Effect of dietary energy and protein on the production parameters of slaughter ostriches (*Struthio camelus* var. *domesticus*)

by
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Abstract

When modern man assumed the responsibility of domesticating animals for his own purposes, he directly accepted the responsibility associated with feeding and caring for them. Considering intensive production systems, nutrition is one of the most important aspects in maintaining healthy livestock as well as ensuring profitability is achieved. This is due to the fact that the feeding of the livestock is often the most expensive overhead cost encountered. In ostrich production systems, nutrition costs total an estimated 70 – 80% of the costs associated with rearing the birds from chick to slaughter. When dissecting the typical composition of these ostrich diets, it becomes evident energy and protein are two of the most important, and abundant, nutrients found. Therefore, this study was conducted to investigate the effects of different concentrations of protein and energy in the diets of slaughter ostriches, on their production parameters.

In the first study (Chapter 3), five diets with different protein concentrations were formulated across the four feeding phases of slaughter ostriches (pre-starter, starter, grower and finisher). Three replications per treatment were conducted resulting in 15 camps of ostriches. Significant differences ($P < 0.05$) were found in the live weights of the birds at the end of each feeding phase except the finisher phase. In terms of the production parameters, differences ($P < 0.05$) were found for the dry matter intake (DMI), average daily gain (ADG) and the feed conversion ratio (FCR). Results indicated that the birds on the middle diet (control) and on the diets containing proportionally higher protein concentrations, although not different from each other, consistently outperformed those on diets containing lower concentrations of protein. These trends were also evident when comparing the cold carcass and thigh weights of the treatment birds post-slaughter. Therefore, from a financial standpoint, it could be concluded that increasing the protein content of the diets beyond that level currently used in industry (control) is not sensible.

The second study (Chapter 4) was an evaluation on the primary products harvested from the birds utilized in the first study, namely the feathers, skin and meat. The aim of the investigation was to determine if the dietary protein concentrations had any effect on these products. No differences ($P > 0.05$) were observed across the feather yields or classes measured, except for the 'tail feathers', where the birds fed the lowest protein levels in their diets yielded the fewest. Differences ($P < 0.05$) were however found in selected skin parameters measured. Decreased dietary protein resulted in smaller wet skin size, smaller sizes of the feather nodules, as well as smaller crust size after the tanning process was completed. However,

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this had no impact (*P* > 0.05) on the skin grades achieved. Hence it became clear that dietary protein has an impact on the skin size achieved, which did not translate into differences in skin quality. Similarly, it did not affect the feather yields or quality.

Energy is the most important nutrient in livestock diets as it is the first limiting nutrient influencing intake. Therefore, in the third study (Chapter 5), treatments in the form of five different levels of energy in the diets of ostriches, were investigated. Structurally, the layout was similar to the first study with three replications per treatment yielding 15 camps of ostriches. Significant differences (*P* < 0.05) were found between the live weights of the birds after the pre-starter phase, but not overall after the completion of the trial. The middle diet (diet 3) containing 14.5 MJ ME/kg displayed the highest gains per day of 216.0 ± 8.08 g per chick. The results of the growth were mirrored in the production parameters (DMI, ADG, FCR), where no differences (P > 0.05) were found for the rest of the feeding phases.

In a follow up investigation of the effects of dietary, this chapter focused on the impact these different energy levels (Chapter 5) had on the primary products harvested after slaughter (Chapter 6). In particular, the feather yield and quality, skin yield and selected quality parameters, as well as the chemical composition of the meat was studied. No differences were found (*P* > 0.05) across any of the feather yields or classes measured. Concerning the skin yields and quality, similar results were found with no differences (*P* > 0.05) between the crust sizes or grades. With regards to the proximate composition of the meat, no major effect (P > 0.05) was found as a result of the treatment diets. Therefore, dietary energy content exhibited little influence over the feather, skin and meat parameters measured in this study.

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Opsomming

Die oomblik toe die nuwerwetse mens die verantwoordelikheid aanvaar het vir die mak maak van diere vir sy eie gebruik, het hy direk die verantwoordelikheid aanvaar wat geassosieer word met hul voeding en versorging. Met inagneming van intensiewe produksiestelsels is voeding een van die belangrikste aspekte in die handhawing van gesonde vee asook om winsgewendheid te verseker. Dit is as gevolg van die feit dat die voeding van diere dikwels die grootste oorhoofse uitgawe is. In volstruisproduksiestelsels bereik die voedingskostes ‘n totale geskatte hoeveelheid van 70 – 80% van die kostes wat geassosieer word met die grootmaak van die voëls vanaf kuiken tot slagvoël. Wanneer die tipiese samestelling van hierdie volstruisdiëte ontleed word, is dit duidelik dat energie en proteïene twee van die mees belangrike en volopste voedingstowwe is wat gevind word. Hierdie studie was dus onderneem om die effek van verskillende konsentrasies proteïene en energie in die diëte van slagvoëls en hulle produksieparameters te ondersoek.

Vir die eerste studie (Hoofstuk 3) is vyf diëte met verskillende proteïenkonsentrasies geformuleer vir die vier voedingsfases van slagvolstruise (voor-aanvangs, aanvangs, groei en afronding). Drie herhalings per behandeling is gebruik wat 15 volstruiskampe tot gevolg gehad het. Betekenisvolle verskille ($P < 0.05$) in die lewende gewig van die voëls is aan die einde van elke voedingsfase gevind, behalwe vir die afrondingsfase. In terme van die produksieparameters is verskille ($P < 0.05$) gevind vir die droë materiaalinname (DMI), gemiddelde daaglikse toename (GDT) en die voeromsetverhouding (VOV). Resultate het getoon dat voëls wat die middelste dieet (kontrole) en diëte wat proporsioneel hoër proteïenkonsentrasies bevat het, alhoewel hulle nie van mekaar verskil nie, konsekwent beter presteer het as die wat diëte met laer proteïenkonsentrasies ontvang het. Hierdie tendense is ook waargeneem toe die koue karkas- en dygewigte van die eksperimentele voëls na-doods vergelyk is. Vanuit ‘n finansiële oogpunt kan daar dus tot die gevolgtrekking gekom word dat dit nie sinvol sal wees om die proteïeninhoud van volstruisdiëte te verhoog bo die vlak wat tans in die industrie (kontrole) gebruik word nie.

Tydens die tweede studie (Hoofstuk 4) is die primêre produkte (vere, velle en vleis) wat vanaf die volstruise in die eerste studie geoes is, geëvalueer. Die doel van hierdie studie was om te bepaal of die verskillende proteïenkonsentrasies in die dieet enige effek op hierdie produkte het. Geen verskille ($P > 0.05$) is by die veeropbrengste of die verskillende veertipes wat gemeet is, waargeneem nie, behalwe vir die stertvere, waar die voëls wat die laagste

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proteïenvlakke in hulle diëte ontvang het, die laagste opbrengs gelewer het. Verskille ($P < 0.05$) is egter gevind in die geselekteerde velparameters wat gemeet is. ‘n Vermindering in die proteïenkonsentrasie het ‘n kleiner nat velgrootte tot gevolg gehad, asook ‘n afname in knoppiegrootte nadat die looiproses voltooi is. Hierdie waarneming het egter geen invloed ($P > 0.05$) op die gradering van die velle gehad nie. Dit het dus duidelik na vore gekom dat die dieetproteïen wel die velgrootte wat bereik is, beïnvloed het, maar nie tot verskille in velkwaliteit gelei het nie. Veeropbrengs en –kwaliteit is ook nie deur die dieetproteïen beïnvloed nie.

Energie is die eerste beperkende voedingskomponent wat voerinname bepaal. Gegewe die groot invloed wat dit op voerinname het, is dit dus die mees belangrike komponent in die dieet van vee. Vandaar dan die derde studie (Hoofstuk 5) waar die behandelings in die vorm van vyf verskillende energievlakke in die diëte van volstruise ondersoek is. Die struktuur en uitleg van die studie was soortgelyk aan die eerste studie met drie herhalings per behandeling wat 15 volstruiskampe tot gevolg gehad het. Betekenisvolle verskille ($P < 0.05$) is gevind tussen die lewende gewigte van die voëls na die voor-aanvangsfase, maar nie nadat die hele proefneming voltooi is nie. Die middelste dieet (dieet 3) wat 14.5 MJ ME/kg bevat het, het die hoogste toename per dag van 216.0 ± 8.08 g per kuiken opgelewer. Groeiresultate is weerspieël in die produksieparameters (DMI, GDT, VOV), waar geen verskille ($P > 0.05$) in die res van die voedingsfases gevind is nie.

Tydens ‘n opvolgondersoek rakende die effek van dieet, het hierdie hoofstuk gefokus op die impak wat die verskillende energievlakke (Hoofstuk 5) op die primêre produkte wat na-doods geoes is. Daar is in besonder na die vere-opbrengs en –kwaliteit, velgrootte en geselekteerde kwaliteitparameters, asook die chemiese samestelling van die vleis gekyk. Geen verskille ($P > 0.05$) is by die veeropbrengste of die verskillende veertipes wat gemeet is, gevind nie. Met betrekking tot die velgroottes en -kwaliteit, is soortgelyke resultate gevind met geen verskille ($P > 0.05$) tussen die knoppiegrootte en –gradering nie. Met verwysing na die proksimale samestelling van die vleis is geen betekenisvolle effek ($P > 0.05$) as gevolg van die eksperimentele diëte waargeneem nie. Die inhoud van die dieetenergie het dus ‘n klein invloed op die vere-, vel- en vleisparameters wat in hierdie studie geëvalueer is, gehad.

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Notes

The language and referencing style used in this thesis are in accordance with the requirements of British Poultry Science. This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetition between chapters was therefore unavoidable. It should be known that each chapter has its own reference list instead of one comprehensive list appearing at the end of this thesis.

The following parts of this thesis were presented at the following symposiums:

1. **47th South African Society for Animal Science congress (SASAS), 6-8 July 2014, Pretoria, Gauteng, South Africa**

   VIVIERS, S.F, & BRAND, T.S. (2014) Correlation between the ambient and body temperatures of ostriches. *47th South African Journal of Animal Science Congress*. Pretoria, South Africa.

2. **48th South African Society for Animal Science congress (SASAS), 21 - 23 September 2015, Empangeni, Kwa-Zulu Natal, South Africa**

   VIVIERS, S.F., BRAND, T.S., HOFFMAN, L.C., SWART, E. & ENGELBRECHT, J.A. (2015) Effect of varying levels of protein and amino acid concentrations on the production parameters of growing ostriches. *48th South African Journal of Animal Science Congress*. Empangeni, South Africa.

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List of abbreviations

%	percent
ADF	acid detergent fibre
ADG	average daily gain
AI	avian influenza
ANOVA	analysis of variance
BSE	bovine spongiform encephalopathy
cm	centimetre
CP	crude protein
CVD	cardiovascular disease
DM	dry matter
dm^2	decimetre squared
DMI	dry matter intake
EU	European Union
FCR	feed conversion ratio
g	gram
GIT	gastro-intestinal tract
IMF	intramuscular fat
IVOMD	*in vitro* organic matter digestibility
kg	kilogram
LDL	low density lipoproteins
LSM	least square mean
m	metre
MJ	mega joules
mM	milli molar
mm	millimetre
NDF	neutral detergent fibre
ºC	degrees Celsius
PUFA	polyunsaturated fatty acid
SD	standard deviation
SE	standard error
TME	total metabolizable energy
VFA	volatile fatty acids
Vol	volume
W	body weight

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WOA	World Ostrich Association
ω-3	omega 3

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Chapter 1

General Introduction

From the dawn of the age when ostrich feathers were a sought after fashion item in the 19th century, South Africa has established itself as the world leader in producing commodities of ostrich origin. In particular, the small town of Oudtshoorn, situated in the Western Cape Province, earned the term the ostrich capital of the world. Fortunes were initially made and subsequently lost by entrepreneurs and farmers alike during the explosion of the feather exports; which became one of the top four exported commodities from the South African shores.

Nowadays, the R1 billion ostrich industry continues to be the most viable method of livestock farming in the semi-arid Klein Karoo region, providing employment and income for a large proportion of those populations. The industry relies on generating income from the three primary products harvested from ostriches, namely the feathers, skin and meat. As a result of the market structure, where more than 90% of income is generated via export earnings, the parity power of the rand (R) to the US dollar (R/US$) and the euro (R/€) is very important in influencing relative income.

With regards to the input costs associated with an ostrich enterprise, an estimated 70 – 80% of the costs are solely attributed to the feeding of the birds. The volatility of the prices of the raw materials used in the feed formulation has a large impact on the overall profitability of the system. This is as a result of the big dependence of feedstuff production on local climatic factors, as well as worldwide production which may result in cheap product imports competing with local producers for market participation.

In an attempt to minimize the feeding costs, least cost formulation is applied by animal nutritionist. The challenge for the nutritionists however, is to ensure the composition of the formulated diet is balanced with regards to the nutrient make-up, as well as a balanced amino acid profile; particularly in monogastric formulations as is the case for ostriches. An over- or undersupply of certain dietary nutrients can result in wastage of raw materials, but more importantly can negatively impact the production performance of the growing ostriches.

The initial management of slaughter ostriches saw them reared in much the same fashion as was used in poultry production, as little literature or studies had been conducted on the nutrition of ostriches. Therefore, the principles of ostrich chick rearing are fundamentally the same as with broilers; with them receiving a pre-starter diet, and then a starter, grower, and

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finally a finisher diet before suitability for slaughter is achieved. Depending on the proportion of revenue generated from the three products, the age of slaughter of ostriches tends to vary in order to realise maximum returns. Generally however, producers tend to slaughter their birds at 11 – 12 months of age when the gains of further feeding become offset by the relative decrease in feed conversion by the birds.

Therefore this study was conducted in an attempt to quantify the optimal feeding levels of two of the most important nutrients in livestock diets, energy and protein (amino acids), throughout the slaughter ostrich's lifetime. Importantly, least cost formulations of the diets were utilized in order to conclusively quantify the optimal feeding levels, while ensuring the performance of the birds was not compromised by the practice of underfeeding certain ingredients.

The effects of the treatment diets on the production parameters such as the growth of the birds, the dry matter intake (DMI), average daily gains (ADG) and therefore the feed conversion ratios (FCR) was investigated. The primary products were also investigated post – slaughter, in an attempt to fully clarify potential advantages or disadvantages associated with certain nutrient levels.

Parts of the results found in this study will be used in furthering the knowledge of ostrich nutrition gained by the mathematical optimization model designed by Professor Robert Gous of the University of Kwa-Zulu Natal and Professor Tertius Brand of the Western Cape Department of Agriculture (Gous & Brand, 2008). This growth model is somewhat unique to ostriches as it is necessary to incorporate the three tier character of the products, which complicates matters when contrasting with pigs for example, where meat is the sole product harvested.

In the ostrich industry, more specifically during the tanning of the skins, a grading system was established to evaluate the nodule quality and was subsequently implemented in this dissertation in an attempt to provide industry with this knowledge. Thus, the effect of dietary energy and protein on nodule quality, if any, was studied.

The local ostrich industry recently received a massive boost with the decision taken by the European Union to lift the ban imposed on the export of raw meat products, as a result of the avian influenza (AI) epidemic that broke out four years ago. Therefore, producers may have reason to feel optimistic going forward, but this cannot detract from the fact that nutrition

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continues to play a significant role in the industry dynamic; and therefore must constantly be optimized, finding the balance between cost efficiency and production potential.

1.1 References

GOUS, R.M. & BRAND, T.S. (2008) Simulation models used for determining food intake and growth of ostriches: an overview. *Australian Journal of Experimental Agriculture*, **48**: 1266-1269.

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Chapter 2

Literature Review

2.1 Introduction

Ostriches belong to the ratite family, typically characterized by their inability to fly and the minimal or non-existent breast muscle as is seen in other birds (Angel, 1996). Three products, namely the meat, skin for leather, and feathers generate income for producers. The leather and feather markets are predominantly fashion orientated, thus consumer preferences and more importantly, spending patterns are influenced by their incomes; which in turn is reliant on the present economic climate. Ostrich meat has gained much attention in the past two decades, and is slowly transforming its image from a niche-like commodity to a genuine competitor in the red meat market.

Due to the nature of the industry, the revenue generated from the three products constantly changes, and therefore so does the proportion of income for each separate commodity (Carstens, 2013). Currently, producer's revenue will be divided into approximately 65%, 20% and 15% for the leather, meat and feathers respectively (Stumpf, J., Pers. Comm., Klein Karoo International, P.O. Box 241, Oudtshoorn, 6620, South Africa, 14th June 2014). However, this will imminently change over time and affect the industry, resulting in the need for adaption, especially by producers.

The main problem encountered by ostrich farmers and producers is the fact that nutrition alone comprises 70 to 80% of their input costs (Brand, 2007). The two main nutrients in most livestock diets are energy and protein (amino acids), and the effectiveness of the diets are largely determined by the correct formulations and ratios with respect to one another of energy and protein. Diets with imbalances or simply not enough protein (amino acids) and/or energy will result in the ostriches not realizing their maximum production potential, incurring financial losses onto the producer (Brand *et al*., 2002).

As a result of the anatomical development of the ostrich, the diets need to be modified as the bird grows to compensate for gastro-intestinal tract (GIT) changes (Swart, 1988). During an ostrich's lifetime under intensive conditions, it will be fed the following: pre-starter, starter, grower, finisher and maintenance or breeder diets (Du Preez, 1991; Cilliers *et al*., 1998; Brand & Gous, 2006; Gussekloo, 2006; Brand, 2007; Brand & Olivier, 2011). Optimal ratios of the most important nutrients during each phase will yield the best possible production from the

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ostriches, and the importance thereof in an industry as fickle as is the ostrich one, cannot be stressed enough.

Therefore, the aim of this research is to further studies by Carstens (2013) to investigate the optimal protein and energy requirements of slaughter ostriches. The ostrich industry is currently under severe pressure, and the development of optimal diets at the least possible cost while not compromising the quality, is paramount to ensure producers stay in business.

2.2 History of the industry

The ostrich industry has undergone significant structural changes in its relatively short history. The ostrich feather market was established in the 19th century in South Africa, where they were a highly valued item of fashion. Smit (1963) specifies that in the Karoo and Eastern Cape regions of the country, ostriches were captured for domestication primarily for their feathers in the 1860's. The export of ostrich feathers generated significant income revenue, particularly to the Oudtshoorn area, which is now recognized as the ostrich capital of the world. Consequently, the development of the ostrich farming enterprise increased rapidly (Smit, 1963).

With the advent of World War I in 1913 however, the ostrich industry suffered severe losses in terms of production as a result of the decline in demand. At this point in time, it was the country's fourth largest export market. The nature of the fashion industry and its changing trends, as well as the difficulties associated with marketing the product as a result of the war, contributed to the collapse of the feather market (Anon, 2004). A contributing factor to the demise of the fashion component of the industry was the introduction of the motor vehicle (open cabin), which resulted in ladies' hats adorned with feathers being impractical (Anon, 2010). The ostrich numbers declined from an estimated 770000 to 23000 by 1930.

The Klein Karoo Landbou Koöperasie (KKLK) in Oudtshoorn was established in 1945 in an attempt to revive the industry. Subsequently, the first abattoir was opened early in the 1960's, followed by a leather tannery towards the end of that decade (Drenowatz *et al*., 1995; Anon, 2004). From this period until the 1990's, ostrich leather products constituted the main source of income for the producers, with gaining prominence in terms of the meat products. Ostrich meat gained much attention and is perceived to be a healthy alternative to other red meats due to a favourable fatty acid profile (intramuscular ostrich fat contains 16.50% polyunsaturated ω-3 fatty acids) as well as a low intramuscular fat content (Mellet, 1992). In 1993, the first

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ostrich abattoir for export to Europe was opened, complying with the phyto-sanitary requirements for the export of meat (Anon, 2010).

Early in the new millennium in Britain, the outbreak of bovine spongiform encephalopathy (BSE), or more commonly mad cow disease, led to an increased demand in ostrich meat. The price of the meat increased by 40%, resulting in increased revenue for producers and a high income per ostrich. Following the BSE scare, the ostrich meat price subsequently dropped by 30%, affecting many producers' incomes. Thus, it is clear to see a trend in terms of ostrich numbers slaughtered (Figure 2.1) and trade in their products, where boom and bust cycles are commonly observed due to the volatility of the product prices. (Anon, 2010)

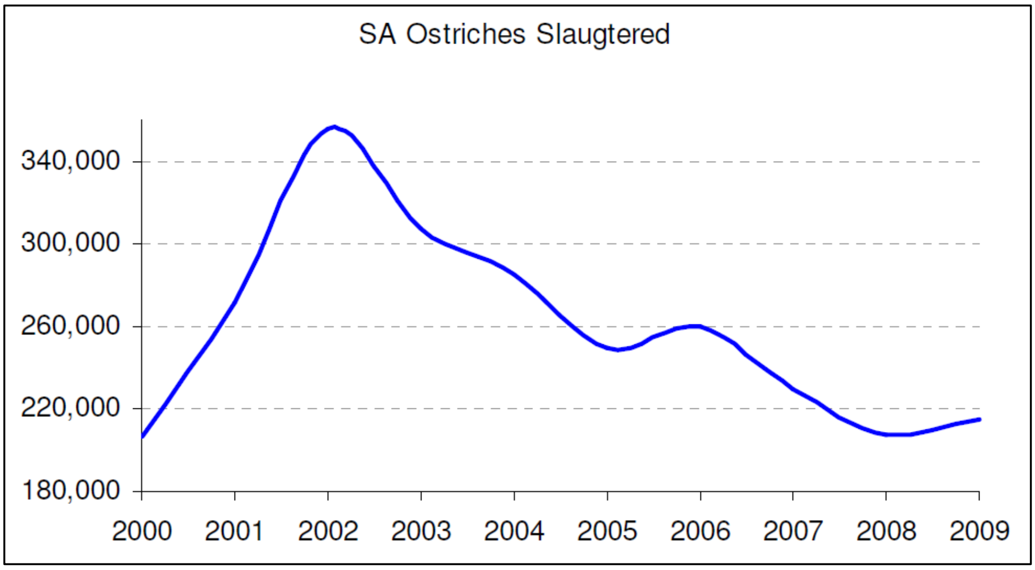

Figure 2.1. Ostrich slaughter numbers in South Africa from 2000 – 2009 (Anon, 2010)

Recently (2011), the South African ostrich industry incurred severe losses due to an outbreak of the H5N2 virus (avian flu) in the Klein Karoo region. It was losing an estimated R108 million per month as a result of the ban of raw meat exports to the European Union (Erasmus, 2011). Even though the ostrich industry started exporting meat cooked (*sous vide*), the industry is still currently feeling the effects of the ban, with losses estimated at R1 billion due to the virus (Erasmus, 2013).

Export earnings are dependant on the exchange rates between the United States Dollar (US$) and Rand (R) for the leather exports and the Euro (€) and Rand (R) in terms of the meat exports. Therefore, the relative strength of the South African Rand to leading foreign currencies in the world is paramount to the success of the export market. Erasmus (2013) highlights that the local market is not sufficiently developed to consume the supply of the high priced ostrich

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meat, thus export of the meat is necessary to keep ostrich enterprises feasible. Hoffman *et al.* (2005) also showed that approximately 90% of the ostrich meat produced in South Africa is exported.

The structure of the industry shows a marked change from one century ago. Early studies by Mellet (1992) and Sales (1998) may have contributed favourably to the awareness of ostrich meat and the documented health benefits with low intramuscular fat levels and favourable fatty acid profiles.

Therefore, it is clear that the industry as a whole constantly faces many challenges and the onus falls on the producers to optimize the controllable variables in their systems such as the nutrition and management practises.

2.3 Nutritional information regarding ostriches

One of the parameters that producers have the most influence over in terms of ostrich production is the nutrition. This becomes a critically important link in the chain as feed costs comprise 70-80% of the total operational costs of an ostrich farming enterprise (Brand, 2007). Brand (2007) further estimates that with the use of least cost feed formulations and optimization models, a saving of 10% with respect to feed costs would equate to a saving of R55 million annually for the ostrich industry.

2.3.1 Anatomy of the digestive tract

As a result of their adaption to arid areas with a narrow range of fibrous material, ostriches have relatively large digestive tracts which create an ideal environment for the fermentation of plant material (Ullrey & Allen, 1996; Brand & Gous, 2006). This is one of the key areas distinguishing ostriches from other monogastric animals such as pigs and poultry with regards to the digestive tracts. However, other components of the digestive tracts of poultry and ostriches are similar as the ostrich is still a bird, albeit incapable of flying (Figure 2.2). It consists of a beak and mouth, oesophagus, proventriculus (glandular stomach where enzyme secretion takes place), gizzard (smooth muscle stomach), small intestine, large intestine and the cloaca (Gussekloo, 2006).

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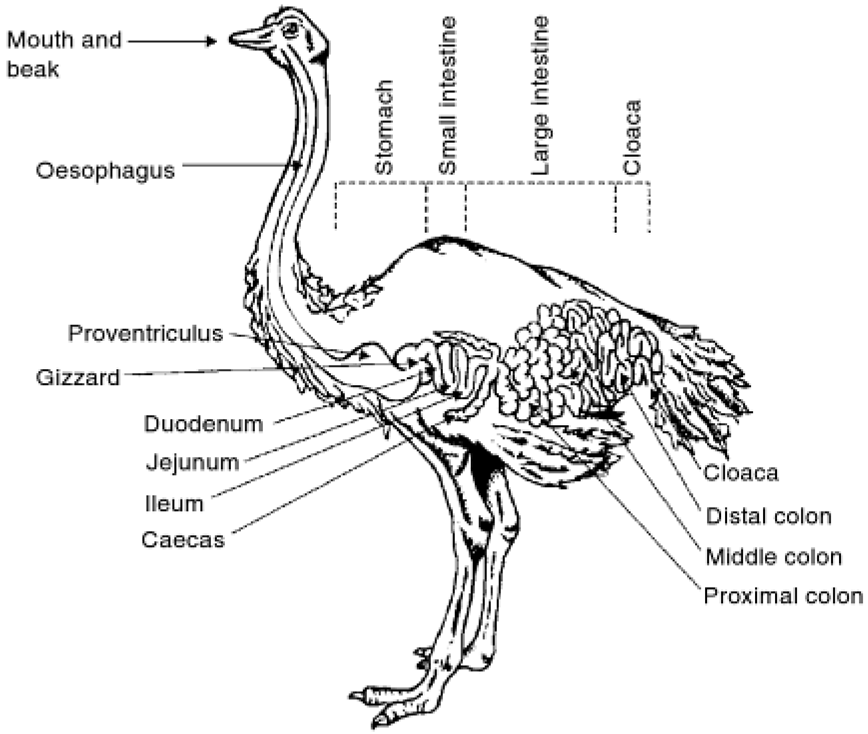

Figure 2.2. The digestive system of the ostrich (Brand & Gous, 2006)

The ostrich, along with the other ratites, does not have a crop as other birds; but according to Brand & Gous (2006) does have an enlarged upper oesophagus for the accumulation of food. The large proventriculus as well as the gizzard may also play a storage role (Angel, 1996).

The proventriculus (glandular stomach) is a thick walled organ where the main action of digestion begins to play a role (Champion & Weatherley, 2000). Secretion of digestive enzymes containing hydrochloric acid and pepsin starts the digestion process on the nutrients present in the digesta (Gussekloo, 2006). Champion & Weatherley (2000) suggest that the secretion of the enzymes is rapid and minimal digestion occurs in this specific phase of the digestion. Digestion in the form of foregut fermentation does nevertheless take place to a degree, as documented by Swart *et al.* (1987) when they found volatile fatty acids (158.8 mM) in the proventriculus.

The ostrich gizzard has strong, thick walls composed of smooth muscle to aid in the breakdown of the digesta. Essentially, that is the function of the gizzard; to mechanically grind the ingested material into a finer form before it is passed onto the small intestine for further digestion. The smooth muscle contractions and the ingestion of pebbles and stones aid the grinding, with the net result being an increased surface area for the action of enzymes (Strydom, 2010). The muscles of the gizzard are protected from the effects of the gastric enzymes and

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mechanical grinding due to a layer of secretion known as the *cuticula gastris* (Gussekloo, 2006).

Following this, the ground digesta moves into the small intestine which is comprised of the duodenum, jejenum and ileum. Various enzymatic secretions such as amylase, trypsin, maltase, sucrose, chymotrypsin and lipase take place here courtesy of ducts from the pancreas (Iji *et al*., 2003; Gussekloo, 2006). True digestion of the nutrients then takes place with the aid of the mentioned enzymes.

The ability of the ostrich to utilize fibrous material is due to the anatomy of the large intestine, which comprises up to 60% of the total length of the digestive tract (Brand & Gous, 2006). As a result of their preferred habitat of arid regions (Ullrey & Allen, 1996) which constitutes predominantly fibre rich forages, ostriches have adapted their digestive tracts to better utilize the fibre component. Swart (1988) found that they effectively digest hemicellulose (66%) and cellulose (38%). Brand *et al.* (2000a) found ostriches obtained 30% more metabolizable energy than poultry on the same high fibre diet. Importantly, this ability they have only develops after approximately 10 weeks of age (Angel, 1996); therefore the chicks do not utilize fibre well. This gives rise to the need for different diets at specific stages of growth for the ostriches when they are reared intensively.

2.3.2 Nutrient requirements

The nutrient requirements of an ostrich depend on its stage of growth (Brand & Olivier, 2011); therefore their growth rates are depicted in Table 2.1.

The goal of any profit oriented organization is to optimize profitability. With ostriches for instance, producers aim to maximize meat, leather and feather production. To achieve this, an understanding of the nutrient requirements of ostriches (Table 2.2) is necessary (Cilliers *et al*., 1998).

The nutrient requirements change over time due to the changes observed in the body composition in terms of the protein to fat ratio (Brand & Olivier, 2011). Similarly, the physiological development of the gastrointestinal tract requires alterations to the diet. Fibre can be efficiently utilized by the ostrich to produce volatile fatty acids (VFA), and thereby supplying energy (Swart, 1988) due to the enlarged large intestine resembling that of a hindgut fermenter (Aganga *et al*., 2003).

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Table 2.1. Average growth rates of ostriches (Brand & Olivier, 2011)

Age (months)	Live weight (kg)	Growth rate (g/bird/day)
0-1	0.85 – 5.1	107
1-2	5.1 – 10.8	191
2-3	10.8 – 19.2	280
3-4	19.2 – 29.7	350
4-5	29.7 – 41.5	390
5-6	41.5 – 53.4	397
6-7	53.4 – 64.7	377
7-8	64.7 – 74.9	340
8-9	74.9 – 83.7	294
9-10	83.7 – 91.1	247
10-11	91.1 – 97.2	203
11-12	97.2 – 102.1	163
12-13	102.1 – 105.9	130
13-14	105.9 – 109.1	102

Table 2.2. Commercial guidelines for the composition of ostrich feed (Brand, 2006)

Feed Type	Min. crude protein (g/kg)	Min. lysine (g/kg)	Max. moisture (g/kg)	Min. crude fat (g/kg)	Max. crude fibre (g/kg)	Calcium		Min. phosphate (g/kg)
						Min. (g/kg)	Max. (g/kg)	
Pre-starter	190	10	120	25	100	12	15	6
Starter	170	9	120	25	135	12	15	6
Grower	150	7.5	120	25	175	10	16	5
Finisher	120	5.5	120	25	225	9	18	5
Maintenance	100	3	120	20	300	8	18	5

Brand and Gous (2006) pointed out that data for the vitamin and mineral requirements of ostriches is minimal, and premixes are formulated with the aid of data published from other species. Sufficient literature is however available on the energy and protein requirements due to extensive research.

2.3.3 Energy and protein requirements

The energy requirements of ostriches were found to be 0.44 MJ/kg $W^{0.75}$ per day with an efficiency of metabolizable energy utilization for growth of 0.32 by Swart *et al*. (1993). The total metabolizable energy (TME) from a feed is a more accurate estimate of the value of the feed in terms of metabolizable energy as it is corrected for nitrogen retention. Ostriches obtained approximately 30% more TME than poultry from low energy, high fibre diets (Brand *et al*., 2000a). They also found that ostriches display the highest TME when fed high fibre diets when compared to pigs and poultry.

Energy has the greatest influence on feed intake. The density of the energy in the feed is inversely correlated to the feed intake; high density feed will lead to a proportional decrease in intake (Brand *et al*., 2000; Brand & Olivier, 2011). Therefore, the optimal composition of the diet with regards to energy will alter with the stages of physiological development as displayed in Table 2.3.

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Table 2.3. Average feed intake and feed energy values of the different ostrich feed stages; adapted from Brand and Gous (2006) and Brand and Olivier (2011)

Feeding stages	Age (months)	Feed intake (g/bird/day)	TME (MJ ME/kg feed)
Pre – starter	0 – 2	275	14.5
Starter	2 – 4.5	875	13.5
Grower	4.5 – 6.5	1603	11.5
Finisher	6.5 – 10.5	1915	9.5
Maintenance	10.5 - 12	2440	8.5

Energy levels in the feeding stages decrease as the ostrich ages, according to the stage of growth. Younger birds require more energy to accompany high levels of protein in the pre-starter phase to accommodate rapid growth of muscle, bone and tissues. Concurrently, the physiological state of the ostrich gastrointestinal tract progresses toward a hindgut fermenter (Aganga *et al*., 2003), resulting in the increased ability to utilize fibre to produce VFA's.

Protein is one of the most important nutrients in diets of all living organisms as it constitutes a large portion of the tissues and general bodily functions. Protein, along with energy, is a macronutrient, and both comprise the bulk of the digestible matter contained in animal diets (Bowen *et al*., 1995). Of equal importance in terms of proteins, is the composition of the amino acid profile; where imbalances are often found to be costly due to inefficient utilisation of the individual amino acids.

Carstens (2013) cites several factors such as age, live weight, stage of production and feed intake as paramount when determining the protein and amino acid requirements of ostriches. Concentrations of proteins that are too high (28%) can have negative cost implications as well as lead to physical deformities in ostriches which also impact the financial outcomes of the enterprise (Carstens, 2013).

Studies by Du Preez (1991), Du Preez *et al*. (1992), Cilliers *et al*. (1998) and Brand and Olivier (2011) have resulted in information regarding the protein and essential amino acid requirements of ostriches at different growth stages (Table 2.4).

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Table 2.4. Mean dry matter intake with protein and amino acid requirements of ostriches; adapted from Du Preez (1991), Du Preez *et al*. (1992), Cilliers *et al*. (1998) and Brand and Olivier (2011)

Predicted parameter	Stage of Production				
	Pre - starter	Starter	Grower	Finisher	Maintenanc
Live mass (kg)	0.85 – 10	10 – 40	40 – 60	60 – 90	90 – 120
Age (months)	0 – 2	2 – 5	5 – 7	7 – 10	10 – 20
Feed intake (g/day)	275	875	1603	1915	2440
Protein (g/100 g feed)	22.89	19.72	14.71	12.15	6.92
Lysine (g/100 g feed)	1.10	1.02	0.84	0.79	0.58
Methionine (g/100 g feed)	0.33	0.33	0.29	0.28	0.24
Cystine (g/100 g feed)	0.23	0.22	0.18	0.17	0.14
Total SAA (g/100 g feed)	0.56	0.55	0.47	0.45	0.38
Threonine (g/100 g feed)	0.63	0.59	0.49	0.47	0.36
Arginine (g/100 g feed)	0.97	0.93	0.80	0.78	0.63
Leucine (g/100 g feed)	1.38	1.24	0.99	0.88	0.59
Isoleucine (g/100 g feed)	0.70	0.65	0.54	0.51	0.38
Valine (g/100 g feed)	0.74	0.69	0.57	0.53	0.36
Histidine (g/100 g feed)	0.40	0.43	0.40	0.40	0.37
Phenylalanine (g/100 g	0.85	0.79	0.65	0.61	0.45
Tyrosine (g/100 g feed)	0.45	0.44	0.38	0.38	0.31
Phenylalanine and tyrosine (g/100 g feed)	1.30	1.23	1.03	0.99	0.76

2.4 Ostrich meat

2.4.1 Dietary specifications and dynamics

As a result of the industry structural change in the past two decades towards increased ostrich meat production, they are predominantly raised in intensive feedlot systems. Thus, forage is limited and they are entirely dependent on formulated diets. Due to limited research up until 1995, the diets were formulated based on templates used for poultry (Angel, 1996). Consequent studies have resulted in progress in terms of nutritional requirements, with ostriches reared in intensive feedlot systems being fed four different diets before slaughter quality is deemed acceptable. The diets are based on age and therefore physiological

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development, as well as the form it is fed in, shown in Table 2.5. Brand (2006) states the conversion of the feed into pellets increases the feed conversion by 10-15% during the grower and finisher phases.

Table 2.5. Ostrich feeding stage outline and form of the feed, adapted from Brand and Gous (2006) and (Brand, 2006)

Production Stage	Live weight (kg)	Age (months)	Processing (size of sieve)
Pre-starter	0.85 - 10	0 - 2	Meal
Starter	10 - 40	2 - 5	Crumbs
Grower	40 - 60	5 - 7	Pellets (6 – 8mm)
Finisher	60 - 90	7 - 10	Pellets (6 – 8mm)
Maintenance	90 - 100	10 - 20	Pellets (6 – 8mm)
Breeder	110+	20+	Pellets (6 – 8mm)

The feed formulations, as is the case with many other livestock nutrition formulations, are based on least cost analysis. This is especially necessary for ostriches where the feed component comprises such a high proportion of the incurred costs (Brand, 2007). Ostriches are either reared extensively where they are totally dependent on the natural veld or planted pasture, semi-intensively where they roam on natural veld or planted pasture with the addition of concentrates as supplementary feed, or intensively where they receive a fully balanced formulated diet. Lucerne is the most common planted pasture used for forage by South African ostrich producers, with an estimated carrying capacity of 10 birds per hectare. They are however, also successfully reared on canola and old man saltbush pastures (Brand, 2006).

As mentioned earlier however, producers commonly raise their ostriches intensively, creating the need to formulate fully balanced diets themselves or purchase the relative feeds from a stock feed company. In the event of producers formulating their own diets, raw materials are mostly obtained by self-production of lucerne under irrigation with the grain and oilseed components purchased (Anon, 2010). The most important raw materials in use for ostrich nutrition are summarised in Table 2.6.

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Table 2.6. Most important raw materials used in ostrich nutrition (Brand, 2006)

Energy Sources	Roughages	Protein Sources	Mineral Sources	Other
Maize	Lucerne hay	Soya bean oilcake	Limestone	Synthetic lysine
Barley	Wheat bran	Canola oilcake	Di-calcium phosphate	Synthetic methionine
Wheat	Oat bran	Sunflower oilcake	Mono-calcium phosphate	Synthetic threonine
Triticale	Barley hay	Fishmeal	Vitamin and mineral pre-mixtures	Molasses products
Oats	Oat hay	Full fat soya		Feed binding agents
Brewers grain	Oats straw	Full fat canola		Medicines (antibiotics)
	Wheat straw	Lupins		Feed additives
	Silage	Beans		Plant oil
		Peas		

2.4.2 Orientation in the market

With the increasing health conscious mind-set of the modern consumer, alternative sources of healthier animal proteins are in increased demand. In general, meat is perceived as a major source of fat, particularly saturated fatty acids (Hoffman *et al*., 2012). Saturated fatty acids increase total blood cholesterol levels as well as the concentration of low-density lipoproteins (LDL) in the blood plasma (Mattson & Grundy, 1985). Stipanuk and Caudill (2013) identify LDL's and total cholesterol as being biomarkers of cardiovascular diseases (CVD) such as congestive heart failure, coronary artery disease and myocardial infarction (heart attack).

Unsaturated fatty acids, particularly polyunsaturated fatty acids (PUFAs), are reported to be essential in the human diet for normal growth, reproduction and prevention of CVD (Simopoulos, 1991; Simopoulos, 1999; Connor, 2000; Stipanuk & Caudill, 2013). PUFA's comprised predominantly of ω-3 fatty acids, which may provide protection against CVD and depression, are particularly sought after (Stipanuk & Caudill, 2013). Sources rich in ω-3 fatty acids include fish, fish products, canola oil and olive oil.

Ostrich meat has a low intramuscular fat content (Mellet, 1992) and a favourable fatty acid profile which contains 16.5% polyunsaturated ω-3 fatty acids (Sales, 1998). Therefore, it is marketed as a healthy alternative to other red meats (Fisher *et al*., 2000). Studies on meat from ostriches as well as from turkey and bovine by Paleari *et al*. (1998) reveal ostrich meat as having the lowest fat content, which is comparable to findings by Mellet (1992) as well as Sales & Hayes (1996). Paleari *et al*. (1998) also found ostrich meat to display the highest protein content, lowest cholesterol content as well as the highest levels of PUFAs.

Therefore, ostrich meat is a proven high quality product with high nutritive and dietetic value. Polawska *et al*. (2011) class the meat as a niche product in Europe, with an increasing popularity among health conscious consumers. Fasone and Privitera (2002) describe the consumers as medium to high cultural and professional status individuals, with purchasing patterns that place an emphasis to the nutritive value of retail products.

2.4.3 Muscles used for retail

Ostrich meat products differ from poultry in terms of retail as whole muscles are sold commercially (Mellet, 1992), as opposed to whole quarters or breasts as is done with poultry. There are ten major muscles (Figure 2.3) which make up at least 60% of the meat yield obtained from the carcass and they are *Muscularis gastrocnemius, M. femorotibialis, M. iliotibialis cranialis, M. iliofibularis, M. iliofemoralis externus, M. fibularis longus, M. iliofemoralis, M. obturatorius medialis, M. iliotibialis lateralis and M. flexor cruris lateralis* (Sales & Deeming, 1999). The remaining yield is obtained from lean trimmings from the remaining 13 usable muscles constituting the ostrich carcass (Mellett, 1985; Mellet, 1992; Sales & Deeming, 1999).

Approximately 70% of the muscles from the carcass are marketed individually; while others are only of practical use in processing (Mellet, 1994). Table 2.7, which includes the anatomical names, commercial names, the industrial application of the muscles as well as their approximate proportion of the thigh, highlights this.

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Table 2.7. Anatomical names, commercial names, industrial application and the proportions of the 23 usable muscles from an ostrich carcass (Mellett, 1985; Mellet, 1992; Mellett, 1994; Kritzinger, 2011; Carstens, 2013)

Muscle name	Commercial name	Application	Percentage of thigh
Pre-acetabular			
M. iliotibialis cranialis	Top loin	Whole muscle	
M. ambiens	Tournedos; Top	Whole muscle	2.386
M. pectineus		Whole muscle	
Acetabular muscles			
M. iliofemoralis	Oyster	Whole muscle	4.416
M. iliofemoralis		Processing	
M. iliotrochantericus		Processing	
M. iliotrochantericus		Processing	
Post-acetabular			
M. iliotibialis lateralis	Round; Rump steak	Whole muscle	13.909
M. iliofibularis	Fan fillet	Whole muscle	16.142
M. iliofemoralis	Inside strip; Eye	Whole muscle	4.213
M. flexor cruris	Outside strip;	Whole muscle	3.858
M. flexor cruris	Small steak; Fillet	Whole muscle	1.624
M. pubio-ischio-	Tender steak; Fillet	Whole muscle	3.452
M. ischiofemoralis		Processing only	
M. obturatorius	Tenderloin	Whole muscle	5.533
M. obturatorius		Carcass meal	
Femoral muscles			
M. femorotibialis	Moon steak	Whole muscle	8.934
M. femorotibialis	Tip	Whole muscle	
M. femorotibialis	Minute steak 1	Whole muscle	1.269
M. femorotibialis	Minute steak 2	Whole muscle	1.827
Lower leg muscles			
M. gastrocnemius	Big drum	Whole muscle	10.710
M. fibularis longus	Mid leg	Processing	
Flexor and extensor		Processing	

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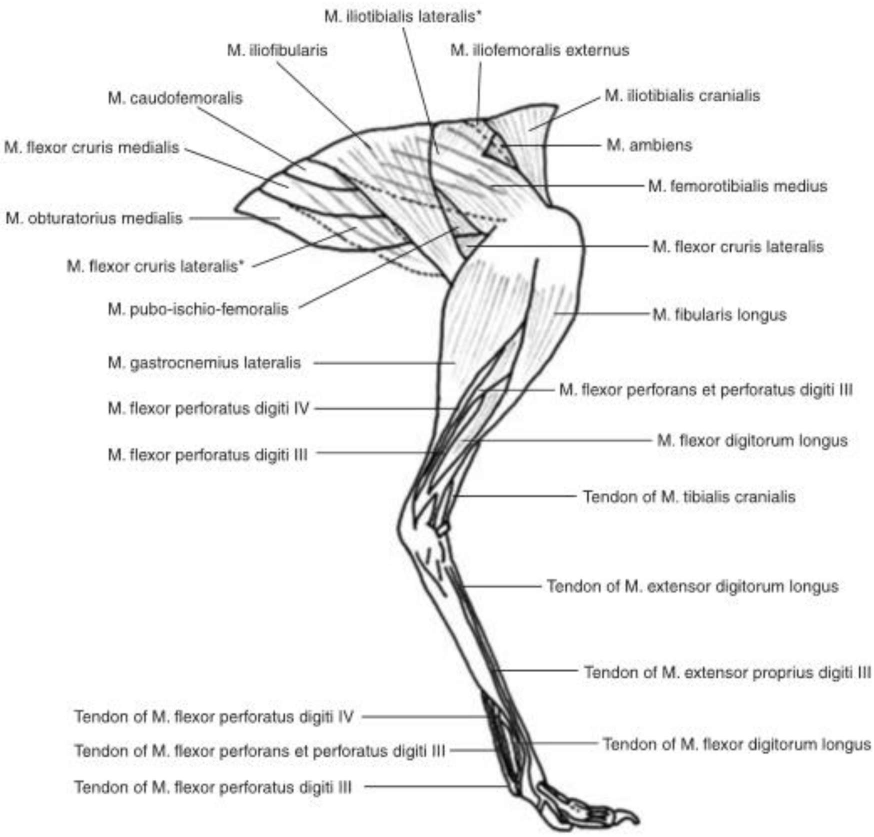

Figure 2.3. An illustration of some muscles in the pelvic limb described in Table 2.7 (Smith *et al*., 2006; Carstens, 2013)

2.4.4 Chemical characteristics of the meat

At the point in the early 1990's where ostrich meat started gaining recognition as a possible alternative red meat source to beef and lamb, little was known with regards to the chemical composition of the meat. Significant research by Sales and Hayes (1996), Paleari *et al*. (1998); Sales (1998), Hoffman *et al.* (2005), Hoffman *et al.* (2012) to cite only a few, has taken place to the present providing adequate knowledge as to the composition of ostrich meat.

Interestingly, a common finding in most of the research indicates that nutrition has little impact on the chemical composition of the meat. In a study by Hoffman *et al.* (2005), there were no significant differences found in any proximate analysis parameters between ostriches subjected to four different levels of energy in the form of fish oil in their diets. It was postulated that most of the excess energy is stored as excess fat in the abdominal cavity of ostriches. Hoffman *et al.* (2005) evaluated the sensory characteristics of the fat pads, however limited information is available regarding the yield of the fat pads as influenced by dietary energy and it is subsequently examined in Chapter 6 of this study.

Literature published by selected researchers is presented in Table 2.8 below, in an attempt to give clarity on the information available on the chemical composition of ostriches.

Table 2.8. Proximate composition (g/100 g edible meat) of ostrich meat (*M. iliofibularis*) contrasted between separate research teams; with comparison to turkey and beef (Mean ± SD)

	Studies conducted on respective species				
Chemical parameters	Hoffman *et al.* (2005)	Sales and Hayes (1996)	Paleari *et al.* (1998)		
	Ostrich	Ostrich	Ostrich	Turkey	Bovine
Moisture	76.66 ± 0.52	76.24 ± 0.53	75.10 ± 1.10	74.80 ± 0.68	74.20 ± 0.77
Protein	21.66 ± 0.33	21.00 ± 0.58	22.20 ± 1.13	20.40 ± 0.77	20.1 ± 0.85
Fat	2.05 ± 0.10	0.92 ± 0.23	1.60 ± 0.60	3.80 ± 0.79	4.5 ± 0.93
Ash	1.22 ± 0.07	1.03 ± 0.13	1.10 ± 0.22	1.00 ± 0.22	1.2 ± 0.22

Table 2.8 is simply an informative one and in no way attempts to statistically compare the studies done by the researchers mentioned, but the information presented does make for interesting observations. The protein content of ostrich meat is visibly higher than the two other species presented in the table, as well as a decreased fat content as observed by Mellet (1992).

2.5 Ostrich skin and leather

Ostrich leather is distinctive and unique due to the presence of the feather follicles, making it a quality end product from the bird, which attracts a high demand (Cooper, 2001). Currently, 65% of the profit for a South African ostrich producer is generated from the sale of the skins at slaughter (Stumpf, J., Pers. Comm., Klein Karoo International, P.O. Box 241, Oudtshoorn, 6620, South Africa, 14th June 2014). There are three parameters which are judged in the grading process of a skin, and only one of those, the size of the skin, is objective. The

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other two, namely visible damage to the skin and the appearance of the feather nodules are subjective (Engelbrecht *et al*., 2005). Objective methods have been used to physically measure the base diameter of the nodules (Cloete *et al*., 2007), however these methods are time consuming and impractical from a commercial point of view. Therefore, inconsistencies have been shown to occur during the assessment of leather quality as a result of the subjective nature of grading the skins (Van Schalkwyk *et al*., 2005).

2.5.1 Structure of the skin

Ostrich skin is reported to attain its strength and flexibility from the three dimensional arrangement of the collagen fibres which make up the grain layer and corium of the dermis (Lunam & Weir, 2006). The dermis forms the main component of the tanned crust owing to the fact that the epidermis is removed during the liming process that takes place during tanning. The arrangement of the collagen fibres is such that they predominantly lie perpendicular to each other and in parallel with the surface of the skin (Lunam & Weir, 2006).

Lunam & Weir (2006) also reported the grain layer and corium as being separated by a thin layer of connective tissue comprised of numerous blood vessels. This has direct implications on the leather quality grading as it exposes the birds to an increased risk of bruising and lamination, which result in a degrading of the skin (Engelbrecht *et al*., 2009).

2.5.2 Grading

The crown area is a diamond shaped, nodulated area of the ostrich skin, and Engelbrecht *et al*. (2007) report it to be the most commercially valuable (Figure 2.4). All the areas denoted by the dotted lines (Figure 2.4) are where the nodules formed by the feather shafts are found.

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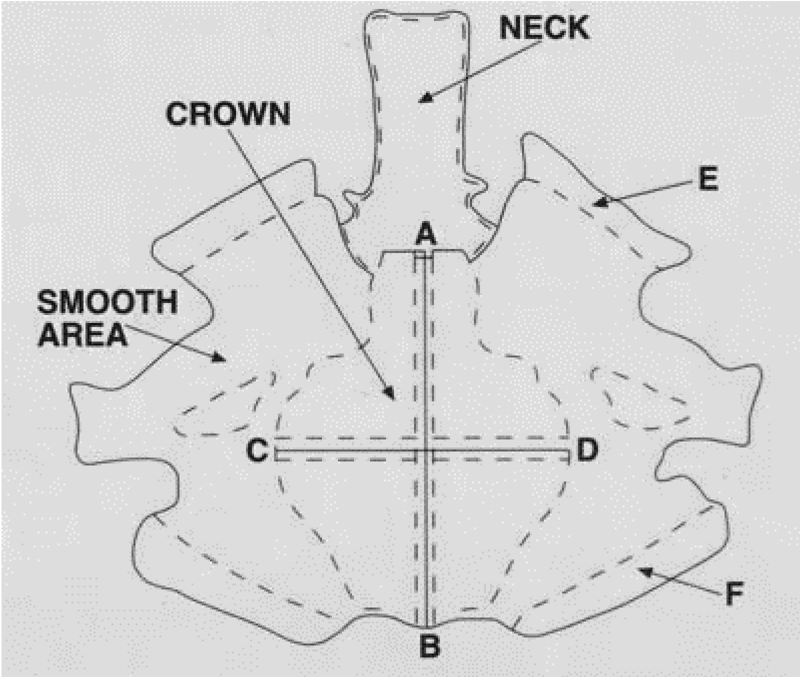

Figure 2.4. Dorsal view of a tanned ostrich skin. The line 'AB' stretches from the base of the neck to the bottom of the crown; 'CD' stretches between the widest nodulated areas of the crown. The length of 'E' and 'F' must be equal, elsewise it gives cause for down-grading by one grade (SCOT, Mossel Bay, South Africa; (Anon, 2006)

General guidelines as set out by the World Ostrich Association (WOA) (2006) give a brief overview of the grading system that is employed when classifying ostrich skins, using a numbered sequence from one to four. Skins deemed fit for Grade 1 yield the highest revenue as they are of the highest quality and must not display any defects across all four quarters, as well as the areas free of nodules. Defects can encompass any damage as a result of scars or wounds, simple cuts and holes present in the skin, loose scabs, rough surfaces due to sunburn or feather pecking, bacterial damage, tick bites and general scratches (Anon, 2006).

A skin classified in the Grade 2 category must be at least three quarters free from defects; however one defect no larger than 40 mm in diameter is permitted. Similarly, one healed wound on the crown is acceptable, permitted its length is no longer than the distance between two nodules. Minimal visible defects are also allowed outside the crown area, bringing into evidence the subjectivity of the grading system.

Grade 3 quality ostrich skins have been subjected to various forms of defects. However, they are permitted acceptance if they have a defect in any adjacent quarters so long it is no larger than 80 mm in diameter, while at least two continuous quarters are free from defects

(Anon, 2006). Furthermore, two more defects are permitted in any two simultaneous quarters if they are smaller than 40 mm in diameter and two healed wounds shorter in length than three consecutive nodules on the crown area are acceptable. Minimal visible defects are also permitted outside the crown area. Any skin that fails to make any of the first three grades is placed into Grade 4 (Anon, 2006).

2.5.3 Influence of age and weight on skin quality

Several studies have been conducted to investigate the effect of age and live weight on the skin yield. With an increased age comes an expected increase in skin yield as confirmed by various authors (Meyer *et al*., 2002; Cloete *et al*., 2004; Bhiya, 2006). Swart (1981) conducted research to initially indicate 14 months as the optimal slaughter age for ostriches to realize maximum returns with regards to the skin. However, with an increased research focus on the ostrich's meat and the need to minimize the time spent under intensive conditions, feeding regimes were improved (Engelbrecht *et al*., 2009).

The consequences of the improved feeding practices was birds reaching optimal slaughter condition earlier, and were therefore slaughtered at 10 to 12 months of age (Meyer, 2003). Swart (1981) contended that leather quality would be compromised if this was the scenario. However, before the abovementioned improved feeding strategies, slaughter birds typically achieved a final mass of 75 - 80 kg's at 14 months of age. Presently, it is possible to achieve slaughter weights over 100 kg at 14 months of age and even younger.

This obviously results in an increase in raw skin size as highlighted by (Cloete *et al*., 2004), who also found the largest nodule sizes in the oldest (in terms of slaughter age) group of ostrich skins at 14 months. These findings by Cloete *et al*. (2004) were later endorsed in a study by Van Schalkwyk *et al*. (2005). Detrimentally however, an increased live weight resulted in significant skin damage in the area outside of the crown as well as the total skin area when contrasted with birds of the same age but at a lower live weight (Meyer *et al*., 2004). This is where the conundrum of poorer grading arises based on the evidence of increased skin damage resulting from older and heavier birds.

Thus, it is clear that age as well as weight have an impact on skin damage and therefore skin quality. They also impact the nodule size and diameter, and Cloete *et al.* (2004) suggest alternative methods such as breeding and nutrition to achieve the largest nodule sizes in order to neutralize the negative impact of damage that is associated with age and weight.

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2.5.4 Skin quality as affected by nutrition

Brand *et al.* (2000b) investigated the influence of nutrition on the production of ostriches and found protein to have an influence on the degree of skin damage. The high protein diet (17%) had significantly less grade 1 skins than the medium (15%) and low protein diet (13%). They postulated that reasons for the findings may be due to an increased restlessness amongst the birds on the high protein diet. In terms of the skin surface area, no differences were found as a result of the different protein diets. Skin surface areas did however differ significantly among ostriches fed different levels of energy. The birds fed the high energy (12 MJ ME/kg DM) yielded the largest skin surface areas whilst there was no difference between the diets in terms of the percentage of grade 1 skins achieved.

2.6 Ostrich feathers

In the early 20th century when ostrich feathers were an extremely desired commodity, they were fourth on the list of total exports from South Africa, only behind commodities such as gold, diamonds and wool (Smit, 1964). Following the fall of the feather industry however, it took approximately 30 years for any semblance of a market for ostrich feathers to form again. Smit (1964) reports that a market for feather dusters was developed following the end of the second world war, creating uses for certain classes of feathers. Other applications of the feathers became the norm; including uses such as seen in fans, gowns, artificial flowers, handbags, hat trimmings and trimmings on dresses.

These uses for feathers are still in practise nowadays, with additions such as hair pieces, key holders, neck warmers and an array of dusters to highlight a few. Optimal feather production is thus of relevance to the producer, and Sales (1999) suggests clipping the feathers of ostriches at approximately 6 months of age in order to enhance new feather growth. Smit (1964) reported on the practise of 'picking' feathers by hand, which was the action of removing the whole ripe feather – the plume as well as the shaft – from the shaft opening. Nowadays however, 'clipping' is the standard procedure used whereby a feather clipper is used to clip the plume and a short piece of the shaft, usually above the bloodline of the shaft (Figure 2.5) (Smit, 1964; Carstens, 2013). The 'green' section still left attached to the skin is left to dry out before being removed.

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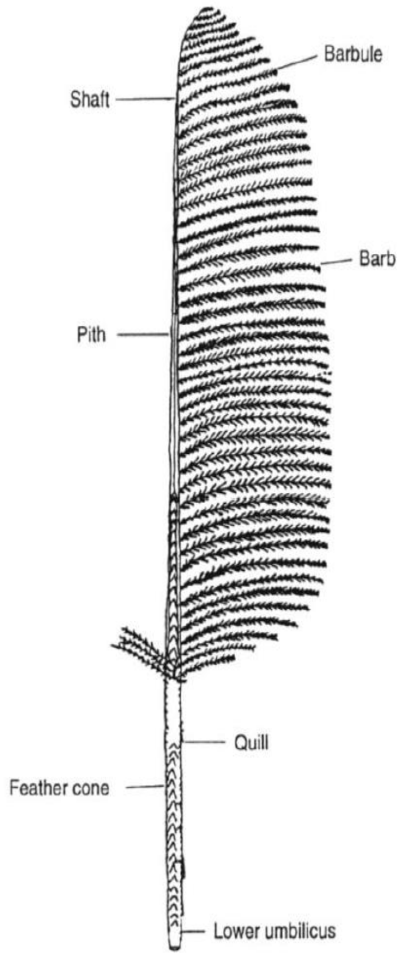

Figure 2.5. Ostrich feather with the separate parts labelled accordingly (Sales & Deeming, 1995)

2.6.1 Feather characteristics of commercial value

The feather characteristics that determine the commercial value as described in detail by Smith in 1964 are still applicable today. Length is used to distinguish the feathers if all the other characteristics for grading are similar. In extraordinary circumstances, shorter feathers are desirable, but generally the longer the feather the better; 24″ is an average length, 30 - 35″ being exceptional. (Smit, 1964)

Smit (1964) documented that a wider feather is of more commercial value than a narrow one. Width is determined by the length of the barbs and the angle they connect to the feather shaft. The density of the flue is an equally important characteristic, which is determined by the density of the barbs, the density of the barbules and the length of the barbules (Smit, 1964).

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The strength and durability of the flue is another characteristic Smit (1964) discussed, specifically the stiffness of the individual barbs and their tendency to be at right angles with the shaft and not droop down parallel with it. A poor quality flue would typically have the barbs hanging parallel with the shaft as opposed to a high quality one with barbs positioned at right angles to the shaft.

The following characteristics used in feather grading, quality and shape, are somewhat subjective; the fineness of the texture, softness to the touch, sheen and fat content altogether determine the quality of the feather (Smit, 1964). The shape of the feather is ideally symmetrical, with equal widths of the flue's, round points and square in shape.

Smit (1964) reported the shaft of the feather to ideally be fine and thin, strong enough to support the flue but supple enough for the tip of the feather to overhang. Finally, the absence of injuries or other deformities from the feather are desirable as they weaken the structure and overall quality. Poor nutrition, disease, parasites and inclement weather patterns can all be contributors to the deformation or damage that may occur to ostrich feathers (Smit, 1964).

2.6.2 Effect of nutrition

Little literature is available on the effects of nutrition on the quality of ostrich feathers. However, Brand *et al.* (2004) investigated the effects of dietary energy and protein on the quantity of saleable feathers harvested from slaughter ostriches. Interestingly, they found no differences between treatments for protein levels, but there were indeed differences as a result of the energy treatment diets. The highest energy diet (11.5 MJ ME/kg) yielded the heaviest harvest of saleable feathers; which is interesting given the nutrient make-up of feathers comprising of significant levels of proteins and amino acids.

Carstens (2013) found similar results, with protein having no significant effect on the harvest of feathers with commercial value; whereas the medium energy diet yielded the heaviest feathers of commercial value. Notably, Carstens (2013) also investigated the effect of clipping the feathers of slaughter ostriches at eight months of age, and proved Smit's (1964) belief that it was of benefit to the producer as the practise indeed yielded significantly heavier saleable feathers from ostriches slaughtered at 11.5 months of age.

2.7 Conclusion and objectives

Energy and protein are the most important nutrients used in the composition of not only ostrich diets, but across the board from a livestock nutrition perspective. With the ostrich industry currently under severe pressure as a result of the recent export ban on meat products to the European Union, the need to minimize costs from a nutrition standpoint has never been greater. In this regard, studies will be conducted to determine the optimal energy requirements of slaughter ostriches, as well as the optimal protein (and amino acid) requirements. Production parameters will be measured and recorded in an attempt to give assured advice with regards to the optimal diet compositions in terms of these nutrients. The results found in the study will also be used in a broader sense with regards to the continued development of an optimization model for the nutrient requirements of ostriches as developed by Gous and Brand (2008).

The effect of the energy on the meat characteristics will also be evaluated, as well as the impact on the skin and feather yield and quality. Similarly, the effect of the different protein concentrations in the diets of slaughter ostriches will be assessed in terms of their impact on the skin and feather yield as well as quality.

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Chapter 3

Effect of varying levels of protein concentrations on the production parameters of ostriches (*Struthio camelus* var. *domesticus*)

Abstract

The ostrich industry is poised to recover from the recent lifting of the four-year export ban on fresh meat products to the European Union. However, during this period, profit margins were severely affected and the need to minimize input costs was as important as it ever was, particularly nutrition. Protein is one of the most important nutrients in ostrich nutrition, and the aim of this study was to evaluate the influence of varying protein concentrations in the diets of slaughter ostriches in terms of the production parameters. In total, five treatment diets for each feeding phase (pre-starter, starter, grower and finisher) were formulated, with a control diet formulated and two treatment diets decreasing in protein content while two treatment diets increased in protein concentration per feeding phase. There were three replications per treatment diet, resulting in 15 camps containing 20 chicks each. Feed and water were available *ad libitum.* Significant differences (P < 0.05) were found in live weight of the birds at the end of each feeding phase except for the finisher phase. In terms of the production parameters, differences were found between the treatment diets for dry matter intake (DMI), average daily gain (ADG) as well as feed conversion ratio (FCR). The control diet, as well as the two diets formulated with higher protein concentrations, had higher DMI values, better ADG's as well as more efficient feed conversion ratios. Differences were also found in terms of cold carcass weights and thigh weights for the birds exposed to the different treatment diets. Results thus indicated that the birds on the control diet and on the diets containing higher concentrations of protein, although not differing from each other, consistently outperformed the diets with lower concentrations of protein. Thus, from a financial standpoint it can be concluded that it does not make sense to increase the protein concentration in the diets beyond that currently predicted by the optimization model (diet 3); while a decrease in protein concentration will result in decreased production performance.

3.1 Introduction

Ostriches are a recently domesticated species in relation to other animals such as poultry and cattle for example, which leaves scope for dramatic advances in terms of their production. In the

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Cape region of South Africa, the domestication process started in 1865 with 80 tame birds (Mellet, 1985). Consequently the behaviour, in particular the temperament of ostriches, is volatile in comparison to other livestock species currently produced world-wide. That being as it is, with domestication comes human control and influence over factors such as nutrition. Consequently, various studies have been conducted and results successfully implemented to better understand the nutritional requirements of ostriches (Smit, 1963; Mellett, 1985; Gandini *et al*., 1986; Du Preez, 1991; Mellet, 1992; Ullrey & Allen, 1996; Cilliers *et al*., 1998; Brand *et al*., 2000; Brand, 2006; Brand & Olivier, 2011).

Nutritionally, a source of protein in any livestock species' diet is of significant importance. An estimated 70 – 80% of the input costs in an ostrich enterprise are attributed to the feeding of the birds (Brand & Gous, 2006). Slaughter ostriches generally receive four diets according to their age and physiological development; pre-starter, starter, grower and finisher diets. With protein comprising up to 22.9%, depending on the feeding phase, of the diet fed to ostriches (Brand & Gous, 2006); optimizing and understanding the protein requirements of the birds becomes of paramount importance.

From a producer's point of view the most viable solution in terms of nutrition, without compromising on the quality of the end products, is the most desirable. Therefore in this study, the effect of the varying concentrations of protein in the diets of slaughter ostriches was evaluated in terms of the feed intake, average daily gains and feed conversion ratio. The bulk of the revenue is generated from three products, namely the skin, meat and feathers of ostriches. The resultant growth response was also analysed, with the impact on the slaughter parameters.

3.2 Materials and Methods

This trial was conducted at the Oudtshoorn Research farm (situated 22˚20' E, 33˚58' S and at an altitude of 307 m) in the Klein Karoo region of South Africa. The trial was structured with five treatments including three replications per treatment. There were a total of 300 birds randomly assigned into the 15 separate groups, with each individual group containing 20 young growing chicks. The 15 groups were kept in separate camps with adequate shelter and approximate dimensions of 20 m x 5 m until they reached an age of 213 days. They were then transferred to larger camps of approximately 25 m x 25 m to accommodate their growth and prevent unnecessary damage to their skins that may be caused by overcrowded conditions.

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The five treatment groups each received separate diets formulated to contain different levels of essential amino acids with a specific profile (refer to protein level), namely diet 1 through diet 5. Diet 3 was formulated according to that which is predicted by the optimization model developed by Gous and Brand (2008), and therefore acted as the control treatment for the study. Four separate feeding stages are present in a slaughter ostrich's lifespan; starting with pre-starter, onto starter, then grower, and finally a finisher diet. Thus, in this trial the ostriches were fed according to standard practices, but in the five treatments mentioned. The compositions of these diets which were formulated on a least cost basis are presented in Tables 3.1 – 3.4. The chemical compositions of the diets are presented in Tables 3.5 and 3.6, while the amino acid profiles are displayed in Tables 3.7 and 3.8.

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Table 3.1. Composition of the five treatment diets (as fed basis) in the pre-starter phase of slaughter ostriches (kg/ton) fed from 0 – 79 days of age

Raw materials (kg)	**Diet number (% CP)**				
	1 (15.2%)	**2 (17.1%)**	**3 (19.0%)**	**4 (20.9%)**	**5 (22.8%)**
Maize meal	575.00	550.00	525.00	500.00	475.00
Soybean oilcake meal	105.40	142.83	180.25	217.68	255.10
Fishmeal	50.00	62.50	75.00	87.50	100.00
Full fat soybean meal	50.00	40.53	31.05	21.58	12.10
Bentonite	25.00	25.00	25.00	25.00	50.00
Lucerne meal	50.00	43.75	37.50	31.25	25.00
Wheat bran	43.70	32.78	21.85	10.93	0.00
Plant oil	47.10	45.48	43.85	42.23	40.60
Monocalcium phosphate	24.00	23.73	23.45	23.18	22.90
Limestone	13.00	10.43	7.85	5.28	2.70
Salt	10.00	10.00	10.00	10.00	10.00
Synthetic lysine	1.80	1.75	1.70	1.65	1.60
Mineral and vitamin premix*	5.00	5.00	5.00	5.00	5.00

*Refer to ANNEXURE A for the composition of the vitamin and mineral premix.

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Table 3.2. Composition of the five treatment diets (as fed basis) in the starter phase of slaughter ostriches (kg/ton) fed from 80 – 157 days of age

Raw Materials (kg)	**Diet number (% CP)**				
	1 (13.1%)	**2 (14.3%)**	**3 (15.5%)**	**4 (16.7%)**	**5 (17.8%)**
Maize meal	544.60	510.15	475.70	440.60	405.50
Soybean oilcake meal	100.00	132.50	165.00	198.00	231.00
Lucerne meal	100.00	100.00	100.00	100.00	100.00
Wheat bran	100.00	100.00	100.00	100.00	100.00
Bentonite	50.00	50.00	50.00	50.00	50.00
Molasses meal	40.00	40.00	40.00	40.00	40.00
Plant oils	15.50	17.75	20.00	22.50	25.00
Monocalcium phosphate	10.60	10.10	9.60	9.05	8.50
Limestone	22.00	22.00	22.00	22.00	22.00
Salt	10.00	10.00	10.00	10.00	10.00
Synthetic lysine	2.30	2.50	2.70	2.85	3.00
Mineral and vitamin premix*	5.00	5.00	5.00	5.00	5.00

*Refer to ANNEXURE A for the composition of the vitamin and mineral premix.

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Table 3.3. Composition of the five treatment diets (as fed basis) in the grower phase of slaughter ostriches (kg/ton) fed from 158 – 241 days of age

Raw Materials (kg)	**Diet number (% CP)**				
	1 (12.30%)	**2 (13.28%)**	**3 (14.25%)**	**4 (15.23%)**	**5 (16.20%)**
Maize meal	451.00	432.00	413.00	393.50	374.00
Soybean oilcake meal	37.90	63.65	89.40	115.15	140.90
Lucerne meal	444.87	438.33	431.78	425.74	419.70
Molasses meal	40.00	40.00	40.00	40.00	40.00
Monocalcium phosphate	18.30	17.70	17.10	16.50	15.90
Limestone	6.00	6.30	6.60	6.91	7.21
Salt	10.00	10.00	10.00	10.00	10.00
Synthetic lysine	1.25	1.29	1.32	1.35	1.38
Synthetic methionine	0.68	0.74	0.80	0.86	0.91
Mineral and vitamin premix*	5.00	5.00	5.00	5.00	5.00

*Refer to ANNEXURE A for the composition of the vitamin and mineral premix.

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Table 3.4. Composition of the five treatment diets (as fed basis) in the finisher phase of slaughter ostriches (kg/ton) fed from 242 – 360 days of age

Raw Materials (kg)	**Diet number (% CP)**				
	1 (11.8%)	**2 (12.2%)**	**3 (12.6%)**	**4 (13.0%)**	**5 (13.4%)**
Maize meal	200.00	200.00	200.00	200.00	200.00
Soybean oilcake meal	0.00	12.50	25.00	37.50	50.00
Lucerne meal	250.00	250.00	250.00	250.00	250.00
Wheat bran	306.00	293.00	280.00	266.90	253.90
Oat bran	97.00	97.00	97.00	97.00	97.00
Molasses meal	50.00	50.00	50.00	50.00	50.00
Bentonite	50.00	50.00	50.00	50.00	50.00
Monocalcium phosphate	20.40	20.10	19.90	19.60	19.30
Limestone	10.70	10.80	10.90	10.90	11.00
Salt	10.00	10.00	10.00	10.00	10.00
Synthetic lysine	0.30	0.60	1.00	1.30	1.60
Synthetic methionine	0.60	1.00	1.40	1.80	2.20
Mineral and vitamin premix	5.00	5.00	5.00	5.00	5.00

*Refer to ANNEXURE A for the composition of the vitamin and mineral premix.

Table 3.5. Proximate analysis (as formulated basis) of experimental diets containing five levels of protein (1, 2, 3, 4 and 5) fed to ostriches during the pre-starter (0 – 79 days) and starter (80 - 157 days) phases

Nutrient	**Diet number**									
	Pre-starter					**Starter**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
ME MJ/kg feed*	14.5	14.5	14.5	14.5	14.5	13.5	13.5	13.5	13.5	13.5
Dry material (g/kg)	903.1	902.9	902.7	902.5	902.3	898.0	898.2	898.4	898.6	898.8
Crude protein(g/kg)	152.0	171.3	190.4	209.2	228.0	131.1	142.8	154.5	166.2	177.9
Ash (g/kg)	24.9	25.3	25.8	26.2	26.6	23.8	23.4	22.9	22.5	22.0
Crude fibre (g/kg)	40.4	40.9	41.4	41.9	42.3	55.5	57.1	58.6	60.2	61.7
Fat (g/kg)	84.0	80.4	76.7	73.0	69.5	45.5	46.8	48.1	49.4	50.7
Calcium (g/kg)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Phosphorous (g/kg)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00

*As formulated

Table 3.6. Proximate analysis (as formulated basis) of experimental diets containing five levels of protein (1, 2, 3, 4 and 5) fed to ostriches during the grower (158 – 241 days) and finisher (242 - 360 days) phases

Nutrient	**Diet number**									
	Grower					**Finisher**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
ME MJ/kg feed*	11.5	11.5	11.5	11.5	11.5	10.7	10.7	10.7	10.7	10.7
Dry material (g/kg)	909.4	909.1	908.9	908.6	908.5	908.3	908.4	908.5	908.6	908.6
Crude protein (g/kg)	123.5	133.1	142.7	152.3	161.9	117.7	121.9	126.0	130.1	134.1
Ash (g/kg)	49.0	48.1	47.3	46.5	45.6	54.7	53.8	53.0	52.3	51.5
Crude fibre (g/kg)	120.0	119.8	119.6	119.4	119.2	132.5	132.0	131.4	130.9	130.3
Fat (g/kg)	24.4	24.2	24.0	23.8	23.5	23.9	23.8	23.6	23.5	23.3
Calcium (g/kg)	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0
Phosphorous (g/kg)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00

*As formulated

Table 3.7. Amino acid composition of the treatment diets (g/kg) on an as formulated basis for the pre-starter and starter phases

Amino acids	**Diet number**									
	Pre-starter					**Starter**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Protein %	152.0	171.3	190.4	209.2	228.0	131.1	142.8	154.5	166.2	177.9
Lysine	10.1	11.4	12.6	13.9	15.1	7.40	8.35	9.30	10.25	11.2
Methionine	3.50	3.95	4.40	4.85	5.30	2.60	2.95	3.30	3.65	4.00
Cysteine	1.00	1.10	1.20	1.30	1.40	0.80	0.90	1.00	1.10	1.20
TSA*	4.50	5.05	5.60	6.15	6.70	3.40	3.85	4.30	4.75	5.20
Threonine	5.80	6.50	7.20	7.90	8.60	4.30	4.85	5.40	5.95	6.50
Tryptophan	1.40	1.60	1.80	2.00	2.20	1.10	1.25	1.40	1.55	1.70
Arginine	9.50	10.7	11.9	13.1	14.3	7.10	8.00	8.90	9.80	10.7

*Total sulphur containing amino acids

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Table 3.8. Amino acid composition of the treatment diets (g/kg) on an as formulated basis for the grower and finisher phases

Amino acids	**Diet number**									
	Grower					**Finisher**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Protein %	123.5	133.1	142.7	152.3	161.9	117.7	121.9	126.0	130.1	134.1
Lysine	5.60	6.30	7.00	7.80	8.40	4.40	4.95	5.50	6.05	6.60
Methionine	2.00	2.25	2.50	2.75	3.00	1.50	1.70	1.90	2.10	2.30
Cysteine	0.70	0.80	0.90	1.00	1.10	1.50	1.55	1.60	1.65	1.70
TSA	2.70	3.05	3.40	3.75	4.10	3.00	3.25	3.50	3.75	4.00
Threonine	3.40	3.80	4.20	4.60	5.00	3.60	3.75	3.90	4.05	4.20
Tryptophan	0.90	1.00	1.10	1.20	1.30	1.60	1.65	1.70	1.75	1.80
Arginine	5.40	6.10	6.80	7.50	8.20	5.90	5.93	5.95	5.98	6.00

*Total sulphur containing amino acids

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As mentioned, the middle diet (Diet 3) served the purpose of the control diet and the diets were decreased and increased by a factor 10% (twice lower and twice higher) in terms of the crude protein levels to yield two lower and two higher diets in terms of protein content. The energy contents of the diets were kept constant in order to investigate the effects that protein as the treatment had on the production parameters of ostriches.

The ostriches were fed their respective diets *ad libitum* and had free access to clean, fresh water. They were weighed once weekly on the same day for the duration of the trial, and their live weights recorded in order to determine average daily gain (ADG). Feed intake per camp was measured weekly by weighing back the refusals for the week and subtracting the value from the quantity of feed offered during the week. The feed conversion ratios (FCR) per treatment were then calculated by dividing the dry matter intake (DMI) by the total ADG per phase. The protein efficiency ratio (PER) was also determined using the percentage of protein in the diet as a factor of the daily intake per bird to give the protein intake (PI) (kg), per kilogram weight gain per bird. Therefore the calculation yielding the PER was the ADG divided by the PI. The recording of both live weights and feed refusals occurred on the same day every week. Inclement weather resulted in the cancellation of three weighing sessions to prevent any injury to the animals themselves as well as the handlers; however the feed refusals were still able to be recorded.

At 12 months of age, the birds were placed into a quarantine camp for 14 days as depicted by the European Union (EU) meat quality standards highlighted in the report by the Department of Agriculture (2013). At this point they all received a standard diet due to the facilities available, one large quarantine camp, dictating the decision. The birds were also tested for strains of avian influenza (AI), which subsequently resulted in positive sera screening for the H5N2 and the H6N2 strains. The consequences thereof meant that the slaughter of the ostriches would not be permitted until the collective flock was free from the strains of the virus, and they were reassigned into their camps for a further six weeks; where they received the treatment diets once more. Consequently, the ostriches were placed into the quarantine camp again after this period for the mandatory 14 days before slaughter. Thus, the birds had attained an age of 13.5 months before they were finally slaughtered.

The birds were transported to be slaughtered at the Mosstrich abattoir in Mossel Bay, approximately 100 kilometres from the research farm due to limited availability at Klein Karoo

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International abattoir in Oudtshoorn. The live weight of each animal was recorded and the standard slaughtering procedures as described by Hoffman (2012) were followed, with the use of The Divac Ostrich Stunning box®.

Warm carcass weights were also recorded once skinning and evisceration had taken place, where after the carcasses were moved into the cold storage facility. The cold carcass weights were only measured after a period of 72 hours due to the slaughter day being at the end of the working week. The carcass is comprised of only the neck, wings, chest and thighs of the bird; and the cold carcass weight is used to calculate it's percentage of the live weight, commonly known as the dressing percentage. The right thigh weight of each individual ostrich was recorded and multiplied by two to give an indication of the proportion of the total weight of the carcass.

Statistical analysis was done using SAS Enterprise Guide (version 9.2). A regression analysis was done per treatment diet over age to assess the weight gains by the birds. Gompertz growth models were fitted and the slopes compared to assess any differences in weight gain using analysis of variances (ANOVA). Furthermore, regression was run per treatment over age within each feeding phase and the slopes compared per physiological phase (pre-starter, starter, grower and finisher). In the pre-starter phase, a linear function was fitted to the data, as well as the starter phase. In the grower phase, the Mitscherlich function (natural growth) was fitted over age. This was due to a severe decline in feed intake by the ostriches during this phase as a result of sickness within the flock, aggravated by the clipping of feathers (standard operating procedures in a commercial flock) at 240 days of age and the onset of winter; which subsequently affected their daily gains and therefore their overall body weight gains during this period. A linear function was then applied to the data in the final finisher phase. ANOVA's were conducted on averages for the production parameters measured, namely dry matter intake (DMI), average daily gain (ADG), feed conversion ratio (FCR) and protein efficiency ratio (PER) as no distinct trends were observed in the slopes obtained per treatment. One – way ANOVA's were then done on the parameters measured at slaughter such as the live weight, cold carcass weight, right thigh weight and dressing percentages.

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3.3 Results

The treatment diets had an effect ($P < 0.05$) on all the production parameters in at least one of the four feeding phases (Table 3.9). Diet had an effect ($P < 0.05$) on the ADG in the pre-starter and starter phases. Diets 4 and 5 had the highest gains in the pre-starter phase, whilst diet 1 resulted in the lowest gains across the pre-starter and starter phases. The gains (LSM ± SE) for the pre-starter and starter phases for diet 1 were 137.2 ± 12.4 and 291.7 ± 17.1 g/bird/day, respectively; while they were significantly higher for diet 5 (277.3 ± 6.9 and 456.0 ± 19.1 g/bird/day, respectively) for the two phases. No differences ($P > 0.05$) were found between any of the treatment diets for the grower and finisher phases. However, over the whole trial period, there were differences ($P < 0.05$) between the treatments with diets 3 (340.4 ± 15.1 g/bird/day), 4 (346.9 ± 9.0 g/bird/day) and 5 (344.9 ± 3.8 g/bird/day) yielding higher gains than diets 1 (259.4 ± 7.1 g/bird/day) and 2 (298.9 ± 1.4 g/bird/day). The latter two diets also differed ($P < 0.05$) between themselves.

With regards to dry matter intake (DMI), differences ($P < 0.05$) were found between the treatment diets over the trial, as well as in the pre-starter, starter and grower phases. No differences ($P > 0.05$) were found in the finisher phase, as was the case for ADG. The ostriches on the high protein concentration diets (4 and 5), had the highest daily intakes of 0.56 ± 0.001 and 0.61 ± 0.04 kg/bird/day for the pre-starter phase. Diet 3 (0.48 ± 0.02 kg/bird/day) did not differ ($P > 0.05$) from diet 4, but diets 1 and 2 had lower intakes ($P < 0.05$) than the other diets of 0.40 ± 0.04 and 0.42 ± 0.02 kg/bird/day, respectively. For the starter phase, only diet 1 differed ($P < 0.05$) from the other diets with the lowest intake of 1.06 ± 0.09 kg/bird/day. Diet 4 had the highest DMI of 1.50 ± 0.01 kg/bird/day. A similar pattern was evident in the grower phase, where birds from diet 1 again had the lowest intake of 1.73 ± 0.06 kg/bird/day. Although diet 2 (1.97 ± 0.21 kg/bird/day) did not differ ($P > 0.05$) from diet 1, all the other diets had significantly higher ($P < 0.05$) intakes with birds on diet 3 consuming the most feed (2.32 ± 0.15 kg/bird/day). No differences ($P > 0.05$) were found in the finisher phase between the treatments. However, ostriches fed diets 3, 4 and 5 had higher intakes per day over the whole trial period. They were higher ($P < 0.05$) with the intakes 1.65 ± 0.03, 1.64 ± 0.02 and 1.68 ± 0.03 kg/bird/day respectively, than those attained by birds fed diets 1 and 2 (1.43 ± 0.02 and 1.51 ± 0.06 kg/bird/day, respectively).

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The feed conversion ratio (FCR) expressed as kilograms feed required to realize a kilogram body weight gain, also differed ($P < 0.05$) between treatment diets for the pre-starter, starter and grower phases. No differences ($P > 0.05$) were found between the diets for the finisher phase. In the pre-starter phase, there were no differences ($P > 0.05$) between diets 3, 4 and 5, with FCR's of 2.32 ± 0.06, 2.33 ± 0.14 and 2.18 ± 0.08, respectively. Diet 2, with an FCR of 2.48 ± 0.10 did not differ ($P > 0.05$) from diets 3 and 4, but it did indeed differ ($P < 0.05$) from diet 1. Birds fed diet 1 required the most feed (2.88 ± 0.04 kg) in order to attain a body weight gain of one kilogram. In the starter phase, diets 1 and 2 differed ($P < 0.05$) from diet 5, both with FCR's of 3.63 contrasted with a FCR of 3.21 ± 0.18 for diet 5. Diets 3 and 4 did not differ with either of the other treatments, with FCR's of 3.41 ± 0.11 and 3.36 ± 0.08 respectively. Interestingly, in the grower phase diets 1 (4.04 ± 0.12) and 2 (4.40 ± 0.30) attained lower FCR values than the other diets. Diet 1 differed ($P < 0.05$) from diets 3 (5.11 ± 0.36), 4 (5.20 ± 0.22) and 5 (5.46 ± 0.13), while no differences ($P > 0.05$) were found between diets 2 and 3. These findings are completely opposite to the general trends seen over the course of the trial as well as every other feeding phase. As was the case with the other production parameters in the finisher phase, no differences ($P > 0.05$) were found between the treatment diets. Over the whole trial however, birds fed diet 1 differed ($P < 0.05$) from the rest of the birds with a FCR of 5.52 ± 0.06. Although not statistically different ($P > 0.05$) from the remaining four diets, birds fed diet 4 had the lowest FCR of 4.72 ± 0.18.

With regards to the protein efficiency ratio (PER), differences ($P < 0.05$) were found during the grower phase of the trial, whilst no differences ($P > 0.05$) were found across any of the other feeding phases. Interestingly, in the grower phase the PER values obtained mirrored those found in the same phase for FCR, with diet 1 (2.01 ± 0.07) outperforming diet 2 (1.73 ± 0.12) which in turn had a higher PER value than the other three diets. Although the values for the PER decrease, whereas those for the FCR increase in this example, the effect is the same due to the formula used to calculate the PER; which is in effect an inverse of the FCR.

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Table 3.9. Least square means ± standard error (LSM ± SE) for the effect of dietary protein concentrations on the production parameters of slaughter ostriches

Parameter	Phase	Diet				
		1	2	3	4	5
Dry Matter Intake (DMI) (kg/bird/day)	All phases	$1.43^{a} \pm 0.02$	$1.51^{a} \pm 0.06$	$1.65^{b} \pm 0.03$	$1.64^{b} \pm 0.02$	$1.68^{b} \pm 0.03$
	Pre-starter	$0.40^{a} \pm 0.04$	$0.42^{a} \pm 0.02$	$0.48^{ab} \pm 0.02$	$0.56^{bc} \pm 0.001$	$0.61^{c} \pm 0.04$
	Starter	$1.06^{a} \pm 0.09$	$1.32^{b} \pm 0.07$	$1.46^{b} \pm 0.08$	$1.50^{b} \pm 0.01$	$1.46^{b} \pm 0.02$
	Grower	$1.73^{a} \pm 0.06$	$1.97^{ab} \pm 0.21$	$2.32^{b} \pm 0.15$	$2.26^{b} \pm 0.07$	$2.27^{b} \pm 0.01$
	Finisher	2.29 ± 0.02	2.38 ± 0.09	2.45 ± 0.07	2.36 ± 0.09	2.40 ± 0.06
Average Daily Gain (ADG) (g/bird/day)	All phases	$259.4^{a} \pm 7.1$	$298.9^{b} \pm 1.4$	$340.4^{c} \pm 15.1$	$346.9^{c} \pm 9.0$	$344.9^{c} \pm 3.8$
	Pre-starter	$137.2^{a} \pm 12.4$	$171.7^{ab} \pm 14.8$	$208.1^{bc} \pm 12.7$	$243.4^{cd} \pm 11.9$	$277.3^{d} \pm 6.9$
	Starter	$291.7^{a} \pm 17.1$	$362.6^{b} \pm 18.7$	$427.3^{c} \pm 11.3$	$445.9^{c} \pm 13.5$	$456.0^{c} \pm 19.1$
	Grower	428.4 ± 21.8	446.4 ± 29.8	456.0 ± 12.6	435.3 ± 17.2	415.6 ± 11.5
	Finisher	250.0 ± 6.8	296.0 ± 27.7	310.4 ± 41.7	309.4 ± 43.3	276.0 ± 13.6
Feed Conversion Ratio (FCR) (kg feed/kg weight gain)	All phases	$5.52^{a} \pm 0.06$	$5.07^{b} \pm 0.21$	$4.86^{b} \pm 0.12$	$4.72^{b} \pm 0.18$	$4.88^{b} \pm 0.04$
	Pre-starter	$2.88^{a} \pm 0.04$	$2.48^{b} \pm 0.10$	$2.32^{bc} \pm 0.06$	$2.33^{bc} \pm 0.14$	$2.18^{c} \pm 0.08$
	Starter	$3.63^{a} \pm 0.12$	$3.63^{a} \pm 0.06$	$3.41^{ab} \pm 0.11$	$3.36^{ab} \pm 0.08$	$3.21^{b} \pm 0.18$
	Grower	$4.04^{a} \pm 0.12$	$4.40^{ab} \pm 0.30$	$5.11^{bc} \pm 0.36$	$5.20^{c} \pm 0.22$	$5.46^{c} \pm 0.13$
	Finisher	9.17 ± 0.22	8.24 ± 1.13	8.14 ± 0.93	7.95 ± 1.21	8.74 ± 0.37
Protein efficiency ratio (PER)	Pre-starter	2.21 ± 0.04	2.30 ± 0.12	2.18 ± 0.09	2.04 ± 0.13	2.01 ± 0.09
	Starter	2.12 ± 0.09	1.93 ± 0.04	1.92 ± 0.08	1.81 ± 0.06	1.78 ± 0.10
	Grower	$2.01^{a} \pm 0.07$	$1.73^{b} \pm 0.12$	$1.41^{c} \pm 0.10$	$1.27^{cd} \pm 0.05$	$1.13^{d} \pm 0.02$
	Finisher	0.92 ± 0.06	1.05 ± 0.13	1.01 ± 0.13	1.08 ± .0.19	0.88 ± 0.02

^{a,b,c,d} Row means with different superscripts differ significantly (*P* < 0.05)

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Various regression models fitted over the four separate phases are presented in Table 3.10. At the end of the pre-starter phase, differences ($P < 0.05$) were evident between the weights of the birds receiving the separate diets. No differences ($P > 0.05$) were found between diets 1 and 2, but collectively they differed ($P < 0.05$) from diets 3, 4 and 5. Diet 1 had on average the lightest group of birds at 12.6 ± 1.50 kg each, whereas birds receiving diet 5 were the heaviest at 22.8 ± 0.74 kg.

At the end of the starter phase, differences ($P < 0.05$) were evident between birds fed diets 1 (35.9 ± 2.39 kg) and 2 (45.7 ± 3.42 kg). Although diets 3 (55.5 ± 1.47 kg), 4 (56.0 ± 2.46 kg) and 5 (58.2 ± 1.23 kg) did not differ ($P > 0.05$) from each other, they collectively had significantly higher ($P < 0.05$) weights than both the other diets at the end of the phase.

The results from the grower phase mirrored those observed during the pre-starter phase. Diets 1 (58.0 ± 2.05 kg) and 2 (63.3 ± 4.08 kg) did not differ ($P > 0.05$) from each other, but together they differed ($P < 0.05$) from diets 3, 4 and 5 which had average weights of 73.6 ± 1.85 kg, 76.3 ± 3.26 kg and 74.1 ± 1.51 kg, respectively. The latter three diets did not differ ($P > 0.05$) from each other.

Finally, in the finisher phase, no differences ($P > 0.05$) were found between the treatments for the average weight of the birds at the end of this phase (Table 3.10).

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Table 3.10. Least square means ± standard error (LSM ± SE) for the effect of dietary protein concentrations on phase by phase weight of slaughter ostriches with the fitted functions

Dietary phase	Diets					
	Function fitted	1	2	3	4	5
Pre-starter (0 – 79 days)	Exponential $BW = a.\exp(b.x)$	12.6[a] ± 1.50	14.4[a] ± 2.34	20.4[b] ± 1.38	20.4[b] ± 1.60	22.8[b] ± 0.74
Starter (80 – 157 days)	Linear $BW = a + (b.x)$	35.9[a] ± 2.39	45.7[b] ± 3.42	55.5[c] ± 1.47	56.0[c] ± 2.46	58.2[c] ± 1.23
Grower (158 – 241 days)	Mitscherlich $BW = a + b(1 - \exp(c.x))$	58.0[a] ± 2.05	63.3[a] ± 4.08	73.6[b] ± 1.85	76.3[b] ± 3.26	74.1[b] ± 1.51
Finisher (242 – 360 days)	Linear $BW = a + (b.x)$	101.9 ± 5.10	97.3 ± 3.12	104.7 ± 3.92	105.7 ± 3.12	102.7 ± 3.32

[a,b] Row means with different superscripts differ significantly ($P < 0.05$)
BW = live weight; a =mature BW in kg; *b,c* = parameter specific for each function

Gompertz growth curves were fitted to the data over the course of the feeding period. (Figure 3.1).

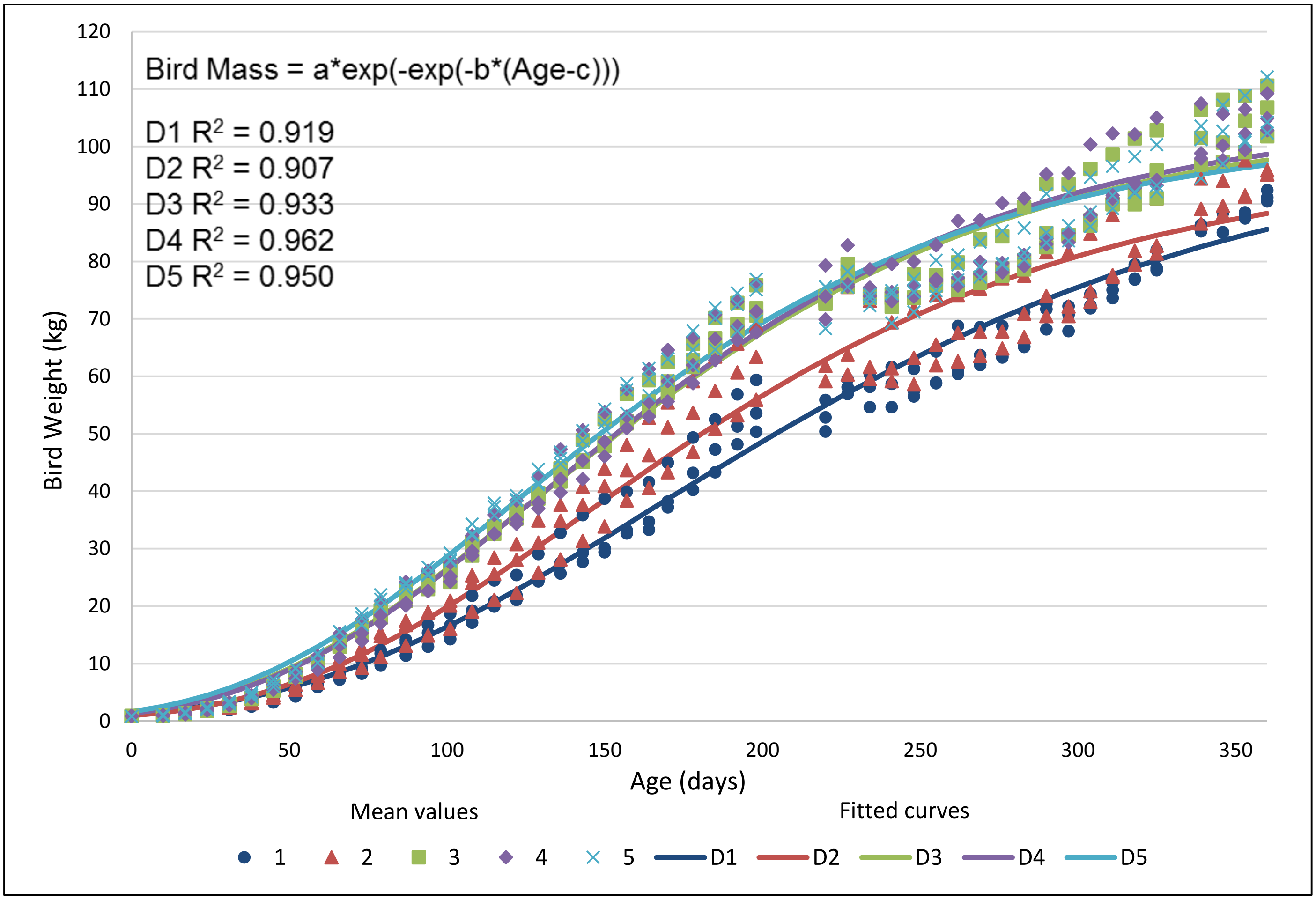

Figure 3.1. Gompertz growth curves fitted to ostriches body weight increase over time per treatment diet [a (maximum weight, kg), b (rate of maturing parameter) and c (age of maximum growth, days)]

The growth parameters a (maximum weight), b (rate of maturing parameter) and c (age of maximum growth) are presented for all of the treatment diets in Table 3.11. There were no differences for the a-values obtained. Differences were however found in the b- and c- growth parameter estimates. Birds fed diet 1 had the lowest estimates in terms of the value for the rate of maturing (b = 0.009), while reaching their maximum growth at 167 days of age. There were no differences between the other four treatment diets, but diet 5 did have the highest rate of maturing (b = 0.012) which reflected in those birds reaching a (predicted) maximum age of growth in the least number of days (121 days) after the start of the trial (Table 3.11).

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Table 3.11. Growth parameters ± standard error (S.E) of slaughter ostriches fed different diets as predicted by the Gompertz growth curve

Diet	Gompertz model parameters			
	a	b	c	R^2
1	101.9 ± 5.10	0.009^{a} ± 0.0007	167^{a} ± 12.14	0.919
2	97.3 ± 3.12	0.011^{ab} ± 0.0010	143^{ab} ± 10.77	0.907
3	104.7 ± 3.92	0.011^{b} ± 0.0002	128^{b} ± 2.86	0.933
4	105.7 ± 3.14	0.012^{b} ± 0.0002	128^{b} ± 1.86	0.962
5	102.7 ± 4.05	0.012^{b} ± 0.0008	121^{b} ± 3.32	0.950

^{a,b} Column means with different superscripts differ significantly ($P < 0.05$)
a – maximum weight (kg), b – rate of maturing parameter, c – age of maximum growth (days)

Differences ($P < 0.05$) were found between the treatments when the average live weight at slaughter was considered (Table 3.12). Diets 1 (91.4 ± 1.37 kg) and 2 (96.8 ± 0.38 kg) had the lightest birds, while diets 3 (106.5 ± 2.23 kg), 4 (102.1 ± 1.46 kg) and 5 (104.4 ± 2.55 kg) did not differ ($P > 0.05$) in terms of live weight at slaughter. Diets 2 and 4 also did not differ ($P > 0.05$) from each other. These differences logically filtered down to the cold carcass weights, with diets 3, 4 and 5 having the highest weights of 51.6 ± 0.81 kg, 50.6 ± 0.66 kg and 52.0 ± 0.65 kg respectively; which did not differ ($P < 0.05$). Birds fed diet 2 had lighter carcasses (47.0 ± 0.27 kg) which differed ($P < 0.05$) from the three treatments above as well as treatment diet 1, with the lightest carcasses at 44.5 ± 0.62 kg. The right thigh weight from each bird was weighed, and differences ($P < 0.05$) were again evident that correlated with the live weights and cold carcass weights of the birds. Diet 1 (16.2 ± 0.11 kg) had the lightest thigh weights, significantly different ($P < 0.05$) from diet 2 (17.2 ± 0.14 kg), which in turn was different ($P < 0.05$) from diets 3, 4 and 5. The latter three treatment diets had right thigh weights that measured 18.8 ± 0.34 kg, 18.6 ± 0.24 kg and 19.2 ± 0.29 kg respectively.

No differences ($P > 0.05$) were found between treatments in terms of the dressing percentages (Table 3.12). The right thigh weights were multiplied by two to give the weight of both thighs together, from which the percentage of the thigh weights calculated as a whole of the

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carcass weight was calculated. No differences (P < 0.05) were found between the treatments (~73%) in this regard.

Table 3.12. Least square means ± standard error (LSM ± SE) for the effect of dietary protein concentrations on the slaughter parameters measured for slaughter ostriches

Parameters	Diets				
	1	2	3	4	5
Live weight (kg)	$91.4^{a} \pm 1.37$	$96.8^{ab} \pm 0.38$	$106.5^{c} \pm 2.23$	$102.1^{bc} \pm 1.46$	$104.4^{c} \pm 2.55$
Cold carcass (kg)	$44.5^{a} \pm 0.62$	$47.0^{b} \pm 0.27$	$51.6^{c} \pm 0.81$	$50.6^{c} \pm 0.66$	$52.0^{c} \pm 0.65$
Dressing percentage (%)	49.20 ± 0.25	48.74 ± 0.64	48.80 ± 0.37	49.64 ± 0.39	49.90 ± 0.64
Right thigh weight (kg)	$16.2^{a} \pm 0.11$	$17.2^{b} \pm 0.14$	$18.8^{c} \pm 0.34$	$18.6^{c} \pm 0.24$	$19.2^{c} \pm 0.29$
Thigh (both) percentage of carcass (%)	73.02 ± 0.28	73.02 ± 0.15	73.05 ± 0.23	73.27 ± 0.23	73.11 ± 0.13

^{a,b,c} Row means with different superscripts differ significantly (P < 0.05)

3.4 Discussion

With such a wide variation around the control diet (3) used in this study in terms of protein concentrations, differences were expected with regards to the production parameters across most of the four feeding phases. Brand *et al.* (2000) fed ostriches from four to eleven months of age three different concentrations of protein in their treatment diets. They however, found no differences in the production parameters DMI, ADG and FCR. Conversely, in this study with regards to the whole trial period, differences were found across each parameter between at least one of the treatment diets. This may be explained by the simple increase in number of treatments used in this study, as well as progress made in terms of the understanding of ostrich nutrition since the work by Brand *et al*. (2000). The results in this study also support those by Carstens (2013) to an extent, where differences were found between three treatment diets, with varying protein concentrations, in the ADG and DMI, but not in the FCR. Interestingly, when examining the results for the whole trial period, there are no differences across any of the production parameters between diets 3, 4 and 5. Therefore, it can be argued that an increase in protein concentrations above that

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currently in use by producers does not yield better performance results and is more expensive to maintain.

Having said that however, stark differences were found between the treatment diets fed in each of the four separate phases, none more so than the pre-starter phase. With an increase in protein concentration in the diets from 1 to 5, there was an increase in DMI, therefore ADG and a resultant decrease in FCR. The daily gains by the chicks receiving diet 5 (228 g protein/kg feed) were more than double those achieved by the chicks fed diet 1 (152 g protein/kg feed). This supports findings by Gandini *et al.* (1986), who found superior growth in the pre-starter phase if protein ranging from 160 g/kg to 180 g/kg feed was present in the diet. However, more recent work by Carstens (2013), found no differences between the ADG for three treatment groups (168 g protein/kg feed, 202.8 g protein/kg feed and 234.8 g/kg feed respectively) that were used in the pre-starter phase. A limitation identified in his study however, was the fact that only three treatment diets were used, which may explain differences found in the current study with a wider range of protein levels implemented. Brand *et al.* (2005) found that given the free choice of diet, slaughter ostriches preferred the diet containing the highest protein concentration. Therefore, although the aims of the work by Brand *et al.* (2005) differs to this study, the underlying principle of increased intake by birds with access to higher protein levels was fundamentally the same. An increased intake thus translates into increased ADG's, which was the case in this study.

During the starter phase, only diet 1 differed from the other treatment diets from a DMI point of view. Interestingly though, diets 3, 4 and 5 had higher ADG's throughout this period although their intakes did not differ from each other and diet 2. This was as a consequence of a decreased FCR by birds fed diets 3, 4 and 5 in comparison to diets 1 and 2. Aganga *et al.* (2003) suggested protein levels ranging from 170 to 200 g/kg of feed in the starter diet of ostriches. In this study, only diet 5 met those specifications with 178 g/kg feed; and although diet 5 did yield higher gains per day per bird and the FCR was below that acquired by diets 1 (131 g protein/kg feed) and 2 (143 g protein/kg feed), there were no differences with regards to these parameters between diets 3 (155 g protein/kg feed), 4 (167 g protein/kg feed) and 5. Therefore, it is possible that those specifications were higher than necessary, and costly from a financial standpoint to manufacture such diets. This theory seems to be supported by lower levels of protein used in starter diets in various studies (Brand *et al*., 2000; Ahmed *et al*., 2009; Carstens, 2013). Ahmed *et al.* (2009) fed ostriches 125 g protein/kg (LP), 175 g protein/kg (MP) and 225 g protein/kg (HP) and found

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intakes and weight gains to be more in the MP and HP diets, while consuming less feed per kilogram of weight gained. No differences were found between these two diets however, which again suggests an oversupply of protein than is necessary for optimal growth and production. The costs of deamination of the excess protein by the internal organs of the birds also place an unnecessary strain on these organs, while consuming extra energy to drive the process.

During the grower phase, the levels of protein in the five respective diets were as follows: 123 g/kg feed, 133 g/kg feed, 143 g/kg feed, 152 g/kg feed and 162 g/kg feed. These protein concentrations used were somewhat lower than those implemented by Brand *et al.* (2004), who only measured the end products of slaughter ostriches. In a more recent study, Glatz *et al.* (2008) found birds fed a lower protein concentration (126 g/kg feed) outperformed birds fed a high protein concentration (143 g/kg feed) in terms of DMI and ADG. The results found in this study are contradictory as no differences were found between the treatments for ADG. However, differences were found for DMI, with the higher levels of protein (diets 2, 3, 4 and 5) resulting in birds consuming more feed per day than those subjected to the lowest protein level (diet 1). The FCR results for the grower phase interestingly indicate that birds fed diets 1 and 2 were more efficient in converting the feed to body mass, which was somewhat unexpected and different to the trend seen across the other phases. On the other hand, it does explain how with a decreased intake per bird, those in diets 1 and 2 still managed the same daily gains as those birds that consumed more feed in the other three treatment diets. These results were confirmed when considering the PER values obtained, which displayed a similar trend. Results for this phase may also have been affected by an extended period of decreased intakes and therefore weight gains across all the camps used. The onset of the cold winter weather, as well as managerial plucking of the birds' feathers may have contributed, but in all likelihood was rather a common disease that affected the whole flock of birds.

In the finisher phase, no differences were found between the treatments for any of the three production parameters measured in this trial. This may be due to the characteristic plateau observed in normal growth curves associated with slaughter ostriches (Cooper & Mahroze, 2004), as indicated by the Gompertz growth curves in Figure 3.1.

In terms of the DMI broken down into the separate phases of the trial, it is interesting to note the increase in feed intake in general throughout the trial. This was expected due to the increased

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requirements by the birds as growth proceeded and gains in bodyweight were realised. Consequently, the maintenance requirement increased as the birds grew, therefore more nutrients would be needed over and above those for bodily functions for production (meat, skin and feathers). With regards to the average daily gains between each phase of the trial, it is noteworthy that the grower phase yielded the best gains. These results support those produced by Carstens (2013), who also found the daily gains to increase from pre-starter through grower phases, and then decrease in the finisher phase. Kritzinger (2011) displayed results in the form of a graph describing the allometry of growth of slaughter ostriches which are supported by the results found in this study.

With regards to the FCR values calculated over the course of the trial, a clear trend is seen in the results indicating an increase in feed ingested for a corresponding increase per kilogram in body weight as age increases. From a producers viewpoint therefore, it is paramount to ensure an optimal slaughter age when the growth rate of the birds' decreases beyond a point rendering the continued feeding of them, unviable.

With the aid of the Gompertz growth curves and parameter estimates made by the model, an educated reference to this point in the growth of the ostriches can be accurately predicted. Although no differences were predicted in the final weights of the ostriches at slaughter, differences were observed in terms of the growth rates of the birds exposed to the different treatment diets. Birds subjected to higher levels of protein in their diets achieved faster growth rates and reached their maximum growth rate at a younger age than those birds with protein levels in their diet lower than that predicted as optimal by Brand (2006). A possible explanation for the birds fed the lower protein concentrations in their diets still managing to have predicted slaughter weights not significantly different to those on higher protein feeds, may be attributed to the phenomenon of compensatory growth. Strictly speaking, compensatory growth is said to have the ability to occur when the plane of nutrition is increased beyond the current plane at the time of feeding (Lawrence & Fowler, 2002). This may have taken place when the feeding phase changed from grower to finisher at 242 days of age. It is however not being insinuated that birds fed the lower protein diets received better quality nutrition at the finisher phase, but simply that those birds may have responded in a more favourable manner than those birds fed the higher concentrations of protein to the change in diet.

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Thus, though no differences in predicted final body weights estimated by regression were found, differences were found between the treatments for average body weight of the birds at slaughter. These differences filtered down as expected to the cold carcass weights, which can lose about 3-5% of their warm carcass weight in the first 24 hours of chilling (Rentfrow, 2010). Interestingly, the dressing percentages did not differ in this trial, which supports the results from other studies by Brand *et al*. (2004), Hoffman *et al*. (2008) and Carstens (2013). Although the specific values attained for dressing percentages in these trials did not differ within trials, it was interesting to note an increase in dressing percentage with an increase in slaughter age across the studies. Although affected by a number of factors such as gut fill for example, there is a tendency for birds to have higher dressing percentages with age due to a decrease in total body water (McMillin *et al*., 2009). In addition, with an increase in age there is a resultant increase in fat percentage as described by Kritzinger (2011), which further enhances the increase in dressing percentage. The thigh weights in this study were heavier than those in a similar study by Carstens (2013), and this may be due to the birds in this trial being older by two months.

3.5 Conclusion

Generally, the results produced in this study tend to support the assumption that predicted values in terms of protein in ostrich diets are relatively optimal. With diet 3 in this particular study formulated in accordance with the formulations predicted by the model proposed by Gous and Brand (2008), the findings back this assumption.

Levels of protein below the middle concentration used as a control diet yielded decreased production performance by the ostriches as the quantity of proteins and amino acids present in their diets was simply inadequate. On the other hand, an increase in the protein concentrations above the control diet did not generally yield any significant increase in performance. Therefore, it would be recommended that an increase in protein levels in the diets of slaughter ostriches above the middle diet not be practiced. Advantages from a production stand point are simply not vindicated from a financial one; which in the ostrich industry is of paramount importance to producers.

As far as the protein in the diets fed to slaughter ostriches is concerned, optimal levels seem to have been established across the four feeding phases.

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Chapter 4

Effect of different concentrations of protein in the diets of ostriches on the skin and feather yields and quality

Abstract

The recent state of affairs within the ostrich industry regarding the stringent export requirements on ostrich meat increased the importance of the other two primary products, the feathers and leather. The problem becomes two-fold when taking into consideration the high input costs of feeding ostriches. Thus, the aim of this study was to determine if dietary protein content had a significant influence on the feather and skin yields as well as quality. Five treatment diets with varying protein concentrations were formulated, with three replications per treatment. The middle diet served as the control protein content (pre-starter, 19.0%; starter, 15.5%; grower 14.25%; finisher, 12.6%), with two diets formulated each with less protein than before, as well as two diets both containing more protein than before. Therefore there were 15 camps, containing 20 ostrich chicks each which were fed *ad libitum* over the aforementioned feeding stages. The diets were adapted accordingly for each of the phases. No significant differences were found with respect to the feather parameters measured except for the class of tail feathers. Differences were however found in selected skin parameters measured, where decreased dietary protein resulted in smaller wet skin size as well as crust size after the tanning process was completed. However, this did not have an impact on the skin grades achieved with no differences to report. Hence it became clear that dietary protein has an impact on the skin size achieved, which does not translate into differences in skin quality. Similarly, it does not affect the feather yields or quality; ultimately leading to the conclusion that increased dietary protein concentrations do not necessarily translate into better quality products.

4.1 Introduction

Although the feathers harvested from ostriches generally do not contribute more than 10-15% of the income in an ostrich enterprise, it can often be the vital difference between producers realising a net profit or loss (Brand & Cloete, 2015). In this study, the impact of dietary protein on feather yields was investigated in an attempt to confirm results found by Carstens (2013), where

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no differences were reported; or similarly disprove them if differences were indeed found. Also, the effects of the treatments were to be tested on the skins of the birds.

Currently leather contributes approximately 65% of the revenue generated in an ostrich enterprise (Stumpf, J., Pers. Comm., Klein Karoo International, P.O. Box 241, Oudtshoorn, 6620, South Africa, 14th June 2014). However, this is dependent on the quality of the product. Thus from a prudency viewpoint, leather contributes more than 50% of the total income for ostrich producers (Hoffman & Carbajo, 2005). The importance of the quality and optimization of the yields therefore cannot be over-emphasized.

The high demand for ostrich leather stems from its distinctive quill pattern, as well as flexibility and robustness which resulted in Cooper (2001) categorizing it as a luxury product. A variety of factors such as the skin size, the absence or presence of defects and appearance of the nodules contribute to the final grade given to a skin (Engelbrecht *et al.*, 2005). Previous studies by Cloete *et al.* (2004) indicate nodule size to be influenced by the age at slaughter of ostriches; older birds yielding larger nodule diameters. Logically, the nodule density simply decreases due to the increase in skin area with growth, while the nodule count remains the same) With emphasis placed on the nodule size and nodule development by graders (Brand *et al*., 2010), it is important to quantify the influence of dietary protein concentrations on these aspects which bear a significant influence on the final grade of the crusted skin. Furthermore the presence of pin-holes, which are remnants left on the skin by the removal of the hair follicles at slaughter and during the tanning process, result in the downgrading of the skin depending on the their density.

Kritzinger (2011) investigated the effect of dietary protein on the nodule sizes. However, in that study it was not possible to quantify the effects of the treatments due to several factors including age being co-linear. Therefore, in this study where all the birds were slaughtered at the same age, the effect of dietary protein on the nodule size was investigated. Additionally, the density of nodules, density of pin-holes as well as a subjective grading of the nodules was conducted to determine if dietary protein had an impact.

4.2 Materials and methods

The trial was carried out at the Oudtshoorn Research farm (22˚20̍ E, 33˚58̍ S) in Oudtshoorn from October 2013 until November 2014. The structural layout of the trial included five

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treatments, with three replications per treatment. The treatments were five separate diets fed to the ostriches, each containing a specific concentration of protein in order to study the effect, if any, on the skin and feather yields and qualities. Five treatment groups with three replications resulted in a total of 15 camps of ostriches, with each camp containing a starting figure of 20 chicks. This trial was a follow on study from the birds used in the production investigation as highlighted in Chapter 3. Therefore, the management procedures apply for this study as they were explained in the previous chapter.

Slaughter ostriches are fed according to four separate phases as required by their anatomical and physiological development, as well as decreasing feeding costs to producers. Thus, the birds received specially formulated, least cost treatment diets for the pre-starter, starter, grower and finisher phases as indicated in Tables 3.1 – 3.4.

The feed was available to the ostriches *ad libitum* and they also had free access to fresh drinking water. They were kept in camps with approximate dimensions of 20 m x 5 m initially as chicks, but later moved into larger camps (25 m x 25 m) at approximately seven months of age to prevent overcrowding and unnecessary damage to their skin which has financial implications on the tanned products. The birds' feathers were harvested at 240 days of age as is common practice in industry (Shanawany, 1999).

Initial trial planning saw the birds slaughtered at 12 months of age, but after testing positive for strains of the avian influenza virus (H5N2, H6N2) during the standard routine testing as required for all ostriches slaughtered commercially in South Africa (Anon, 2012), they were replaced into their camps and the trial extended for a further six weeks. Thus, they had attained an age of 13.5 months before they were cleared of the virus. A private contractor was hired to transport the birds in a vehicle designed for the transportation of ostriches to Mosstrich abattoir in Mossel Bay. They were offloaded into the designed lairage area where they had free access to fresh clean water as well as shelter from the elements. The birds stood in lairage overnight after offloading, for a period of 18 hours before where they were slaughtered following the procedures set out by Hoffman (2012), using The Divac Ostrich Stunning box®.

The feathers from each individual bird were harvested, kept separately and weighed to determine if the treatment diets had any effect on wet feather weight. They were then transported to the feather department of Klein Karoo International Limited in Oudtshoorn for drying and

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processing. Upon arrival, each individually marked bag of feathers was weighed and placed into a large oven set at 50ºC. The feathers were dried under these conditions for a period of 48 hours, with the final half an hour's temperature increased to 70ºC in order to sterilize the batch of feathers. The individual batches were then weighed again, before they were separated per batch into the economically important classes, and subsequently graded by qualified graders. Each separate class of feathers was also weighed and the records kept for statistical analysis. The classes used to group the feathers were the following: 'wings', 'reject wings', 'drab bloods', 'drab silver floss', 'drab body long young', 'back', 'drab body slope', 'tails butts', and 'unmarketable feathers'. The 'wings' and 'reject wings' were harvested from the wings of the birds, while any feather class labelled as 'drab' originated from the body of the bird meaning it was generally shorter in length. 'Drab bloods' were feathers that were harvested from the body of the bird, which still contained fragments of blood in the shafts. The origins of the remaining feather classes are self-explanatory, *viz.* the back and tail feathers. The shaft diameters of ten randomly selected wing feathers were measured in millimetres using a Mitutoyo Digital Caliper (model number: CD-8″ C), five centimetres from the base of the shaft (skin entry).

The skin from each bird was removed, individually marked and transported to the premises of Southern Cape Ostrich Tanning (SCOT), located in the same industrial complex as Mosstrich. The subcutaneous fat was removed by a process called hand fleshing from each skin, before each skin was assigned a marked microchip to aid in identification and location at any point along the tanning phases. The wet skin size (dm^2) of all the trial birds was measured before the skins were placed into a brine solution containing bactericides and salt for two hours. After this, wet grading took place and the skins were then classed into weight groups where they were stored at 5ºC until further tanning was possible. Once the pressure on the line alleviated, the raw skins were selected into specific tan batches where they were washed to remove the excess salt from storage.

The skins were then placed into the tanning drums where a process called 'liming' took place. The pH in the drum was increased up to 14 and the revolutions per minute of the drum were reduced. The following step is referred to as 'bating', where the skins were subjected to various enzymes to breakdown the soluble proteins and fats still in the skin. The enzymes are manufactured so as to prevent any damage to the skin itself. 'Pickling' of the skins then followed, where the skins were subjected to a salt and acid solution to prepare them for bleaching. Loose fibres from

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each skin were then shaved off for better penetration of the chemicals that were to follow in the subsequent steps.

The next process is known as ‘degreasing’, and the skins were subjected to a saponification agent specially manufactured for ostrich skins. After this, they entered a phase known as ‘re-tanning’, wherein the style of the individual tanner becomes evident (leather characteristics). The skins were then dried in an industrial tumble drier, specifically due to the fat content, and then their dry crust size was measured (dm^2). They were then sorted, graded and stored by qualified graders.

At a later stage, the skins in their chrome crusted form were transported to Elsenburg for further data collection. The skins were evaluated at the five different localities as depicted in Figure 4.1 for the number of nodules in each locality measuring one dm^2. The pin-holes, which are remnants from the removal of the hair follicles on the skin, in a smaller 5 cm x 5 cm area within the dm^2 were also counted. The base diameter of five randomly selected nodules within each site were measured using a Mitutoyo Digital Caliper (model number: CD-8″ C) and an average calculated per site per treatment.

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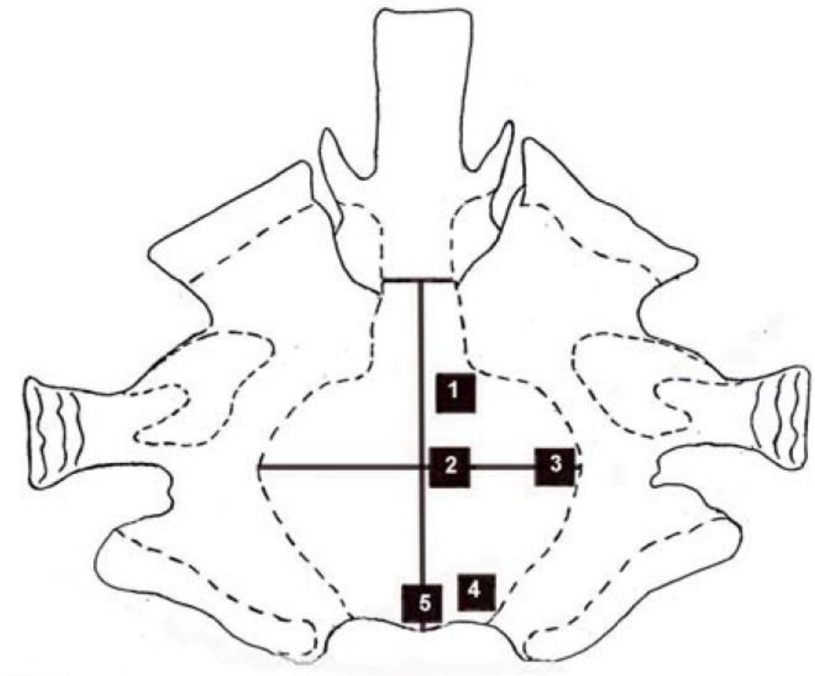

Figure 4.1. Ostrich skin depicting the five localities from which sampling and data collection was done, viz. localities: 1 – neck; 2 – mid-crown; 3 – upper leg; 4 – lower flank; 5 – butt

The nodule quality was subjectively assessed based on correspondence between the author and the employees of SCOT involved with the grading of ostrich crusts. The nodules collectively on the whole crown area were given a grade between one and four; one the best quality and four the poorest quality.

Statistical analyses were done using SAS Enterprise Guide 9.2. One-way analyses of variances (ANOVA's) were performed on all the parameters measured (feather classes and skin parameters) to investigate any differences between the impacts of the treatment diets on the recorded parameters. Differences were deemed significant on a 5% level, ($P < 0.05$) and thus are reported accordingly.

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4.3 Results

The treatment diets had no effect ($P > 0.05$) on the wet feather weights harvested from the birds directly after exsanguination (Table 4.1). After the feathers were dried, they were weighed again with the weights of the collective feathers with commercial value recorded. No differences ($P > 0.05$) were found between the total yields of the dried valuable feathers from birds fed the different treatment diets.

In terms of the separate classes of feathers, specifically with regards to the 'tail feathers' harvested from the birds, only those fed diet 1 (lowest protein content) differed ($P < 0.05$) from the other treatment diets, having the lightest yields of 85.4 ± 6.3 g per bird. Although not different ($P > 0.05$) from the other four treatments, the highest yields were obtained from birds fed diet 5 with 115.0 ± 8.1 g of tail feathers per bird.

No differences ($P > 0.05$) were found for any of the other separate feather classes; 'adult wings', 'back feathers', 'drab bloods', 'drab body long young' and 'drab silver floss'. Likewise, no differences ($P > 0.05$) were found between the treatments in terms of the diameters of the shafts from the wings' from each bird.

Table 4.1. Least square means ± standard error (LSM ± SE) for the effect of dietary protein concentrations on the feather parameters of slaughter ostriches on a dry basis (after oven drying)

Parameters	Diets				
	1	2	3	4	5
Shaft diameter (mm)	6.10 ± 0.06	6.10 ± 0.06	6.04 ± 0.04	6.19 ± 0.09	6.04 ± 0.08
Fresh feather weight (kg)	1.32 ± 0.01	1.42 ± 0.01	1.37 ± 0.04	1.42 ± 0.01	1.44 ± 0.06
Feathers with commercial value (g)	872.1 ± 24.1	949.4 ± 19.6	930.5 ± 36.9	999.1 ± 9.7	976.4 ± 56.9
Wings (g)	229.9 ± 4.8	255.7 ± 8.3	252.9 ± 9.1	245.5 ± 5.7	239.9 ± 14.1
Tail feathers (g)	85.4^{a} ± 6.3	107.9^{b} ± 5.0	105.5^{b} ± 4.3	112.0^{b} ± 1.5	115.0^{b} ± 8.1
Back feathers (g)	209.3 ± 10.7	198.1 ± 9.9	199.8 ± 18.6	208.1 ± 11.4	205.3 ± 12.1
Drab bloods (g)	215.5 ± 7.8	226.2 ± 11.9	237.1 ± 13.0	246.1 ± 11.1	237.0 ± 19.0
Drab body long young (g)	81.9 ± 4.3	90.8 ± 1.8	92.1 ± 1.8	94.4 ± 1.7	95.5 ± 4.7
Drab silver floss (g)	100.6 ± 19.2	113.0 ± 17.4	88.4 ± 3.4	97.3 ± 6.2	103.5 ± 10.1

$^{a, b}$ Row means with different superscripts differ significantly ($P < 0.05$)

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Concerning the skin yields and quality parameters measured, differences ($P < 0.05$) were found between the wet skin sizes of the birds exposed to different treatment diets (Table 4.2). Only birds fed diet 1 had wet skins sizes that were different from the other treatment diets fed, on average measuring 135.5 ± 0.66 dm^2. The wet skin sizes from the birds on the other four diets were significantly ($P < 0.05$) larger, with birds fed diet 3 yielding the largest on average (144.8 ± 1.35 dm^2). This translated into the crust sizes obtained after the tanning processes used, with birds fed diet 1 again, significantly ($P < 0.05$) yielding the smallest crust sizes on average (143.9 ± 1.04 dm^2). No differences ($P > 0.05$) were found between the treatment diets 2, 4 and 5 in terms of the crust sizes obtained. As was the case for the wet skin size, birds fed diet 3 had the largest crust sizes (155.3 ± 1.55 dm^2 per bird), although not larger ($P > 0.05$) than those obtained by birds fed diets 4 and 5 (152.6 ± 0.60 dm^2 and 154.1 ± 1.21 dm^2 respectively).

The skin thickness was measured in the crust form, and no differences ($P > 0.05$) were found between the treatment diets administered.

Table 4.2. Least square means ± standard error (LSM ± SE) for the effect of dietary protein concentrations on the skin yield and quality of slaughter ostriches

Parameters	Diets				
	1	2	3	4	5
Wet skin size (dm^2)	135.5^a ± 0.66	141.8^b ± 1.37	144.8^b ± 1.35	142.5^b ± 1.45	143.8^b ± 2.29
Crust size (dm^2)	143.9^a ± 1.04	150.6^b ± 1.30	155.3^c ± 1.55	152.6^{bc} ± 0.60	154.1^{bc} ± 1.21
Skin thickness (mm)	1.43 ± 0.05	1.40 ± 0.03	1.54 ± 0.01	1.51 ± 0.03	1.49 ± 0.09

$^{a, b, c}$ Row means with different superscripts differ significantly ($P < 0.05$)

The crusts were graded according to industry standards and the results are presented in Table 4.3. Concerning the simple means of the grades given to the crusts, no differences ($P > 0.05$) were found between effects of the treatment diets. Similarly, with regards to the breakdown of the percentage of crusts in each grade, no differences ($P > 0.05$) were observed between treatments between any of the four grades given.

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Table 4.3. Proportion (%) ± standard error (SE) of each grade for the crusts as affected by different concentrations of protein in the diet of slaughter ostriches

Diet	Mean	1st Grade (%)	2nd Grade (%)	3rd Grade (%)	4th Grade (%)
1	2.50 ± 0.10	6.06 ± 3.03	55.94 ± 10.49	20.28 ± 3.59	17.72 ± 5.66
2	2.57 ± 0.13	2.38 ± 2.38	46.12 ± 3.87	43.16 ± 5.04	8.33 ± 8.33
3	2.75 ± 0.20	3.70 ± 3.70	34.39 ± 15.03	45.24 ± 10.74	16.67 ± 9.62
4	2.48 ± 0.06	13.62 ± 4.90	36.18 ± 4.20	39.15 ± 7.13	11.05 ± 5.52
5	2.73 ± 0.13	1.96 ± 1.96	37.11 ± 5.38	47.06 ± 5.07	13.87 ± 4.49

Subjectively assessed nodule quality resulted in no differences ($P > 0.05$) between the crusts harvested from the ostriches fed the different treatment diets (Table 4.4).

Table 4.4. Proportion (%) ± standard error (SE) of each subjective grade for the nodules as affected by different concentrations of protein in the diet of slaughter ostriches

Diet	Mean*	1st Grade (%)	2nd Grade (%)	3rd Grade (%)	4th Grade (%)
1	2.58 ± 0.20	10.23 ± 5.37	32.65 ± 10.20	46.29 ± 8.17	10.83 ± 5.83
2	2.14 ± 0.07	23.19 ± 8.05	45.44 ± 7.51	25.47 ± 4.03	5.90 ± 3.02
3	2.52 ± 0.24	5.13 ± 5.13	52.67 ± 8.44	27.14 ± 3.15	15.06 ± 11.44
4	2.52 ± 0.26	16.43 ± 4.46	33.81 ± 8.46	35.95 ± 5.54	13.81 ± 7.43
5	2.36 ± 0.18	16.92 ± 4.70	43.08 ± 8.75	27.52 ± 7.43	12.48 ± 5.31

*Refer to Annexure B for pictorial representations of the nodule grades assigned

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The nodule diameters in each of the five locations on the crust were measured, and differences ($P < 0.05$) were found on the lower flank and butt areas on the skins harvested from the birds fed the treatment diets (Table 4.5). In both sites, the tendency was for the nodule size to increase with an incremental increase in the protein content of the treatment diets. In locality 4 (lower flank), the nodule diameters on the crusts of birds fed diet 4 were the largest on average (4.48 mm), although only significantly ($P < 0.05$) from those fed diet 1 (4.21 ± 0.06 mm). In the same way, the birds fed diets 3, 4 and 5 had the largest nodules in the butt area, significantly ($P < 0.05$) so compared to those recorded from birds fed diets 1 and 2. However, no differences ($P > 0.05$) were found between the nodule diameters of the crusts when analysing the other three sample sites.

Table 4.5. Least square means ± standard error (LSM ± SE) for the effect of different dietary protein concentrations on the nodule diameters on the crust measured at different localities

Locality	Diets				
	1	2	3	4	5
Locality 1 – Neck	3.22 ± 0.09	3.31 ± 0.02	3.36 ± 0.06	3.34 ± 0.01	3.42 ± 0.04
Locality 2 – Mid-crown	3.40 ± 0.02	3.52 ± 0.05	3.53 ± 0.04	3.56 ± 0.03	3.60 ± 0.07
Locality 3 – Upper leg	4.06 ± 0.06	4.23 ± 0.03	4.22 ± 0.07	4.18 ± 0.08	4.29 ± 0.03
Locality 4 – Lower flank	4.21^{a} ± 0.06	4.33^{ab} ± 0.04	4.41^{b} ± 0.05	4.48^{b} ± 0.07	4.40^{b} ± 0.04
Locality 5 – Butt	4.23^{a} ± 0.06	4.45^{b} ± 0.04	4.60^{bc} ± 0.01	4.61^{c} ± 0.06	4.61^{c} ± 0.05

$^{a, b, c}$ Row means with different superscripts differ significantly ($P < 0.05$)

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Within the same five locations on the crust, the nodule count as well as the number of pin-holes in each were measured and recorded in Table 4.6. Differences ($P < 0.05$) in nodule count were found in only two of the five localities' of the crusts as a result of the treatment diets administered. These were the upper leg (locality 3) and lower flank (locality 4) areas. In locality 3, the general trend seen was for the nodule number to decrease with an increase in the protein concentration in the diet (from diet 1 through to diet 5). Treatment diet 1 had the most nodules (22.5 ± 0.08), while treatment diet 5 had the least number of nodules (21.1 ± 0.29) in the upper leg area.

A similar trend was present in locality 4 (lower flank) with respect to the nodule density and protein content of the diet. Birds fed diets 1 and 2 did not differ ($P > 0.05$) between themselves and had the most nodules in this specific locality (29.2 ± 0.35 and 28.5 ± 0.29, respectively). Those birds fed the other three treatment diets (3, 4 and 5) did not differ ($P > 0.05$) between one another in terms of the number of nodules in locality 4; but they did contain fewer nodules than the other two treatments.

When dissecting the results obtained for the pin-hole count across the five localities, it was found that no differences ($P > 0.05$) occurred between the counts recorded on the crusts from any of the birds exposed to the five treatment diets.

Table 4.6. Least square means ± standard error (LSM ± SE) for the effect of dietary protein concentrations on the nodule and pin-hole counts of skin crusts of slaughter ostriches

Parameters	Diets				
	1	2	3	4	5
Nodule number locality 1	44.8 ± 1.97	42.7 ± 0.69	40.6 ± 1.05	41.7 ± 0.53	41.3 ± 0.16
Nodule number locality 2	55.7 ± 1.93	54.8 ± 0.27	51.9 ± 1.01	53.1 ± 0.89	52.6 ± 0.48
Nodule number locality 3	22.5^{a} ± 0.08	22.0^{ab} ± 0.29	21.5^{bc} ± 0.23	22.1^{ab} ± 0.22	21.1^{c} ± 0.29
Nodule number locality 4	29.2^{a} ± 0.35	28.5^{ab} ± 0.29	27.0^{c} ± 0.42	27.7^{bc} ± 0.36	27.0^{c} ± 0.47
Nodule number locality 5	48.0 ± 0.61	46.6 ± 0.78	44.4 ± 1.58	47.9 ± 0.56	46.4 ± 0.60
Pin hole number locality 1	31.4 ± 2.74	32.8 ± 5.74	31.8 ± 3.76	30.0 ± 1.92	31.0 ± 4.02
Pin hole number locality 2	40.7 ± 1.25	43.2 ± 5.98	39.1 ± 4.89	35.3 ± 1.58	44.2 ± 5.32
Pin hole number locality 3	7.5 ± 1.00	9.8 ± 2.34	11.5 ± 2.36	7.9 ± 0.84	10.5 ± 2.31
Pin hole number locality 4	14.2 ± 1.05	17.0 ± 4.23	16.2 ± 3.27	15.1 ± 1.88	17.0 ± 1.40
Pin hole number locality 5	47.0 ± 1.63	47.4 ± 8.19	49.4 ± 8.32	39.5 ± 2.68	48.0 ± 7.02

$^{a, b, c}$ Row means with different superscripts differ significantly ($P < 0.05$)

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4.4 Discussion

It stands to reason that the wet (fresh) feather weights harvested from each bird were to a certain extent influenced by the final slaughter weight of each individual. However, no differences were observed in the final feather weights from birds fed the different treatment diets which is consistent with results found by Kritzinger (2011). Similar studies to determine the effect of protein concentrations on feather yield and quality are lacking, however Carstens (2013) also investigated the effect of differing protein concentrations on the performance of slaughter ostriches. He however found no differences in the yields obtained per specific class of feathers as a result of the treatment diets fed to the birds. Interestingly in this study though, one class of feathers from the birds was influenced by the treatment diets fed; that of the tail feathers. The birds fed diet 1 with the lowest protein concentration, yielded the lightest feathers.

With no differences found between the yields of feathers from birds fed the different treatment diets in terms of the other classes, the allocation of nutrients for feather growth in different parts of the body become of interest. This may warrant further research into better understanding the influence of nutrition on feather yield and quality. However, with the dynamics of the industry where feathers comprise proportionally less of the income generated, research and therefore scientifically based selection programmes for feather quality have not been implemented (Brand & Cloete, 2015); and this trend may continue.

When analysing the quantitative parameters of the skin, the same trend that was expected but not found for the wet feather weights, was evident for the wet skin sizes of the birds. The birds fed the diet with the lowest concentration of protein in their diets across the four feeding phases had significantly smaller skin sizes immediately post-slaughter. Previous work by Brand *et al.* (2000) found no differences between the wet skin sizes of birds fed three different protein concentrations in their diets. Brand *et al.* (2004) later investigated the effect of protein on the end products of slaughter ostriches, then with five treatment diets, and still found no differences in terms of the wet skin size. Although in this study the five treatment diet experimental layout was mimicked, the birds were slaughtered at 13.5 months of age as opposed to 11 months in the first study, and 12 months in the follow up investigation. Cloete *et al.* (2004) and later Engelbrecht *et al.* (2005; 2007) indicated that raw skin yields increase linearly with slaughter age and slaughter weight. The interaction of the nutritional components of the diets with the increased age of the

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birds may have resulted in the differences found in this study; but in all likelihood was as a result of the differences present in the slaughter weights of the birds exposed to the different treatments.

With regards to the crust size, it is interesting to note an increase of ~7% from the wet skin size measured immediately post slaughter. Although no differences were found between the wet skins harvested from birds fed diets 2, 3, 4 and 5; there were differences between these treatments in terms of the dry crust size after the tanning process took place. Birds exposed to the higher protein concentrations (diets 3, 4 and 5) yielded larger crusts than those for birds fed diet 2. A possible cause for this may have been the interactions between the proteins present in the ostrich skins and the variety of enzyme processes present in the tanning methods utilized. However, a more practical explanation may be that the measuring of the wet skin size was subject to human error during the stretching process for measurement; whereas the measurement of the crust was done by clamping the skin in a consistent fixed position. In addition, skin size will expectedly show a correlation to the final bird size at slaughter.

When examining the results found for the crust grades achieved by the ostriches from the different treatment groups, it is interesting to note no differences were present between the grades of the crusts. Differences were tentatively expected due to the knowledge of the strong protein contingent found in the structure of a skin, as described by Lunam & Weir (2006). Similarly, Brand *et al.* (2004) reported differences in the grades found after treatment diets with varying protein levels were fed to the experimental birds. Yet, the slaughter age of these birds from the two separate studies may shed light on the reason for the differences, and lack thereof.

Meyer *et al.* (2002) showed that an increase in slaughter age results in a greater incidence of skin damage which has a detrimental effect on the skin quality and therefore results in a downgrade. The percentage of first grade skins in this study was considerably less than in the study by Brand *et al.* (2004). However, with regards to the lack of differences between treatments, any differences that may have been present were possibly negated by the increased slaughter age. This is further plausible considering Meyer (2003) found a positive correlation between weight and aggression amongst slaughter ostriches.

Previous studies had been conducted subjectively assessing the nodule development with age by Van Schalkwyk *et al.* (2005), where they suggested the nodule size and shape reached acceptability at ~11 months of age. In this study, the nodules were also subjectively assessed and

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graded, which has previously not been investigated. However, no differences were found in the nodule grades attained on the crusts from the birds fed the different diets. Therefore, it can be stated that varying protein concentrations in the diets of slaughter ostriches do not influence the quality of the nodules.

When examining the nodule diameters in the five sampling sites however, differences were found in the lower flank and butt areas of the crusts from the birds exposed to the different treatment diets. Birds fed diets containing higher protein concentrations returned larger nodule diameters than those on the lower protein content. Although not significantly so, there was a similar pattern observed across the other three localities; which indicates that protein concentrations in the diets of ostriches do influence nodule diameter. This may warrant further research, particularly considering the tendency for graders to assess the nodule size and quality when grading the skins (Fourie, N. Pers. Comm., Southern Cape Ostrich Tanning (SCOT), P.O. Box 2629, Mossel Bay, South Africa, 11th May 2015).

Concerning the actual number of nodules within each of the five localities, only differences were found in the upper flank (locality 3) and lower leg (locality 4) areas. The trend was an inverse relationship, where an incremental increase in the protein concentration in the diets resulted in a decrease in the number of nodules per area (e.g. 1 dm^2). With reference to the nodule diameters, although they increase in size; their density will decrease given the area (1 dm^2) remains the same. Therefore the density of the nodules becomes a function of the size of the skin, and in addition the nodule diameters also seem to be influenced by the concentration of protein in the treatment diets fed to the birds.

No differences were found in terms of the pin-hole density within each of the five locations on the crust. However, the extreme difficulty in accurately counting each tiny pin-hole must be taken into consideration, which resulted in large deviations around the mean and possibly affected the statistical outcome. Therefore it cannot definitively be stated that different dietary protein concentrations does not influence pin-hole count; however, the likelihood of protein affecting the pin-hole density seems small.

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4.5 Conclusion

Concerning the results on the feather parameters in this study, it is clear that dietary protein concentrations do not have an impact on the feather yields except for the tail feathers. With these results confirming those by previous studies (Carstens, 2013; Kritzinger, 2011) with regards to feather growth not being influenced by the dietary composition, it stands to reason that simply feeding the birds a well-balanced ration will give adequate yields and quality.

In respect of the results found for the skin parameters measured, dietary protein influenced the wet skin size as well as the crust size. This has ramifications with respect to the grading of the crusts, therefore it can be suggested that feeding protein concentrations below that predicted as optimal by the model (diet 3) (Gous & Brand, 2008) should be avoided as it will result in smaller crusts. Having said that however, no differences were found in terms of the crust grade as well as the subjectively assessed nodule quality. Therefore, it can be concluded that dietary protein has no impact on the nodule quality; although it does influence the size of the nodules in certain areas of the crust (lower leg and butt). An increase in protein concentration to the control level led to increased nodule diameters, but increasing the level of protein in the diet beyond this point did not continue to increase the nodule diameters.

In addition, the dietary protein content influenced the nodule density in the upper leg and lower flank regions; decreasing in number with a subsequent increase in protein content but only up until the control level again (diet 3). Therefore, increases in dietary protein beyond the current formulations do not yield any significant quality improvements from a feather and leather perspective. These findings assure producers that increasing the plane of nutrition will not yield similar quality returns, thus ensuring that the optimal protein concentrations in the diets of slaughter ostriches seem to have been established due to the developed optimization model by Gous and Brand (2008).

4.6 References

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Chapter 5

The influence of different dietary energy concentrations on the production parameters of feedlot ostriches (*Struthio camelus* var. *domesticus*)

Abstract

Energy is an essential nutrient for the continuous survival of any living organism and is generally the first limiting nutrient in livestock diets. In ostrich diets, the energy is more often than not derived from maize, which is often a crop subject to fluctuations in yields as a result of drought conditions. Therefore, the optimal utilization of energy within the diets of ostriches becomes of paramount importance, without negatively impacting the performance of the birds. This study was conducted to investigate the influence of five different treatment diets, each with a different energy concentration, on the growth performance of slaughter ostriches. Three replications per treatment resulted in 15 camps of ostriches being fed through the four feeding phases; from the pre-starter, to the starter, then the grower, and finally the finisher phase. A high mortality rate was experienced during the pre-starter phase, while the chicks were still young. Differences ($P < 0.05$) were found between the live weights of the birds after the pre-starter phase, with birds consuming the middle diet (diet 3) being the heaviest at an average of 22.3 ± 0.33 kg. However, by the end of the trial differences were not significant ($P > 0.05$) with regards to the live weight of the birds fed the different diets. This was reflected when considering the production parameters, namely the dry matter intakes (DMI), average daily gains (ADG) and feed conversion ratios (FCR). Only differences were found during the pre-starter phase in terms of the ADG, with diet 3 displaying the highest gains per day of 216.0 ± 8.08 g. Thus, in this study, dietary energy above or below the predicted optimum (diet 3) seemed to have little influence on the performance of the ostriches, but results may have been influenced by above average mortalities incurred.

5.1 Introduction

The ostrich (*Struthio camelus* var. *domesticus*) is the largest of the ratites and is of paramount importance to several industries due to its healthy red meat and valuable skin which is used for leather (Cooper & Hornbañczuk, 2002). This applies no more aptly than to South Africa, where

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the ostrich industry is estimated to contribute in the region of R1 billion to the economy (Brand & Jordaan, 2011). Recently the industry received a substantial boost with the decision taken by the European Union (EU) to lift the four year ban on exports of raw ostrich meat from South Africa. Initially, the meat sector incurred a significant knock with a decrease in the number of birds slaughtered in 2011 by ~50% (Vecchiato, 2015), and profit margins became increasingly tighter with many producers forced to exit the industry (Hobasi, 2015). With exports set to resume, producers may feel optimistic with regards to an extra avenue of supply for ostrich meat to overseas consumers; in addition to the pre-cooked *sous vide* market that was established in the four year isolation period to mitigate the effects of the ban on raw meat products.

However, although the markets for the end products from an ostrich production system may look positive, the feeding of the birds still remains an overhead contributing 70 – 80% of the input costs (Brand *et al.*, 2000). A compounding factor producers need to take into consideration is the fact that maize meal is often the primary energy source in an ostrich ration (Brand, 2007), and prices thereof are heavily dependent on precipitation figures during the rainfall season. Prices are currently set to increase as a result of drought conditions experienced in the main growing areas of the Free State and the North-West provinces, necessitating imports to meet domestic demand (Mokhem & Janse Van Vuuren, 2015). In addition, the growth of the human population brings with it the ethical consideration of whether feeding energy sources to livestock which are suitable for humans is acceptable. Thus, the need to minimize wastage is in the wider interests of not only ostrich producers. However, the producers are also concerned with the knowledge that relates to optimum levels of energy in the diets without compromising the product quality.

This study aims at quantifying the optimum energy concentrations required in intensive slaughter ostrich rearing through the four feeding stages; namely pre-starter, starter, grower and finisher. Previous work by Brand *et al.* (2000) was conducted to assess the impact of energy on the production parameters; however this study aims at doing so with five treatment diets as used by Brand *et al*. (2014). Thus, the effects of the treatment diets on the growth response of the chicks through to slaughter were analysed. This encompasses production parameters such as feed intake, average daily gain (ADG) and feed conversion ratio (FCR). The effect of dietary energy on the abdominal fat pad was investigated due to a theorem postulated by Hoffman *et al.* (2005), who suggested the extra energy in the diet was stored here and not in the intra-muscular fat reserves.

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5.2 Materials and Methods

The trial was conducted at the Kromme Rhee experimental farm (situated 18º50’ E, 33º51’ S with an altitude of 177 m) outside Stellenbosch in the Western Cape, South Africa. The trial period extended from December 2013 to December 2014, incorporating full seasonal changes over the course of a year. The experiment was designed with five treatment diets with varying energy concentrations for each of the four physiological feeding phases associated with ostrich production; namely pre-starter, starter, grower and finisher (Tables 5.1 – 5.4). The actual diets after chemical analysis that were available to the birds throughout the trial are presented in Tables 5.5 and 5.6; with corresponding amino acid profiles in Tables 5.7 and 5.8. Each treatment diet was replicated three times, thus yielding 15 camps of ostriches in total with an average of 16 chicks per camp. The treatment diets were labelled diet 1, 2, 3, 4 and 5 with increasing energy concentrations in each diet. Diet 3 was formulated to contain standard energy concentrations (pre-starter, 14.5 MJ ME/kg; starter, 13.5 MJ ME/kg; grower, 11.5 MJ ME/kg; finisher, 10.5 MJ ME/kg) similar to those used in the ostrich feed industry, with incremental decreases and increases constituting the other four treatment diets. For ease of identification and clarity this identification system will be employed throughout the results and discussion.

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Table 5.1. Composition of the five treatment diets (as fed basis) in the pre-starter phase of slaughter ostriches (kg/ton) fed from 0 – 83 days of age

Raw materials (kg)	**Diet number (MJ ME/kg)**				
	1 (13.5)	**2 (14.0)**	**3 (14.5)**	**4 (15.0)**	**5 (15.5)**
Maize meal	476.70	480.55	484.40	488.25	492.10
Soybean oilcake meal	160.00	172.50	185.00	197.50	210.00
Fishmeal	75.00	75.00	75.00	75.00	75.00
Bentonite	25.00	25.00	25.00	25.00	25.00
Wheat bran	224.00	187.25	150.50	113.75	77.00
Plant oil	0.00	20.00	40.00	60.00	80.00
Monocalcium phosphate	0.00	0.95	1.90	2.85	3.80
Limestone	22.00	21.63	21.25	20.88	20.50
Salt	10.00	10.00	10.00	10.00	10.00
Synthetic lysine	2.30	2.13	1.95	1.78	1.60
Mineral and vitamin premix*	5.00	5.00	5.00	5.00	5.00

*Refer to ANNEXURE A for the composition of the vitamin and mineral premix.

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Table 5.2. Composition of the five treatment diets (as fed basis) in the starter phase of slaughter ostriches (kg/ton) fed from 84 – 149 days of age

Raw Materials (kg)	**Diet number (MJ ME/kg)**				
	1 (12.5)	**2 (13.0)**	**3 (13.5)**	**4 (14.0)**	**5 (14.5)**
Maize meal	309.20	372.40	435.60	498.80	562.00
Soybean oilcake meal	108.00	129.00	150.00	171.00	192.00
Wheat bran	400.00	301.00	202.00	103.00	4.00
Fishmeal	50.00	50.00	50.00	50.00	50.00
Lucerne	100.00	100.00	100.00	100.00	100.00
Plant oils	0.00	12.50	25.00	37.50	50.00
Calorie 3000	25.00	25.00	25.00	25.00	25.00
Monocalcium phosphate	0.00	3.65	7.30	10.95	14.60
Limestone	17.80	16.45	15.10	13.75	12.40
Salt	10.00	10.00	10.00	10.00	10.00
Mineral and vitamin premix	5.00	5.00	5.00	5.00	5.00

*Refer to ANNEXURE A for the composition of the vitamin and mineral premix.

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Table 5.3. Composition of the five treatment diets (as fed basis) in the grower phase of slaughter ostriches (kg/ton) fed from 150 – 228 days of age

Raw Materials (kg)	**Diet number (MJ ME/kg)**				
	1 (10.5)	**2 (11.0)**	**3 (11.5)**	**4 (12.0)**	**5 (12.5)**
Maize meal	254.00	333.75	413.50	493.25	573.00
Soybean oilcake meal	77.00	83.25	89.50	95.75	102.00
Lucerne	609.84	520.61	431.37	342.14	252.90
Calorie 3000	25.00	25.00	25.00	25.00	25.00
Monocalcium phosphate	17.00	17.00	17.00	17.00	17.00
Limestone	0.00	3.25	6.50	9.75	13.00
Salt	10.00	10.00	10.00	10.00	10.00
Synthetic lysine	0.80	1.05	1.30	1.55	1.80
Synthetic methionine	1.36	1.10	0.83	0.57	0.30
Mineral and vitamin premix	5.00	5.00	5.00	5.00	5.00

*Refer to ANNEXURE A for the composition of the vitamin and mineral premix.

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Table 5.4. Composition of the five treatment diets (as fed basis) in the finisher phase of slaughter ostriches (kg/ton) fed from 229 – 344 days of age

Raw Materials (kg)	**Diet number (MJ ME/kg)**				
	1 (9.50)	**2 (10.00)**	**3 (10.5)**	**4 (11.0)**	**5**
Oat bran	394.20	295.65	197.10	98.55	0.00
Wheat bran	191.00	145.00	99.00	53.00	7.00
Maize meal	100.00	175.00	250.00	325.00	400.00
Soybean oilcake meal	113.00	105.50	98.00	90.50	83.00
Lucerne	100.00	179.38	258.75	338.13	417.50
Calorie 3000	50.00	50.00	50.00	50.00	50.00
Monocalcium phosphate	21.00	20.25	19.50	18.75	18.00
Limestone	15.00	13.00	11.00	9.00	7.00
Salt	10.00	10.00	10.00	10.00	10.00
Synthetic methionine	0.80	1.23	1.65	2.08	2.50
Mineral and vitamin premix	5.00	5.00	5.00	5.00	5.00

*Refer to ANNEXURE A for the composition of the vitamin and mineral premix.

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Table 5.5. Analysis (as is basis) of experimental diets containing five levels of energy (1, 2, 3, 4 and 5) fed to ostriches during the pre-starter (0 – 83 days) and starter (84 - 149 days) phases

Nutrient	**Diet number**									
	Pre-starter					**Starter**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
ME MJ/kg feed*	13.5	14.0	14.5	15.0	15.5	12.5	13.0	13.5	14.0	14.5
Dry material (g/kg)	904.7	899.1	905.7	905.8	909.6	885.4	881.2	884.7	856.3	899.3
Crude protein	170.6	179.2	184.7	181.8	191.9	174.8	179.2	182.7	181.1	190.1
Ash (g/kg)	78.1	78.6	80.9	80.7	84.3	79.5	77.8	76.8	74.4	80.6
IVOMD (g/kg)	790.3	802.5	818.6	863.2	872.1	774.7	780.7	822.5	834.7	843.8
Crude fibre (g/kg)	85.0	76.4	71.5	57.5	53.9	101.3	89.6	77.1	72.2	69.9
Fat (g/kg)	30.0	39.7	53.6	62.3	70.1	27.2	39.8	46.5	50.9	52.5
ADF (g/kg)	98.4	90.3	77.5	55.5	58.5	119.6	99.3	89.9	79.9	68.7
NDF (g/kg)	260.8	245.0	212.1	194.1	167.0	274.6	238.8	231.5	205.3	194.3
Calcium (g/kg)	12.4	12.2	12.6	13.3	13.4	12.4	12.5	12.3	12.8	12.1
Phosphorous	7.6	7.7	8.1	7.5	8.0	7.4	7.7	7.6	7.4	7.2

*As formulated
***In vitro* organic matter digestibility

Table 5.6. Analysis (as is basis) of experimental diets containing five levels of energy (1, 2, 3, 4 and 5) fed to ostriches during the grower (150 - 228 days) and finisher (229 - 344 days) phases

Nutrient	**Diet number**									
	Grower					**Finisher**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
ME MJ/kg feed*	10.5	11.0	11.5	12.0	12.5	9.5	10.0	10.5	11.0	11.5
Dry material (g/kg)	901.2	896.1	896.5	895.6	893.3	885.9	879.0	892.9	883.8	884.7
Crude protein	148.4	153.2	155.3	143.0	137.2	142.8	143.4	154.2	166.3	180.3
Ash (g/kg)	80.5	81.7	83.2	81.7	76.8	96.7	94.6	93.1	99.6	103.3
IVOMD** (g/kg)	708.6	720.2	752.7	793.4	811.2	605.5	631.6	709.0	725.3	768.8
Crude fibre (g/kg)	210.3	172.8	147.9	122.6	102.1	158.5	156.6	154.2	150.9	131.4
Fat (g/kg)	16.7	20.5	19.8	19.6	21.1	14.3	15.3	16.0	19.4	19.3
ADF (g/kg)	229.9	211.4	179.5	148.1	118.0	196.3	191.7	179.1	176.8	167.0
NDF (g/kg)	335.9	307.5	293.3	261.7	221.7	381.0	356.5	325.2	308.1	297.4
Calcium (g/kg)	12.1	13.0	13.0	13.6	14.3	15.9	18.1	14.7	13.0	12.6
Phosphorous	0.69	0.69	0.70	0.68	0.72	9.6	8.9	8.6	6.8	6.5

*As formulated
***In vitro* organic matter digestibility

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Table 5.7. Amino acid composition of the treatment diets (g/kg) on an as fed basis for the pre-starter and starter phases

Amino acids	Diet number									
	Pre-starter					Starter				
	1	2	3	4	5	1	2	3	4	5
Lysine	8.95	9.86	8.80	9.79	9.84	11.43	11.18	12.46	10.14	11.15
Methionine	1.25	1.21	1.13	0.83	1.41	1.28	1.31	1.37	0.95	1.05
Arginine	8.13	8.24	8.34	8.89	8.24	8.65	8.32	10.41	8.64	9.15
Threonine	2.29	2.58	4.09	6.48	4.53	7.31	7.00	7.54	6.46	6.94
Tyrosine	5.88	5.41	5.78	6.18	6.23	7.07	6.78	8.01	6.78	7.14
Aspartic acid	11.32	11.47	12.14	14.85	13.83	17.32	16.89	18.42	15.70	16.71
Glutamic acid	25.58	25.99	25.21	28.60	27.88	32.39	31.63	34.39	28.79	29.12
Serine	7.25	7.06	7.34	8.04	7.82	8.64	8.38	9.08	7.92	8.50
Histidine	2.11	2.15	1.27	1.95	1.88	3.33	3.23	3.58	2.97	3.01
Glycine	8.31	7.87	8.65	9.48	8.77	8.03	7.74	8.16	7.27	8.02
Alanine	7.81	7.63	7.95	8.76	8.24	8.65	8.32	9.19	7.93	8.94
Valine	7.03	7.16	6.70	8.89	7.83	10.07	9.78	10.48	8.95	9.87
Phenylalanine	6.91	6.99	7.01	7.87	7.69	9.04	8.94	9.79	8.49	8.46
Isoleucine	5.60	5.82	5.73	6.74	6.43	7.60	7.52	8.15	7.13	7.54
Leucine	12.74	12.63	12.79	13.45	13.41	14.50	14.61	16.24	14.46	15.61

Table 5.8. Amino acid composition of the treatment diets (g/kg) on an as fed basis for the grower and finisher phases

Amino acids	**Diet number**									
	Grower					**Finisher**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
Lysine	8.07	8.79	9.05	7.96	7.14	6.25	6.45	5.88	6.55	7.07
Methionine	0.72	0.59	0.66	0.55	0.55	0.42	0.59	0.70	1.15	2.43
Arginine	5.81	6.33	6.61	5.76	5.37	6.05	6.12	5.34	5.98	6.27
Threonine	4.93	5.23	5.13	4.43	4.06	3.72	3.85	4.34	4.92	5.36
Tyrosine	4.76	5.21	5.53	4.91	4.45	4.18	4.04	4.12	4.75	5.19
Aspartic acid	14.47	15.38	14.87	12.52	11.58	10.87	11.43	12.69	14.24	15.87
Glutamic acid	16.97	19.62	20.60	18.67	18.34	19.67	19.53	17.29	18.44	19.03
Serine	6.66	7.10	6.97	6.04	5.80	5.45	5.91	6.15	6.77	7.37
Histidine	1.81	2.04	2.09	1.77	1.64	1.63	1.54	1.86	1.94	1.98
Glycine	5.13	5.38	5.26	4.75	4.49	4.61	4.81	4.61	5.22	5.58
Alanine	5.77	6.37	6.37	5.85	5.68	4.61	5.06	5.20	5.85	6.44
Valine	6.67	7.17	7.37	6.48	5.96	5.79	6.00	6.52	7.31	7.37
Phenylalanine	6.27	6.91	7.00	6.16	5.72	5.50	5.68	5.73	6.31	6.90
Isoleucine	5.25	5.73	5.78	5.02	4.63	4.51	4.61	4.60	5.11	5.54
Leucine	9.81	11.18	11.50	10.51	10.07	8.29	8.74	8.69	9.68	10.76

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The chicks were initially kept indoors with free access to roam outdoors during the day but closed up at night for protection against the elements. They were then moved into larger outdoor camps at 10 weeks of age to prevent excessive skin damage. The outdoor camps, with approximate dimensions of 25 m x 20 m contained adequate shelter for the ostriches as well as cover for the feed troughs from exposure to moisture from dew and rainfall. The birds received their respective treatment diets *ad libitum*, as well as constant access to fresh clean water.

Initially, the birds were weighed three times a week until they were moved into the outdoor camps. Thereafter until the commencement of the finisher phase, they were weighed twice a week. During the finisher phase they were weighed once weekly due to the increased difficulty in their handling as a result of their weight gains, and average daily gains (ADG) throughout the trial were determined. The feed refusals were weighed once weekly in order to determine the intake per camp, and subsequently the calculation of the feed conversion ratio (FCR) was possible.

A high mortality rate was experienced in the pre-starter phase of the trial as a result of unseasonal cold spells that occurred. The decision was made to complete the trial with the remaining birds as best as possible. At 12 months of age the birds were placed into quarantine camps as depicted by the European Union (EU) meat quality standards highlighted in the report by the Department of Agriculture (Anon, 2013), where they continued to receive their respective treatment diets. Routine testing for avian influenza (AI) was conducted as stipulated by the EU to meet their phyto-sanitary requirements to determine the AI status of the farm before the birds were presented for slaughter. Initial results indicated that possible strains of the virus were present in some of the individual birds, which prompted further blood collections and testing. The follow up results yielded negative polymerase-chain reaction (PCR) as well as no active circulation of the virus as confirmed by the serology report. However, procedures surrounding such an event resulted in the need to slaughter the birds under a ‘red-cross’ permit as issued by a state veterinarian due to the farm being placed under temporary quarantine.

A private contractor was hired to transport the ostriches approximately 50 km to Swartland abattoir in Malmesbury. The maximum capacity in this particular vehicle was 80 ostriches; therefore the transport of all the birds was completed in two trips. The birds were offloaded into the lairage area specifically designed to receive ostriches at the abattoir, with a supply of fresh clean water. The birds were kept in lairage overnight for approximately 18 hours before slaughter

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commenced early the following morning. The slaughter procedures followed were comparable to those depicted by Hoffman (2012).

Each individual bird was weighed immediately pre-slaughter to give an accurate indication of the final weight at slaughter. After exsanguination, each bird was marked in order to ensure no confusion during the collection of the feathers. Next, individual skins were removed and marked before being prepared for further processing. Following evisceration, the abdominal fat, commonly referred to as the fat pad, was collected and weighed for each bird to determine whether the dietary energy had any effect on the yields.

The carcasses now consisting of the neck, wings, chest and thighs of the birds, were washed and their weights recorded to give the warm carcass yield before being moved into the cold storage facility. The carcasses were then transported to Mosstrich abattoir in Mossel Bay after a period of 60 hours due to the slaughter date falling at the end of the working week. Dressing percentages were determined using the cold carcass weight as a proportion of the live weight at slaughter.

Statistical analysis was done using SAS Enterprise Guide (version 9.2). A regression analysis was done per treatment diet over age to assess the weight gains by the birds. Gompertz growth curves were fitted after investigating the possibility of others, but the Gompertz curves yielded the best fit. The slopes were then compared to assess any differences in weight gain using analysis of variances (ANOVA). Furthermore, regression was run per treatment over age within each feeding phase and the slopes compared per physiological phase (pre-starter, starter, grower and finisher). ANOVA's were conducted on predicted averages for the production parameters measured, namely dry matter intake (DMI), average daily gain (ADG) and feed conversion ratio (FCR) as no distinct trends were observed in the slopes obtained per treatment. One – way ANOVA's were then done on the parameters measured at slaughter such as the live weight, warm carcass weight, cold carcass weight, fat pad weight, right thigh weight, big drum (*M. gastrocnemius*) weight and dressing percentages.

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5.3 Results

When analysing the average weights of the birds at the end of each of the four feeding phases, differences ($P < 0.05$) were found between the treatments after the pre-starter phase (Table 5.9). However, only the birds fed diet 5 had lighter ($P < 0.05$) weights (10.9 ± 0.56 kg) in comparison to those fed the other four treatment diets. During the rest of the trial period, no differences ($P > 0.05$) were found at the end of the remaining phases between the weights of the birds exposed to the five treatment diets.

Table 5.9. Least square means ± standard error (LSM ± SE) of the live weights for the effect of dietary energy concentrations on phase by phase growth of slaughter ostriches

Mean weight (kg) at end of (age):	Diets				
	1	2	3	4	5
Pre-starter (0 – 83 days)	$18.9^{a} \pm 1.76$	$21.7^{a} \pm 2.02$	$22.3^{a} \pm 0.33$	$19.6^{a} \pm 0.10$	$10.9^{b} \pm 0.56$
Starter (84 – 149 days)	44.8 ± 3.35	50.2 ± 2.55	51.5 ± 1.02	46.3 ± 1.48	39.6 ± 1.54
Grower (150 – 228 days)	69.6 ± 3.36	77.0 ± 3.57	78.8 ± 1.77	77.0 ± 0.21	68.1 ± 3.70
Finisher (229 – 344 days)	102.2 ± 3.26	108.5 ± 3.57	109.4 ± 2.04	108.6 ± 2.10	97.2 ± 2.40

^{a,b} Row means with different superscripts differ significantly ($P < 0.05$)

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With regards to the Gompertz model parameters, no differences ($P > 0.05$) were found across the three parameters (Table 5.10). The maximum weight achievable (kg) is denoted by the letter 'a', while 'b' is a measure of the rate of maturity of the birds and 'c' is the age at which the birds achieved their maximum growth rate in days.

Table 5.10. Growth parameters ± standard error (S.E) of slaughter ostriches as predicted by the Gompertz growth curve

Diet	Gompertz model parameters		
	a	b	c
1	107.8 ± 0.68	0.0107 ± 0.0005	141.1 ± 6.31
2	115.3 ± 5.36	0.0110 ± 0.0003	132.9 ± 2.20
3	115.8 ± 4.56	0.0114 ± 0.0007	132.4 ± 6.24
4	118.2 ± 4.62	0.0106 ± 0.0007	141.9 ± 4.92
5	105.8 ± 3.29	0.0117 ± 0.0003	150.0 ± 3.84

a – maximum weight (kg), b – rate of maturing parameter, c – age of maximum growth (days)

The production parameters measured during the trial are presented in Table 5.11, taking into consideration the parameters per phase, as well as for the overall trial period. The only differences to report were between the ADG's attained by the chicks during the pre-starter phase. The chicks fed the intermediary diets 2, 3 and 4 had significantly ($P < 0.05$) higher daily gains than those exposed to the two extreme diets; the lowest energy diet (1) and highest energy diet (5). The chicks that received diet 3 displayed the highest daily gains of 216.0 ± 8.08 g per day, while those fed diet 5 had the lowest daily gains of 137.5 ± 11.3 g per day.

None of the other phases yielded any differences ($P > 0.05$) for any of the three parameters (DMI, ADG, FCR) measured (Table 5.11).

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Table 5.11. Least square means ± standard error (LSM ± SE) for the effect of dietary energy concentrations on the production parameters of slaughter ostriches

Parameter	Phase	Diet				
		1	2	3	4	5
Dry Matter Intake (DMI) (kg/bird/day)	All phases	2.03 ± 0.19	1.83 ± 0.09	1.89 ± 0.12	1.74 ± 0.04	1.62 ± 0.17
	Pre-starter	0.31 ± 0.04	0.36 ± 0.03	0.34 ± 0.03	0.35 ± 0.07	0.21 ± 0.01
	Starter	1.30 ± 0.12	1.07 ± 0.02	1.23 ± 0.12	1.22 ± 0.06	1.20 ± 0.21
	Grower	2.22 ± 0.17	2.10 ± 0.21	2.25 ± 0.25	2.18 ± 0.03	2.24 ± 0.23
	Finisher	3.65 ± 0.52	3.22 ± 0.15	3.21 ± 0.18	2.80 ± 0.06	2.52 ± 0.23
Average Daily Gain (ADG) (g/bird/day)	All phases	280.0 ± 8.57	304.9 ± 12.6	307.2 ± 5.37	302.0 ± 2.96	277.2 ± 8.01
	Pre-starter	$171.6^{ab} \pm 13.3$	$212.0^{c} \pm 8.10$	$216.0^{c} \pm 8.08$	$192.8^{bc} \pm 3.17$	$137.5^{a} \pm 11.3$
	Starter	381.1 ± 25.1	428.1 ± 22.0	444.0 ± 17.9	414.3 ± 14.7	370.0 ± 7.85
	Grower	396.1 ± 13.1	419.5 ± 19.0	423.3 ± 9.79	423.3 ± 2.89	415.6 ± 23.4
	Finisher	219.1 ± 6.35	223.3 ± 10.6	216.1 ± 22.1	233.3 ± 16.5	229.0 ± 11.0
Feed Conversion Ratio (FCR) (kg feed/kg weight gain)	All phases	8.59 ± 1.11	7.46 ± 0.57	7.72 ± 0.53	6.54 ± 0.18	6.24 ± 0.51
	Pre-starter	1.53 ± 0.07	1.51 ± 0.08	1.47 ± 0.15	1.63 ± 0.25	1.54 ± 0.23
	Starter	3.51 ± 0.53	2.52 ± 0.11	2.75 ± 0.20	2.95 ± 0.26	3.24 ± 0.53
	Grower	5.70 ± 0.32	5.10 ± 0.39	5.41 ± 0.50	5.19 ± 0.06	5.43 ± 0.25
	Finisher	16.59 ± 3.42	14.19 ± 1.52	14.64 ± 1.42	11.04 ± 0.82	9.89 ± 0.90

[a,b,c] Row means with different superscripts differ significantly ($P < 0.05$)

Regression equations were fitted to the three production parameters for the overall trial (all phases), despite no statistical differences found between the treatments (Table 5.11). This was done to give an indication of the trends that are evident when analysing the results for all the phases in terms of the DMI, ADG and FCR in Table 5.12.

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Table 5.12. Regression equations across all phases of the trial for the DMI, ADG and FCR

Production Parameter	Function	Equation
Dry matter intake (DMI)	Linear	$y = 2.090 - 0.089x$
Average daily gain (ADG)	Quadratic	$y = 0.243 + 0.045x - 0.077x^2$
Feed conversion ratio (FCR)	Linear	$y = 8.991 - 0.556x$

Concerning the parameters measured pre- and post-slaughter, no differences ($P > 0.05$) were found (Table 5.13). However, focusing on the live weight measured just before slaughter, significance was approached ($P = 0.06$), but fell just outside the bounds used for significance (95%). The birds fed diet 3 yielded the heaviest live weights at an average of 110.1 ± 3.50 kg, while the birds exposed to the highest energy levels (diet 5), were the lightest at 97.1 ± 3.35 kg.

Table 5.13. Least square means ± standard error (LSM ± SE) for the effect of dietary energy concentrations on the slaughter parameters measured for slaughter ostriches

Parameters	Diets				
	1	2	3	4	5
Live weight (kg)	99.0 ± 0.91	108.2 ± 3.16	110.1 ± 3.50	102.0 ± 3.28	97.1 ± 3.35
Warm carcass (kg)	48.5 ± 1.57	53.8 ± 1.27	52.3 ± 1.79	48.1 ± 3.32	45.4 ± 0.31
Cold carcass (kg)	45.5 ± 1.54	50.7 ± 1.28	49.6 ± 1.83	45.0 ± 3.20	42.6 ± 0.58
Dressing percentage (%)	46.0 ± 1.26	46.9 ± 0.50	45.2 ± 0.27	43.6 ± 2.09	43.9 ± 0.95
Right thigh weight (kg)	16.9 ± 0.53	18.6 ± 0.47	18.1 ± 0.67	16.3 ± 1.18	15.9 ± 0.35
Right thigh percentage of carcass (%)	37.1 ± 0.33	36.7 ± 0.12	36.5 ± 0.31	36.3 ± 0.06	37.1 ± 0.34
Abdominal fat pad (kg)	5.11 ± 0.47	5.06 ± 0.39	6.16 ± 0.54	4.56 ± 1.54	6.02 ± 0.50
M. gastrocnemius (big drum) weight (kg)	1.04 ± 0.05	1.20 ± 0.04	1.12 ± 0.05	0.99 ± 0.06	1.01 ± 0.05
M. gastrocnemius percentage of thigh (%)	6.14 ± 0.17	6.35 ± 0.11	6.18 ± 0.04	6.01 ± 0.19	6.30 ± 0.15

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5.4 Discussion

The results achieved by the ostriches in terms of their growth are highlighted in Table 5.9. Differences were limited to a minimum across the four feeding stages, where the weights of the birds were compared at the end of each feeding phase. Only after the pre-starter phase were any differences evident, with the birds fed diet 5 substantially lighter than their counterparts fed the other diets at the same stage. The birds in that treatment group were fed at an energy level of 15.5 MJ ME/kg feed, and attained similar weights to birds fed at the same energy content in a study by Brand *et al.* (2014). The reason for their difference from the rest of the treatment groups may also have been influenced by a high mortality rate experienced in one of the replications (groups) of birds fed diet 5. Furthermore, the high mortality rate across the whole trial may have had a negative impact on the results obtained for the whole period, by magnifying the variation among the birds.

The Gompertz parameters given in Table 5.10 support the results of the weights of the birds at the end of the trial period where no differences were reported. The parameter (b) measuring the rate of maturity of the birds showed no differences, as did the age at which the birds were predicted to reach maximum growth (c).

The results reported thus far, with regards to the growth of the birds fed the different treatment diets, are mirrored and somewhat justified when dissecting the findings of the production parameters (Table 5.11). Previous studies conducted by Brand *et al.* (2000), Brand *et al.* (2004), Glatz *et al.* (2008) tend to indicate some differences when investigating the dietary energy influence on the production parameters. Therefore, the results found in this study are somewhat contradictory to previous investigations into dietary energy levels, but may be explained by the variation within the treatment groups described earlier. The results are however consistent, as any differences between the growth of birds fed different treatment diets would inevitably translate into differences across the production parameters, and *vice versa*.

Although no statistical differences were observed in this study with regards to intake, the lowest energy diet (diet 1) displayed a marginally higher intake value over the course of the study. This could be due to the birds attempting to compensate for a decreased energy concentration by increased intake, while the birds which received the highest energy level (diet 5) required ~20% less feed throughout the trial. The general trend thereof is displayed by the linear function fitted which is highlighted in Table 5.12. Thus, an incremental increase in dietary energy content resulted

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in a corresponding decrease in dry matter intake (DMI) by 0.089 kg. However, it is categorically stated that these findings were not significant ($P > 0.05$), thus a repetition of the trial may result in different findings and conclusions.

With regards to the trend observed for the ADG throughout the trial, a quadratic function best fitted the data with the middle diet (diet 3) yielding the best gains (307.2 ± 5.37 g/bird/day). This highlights the importance of correct formulations with regards to the dietary energy content, as an under- or over-supply resulted in marginally decreased performance of the birds.

Concerning the overall FCR, a linear function again best fitted the data (Table 5.12). Thus, an incremental increase in energy content resulted in a better FCR by a factor of 0.556; therefore birds fed incrementally higher energy diets effectively required 0.556 kg less feed than the others per kilogram weight gain.. Importantly, the FCR values displayed in this study indicate the high importance placed on the decision of when to slaughter the birds. For example, the FCR value during the finisher phase for the middle energy diet (diet 3) was 14.64 ± 1.42 kg feed per kg weight gain. The viability thereof therefore becomes a decision for the producer, where the price of feeding the birds may become offset by the high cost of continued feeding.

Although no differences were found across the parameters measured pre- and post-slaughter of the ostriches (Table 5.13), the *P*-value for the live weight of the ostriches approached significance ($P = 0.06$). Previous work by Glatz *et al.* (2008) and more recently by Brand *et al*. (2014) showed differences were indeed present between the weights of the birds fed different levels of energy. Brand *et al.* (2014) however only fed three treatment diets during the finisher phase, with energy concentrations of 9.5, 10.5 and 11.5 MJ ME/kg feed, whereas this study had an additional two treatment diets. This may have contributed to the results found in this study, which was similar to that of Brand *et al.* (2014); where the two extra diets may have buffered the differences as the energy concentrations were 9.5, 10.0, 10.5, 11.0 and 11.5 MJ ME/kg feed across the five diets. Similarly, the lower number of treatment animals may have contributed to these results; compounded by a degree of variation found within the treatment groups having an influence on the deviations from the treatment means.

Interestingly when considering the losses observed from the warm to the cold carcasses in this study, they were abnormally high. No differences were evident for either parameter between the carcasses fed the different treatment diets, but the losses from warm carcass mass to those

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recorded on the cold carcass were ~6%. This was due to the carcasses hanging in cold storage for an extra 72 hours as a result of the slaughter day falling at the end of the working week. These differences are approximately triple (~2%) those reported by Hoffman *et al.* (2012), highlighting the stark losses which can be experienced simply as a result of hang time in the cold storage units. This also had a knock on effect on the dressing percentages, which were lower by ~3% than those obtained by Brand *et al.* (2014) using ostriches slaughtered at a similar age.

With regards to the thigh weights measured from the birds fed the different treatment diets, no differences were found. This was expected when considering no differences were evident between the cold carcasses. However, what is of interest is the high proportion of the carcass the thigh constitutes (~37%). Doubling this figure sheds light on the large value which is placed on the thighs of ostriches, as the thighs together then account for approximately 74% of an ostrich carcass.

Concerning the yields obtained for the abdominal fat pads in this study, no differences were found (Table 5.12). Hoffman *et al.* (2005) investigated the possibility of excess dietary energy being stored as intra-muscular fat within the muscles of ostriches. However, they found no evidence of diet affecting the fat content within the muscles, postulating that the excess energy may be converted and stored in the abdominal fat pad reserves of the ostriches. The findings in this study therefore suggest dietary energy has no effect on the fat pad yields. Therefore the genetics of the birds may play a more significant role in the influence on the fat pads than the nutrition, and may warrant further research to better understand the mechanisms thereof.

5.5 Conclusion

The results obtained in this study are somewhat contradictory to previous studies involving dietary energy concentrations, and may have been a result of a high mortality rate experienced during the pre-starter phase of the trial. Nevertheless, differences were minimal between the growth rates of the birds on the different treatment diets, which was reflected in the various production parameters measured. Energy also seemed to have minimal effect on the abdominal fat pad yields harvested from the birds fed the different energy concentrations.

It can however be concluded that energy sources, particularly maize, is set to increase in price and producers therefore have to take into careful consideration at what stage they decide to

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slaughter their ostriches. Continual feeding of the birds becomes extremely risky as a result of the increased quantities of feed required for the increase of body weight. Thus, with the recent lifting of the ban of fresh meat export into the EU, coupled with the increase in prices of maize as a result of the drought in South Africa; the current producer may begin to contemplate the prospect of slaughtering the ostriches at a younger age. With least cost feed formulation and optimal nutrient requirements (Gous & Brand, 2008) the ‘ideal’ slaughter weight and skin size is attainable at 85 kg live weight, which is quite possible to attain at 11 to 12 months of age with sound feed management practices.

5.6 References

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Chapter 6

Effect of different dietary energy levels fed to ostriches on the feather, skin and meat yields and quality

Abstract

The under fire ostrich industry recently received a massive boost with the European Union (EU) confirming the lifting of the ban on the export of raw meat products to their shores. Although the meat sector recovered somewhat from the repercussions of the ban from 2011 with the export of pre-heated meat and the development of the local market, a marked increase in contribution of the meat to the R1 billion ostrich industry bodes well for the future. The aim of this study was to assess the influence of different energy concentrations in the diets of slaughter ostriches on the three primary products, the feathers, skin and meat; in an attempt to optimize the feeding regimes used by producers aiding in lowering the nutritional costs incurred. Five treatment diets with varying energy concentrations were formulated for each of the four feeding phases, from pre-starter, to starter, grower and finisher. The middle diet (3), acted as the control and contained 14.5, 13.5, 11.5 and 10.5 MJ ME/kg feed for each of the respective feeding phases. Two diets below and two diets above these energy levels were formulated for each phase respectively to fully assess the impact of different dietary energy on the three products. Three replications per treatment were conducted, thus yielding 15 camps of ostriches fed *ad libitum*. No differences were found across any of the feather parameters measured, as well as between the crust sizes of the skins post-tanning. Furthermore, the energy content of the diet had no effect on the crust grades as well as the nodule grades allocated to the crusts. With regards to the meat, energy content of the diet had no impact on the intra-muscular fat content, moisture or protein. However, the ash content of the meat was influenced with the middle diet (3) yielding the highest ash content (1.21%), significantly different from the other treatments. Therefore, dietary energy content exhibited little influence over the feather, skin and meat parameters measured in this study.

6.1 Introduction

The current economic landscape of the ostrich industry has resulted in the high profit margins once realised in the 1990's (Brand *et al.*, 2003), being much more difficult to achieve and sustain. It is well accepted that feeding the birds comprises about 70-80% of the costs associated with

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intensive ostrich production systems (Brand *et al.*, 2000a). Therefore, the need to quantify the effects the dietary composition has on the end products harvested from the slaughtered birds becomes critical. An over- or under-supply of certain nutrients is detrimental either to the producer by increasing costs or to the ostriches in terms of decreased production; indirectly affecting the profitability of the enterprise (Carstens, 2013). This has a knock on effect onto the primary products harvested from ostriches, namely the skin, meat and feathers.

With the three tier make-up of the products, the incomes generated from the sale of feathers have never reached the pinnacles they did in the early 1900's as fashion items (Anon, 2004). However, with the hardships recently encountered in the export of raw meat products to the EU due to the avian influenza (AI) strains, the income generated from the feathers at an estimated 15% (Stumpf, J., Pers. Comm., Klein Karoo International, P.O. Box 241, Oudtshoorn, 6620, South Africa, 14th June 2014) was critical for the profitability of production systems. Therefore, this study was conducted to provide further insight to the effect of dietary energy on the specific feather classes as conducted by Brand *et al*. (2014), over and above simply 'saleable' feathers as researched by Brand *et al.* (2004). The difference from the work by Brand *et al*. (2014) was that there were extra treatment diets formulated containing a wider variety of energy concentrations.

Although the ostrich meat sector was under considerable pressure due to the export ban of raw meat to the EU, the patterns observed within the overall industry since it's advent in the 19th century suggested a turnaround was imminent. This was recently confirmed with the lifting of the ban imposed by the EU on raw meat products (Anon, 2015). Modern consumers are better informed and thus their desire to know the nutritional composition of their products bought for consumption has increased (Polawska *et al.*, 2011). Although previous studies by Hoffman *et al*. (2005) which were supported by Majewska *et al*. (2009) with regards to the chemical composition of the meat have been published, it was felt that a comprehensive investigation with regards to the effect of dietary energy on the meat was warranted. Carstens (2013) did a similar study, however the birds were slaughtered at a relatively young age of eight months and only three levels of dietary energy were investigated.

The ostrich leather sector of the industry has consistently been a stronghold with regards to the income generated since the first tannery was opened in the late 1960's (Drenowatz *et al.*, 1995). Therefore, as described by Engelbrecht *et al.* (2005), it is the cornerstone of the South African

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ostrich industry and therefore the impact nutrition has on skin quality is well worth investigating. Thus, in this study the effect of dietary energy on the crust sizes as well as nodule sizes were investigated; as well as the nodule and pin-hole densities in selected areas on the leather crust.

6.2 Materials and methods

The birds utilized in this study were the same birds used for the trial described in Chapter 5. Therefore the structural outlay of the trial was precisely the same with the feeding as well as management of the ostriches according to the five treatment diets described. For the composition of the raw materials of the five diets, please refer to Chapter 5, Tables 5.1 – 5.4. Chemical analysis was conducted on feed samples collected periodically throughout the trial and is available in Tables 5.5 and 5.6. The corresponding amino acid profiles are also available in Chapter 5, presented in Tables 5.7 and 5.8.

The middle diet (diet 3) acted as the control and contained 14.5, 13.5, 11.5 and 10.5 MJ ME/kg feed for each of the respective feeding phases (pre-starter, starter, grower and finisher). Two diets below and two diets above these energy levels were formulated for each phase respectively, to fully assess the impact of different dietary energy on the three products.

The ostriches had access to fresh clean water as well as their feed *ad libitum*. As is common practice in the ostrich industry, the feathers of the birds were scheduled to be clipped at 240 days of age (Shanawany, 1999). The lead up to the slaughter date of the ostriches, as well as the management thereof is thoroughly documented in Chapter 5.

After exsanguination of the individual birds, a bag marked for each bird was used to collect the different classes of feathers. The feathers were then transported back to the research farm where they were stored at a temperature of -4ºC for 72 hours before transport to the feather department of Klein Karoo International in Oudtshoorn. Upon arrival, the feathers were treated in exactly the same manner as was described for the feathers harvested in Chapter 4. Once the feathers had undergone the sterilization process, they were grouped into their different classes; namely ‘commercially valuable’, ‘adult wings’, ‘wing rejects’, ‘adult tail butts’, ‘back’, ‘chick body floss’, ‘chick body short’, ‘drab body slope’, ‘drab dry points’ and ‘drab silver floss’.

The classes where there may be some ambiguity include those labelled ‘drab’, where the origin of the feather was from the body of the bird. A general rule of thumb regarding the ‘drab’

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feathers would be the fact they were shorter than the wing feathers due to their location on the body. It is interesting to observe the presence of several 'chick' classes, confirming the relative immaturity of the feathers at slaughter. This was due to the clipping of the feathers having to be postponed by three weeks due to a delayed onset of the spring season, as well as the moving forward of the slaughter date by two weeks due to the lack of availability at the abattoirs. This is due to high demand for slaughter space by producers as a result of the fact that birds are generally at their optimal age for slaughter in the mid-summer months as a result of ostriches being seasonal breeders. Each class of feather per bird was weighed and recorded to determine if the energy content of the diets had any effect on the yields. Also, the shafts of 10 randomly selected 'wing' feathers from each bird were measured 5 cm from the base (point of entry into the skin) with a Mitutoyo Digital Caliper (model number: CD-8″ C).

The skins were harvested from all the birds and thereafter salted and stored in a cold storage unit at 5ºC. They were kept in this state for a period of 72 hours due to the slaughter of the birds taking place at the end of the working week and the arrangement of transport only occurring the following week. They were then transported to Southern Cape Ostrich Tannery (SCOT) in Mossel Bay where they underwent exactly the same treatment as the skins described in Chapter 4. However, a minor difference was that it was not possible to measure the wet skin sizes upon arrival at SCOT due to changes enforced to their protocols regarding arrivals of new skins. However, the skin crust sizes were measured once the tanning processes were completed.

Similarly, the data collection methods used and described were employed for these skins once they were in their crust form. The five localities used for measuring the nodule density, nodule diameters and pin-hole counts are highlighted in Figure 6.1. The nodules were again subjectively assessed with a grade one skin deemed the finest while a skin given a grade four was adjudged to be the poorest.

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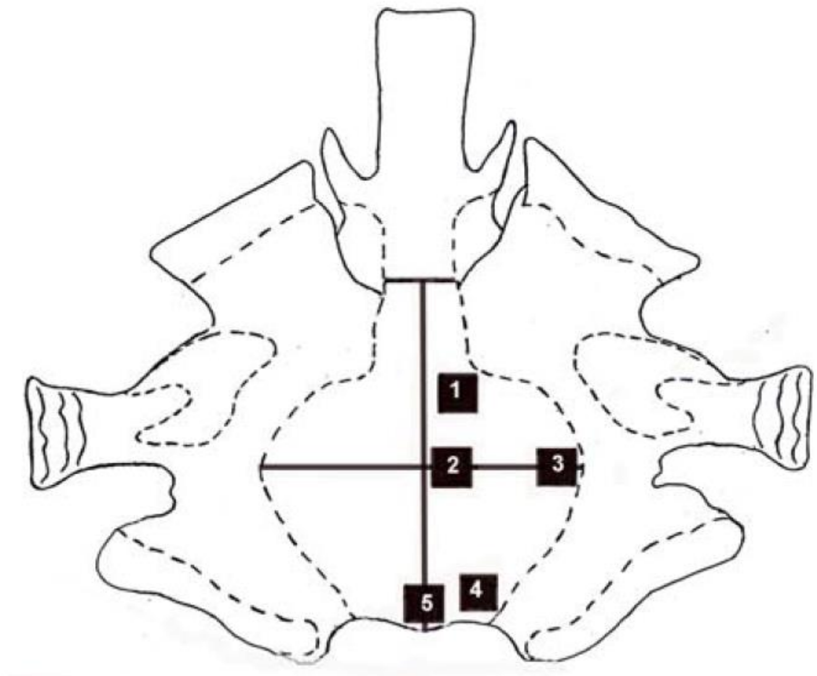

Figure 6.1. Ostrich skin depicting the five localities from which sampling and data collection was done, viz. localities: 1 – neck; 2 – mid-crown; 3 – upper leg; 4 – lower flank; 5 – butt

Following skinning and evisceration, the carcasses were moved into the cold room at Swartland abattoir where they were stored for a period of 60 hours once again due to the slaughter taking place at the end of the working week. They were then transported to Mosstrich abattoir in Mossel Bay for further deboning and packaging. The *M.gastrocnemius* (big drum) muscle from each individual bird's right thigh was collected and weighed, and then transported back to Stellenbosch University laboratories for further chemical analysis. The reason for sampling from the right thigh was simply in order to maintain a level consistency throughout the harvesting process.

Proximate analysis was then performed on a homogenized meat sample of the steak with any subcutaneous fat removed. The moisture content (%) was determined using method 934.01 (AOAC International, 2002a) and then the ash content analysed on the moisture free sample using method 942.05 (AOAC International, 2002b). The protein content of the meat sample was determined using the AOAC International (2002c) method, procedure 992.15. Finally, the total

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lipid content of the raw meat sample (intra-muscular fat, IMF; %) was determined using the AOAC International (2002d) chloroform/methanol (1:2 vol/vol) extraction method (920.39).

Statistical analyses were run using SAS Enterprise Guide (version 9.2). One-way analysis of variance's (ANOVA) were performed on all the parameters measured in terms of the feathers and skins to determine if treatment had any affect. The Shapiro-Wilk test was conducted to test for normality (Shapiro & Wilk, 1965), while outliers were identified and removed prior to final analysis. The *t*-least significant differences were calculated on a 5% significance level. The resultant differences were deemed as not significant at $P > 0.05$, while significance was assumed at $P < 0.05$.

6.3 Results

The five treatment diets administered to the ostriches had no effect ($P > 0.05$) on any of the feather parameters or any of the measured classes (Table 6.1).

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Table 6.1. Least square means ± standard error (LSM ± SE) for the effect of dietary energy concentrations on the feather parameters and classes of slaughter ostriches

Parameters	Diets				
	1	2	3	4	5
Shaft diameter (mm)	6.89 ± 0.12	6.66 ± 0.15	6.76 ± 0.01	6.27 ± 0.29	6.21 ± 0.10
Commercially valuable feathers (g)	978.5 ± 83.9	975.5 ± 56.9	1016.0 ± 19.5	1016.9 ± 60.9	932.6 ± 17.0
Wing rejects (g)	164.7 ± 24.3	130.1 ± 5.37	152.4 ± 12.5	132.1 ± 3.58	131.6 ± 13.4
Tail feathers (g)	124.0 ± 20.7	89.5 ± 20.7	103.1 ± 14.6	106.0 ± 19.7	56.0 ± 19.8
Back feathers (g)	197.3 ± 2.25	175.9 ± 28.0	114.8 ± 16.6	145.0 ± 10.6	172.7 ± 22.3
Chick body floss (g)	309.7 ± 41.6	231.3 ± 28.2	272.6 ± 13.8	322.2 ± 30.4	324.3 ± 14.9
Drab bloods (g)	427.4 ± 38.6	506.8 ± 48.8	439.3 ± 1.47	455.6 ± 29.8	369.3 ± 9.8
Worthless feathers (g)	103.2 ± 15.4	103.1 ± 11.1	104.9 ± 12.0	100.6 ± 12.4	102.5 ± 10.2
Drab body slope (g)	89.5 ± 14.1	102.6 ± 10.4	106.1 ± 5.72	129.3 ± 10.0	98.2 ± 4.22
Drab silver floss (g)	335.1 ± 72.9	219.7 ± 28.3	255.1 ± 20.3	279.5 ± 47.1	222.7 ± 80.6

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Similarly, no differences ($P > 0.05$) were observed between the skins of the birds harvested from the different treatment groups in terms of the crust sizes as well as the skin thickness (Table 6.2).

Table 6.2. Least square means ± standard error (LSM ± SE) for the effect of dietary energy concentrations on the skin parameters measured of slaughter ostriches

Parameters	Diets				
	1	2	3	4	5
Crust size (dm^2)	142.9 ± 1.38	146.7 ± 1.97	150.4 ± 1.39	143.2 ± 4.20	144.3 ± 5.75
Skin thickness (mm)	1.54 ± 0.12	1.32 ± 0.05	1.44 ± 0.02	1.31 ± 0.13	1.36 ± 0.01

With regards to the grades allocated to the crusts, as well as the subjective grades assigned to the nodules; no differences ($P > 0.05$) were found with regards to the proportions of skins allocated either first, second, third or fourth grades (Table 6.3 and Table 6.4, respectively).

Table 6.3. Proportion (%) ± standard error (SE) of each grade for the crusts as affected by different concentrations of energy in the diet of slaughter ostriches

Diet	Mean	1^{st} Grade (%)	2^{nd} Grade (%)	3^{rd} Grade (%)	4^{th} Grade (%)
1	2.34 ± 0.09	6.67 ± 6.67	52.2 ± 7.78	41.1 ± 4.84	0.00 ± 0.00
2	2.98 ± 0.25	8.33 ± 8.33	15.4 ± 4.83	46.5 ± 13.0	29.8 ± 7.46
3	2.44 ± 0.19	11.9 ± 2.39	38.5 ± 9.34	42.9 ± 4.97	6.67 ± 6.67
4	2.90 ± 0.55	12.1 ± 1.75	48.6 ± 7.00	32.1 ± 14.6	7.11 ± 5.83
5	2.38 ± 0.50	22.2 ± 18.1	22.2 ± 18.1	50.0 ± 40.8	5.56 ± 4.54

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Table 6.4. Proportion (%) ± standard error (SE) of each grade for the nodules as affected by different concentrations of energy in the diet of slaughter ostriches

Diet	Mean	1st Grade (%)	2nd Grade (%)	3rd Grade (%)	4th Grade (%)
1	2.53 ± 0.29	6.67 ± 6.67	63.3 ± 18.6	0.00 ± 0.00	30.0 ± 15.3
2	2.60 ± 0.09	11.2 ± 0.72	32.8 ± 4.34	41.0 ± 7.58	15.0 ± 7.64
3	2.67 ± 0.12	3.33 ± 3.33	35.5 ± 8.67	52.1 ± 9.77	9.10 ± 9.09
4	2.93 ± 0.54	12.1 ± 1.75	48.6 ± 7.00	27.1 ± 10.5	12.1 ± 1.75
5	2.67 ± 0.54	22.2 ± 18.1	16.7 ± 13.6	33.3 ± 1.75	27.8 ± 4.54

Similarly, when analysing the crusts for the measured parameters, no differences ($P > 0.05$) were found on the crusts from the different treatment groups for the nodule diameters (Table 6.5).

Table 6.5. Least square means ± standard error (LSM ± SE) for the effect of different energy concentrations fed to slaughter ostriches on their nodule diameters measured at different localities

Locality	Diets				
	1	2	3	4	5
Locality 1 – Neck	3.42 ± 0.06	3.47 ± 0.01	3.56 ± 0.05	3.29 ± 0.21	3.38 ± 0.02
Locality 2 – Mid-crown	3.68 ± 0.09	3.80 ± 0.08	3.87 ± 0.10	3.57 ± 0.14	3.61 ± 0.01
Locality 3 – Upper leg	4.50 ± 0.21	4.39 ± 0.11	4.59 ± 0.16	4.40 ± 0.03	4.62 ± 0.11
Locality 4 – Lower flank	4.71 ± 0.03	4.80 ± 0.09	4.88 ± 0.01	4.66 ± 0.10	4.54 ± 0.08
Locality 5 – Butt	4.75 ± 0.11	4.91 ± 0.05	4.86 ± 0.05	4.46 ± 0.31	4.88 ± 0.24

In terms of the nodule and pin-hole densities respectively, no differences ($P > 0.05$) were found in the five locations on the skin crusts between the five treatments (Table 6.6).

Table 6.6. Least square means ± standard error (LSM ± SE) for the effect of dietary energy concentrations on the nodule density and pin-hole densities of slaughter ostriches

Parameters	Diets				
	1	2	3	4	5
Nodule density locality 1	42.1 ± 2.92	43.3 ± 0.53	40.0 ± 0.81	46.8 ± 0.50	42.8 ± 3.64
Nodule density locality 2	50.4 ± 2.48	52.0 ± 0.40	49.9 ± 2.48	53.7 ± 0.35	53.0 ± 3.27
Nodule density locality 3	22.3 ± 0.88	20.9 ± 0.28	20.5 ± 0.73	22.8 ± 1.15	22.2 ± 1.50
Nodule density locality 4	29.2 ± 1.50	29.7 ± 0.40	27.7 ± 1.47	33.4 ± 1.82	29.6 ± 3.25
Nodule density locality 5	48.2 ± 2.72	46.7 ± 0.81	45.7 ± 1.94	53.0 ± 3.99	47.8 ± 1.72
Pin hole number locality 1	26.9 ± 3.25	34.6 ± 7.13	28.8 ± 7.40	31.1 ± 2.82	33.9 ± 3.22
Pin hole number locality 2	27.5 ± 6.45	37.9 ± 4.44	35.5 ± 3.83	32.7 ± 5.63	31.1 ± 4.99
Pin hole number locality 3	5.71 ± 1.72	5.69 ± 1.68	7.47 ± 1.33	7.94 ± 3.11	3.19 ± 2.19
Pin hole number locality 4	9.77 ± 0.50	13.9 ± 4.43	14.6 ± 3.33	10.8 ± 1.54	11.9 ± 0.64
Pin hole number locality 5	46.1 ± 3.32	48.0 ± 10.8	46.3 ± 6.97	35.2 ± 14.5	38.4 ± 0.77

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No differences ($P > 0.05$) were found for the moisture content of the meat, as well as the protein and intra-muscular fat content from the different treatment groups of birds (Table 6.7). However, there was one difference ($P < 0.05$) observed regarding the ash content. Birds fed diet 3 displayed a proportionally higher percentage of ash in the meat (1.21 ± 0.05) when compared to the four other treatment diets administered.

Table 6.7. Percentage least square means ± standard error (LSM ± SE) for the proximate composition of the *M. gastrocnemius* of ostriches fed different levels of energy

Chemical component	Treatment diets administered				
	1	2	3	4	5
Moisture	76.2 ± 0.27	75.8 ± 0.13	75.7 ± 0.20	76.0 ± 0.10	75.7 ± 0.33
Protein	21.2 ± 0.37	21.5 ± 0.12	21.3 ± 0.15	21.3 ± 0.29	21.4 ± 0.09
Fat	2.12 ± 0.13	2.10 ± 0.04	2.52 ± 0.11	2.17 ± 0.18	2.22 ± 0.18
Ash	1.02^{a} ± 0.01	0.99^{a} ± 0.01	1.21^{b} ± 0.05	0.99^{a} ± 0.03	0.96^{a} ± 0.004

6.4 Discussion

In this study there were no differences found between the masses recorded of each of the commercially distinguishable feather classes (Table 6.1). Similarly, the shaft diameters measured yielded no significant differences between the feathers harvested from the birds fed the different treatment diets. In a similar study by Carstens (2013), differences were found in the ‘chick body floss’, ‘drab bloods’, ‘young bird floss’ and ‘total feathers with commercial value’ classes. Previously, Brand *et al*. (2004) simply weighed the total saleable feather yield from ostriches exposed to different energy concentrations in their diets, and also found differences. They found the birds exposed to the higher energy diets gave heavier feather yields. Thus, the findings in this study are somewhat contradictory, as the group ‘commercially valuable’ feathers was effectively a like for like comparison with the total saleable feather yield as measured by Brand *et al.* (2004). This may be, to a large extent, as a result of the relatively ‘young’ feathers on the birds at the time of slaughter. This was as a result of the clipping of the feathers as described by Shanawany (1999) being postponed by three weeks as a result of the delayed onset of spring and therefore higher temperatures. A compounding factor was the slaughter date of the ostriches moving forward by

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two weeks as well, due to limited slaughter availability at the respective abattoirs as birds are generally at their optimal age for slaughter in the mid-summer months as a result of ostriches being seasonal breeders Thus, the feathers that were harvested were immature, inconsistent and therefore downgraded as evidenced by the heavy yields of 'wing rejects'.

Therefore, an amendment that would be recommended for similar studies in the future would be to ensure the feathers on the birds are mature before slaughter. As the feathers were not the primary goal in this particular study, it was felt that slaughter should commence nonetheless, and may be the reason for not observing differences between the feather yields where previous work suggested dietary energy did indeed have an impact on the yields.

Brand *et al.* (2000a) investigated the effects of three different energy concentrations (9.0, 10.5 and 12 MJ ME/kg feed) on the skin yields of slaughter ostriches. They found differences between the treatments, with the birds fed the low (9.0 MJ ME) energy diet yielding the smallest skins. However, this measurement was instrumented on the raw skin size and not the chrome crusted stage size, as was done in this study (Table 6.2). Therefore, comparisons may be drawn, but with a certain degree of circumspect due to the fact that changes may have been a factor during the tanning process as described in Chapter 4. Cloete *et al.* (2006) later reported no differences, although the *P* – value did approach significance (0.08), between the raw skin sizes harvested from birds exposed to the same dietary energy concentrations as those in the study by Brand *et al.* (2000a).

In this study, dietary energy had no effect on the crust sizes obtained from the treatment birds. Perhaps changes did indeed occur during the tanning process which may explain the conflicting results between the three experiments. However, it may also be argued that the two extra treatment groups used in this study, giving energy levels of 9.5, 10.0, 10.5, 11.0 and 11.5 MJ ME/kg feed, may have given a more accurate analysis of the differences obtained between the treatment groups. Carstens (2013) later attempted to clarify the differences in the chrome-crusted stage as was done in this study. Differences were evident between the different energy levels in the treatment feeds fed (9.5, 10.5 and 11.5 MJ ME/kg feed), with the middle diet yielding the largest crusts. However, those birds were slaughtered at the end of the grower phase at approximately 8 months of age, while the birds in this study achieved a slaughter age of 11.5 months. Cloete *et al.* (2004) and Engelbrecht *et al.* (2005) highlighted that an increase in age by

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one month would lead to an increase in skin yield by ~4.3 dm^2, thus confirming that the extra growth in the finisher phase of the birds in this study may have contributed to the results obtained. Furthermore, the change of the gastro-intestinal tract (GIT) of the ostrich with age, enables it to better utilize fibrous material as a source of energy (Brand *et al.*, 2000b); and the phenomenon of compensatory growth among the birds on the lower energy diets may have played a role in the final feeding phase.

With regards to the raw skin thickness, Cloete *et al.* (2006) reported no influence with regards to the energy content of the diet which was subsequently also found by Carstens (2013). This study also found the same results; therefore it seems relatively conclusive that dietary energy differences have no influence on the size of the skin crusts of slaughter ostriches of the same age.

In previous studies conducted to evaluate the crust grades allocated to ostrich crusts exposed to different energy levels in the diet, the means of the grades given were analysed and reported (Brand *et al.* 2004, Carstens, 2013). However, minimal analysis with regards to the actual proportion of skins per treatment assigned to each grade has been reported although Brand *et al.* (2000a) briefly report on this. In this study, the breakdown of the skins per treatment group and the proportion of grades achieved in relation to each other were analysed to conclusively report on the influence of energy on the crust grades (Table 6.3). Therefore, it can definitively be stated that different concentrations of energy in the diets of slaughter ostriches do not have an impact on the grades achieved for their crusts.

The nodules were again subjected to a subjective assessment as thoroughly described in Chapter 4. However, when analysing the results, no differences were found between the nodule grades given to the crusts from the five treatment groups (Table 6.4). The method employed to assess the nodule quality however does allow for improvements which may warrant further investigation. Instead of simple communication between the graders from the industry to the individual conducting the grading procedure, it would possibly be beneficial to have graders themselves assessing the nodule quality and giving the grade based on the numbering system described. This negates the subjective nature of the method from an individual with less experience, to a subjective analysis by a much more experienced individual with regards to ostrich crusts.

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With regards to the quality parameters measured on the crust itself, the sites selected were consistent with those used by Cloete *et al.* (2004). They reported clear differences between the nodule diameters as well as densities between the five locations of the skin as seen in Figure 6.1. However, the goal of this study was to evaluate any differences within those five areas as a result of the different feeding regimes. No differences were found though (Table 6.5), supporting similar findings by Carstens (2013). Thus, the postulation by Engelbrecht *et al.* (2009) that a well-balanced ration with the minimum requirements for protein and energy will yield adequately acceptable skin quality parameters, seems justified.

Furthermore, when assessing the nodule densities as well as the pin-hole densities, no differences were found between the crusts originating from the birds fed the different treatment diets (Table 6.6). Therefore, any correlations between the effects of nutrition on the nodule densities subsequently onto the final crust grade given seem to be negligible. Similarly, the energy content of the diet had no impact on the pin-hole densities counted in the five locations on the crust; further supporting the thoughts of Engelbrecht *et al.* (2009). Perhaps it can be tentatively stated that the effects of energy on the skin grades achieved have been proven to be minimal.

Although the pin-hole counts were not affected by the feeding regime, they remain a threat to the overall quality of the skin (Lunam & Weir, 2006). Coupled with skin damage, these two factors play a large role in determining the final grade of the skin and therefore the revenue generated for the producer (Engelbrecht *et al*., 2005). Therefore, it may be argued that factors that contribute to skin damage such as on-farm management practises, post-slaughter processing, as well as storage methods may need more focused attention when determining the problems facing the leather quality.

When discussing the composition of the meat yields from ostriches fed the different energy concentrations, it is clear to see there is very little difference between the meat of the birds (Table 6.7). This finding is consistent with previous work by several authors when evaluating the chemical composition of ostrich muscles (Sales & Hayes, 1996; Sales, 2002; Hoffman *et al.*, 2005; Majeswka *et al.*, 2009). Polawska *et al.* (2011) correctly point out that an important factor when considering the fat content of the meat of animals is the nutrition they were exposed to, in particular the fat content. Originally, Sales (1997) reported a high energy and low protein diet resulted in elevated fat content in the meat of the birds. However, this theory has been challenged by Hoffman

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et al. (2005) as well as the results shown in this study; where increased energy and fat levels showed no differences from the fat content in the meat from birds fed lower levels of energy/fat. Hoffman *et al.* (2005) suggested the extra energy in the diet is rather stored as fat in the abdominal fat deposits rather than within the muscles of the birds.

Interestingly in this study, there were differences in the ash (mineral) content of the muscles from birds fed the different treatment diets. The birds fed diet 3, therefore the diet that served the purpose of the control, had the highest ash content and the only treatment different from the others. Previously, this has not been reported in any research, even taking into consideration different treatment variables such as age (Sales, 2002). Therefore it is difficult to draw major conclusions from these findings, besides supporting the facts that dietary energy has no impact on the intra-muscular fat content of ostriches.

6.5 Conclusion

Definite conclusions with regards to the feather yields and their separation into separate classes were difficult to draw as a result of the fact that the feathers were immature at slaughter. Furthermore, although contradictory to previous studies in part, fluctuations of dietary energy in the feed had no effect on the crust sizes yielded as well as the skin thickness. Thorough analysis of the data and an evaluation of the proportions of skins assigned to each grading class also resulted in conclusions that dietary energy had no significant effect on the crust grades achieved.

Additionally, no differences were found with regards to the nodule quality as influenced by the energy levels in the diet. In saying that however, the grading system employed warrants further consideration and amendments to give a grade from individuals with more experience in the handling and grading of ostrich skins. The nodule densities as well as the pin-hole densities on ostrich crusts seem to be negligibly affected by the energy concentration in the diet. Therefore, more focused research should possibly be directed towards other factors that affect skin quality such as farm management practices, tanning processes and storage of the skins.

It would seem that the chemical composition of the meat from ostriches has been well established and that dietary energy has no effect with regards to the intramuscular fat content, among other components such as moisture and protein.

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Chapter 7

General Conclusions

The investigations included in this study were done to determine the effects of dietary protein, with corresponding amino acid profiles; as well as dietary energy on the production parameters of ostriches and the effects these diets had on the three primary products, the feathers, skin and meat.

Growth and the production parameters such as dry matter intake (DMI), average daily gain (ADG) and feed conversion ratio (FCR) were monitored during the production studies for protein and energy (Chapter 3 and Chapter 5, respectively). In the protein and amino acid study, it was found that protein concentrations below the middle concentration, used as a control diet, yielded decreased production performance by the ostriches as the quantity of proteins and amino acids present in their diets was simply inadequate. However, the same scenario was not found with regards to the higher concentrations of protein in the diets; even though those birds did not outperform the ones fed the middle (control) diet. Therefore, it may be concluded that increasing the protein content of the diets of slaughter ostriches does not result in increased performance. Furthermore, it seems the optimal formulations as predicted by the model by Gous and Brand (2008) for the protein requirements seem to be accurate across the four feeding phases of slaughter ostriches (pre-starter, 19.0%; starter, 15.5%; grower 14.25%; finisher, 12.6%).

The effects of the dietary protein on the primary products harvested from the ostriches used in Chapter 3, were examined in Chapter 4. Dietary protein concentrations did not have an impact on the feather yields bar the tail feathers, as was found previously by Kritzinger (2011) and Carstens (2013). Therefore, it may be concluded that feeding ostriches well balanced rations devoid of any deficiencies will results in adequate feather yields and quality. In respect of the results found for the skin parameters measured, dietary protein influenced the wet skin size as well as the crust size. Although the nodule sizes were influenced in certain areas of the crust (lower leg and butt), dietary protein had no effect on the nodule quality which was investigated for the first time. Therefore, increases in dietary protein beyond the current formulations did not yield any significant quality improvements from a feather and leather perspective. These findings assure producers that increasing the plane of nutrition will not yield similar quality returns, thus

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confirming that the optimal protein concentrations in the diets of slaughter ostriches seem to have been calculated accurately through the optimization model by Gous and Brand (2008).

The effects of dietary energy on the production parameters as described earlier were investigated in Chapter 5. A high mortality rate experienced during the pre-starter phase of the trial may have contributed to findings that were somewhat contradictory to previous studies involved in investigating the impacts of energy on production of ostriches. These mortalities are unfortunately more common than desired with regards to ostriches, in which normal mortality rates are as high as 40% (Brand & Gous, 2006). Minimal differences between the treatment groups with regards to their growth were translated into minimal differences across the production parameters measured (DMI, ADG, FCR). With regards to the abdominal fat pads, dietary energy did not have an impact on the yields.

The final research chapter incorporated the effects of the dietary energy treatments on the three primary products harvested from the birds. As a result of the feathers being immature at slaughter, conclusions were somewhat difficult to definitely draw. Nonetheless, no differences were found, as was the case for the parameters measured on the skins of the birds once in their tanned state. Nodule density as well as pin-hole density was not affected by the dietary energy content of the birds. The newly developed nodule grading system also rendered no differences when considering effects of energy. The chemical composition of the meat from ostriches has been well established and this study confirmed dietary energy had no effect with regards to the intramuscular fat content.

Therefore, the results from these studies would indicate that the optimization model used by Gous and Brand (2008) accurately predicts the optimal requirements of slaughter ostriches. Parts of the results of this thesis will be incorporated into the model for future use.

Finally, regarding recent developments in the ostrich industry where exports of fresh meat products to the European Union have resumed, producers have reason for optimism. However, the overhead cost of feeding the ostriches remains constant and susceptible to increases as a result of raw material availability, which are heavily dependent on rainfall patterns. Therefore, producers need to maintain a balance between least cost feeding of the birds, without compromising the performance of their flocks.

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Chapter 8

Future Prospective

The results obtained in this study regarding the protein concentrations in the diets of slaughter ostriches may be a telling contribution in finally understanding the optimal requirements in ostrich rations. Perhaps further research is required comparing alternative cheaper protein sources to soybean meal, which is currently commonly used within the industry. This may become necessary in the near future as the human population continues to grow at an alarming rate, calling into question the proportions of quality protein sources used in livestock nutrition.

Similarly, with respect to the dietary protein concentrations, nutrition seems to play a small role in any of the quality parameters used to assess the skins barring perhaps the size of the crust. This however is linked to the final slaughter weight of the bird more than directly as a result of the protein influence on the skin. Furthermore, the feather yields and quality were minimally affected by the protein content of the diets. However, very little is known regarding the factors affecting feather growth, besides the practice of clipping; as little research has been conducted on the feathers as a result of the relatively small proportion of income they contribute in comparison with the other two commodities. Perhaps genetics may play a role with regards to feather yields to an extent that may warrant further research.

The trials conducted to assess the influence of dietary energy content were successfully completed, but not without their complications. Mortality rates among ostrich enterprises are well documented to be higher than other livestock systems, and it is one of the main challenges seasonally presented to producers. Ostrich chicks are highly susceptible to succumb to death as a result of stressful situations, and therefore the need to minimize these during the first couple months of their existence is paramount. Excessive transport distances may have been a contributing factor, as well as the removal of the ostriches from their naturally adapted climatic environment (semi-arid) to the conditions experienced at Kromme Rhee.

Perhaps further research may be focused on alternative energy sources as highlighted for the protein sources. The reasons for this include the ethical validation of using energy sources in livestock diets that are perfectly suitable for human consumption, when considering the rate of population growth worldwide.

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Another behavioural aspect observed during both trials, was the increased aggression and difficulty in handling of the birds during hot weather in comparison to cooler conditions. Perhaps a behavioural profile as a result of weather conditions may be beneficial to producers to attempt to minimize handling during extreme warm spells if results indicate a correlation may exist. Both skin damage as well as bruising may be decreased, ultimately resulting in better returns for those products at the end of the day.

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ANNEXURE A

Table A. The vitamin and mineral premix composition used in the four feeding phases (pre-starter, starter, grower and finisher)

Ingredients (Composition per unit of premix	**Growth Stage**			
	Units	**Pre-Starter & Starter Hatching - 30 kg**	**Grower 30 – 60 kg**	**Finisher 60 – 90 kg**
Vitamin A	IU	15 000 000	12 000 000	8 000 000
Vitamin D3	IU	4 000 000	3 000 000	2 000 000
Vitamin E	mg	60 000	45 000	40 000
Vitamin K3 stab	mg	3 000	3 000	2 000
Vitamin B1	mg	5 000	3 000	2 000
Vitamin B2	mg	10 000	8 000	5 000
Vitamin B6	mg	8 000	6 000	4 000
Vitamin B12	mg	100	100	50
Niacin	mg	100 000	80 000	60 000
Pantothenic Acid	mg	15 000	12 000	12 000
Folic Acid	mg	3 000	2 000	1 500
Biotin	mg	300	200	100
Choline	mg	800 000	600 000	300 000
Magnesium	mg	50 000	50 000	50 000
Manganese	mg	120 000	120 000	100 000
Iron	mg	30 000	25 000	40 000
Zinc	mg	120 000	80 000	100 000
Copper	mg	8 000	8 000	10 000
Cobalt	mg	300	300	500
Iodine	mg	2 000	1 000	2 000
Selenium	mg	300	300	300
Antioxidant	mg	125 000	125 000	125 000
Approximate Unit Size	kg	2.5	2.5	2.5

RECOMMENDATION: Use 1 unit per ton feed as fed basis.

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ANNEXURE B

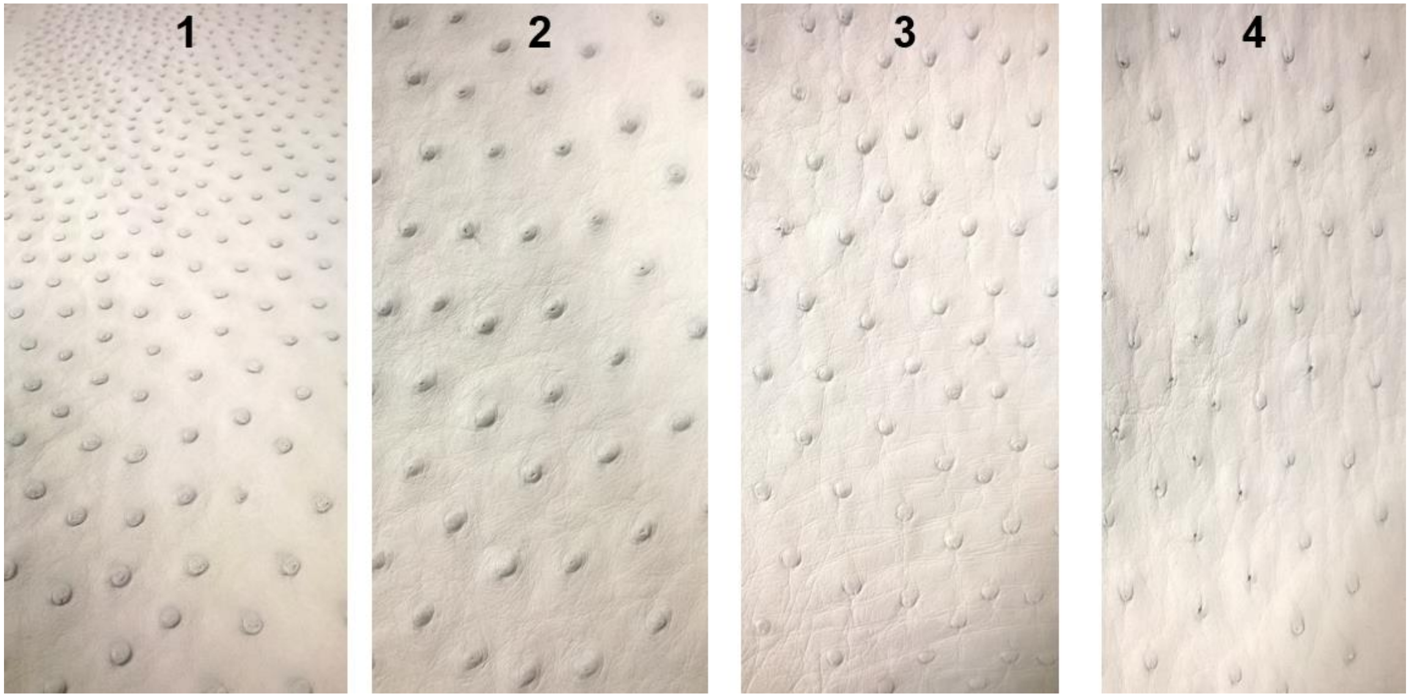

Figure A. Pictorial representation of the nodule grades [1 (best) – 4 (poorest)] assigned according to the quality of the nodules on the crusts of the skins harvested from the birds during the study