
Methionine%	0.65	0.62	0.59
Crude fat%	6.37	7.03	8.95
Calcium%	1.00	0.96	0.92
Avail. Phosphorus%	0.50	0.48	0.45

Measurements and statistical analysis

The body weight of all the birds in a pen were measured at the day of placement (day 0) and weekly thereafter. Feed intake was measured weekly and this was done by weighing the initial amount of feed offered to the chicks and subtracting the feed remaining in the feeders on the day of weighing. Mortalities and morbidities were recorded twice daily. From this data the ADG, live weight, the feed intake, (cumulative and weekly) the FCR, EPEF, PER and mortality (%) or liveability (%) were calculated. The FCR as well as the ADG up until 33 days were calculated as mentioned and compared with the initial treatment groups. If there were any "carry over" effects from the different raw materials in the pre-starter phase, it could be determined. All the data was statistically analysed by means of SAS Enterprise Guide 4 and STATISTICA (data analysis software system), Version 9, by StatSoft Inc. (2009).

Regression analysis was used to determine the effect of the inclusion level of the sugar and the analysis of variance was used to determine the statistical significance of the differences between results in the commercial trial. A test of hypothesis was done to determine whether the contribution of sugar to the ME value of the test material in the pre-starter diet of broiler chicks had an effect on production performance. The H_0 hypothesis was the test where the contribution of sugar to the ME of the experimental products in pre-starter diets given to broiler chicks had no effect on their production performance and H_1 hypothesis was the test where the contribution of sugar to the ME of the experimental products in pre-starter diets of broiler chicks had an effect on their production performance.

ADG was calculated by means of linear regressions and is demonstrated by the following equation:

Equation 5 $y = mx + c$

Where: "y" = live weight per chick against the age of the chick

"m" = ADG

"c" = y-intercept

The FCR was obtained by the following equation:

Equation 6 Cumulative feed intake (g)/ total weight gain (g)

The EPEF was calculated by using the following equation (Butcher & Nilipour, 2002):

Equation 7 EPEF = liveability% × live weight (kg) / age (d) × FCR × 100

Where: EPEF = European production efficiency factor

FCR = feed conversion ratio (feed per kilogram gain)

Liveability% = percentage of number of birds remaining at the end of the trial

The PER was calculated to determine the protein utilization of the birds. This ratio is also given by the following equation: (Buamah & Singsen, 1975)

Equation 8 PER = Live weight gain (g) / Protein intake (g)

Where: Protein intake = feed intake (g) multiplied by protein % in diets.

This parameter mainly determines the efficiency of protein utilization of the chicks.

4.4 Results and discussion

Table 4.11 shows that there were no significant differences (P>0.05) between the treatments for the ADG between the seven treatments during the 33 day period. The R-Square is the percentage of variation of the y parameter that is explained by the regression function or model. The R-Square for each treatment was also found to be near one. The linear models therefore fitted well with R^2 which was 0.94 for all the treatments.

Table 4.11 ADGs g/day predicted from fitted models (33 days)

Treatment	Model	Pr > |t|	R^2
1	57.78[a]	1.0000	0.94
2	58.17[a]	1.0000	0.94
3	57.60[a]	1.0000	0.94
4	57.43[a]	1.0000	0.94
5	57.72[a]	1.0000	0.94
6	57.30[a]	1.0000	0.94
7	57.49[a]	1.0000	0.94

([a]) Values with same superscripts within a column do not differ significantly (P>0.05)

The ADGs for the chicks were calculated for the first seven days where the pre-starter treatment diets were fed to determine if there were any significant differences between the treatments.

Table 4.12 ADGs g/day predicted from fitted models (seven days)

Treatment	Model	Pr > |t|	R^2
1	16.42[a]	1.0000	0.99
2	16.02[a]	1.0000	0.99
3	16.10[a]	1.0000	0.99
4	15.79[a]	1.0000	0.97
5	16.45[a]	1.0000	0.99
6	16.12[a]	1.0000	0.99
7	16.33[a]	1.0000	0.98

([a]) Values with same superscripts within a column do not differ significantly (P>0.05)

Table 4.12 shows that there were no significant differences (P>0.05) between the treatments for the ADG for the first seven days. The R-Square for each treatment was also concluded to be near one. The linear models therefore fitted well with R^2 ranging from 0.97 to 0.99. The total live weight gain at the end of the trial period was found to be 1.8kg average per bird.

In contrast to these results, the study conducted by Batal & Parsons (2004), showed that with the addition of dextrose sugar to the diets of broilers, it resulted in the increase in weight gain, compared to the diets that contained the high amylose starch which had the lowest weight gains. The dextrose diets also had higher growth performance and ME values when compared to diets which contained sucrose sugar. It was seen that the diets that contained dextrose also had the highest ME values when compared to the ME value for the high amylose starch diet which was found to be the lowest. The good growth performance of the chicks that were fed the dextrose diets, suggested that the rapidly and highly digestible carbohydrates may have benefited the young chicks. The decreased growth performance of the birds fed the sucrose diets suggested lower digestibility of this sugar compound compared to dextrose. It was also shown that chicks consumed diets that contained fructose did not affect the growth of the chicks compared with chicks that consumed glucose diets. In the study conducted by Dozier III *et al*. (2007), it was shown that by adding dextrose to a normal maize- soybean meal based diet, it increased the energy value to approximately 8.66 MJ/kg dry matter, compared to basal maize- soybean diets that had an energy value of approximately 7.22 MJ/kg dry matter. Therefore it could be seen that the contribution of certain sugars to the ME of the diets of broilers may have a positive influence on the growth performance of broiler chicks.

Table 4.13 gives the summary of all the data obtained in this trial with the means for every treatment and the standard deviations. The feed intake represents the weekly feed intake and the cumulative feed intake represents the feed intake over the 33 day period. From this table it was clear that there were no significant differences (P>0.05) between the seven treatments for the ADG, total live weight at 33 days, feed intake, cumulative feed intake, FCR, EPEF or PER.

Table 4.13 Summary of all the performance data in the different treatments with their means and standard deviations

	ADG g/day	**Live weight (g)**	**Cumulative feed intake (g)**	**FCR**	**EPEF**	**PER**
Treatmen						
1	57[a] ±2.6	1870[a]±85	2863[a] ±319	1.5[a] ±0.1	338[a] ±25	0.34[a] ±0.03
2	57[a] ±2.7	1889[a] ±89	2881[a] ±271	1.5[a] ±0.1	328[a] ±38	0.35[a] ±0.03
3	57[a] ±1.7	1866[a] ±55	2778[a] ±53	1.5[a] ±0.01	337[a] ±15	0.35[a] ±0.04
4	57[a] ±1.4	1866[a] ±48	2711[a] ±124	1.5[a] ±0.02	345[a] ±20	0.35[a] ±0.03
5	57[a] ±2.2	1868[a] ±73	2783[a] ±101	1.5[a] ±0.02	348[a] ±15	0.34[a] ±0.04
6	57[a] ±2.9	1858[a] ±95	2759[a] ±161	1.5[a] ±0.01	344[a] ±16	0.35[a] ±0.04
7	57[a] ±2.6	1867[a] ±84	2907[a] ±362	1.6[a] ±0.1	324[a] ±27	0.35[a] ±0.04

([a]) Results within columns with the same superscripts do not differ significantly (P>0.05)

The results for cumulative feed intake in the commercial trial were consistent with the findings of Biggs *et al*. (2007). Here, the addition of the two levels of sugars such as oligosaccharides had no significant effect on the feed intake, but the oligosaccharides included at 4g/kg had no negative effect on the ME of the diet and it was seen that with the addition of mannan- oligosaccharides and transgalactooligosaccharids it often led to an increase of the ME of the diet. The results of Biggs *et al*. (2007) were similar to the results found in the study conducted by Wang *et al.* (2009); Biggs *et al*. (2007) and Shelton *et al*. (2003).

The results obtained for the FCR in the current study showed that there were no significant differences (P>0.05) between the treatments for the 33 day trial period. The average FCR that was obtained for this commercial trial was 1.5, which is in range of commercial broiler production. These results were consistent with the findings of Saki (2005) and Meng & Slominski (2005).

In contrast to these results, the study conducted by Batal & Parsons (2004), showed that with the addition of sugars such as dextrose to pre-starter diets of broiler chicks, the FCR was significantly better in the first week compared to the chicks that consumed the sucrose diets and other carbohydrate sources. The ME value of the dextrose diets were also higher when compared to the ME value of the sucrose diets and the other carbohydrate sources. But at week three there were no more significant differences between the different carbohydrate treatments for the FCR of the broiler chicks. In effect the contribution of the sugars such as dextrose and sucrose to the ME of the diets, did not show any significant improvement of the FCR of the broilers and therefore the results so obtained by Batal & Parsons (2004), were consistent with the results found in the present grower trial.

The EPEF was calculated and it was found that there were no significant differences ($p>0.05$) between the seven treatments that were tested in the trial. This parameter mainly measured the liveability percentage of the chicks in the trial as mentioned. The EPEF was found to be near 300 and this is in range with commercial broiler production.

It is believed that the introduction of mannan- oligosaccharides obtained from *saccharomyces cerevisiae* in the starters of broilers would have positive effects on the production performance. These sugars limit the adhesion of pathogenic substances in the intestinal wall of the birds. The results obtained in the commercial grower trial were not consistent with the results obtained in the study conducted by Nollet *et al*. (undated), where the addition of the mannan-oligosaccharides to the starter diets, resulted in the increase of the EPEF. These results were consistent with the findings of Hooge (2004), where the addition of mannan-oligosaccharides to the diets of broilers significantly improved the EPEF. It was shown in the results found by Biggs *et al*. (2007), that the addition of mannan-oligosaccharides to the diets of broilers at 4g/kg, results in the increase of the ME of the diet and for this reason the EPEF could be increased in the results found by Hooge (2004) and Nollet *et al*. (undated).

An analysis of variance was done to determine if there were any significant differences between the treatments for the PER. It was found that there were no significant differences ($P>0.05$) between the treatments for the PER. In contrast to the findings of these results, the study conducted by Cheng *et al*. (1997), found that by increasing the energy levels of the diets, also significantly affected the PER in a positive way in terms of the protein utilization. These results were consistent with the findings of Mohan *et al*. (1996), where the results showed that the PER was significantly increased with the addition of probiotics to the diets of broilers. The probiotic and antibiotic supplementation, which contain certain oligosaccharides such as galacto oligosaccharides and fructo oligosaccharides, resulted in an increased AME of the diet and for this reason the PER could be significantly better.

There were no significant differences ($P>0.05$) found for any of the production parameters that were analysed. The diets were balanced so one would expect similar performance between the treatment diets and the control and therefore these products could also be incorporated into broiler diets with the same positive results as the usual pre-starter diet. But the inclusion of the experimental products in commercial broiler diets would depend on the price of these products. If the price of these products is sufficient for the producer or farmer it could be included with the same positive results of commercial pre-starter diets. The FCR of 1.5 obtained in the trial was in the normal ranges of commercial broiler production as well as a EPEF of more than 300 and this could have been due to the fact that the experimental units were adequately rested and the birds were not posed with any environmental challenges. The H_0 hypothesis of no effect of the contribution of the sugar to the ME of the experimental products on the production performance in broiler chicks can therefore be accepted.

4.5 Conclusion

There were no significant differences (P>0.05) between the treatments for the live weight, ADG, feed intake, cumulative feed intake, FCR, EPEF or PER for this trial. There were therefore no "carry-over" effects of this product in the pre-starter diet on the following growth phases. The average FCR that was obtained in this trial was 1.5 and an EPEF of more than 300. Furthermore, it be concluded that the contribution of the sugar to the ME in the raw materials (0882, 1570 and 3040) had no significant effects on the productive performance of the broiler chicks. Comparing the test treatments to the control treatment, no significant differences (P>0.05) were found. Therefore, the test material could be incorporated into commercial broiler pre-starter diets and it would have the same positive effects on the productive performance of the birds as the usual commercial pre-starter diet, only if the price of the experimental products is not too expensive for the producer or farmer. The H_0 hypothesis of no effect of the contribution of the sugar to the ME value of the experimental products can therefore be accepted.

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CHAPTER 5

GENERAL CONCLUSIONS

Conclusions

1. In the study where the increasing level of inclusion of the test material in pre-starter diets of broilers were tested and what effects it would have on broiler performance, no significant differences were found between the treatments for the average daily gain (ADG) live weight, feed intake, cumulative feed intake, feed conversion ratio (FCR) European production efficiency factor (EPEF) or protein efficiency ratio (PER). Therefore it could be concluded that the increasing levels of inclusion of these highly digestible protein and energy products in the pre-starter diets of broiler chicks, had no significant effects on the chicks' productive performance.
2. The contribution of the sugars to the metabolisable energy (ME) of the raw materials tested, included in pre-starter diets, did not show any significant effects on the productive performance of the broiler chicks. This was due to the fact that no significant differences were obtained for the average daily gain (ADG) live weight, feed intake, cumulative feed intake, feed conversion ratio (FCR) European production efficiency factor (EPEF) or protein efficiency ratio (PER).
3. The test material could therefore be incorporated into broiler pre-starter diets, since it would result in the same positive effects on productive performance of broilers as the normal commercial pre-starter diets, depending on the price of the products.

FUTURE RESEARCH

1. There is still a lot of research needed on the importance of a pre-starter diet in the production of broiler chicks. It was shown in a lot of research that post hatch nutrition is very important, but some research shows that by giving pre-starter diets to broiler chicks, it results in positive production performance of the birds, whereas other research shows that no significant effects are obtained in production performance if broilers are given pre-starter diets.
2. More research is needed on specific raw materials which could be included in pre-starter diets which may result in positive effects on broiler performance. The specific inclusion levels of these raw materials also need to be determined.