The effect of different levels of supplementary feed on the production of finisher ostriches (*Struthio camelus*) grazing irrigated lucerne (*Medicago sativa*) pastures

by

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DECLARATION

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, and that I have not previously in its entirety or in part submitted it for obtaining any other qualification.

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Abstract

The purpose of this study was to evaluate the production of slaughter ostriches in a grazing environment at different levels of supplementary feed.

Two grazing trials were conducted. In the first trial, one group of finisher ostriches (six months old) was put into a feedlot and received a complete finisher diet. The other four groups were allowed to graze lucerne pasture (stocking rate of 15 birds/ha) with 1500, 1000, 500, and 0g supplementary feed/bird/day. Pasture production and intake were measured. There was no difference ($P > 0.05$) between the end mean live weights of the feedlot ostriches and those two grazing groups receiving 1500 or 1000g supplementation. The average daily gain (ADG) of the group receiving 1000g supplementation was lower ($P < 0.05$) than the ADG of the group receiving 1500g supplementation, but all three groups reached a mean target slaughter weight of 95kg within the 154 days of the study. Therefore, pastures together with the correct supplementation (at least 1000g/bird/day) can replace complete feeds in the finishing phase of slaughter ostriches and can play an important role in the production of these birds. For lucerne intake, a quadratic relationship ($P < 0.01$) was found between pasture dry matter (DM) intake (g/bird/day) and supplementary feed intake (g/bird/day). The maximum lucerne intake level (1692.8g/bird/day) was achieved at 619.6g supplementary feed/bird/day.

In the second grazing trial, finisher ostriches were allowed to graze lucerne pastures at two different stocking rates (10 and 15 birds/ha) while receiving either 0 or 800g supplementary feed/bird/day. Ostriches receiving supplementation had higher ($P < 0.05$) mean end live weights than ostriches receiving no supplementation. Ostriches receiving supplementation reached a mean target slaughter weight of 95kg within the timespan of the trial, but ostriches receiving no supplementation did not. Stocking rate had no influence on mean end live weight of the birds. An interaction ($P < 0.05$) was found between the level of supplementation and stocking rate for ADG of the birds. Stocking rate influenced ADG only for birds receiving no supplementation. As stocking rate increased, ADG of birds receiving no supplementation declined. Results of the pasture data indicated an increasing level of replacement of grazed lucerne DM by supplementary feed as the trial progressed and this was more pronounced at the higher stocking rate of 15 birds per hectare. A high stocking rate seems to have had a gradual depressing effect on lucerne DM production, while the less severe levels of defoliation at a lower stocking rate promoted lucerne DM production.

A digestibility trial was conducted with mature ostriches (12 months old) to investigate the effect of supplementation on intake and digestibility of nutrients, as well as to investigate the substitution effect that ostriches may display when they receive supplementary feed in addition to grazing. The same dietary treatments as in the first grazing study were given to ostriches while they were kept in metabolism crates. These diets were also fed to 20-week old roosters to obtain energy values for these diets for roosters. These energy values would be used to predict ostrich energy values for the same diets by means of a regression equation.

For the roosters, each diet treatment was mixed with 50% maize to prevent digestive disorders and ensure maximum feed intake. Ostriches started to substitute supplementary feed for pasture when supplementation was supplied at levels higher than 62% (i.e. 1000g supplementary feed/bird/day) of total feed intake. For each increase of 100g in supplementary feed intake, pasture was replaced at a rate of 4.9%. Higher (P <0.05) total feed intakes were reached by ostriches if they grazed lucerne pastures and received supplementation than if they grazed pasture alone. Pasture grazing alone had lower (P <0.05) dry matter digestibility (DMD) and apparent metabolizable energy (AME) values for both ostriches and roosters than if pastures were supplied with a supplement. A significant stepwise regression could not be computed for the prediction of ostrich AME values from rooster AME values.

The economics of different feeding systems (extensive versus intensive) were evaluated with an economic analysis, which was based on the same materials and methods and results of the first grazing trial. A margin above feed cost (MAFC) analysis was performed to evaluate the economic viability of the different feeding systems. The present value (PV) of the MAFC for the pasture-based system with 1000g/bird/day supplementation was only 8.3% lower than that of the feedlot system over a period of six years, while the PV of the cost of the same pasture-based system was 78.4% lower than that of the feedlot system. Birds finished on lucerne pasture with 1000g supplementation led to a saving of 57% in feeding costs if compared to a feedlot system. A sensitivity analysis of the MAFC revealed that the pasture-based system was less sensitive to changes in feeding costs than the feedlot system. Therefore, the unique circumstances of each ostrich producer will play a role in the decision whether to raise ostriches in a feedlot or on pastures.

Opsomming

Die produksie van slagvolstruise in ‘n ekstensiewe weidingsstelsel met verskillende vlakke van aanvullende voeding is gedurende hierdie studie ge-evalueer.

Twee weidingsstudies is uitgevoer. In die eerste studie is een groep afrondingsvolstruise (ses maande oud) in ‘n voerkraal geplaas en ‘n volledige afrondingsdieet gevoer. Die ander vier groepe is op besproeide lusernweiding geplaas (teen ‘n weidigtheid van 15 voëls/ha) en het onderskeidelik 1500, 1000, 500 en 0g aanvullende voeding/voël/dag ontvang. Weidingproduksie en -inname is gemeet. Daar was geen verskil (P >0.05) tussen die eindgewigte van die voerkraal volstruise en dié van die weidende voëls wat onderskeidelik 1500 en 1000g aanvullende voeding ontvang het nie. Die gemiddelde daaglikse toename (GDT) van die groep weidende voëls wat 1000g aanvullende voeding ontvang het was laer (P <0.05) as die GDT van die groep weidende voëls wat 1500g aanvullende voeding ontvang het, maar al drie hierdie groepe het ‘n gemiddelde teiken slaggewig van 95kg bereik binne die 154 dae van die studie. Weiding, tesame met die korrekte aanvullende voeding (van ten minste 1000g/voël/dag) kan volvoer rantsoene in die afrondingsfase van slagvolstruise vervang en kan dus ‘n belangrike rol speel ten opsigte van die produksie van hierdie voëls. Vir lusern inname is ‘n kwadratiese passing (P <0.01) tussen weiding droë materiaal (DM) inname (g/voël/dag) en aanvullende voeding inname (g/voël/dag) gevind. Die maksimum lusern inname (1692.8g/voël/dag) is bereik wanneer voëls 619.6g aanvullende voeding/voël/dag ingeneem het.

In die tweede weidingsstudie, is afrondingsvolstruise (6 maande oud) toegelaat om lusern te bewei teen twee verskillende weidigthede (10 en 15 voëls/ha) en het ook 0 of 800g aanvullende voeding/voël/dag ontvang. Volstruise wat aanvullende voeding ontvang het, het hoër (P <0.05) gemiddelde eindgewigte bereik as volstruise wat geen aanvullende voeding ontvang het nie. Volstruise wat aanvullende voeding ontvang het, het ook die teiken slaggewig van 95kg bereik binne die tydsduur van die studie, terwyl die volstruise wat geen aanvullende voeding ontvang het nie, nie daarin kon slag nie. Weidigtheid het nie ‘n invloed (P >0.05) gehad op die eindgewigte van die voëls nie, maar ‘n interaksie (P <0.05) is gevind tussen vlak van aanvullende voeding en weidigtheid wat GDT van die voëls betref. Weidigtheid het GDT beïnvloed slegs vir volstruise wat geen aanvullende voeding ontvang het nie. Soos die weidigtheid van die voëls wat geen aanvullende voeding ontvang het nie, toegeneem het, het die GDT van hierdie voëls afgeneem. Ontleding van die weidingsdata het ‘n toenemende vlak van verplasing van die weiding met aanvullende voeding getoon soos die studie gevorder het en dit was meer merkbaar by die hoër weidigtheid. Die hoër weidighteid het ook gelei tot ‘n geleidelike afname in lusern DM produksie, terwyl die minder aggressiewe vlakke van ontblaring by die laer weidigtheid lusern DM produksie bevorder het.

‘n Verteringsstudie is gedoen met volwasse volstruise (12 maande oud) om die invloed van aanvullende voeding op inname en verteerbaarheid van nutriente te toets, asook om die substitusie effek wat volstruise mag toon

wanneer hulle aanvullende voeding ontvang op weiding, te ondersoek. Dieselfde dieet behandelings as in die eerste weidingsstudie is vir die volstruise gegee terwyl hulle in metabolisme kratte aangehou is. Hierdie diëte is ook aan 20-week oue hane gevoer om die energie waardes van die diete vir hane te verkry. Hierdie energiewaardes sal dan gebruik word om volstruis energiewaardes te voorspel vir dieselfde diëte met behulp van 'n regressie vergelyking. Vir die hane is elke dieet gemeng met 50% mielies om inname te handhaaf en spysverteringsstoornisse te voorkom. Volstruise het weiding begin verplaas met aanvullende voeding sodra die vlak van aanvullende voeding hoër as 62% (d.i. meer as 1000g aanvullende voeding/voël/dag) van die totale inname van die voëls was. Vir elke 100g toename in aanvullende voeding, word weiding verplaas teen 'n tempo van 4.9%. Weiding, tesame met aanvullende voeding, het gelei tot hoër totale droë material (DM) voerinnames by volstruise as wanneer weiding alleen beskikbaar was. Wanneer weiding alleen voorsien was, was daar laer ($P < 0.05$) verteerbaarhede van DM en waarskynlike metaboliseerbare energie (WME) waardes vir beide volstruise en hane as wanneer die weiding voorsien word met aanvullende voeding. Geen betekenisvolle stapsgewyse regressie kon gevind word om volstruis energie waardes uit hoender energie waardes te voorspel nie.

Die ekonomie van verskillende sisteme (ekstensief versus intensief) is in hierdie studie vergelyk en is gebaseer op dieselfde materiaal en metodes en resultate van die eerste weidingsstudie. 'n Marge bo voerkoste analise is gebruik om die ekonomiese lewensvatbaarheid van die sisteme met mekaar te vergelyk. Die huidige waarde van die marge bo voerkoste van die weidingssisteem waar 1000g aanvullende voeding gevoer word was 8.3% laer as dié van die voerkraal sisteem oor 'n periode van ses jaar. Daarteenoor was die huidige waarde van die koste van dieselfde weidingssisteem 78.4% laer as dié van die voerkraal sisteem. Die weidingssisteem waar volstruise 1000g aanvullende voeding ontvang het, het 'n besparing van 57% in voerkoste getoon wanneer dit met die voerkraal volstruise vergelyk is. 'n Sensitiwiteitsanalise van die marge bo voerkoste het getoon dat die weidingssisteem minder sensitief is vir wisselende voerkoste as die voerkraal sisteem. Die unieke omstandighede van elke produsent sal 'n rol speel in sy keuse om volstruise op weiding of in 'n voerkraal af te rond.

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Table of Content

Chapter 4

The effect of supplementation to irrigated lucerne pastures on the production of finishing ostriches, their pasture intake and pasture production

Chapter 5

A study of the substitution effect of fresh lucerne by concentrates in the diets of ostriches as well as the digestibility values of these selected diets for ostriches and roosters

Chapter 6

The effect of supplementation to irrigated lucerne pastures and stocking rate on the production of finishing ostriches, their pasture dry matter intake and the dry metter production of the lucerne pasture

Chapter 7

The economics of supplying different levels of supplementary feed for finishing off ostriches on irrigated lucerne pastures

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List of Figures

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Annexure 1

List of Tables

Chapter 3

Chapter 4

Chapter 5

Chapter 6

Chapter 7

Annexure 1

List of Annexures

Chapter 1

General Introduction

Ostriches are important animals of the livestock industry due to its production of healthy red meat, valuable skin and feathers (Cooper & Horbanczuk, 2004). The objective of a modern ostrich farm is to convert feed into skin, meat and feather products through an effective production system (Champion & Weatherley, 2000).

The ostrich, as a mono-gastric animal, has the outstanding ability to utilize high fibre diets. The production of volatile fatty acids and the absorption of these fatty acids from the digestion of fibre in the hind-gut of the ostrich (Swart, 1988), may be used to optimize the use of pastures as feedstuffs for ostriches, especially mature birds (Brand, 2003).

Feed costs are by far the largest cost element in an intensive ostrich production system (Adams & Revell, 2003). In South Africa alone, approximately 250 000 tons of ostrich feed is used annually at a cost of about R494 million. If the industry could save only 10% in feed costs, it would result in a total saving of about R49.4 million per year for the local industry (Brand & Gous, 2003). This may have a major impact on the profitability of a commercial ostrich production unit (Farrell *et al.*, 2000). The ostrich industry therefore, has to focus on maximizing growth and reducing costs associated with feeding to gain competitiveness in the animal agriculture arena (Adams & Revell, 2003).

Typically, management systems for the production of ostriches rely on significant inputs of commercially formulated complete feeds/pellets. The expanded use of pastures as a low-cost feed source may have the potential to play an important role in the future development of the ostrich industry (Champion & Weatherley, 2000) and on the long-term sustainability of the industry (Brand & Gous, 2006). A farmer growing his own food and buying a supplement to complement his pastures can normally produce good slaughter birds with lower feeding costs than farmers making use of complete feeds in feedlot systems. However, the gross margins per hectare for meat production are highly dependent on the feed conversion rates and carcass quality achieved (Adams & Revell, 2003). The quantification of the nutritional requirements of ostriches and the determination of the nutritive value and optimum inclusion levels of various ingredients are also very important for optimizing feeding standards in an attempt to reduce input costs for the ostrich industry (Brand *et al.*, 2003).

Currently there is limited information available with respect to the nutritional management of ostriches produced under systems where grazing is predominant (Champion & Weatherley, 2000). Most information relies on experiments where birds have been produced in an intensive management system where prepared diets are fed. Practical experience of the production of ostriches on different types of pastures and/or grazing systems is limited (Brand & Gous, 2003). Knowledge of the accompanying level of the substitution of supplementary feed for pasture is non-existent (Brand, 2003). Adams & Revell stated in 2003 that research is needed in the field of nutrition, especially in grazing management. Sales (2006) also stated that knowledge about the value of grazing in production systems of ostriches, emus and rheas, is totally absent. According to Cilliers & Angel (1999) the development of cost-effective feeding methods in different areas of the world must be a primary focus of research, if the ostrich industry is to survive in the long term.

The objective of this study, therefore, was firstly to look at the production of slaughter ostriches during the finisher stage on irrigated lucerne pastures with different amounts of supplementary feed supplied. This supplementary feed was formulated to complement the nutrients available from the lucerne pastures so that the ostriches were receiving a balanced diet while grazing. Secondly, animal production on pastures is not only influenced by the level of supplementary feed, but also by plant production and the stand longevity of the pasture itself. The effect of the supplementation of grazing ostriches on the yield of the pasture was therefore also investigated. Animal production on pastures also depends on the stocking rate of the animals, and the yield of lucerne under two different stocking rates of ostriches receiving two different levels of supplementary feed also had to be investigated. The substitution of pasture with the supplementary feed by the ostriches was also investigated in a metabolism study with finisher ostriches. Roosters were also subjected to the same metabolism study in order to predict ostrich energy values of diets by using rooster energy values of the same diets. Finally, a detailed economic analysis was undertaken to determine the optimum supplementary feeding strategy for finisher ostriches grazing irrigated lucerne pasture.

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Chapter 2

Background Information

2.1 The role of ostrich farming in South Africa

The ostrich industry is predominantly a South African industry (Brand *et al.*, 2004), which is found mainly in the Western and Southern Cape, where 80% of all South African ostrich products are produced, primarily for the export market (Brand *et al.*, 2003a). In South Africa, ostrich farming is concentrated in the Western Cape mainly in the following areas: the Little Karoo (65% of the flocks); Southern Cape (25% of the flocks); and the Swartland. The Eastern Cape and Northern Provinces are home to approximately 10% of the flocks, with the Eastern Cape by far the more important area of the two. There are approximately 650 ostrich producers in South Africa (Van Zyl, 2001) of which 588 are registered export farms (NAMC, 2003). South Africa is the world leader in terms of ostrich production and products, with 80% market share. Ninety percent of the ostrich meat produced in South Africa is exported to the EU-countries and 5% to the Far East. According to Kruger (2010, A. Kruger, Pers. Comm., South African Ostrich Business Chamber, P.O. Box 952, Oudtshoorn, 6620), the total meat exports from South Africa amount to 4 400 tons, while 70% of ostrich leather is exported. In the developing world, ostrich production is a valuable source of foreign currency netted from the export of meat and skins (Cooper *et al.*, 2004) and it is estimated that over 90% of the ostrich meat produced in South Africa is exported (Hoffman, 2005).

The turnover of the feed manufacturing companies that supply feed to the ostrich industry is approximately R550 million per year. For every R1 million increase in the primary ostrich industry, 67 employment opportunities are generated. For every R1 million increase in the meat processing industry, a further 21 employment opportunities are created. Also, a R1 million increase in the feed manufacturing industry, will create an additional 42 employment opportunities. The ostrich industry is, however, detrimentally affected by a lack of scientific knowledge of the feeding requirements of ostriches, the true nutritional value of raw materials, and the lack of reliable feeding and management systems for ostriches. Changes in feed quality can also lead to changes in the quality of the end products and this can lead to lower market prices. As feeding costs make up 70 – 80% of the total costs involved in the intensive production of ostriches, an increase in reliable scientific information and management systems will increase the profitability of the ostrich industry (Brand *et al.*, 2004).

2.2 The products of ostrich farming

The ostrich has been regarded as a single-product animal at various times in the past. The focus of market interest has passed through several phases, from feathers to hides and most recently to meat. It is only recently that the multi-product nature of the ostrich has begun to become an economic necessity (Adams & Revell, 2003).

Originally ostriches were domesticated for the harvesting of their feathers, but today ostriches are produced to provide low-cholesterol meat (which makes up 50% of the current commercial income), durable high-quality hides (45% of the current commercial income) and feathers for the fashion market (5% of the current commercial income). A mature ostrich of 14 months can produce 1.4 – 1.8kg of feathers, yield 34 – 41kg of low fat red meat and 108 – 126dm^2 of leather (Cooper, 2000). Apart from these markets, curios and agri-tourism services also play a role in the ostrich industry (South African Ostrich Business Chamber, 2002).

The processed products of ostrich farming that earn the largest returns are meat and skin. If the ostrich industry is compared to the beef industry, the ostrich industry may produce higher and faster financial returns. A cow, for example, produces a calf that will reach market weight 645 days after conception and will yield 250kg of meat. An ostrich breeding pair, however, can produce up to 40 chicks annually. These chicks may reach market age only 407 days after conception and may yield 1800kg of meat, 50m^2 of leather and 36kg of feathers (Cooper, 2000). According to Brand (2010, T.S. Brand, Pers. Comm., Elsenburg Animal Production Institute, Department of Agriculture: Western Cape, Private Bag X1, Elsenburg, 7607), current average production rates in South Africa are about 25 chicks per bird per year, while feed costs for ostriches are also substantially higher than for cattle.

Meat:

Ostrich meat has become an increasingly important product over the last 10 – 15 years due to the worldwide shift in consumer demand for healthier food, as well as the outbreak of cattle diseases like BSE and foot-and-mouth disease in Europe in 2000 (Van Zyl, 2001). In 1977 the export of ostrich meat from South Africa was initiated through ostrich fillets being exported to Switzerland and since then the market for ostrich meat has grown steadily (Lambrechts & Swart, 1998).

In comparison with other meat types, ostrich meat is a product of superior quality in certain respects. Apart from their good nutritional value, ostrich meat also has good qualities for cooking, blending and processing (Lambrechts & Swart, 1998).

The benefits of meat from ostriches have been promoted on the basis of its lower fat content. The excessive consumption of animal fat in red meat like beef and lamb is not conducive to good health. Ostrich meat is a promising substitute for traditional red meat animals in that it produces a fine-grained red meat with similar protein and iron levels to beef, but unlike beef and lamb, fat deposits on the bird are restricted to sub-peritoneal and subcutaneous layers. There is no visible intramuscular fat and therefore it is very easy to separate the fat during processing to produce a very lean red meat (Adams & Revell, 2003). At about 0.5%, the fat content of raw ostrich meat is less than half of that of raw chicken breast (Sales & Horbanczuk, 1998).
Ostrich meat is also higher in poly-unsaturated fatty acids (PUFA) than either beef or chicken (Sales, 1999). The ratio of saturated fatty acids to mono-unsaturated fatty acids to poly-unsaturated fatty acids in ostrich meat is 1:1:1. This makes ostrich meat outstanding in terms of health characteristics (Smith *et al.*, 1995). The risk of

coronary heart disease in humans can be reduced by reducing saturated fatty acid intake and increasing PUFA intake and this fact increases the potential for ostrich meat being a suitable alternative to other red meats (Glatz & Miao, 2006).

The protein content of ostrich meat is 21% and this also compares favorably with the meat of other animal species (Smith *et al.*, 1995). Because ostrich meat has low sodium contents, it has a distinct advantage for people with cardio-vascular problems who have to maintain a low-sodium diet (Sales, 1999).

All the qualities and characteristics of ostrich meat make it an excellent choice for health-conscious consumers who need to reduce the total fat and cholesterol content of their daily diet (Lambrechts & Swart, 1998).

Hides:

The hide of the ostrich is distinctive due to the fact that it has a diamond-shaped “crown” that extends along the back and down the wing fold and stomach. It contains the highly valued quill socket (bud) pattern (Adams & Revell, 2003). These buds are larger in older birds (Sales, 1999).

In South Africa, if ostriches are fed and managed well, they will be slaughtered at 12 – 14 months of age in order to achieve a well developed skin with a minimum size of $120dm^2$. The industry standards for quality ostrich leather is that, apart from a minimum size and minimum lesion and damage specifications, the follicles must be well developed and rounded (Smith *et al.*, 1995). According to Brand (2010), (T.S. Brand, Pers. Comm., Elsenburg Animal Production Institute, Department of Agriculture: Western Cape, Private Bag X1, Elsenburg, 7607), achieving slaughter weight at a younger age through improved nutrition will, however, adversely affect hide quality, which will always be dependent on market requirements. The ideal shape of the follicles cannot be achieved before the age of 14 months, but the optimal size of the follicles can be reached at about 10 months of age (Mellet, 1995).

The crown is normally used in the fashion and upholstery industries and luxury shoes, handbags and purses, which are popular in Europe, the USA, and Japan (NAMC, 2003). The thinner hides of younger ostriches may be used for garments (Holtzhausen & Kotzé, 1990 as cited by Sales, 1999).

Feathers:

A lot of attention was focused on ostriches during the 1900’s. This was due to their feathers, which were high fashion amongst the wealthy (Smith *et al.*, 1995). The market for feathers resulted in the domestication of the ostrich and the development of an ostrich farming industry in South Africa (Sales, 1999). In 1914 the world market for ostrich feathers collapsed completely due to the depression, but in 1946 the world economy revived and there was a renewed interest in the ostrich feather trade. Ostrich numbers steadily increased and in 1983 the South African ostrich industry produced 51 500 hides, 117 tons of feathers and 1500 tons of meat. In that year, of total income, 58% was from hides, 25.9% was from feathers and 16.1% was from meat. During 1993, 76% of the total income was from hides, 7.5% was from feathers and 16.5% was from meat (Smith *et al.*, 1995). Producers do not believe feather processing *per se* is a viable option. This is due to several factors. Feathers have to be graded after plucking into many different categories to meet the requirements of the feather market (Adams & Revell, 2003). Traditionally, feathers of ostrich chicks must also be selectively clipped at the age of 5 – 6 months. This will promote uniform new feather growth for harvesting at 12 to 14 months of age. This will also lead to maturation of the feather follicles for optimal leather quality (Verwoerd *et al.*, 1999).

An adult ostrich can yield 1 – 1.2kg of short feathers and 400 – 450g of white plumes (Holtzhausen & Kotzé, 1990 as cited by Sales, 1999). A slaughter bird can produce about 700g of body feathers (Swart & Kemm, 1985). Fashion items such as fans, fringes, feather boas or hats can be manufactured from the best tail and wing feathers. Ostrich feathers are readily charged with static electricity when stroked, and therefore they are extremely suitable as dusters for domestic use, and in the motor and computer industries (Sales, 1999). Ostrich feathers are also used in the carnival trade (Adams & Revell, 2003).

Value-added products:

The proportional value of the meat relative to that of the whole bird has increased over the last few years and the proportional value of the skin has decreased. The effect of the ostrich avian influenza outbreak on this relationship has not been calculated yet. The immediate impact was that the proportional value of the meat decreased as no fresh meat was permitted to be exported, while South African consumers were not able to afford high export prices. This has, however, forced the South African industry to start producing value-added products commercially (Hoffman, 2005).

The first and easiest value-adding that can be performed is ground ostrich meat (mince). Italian type salami was one of the first value-added products to be made from ostriches. Ostrich sausages and low fat ostrich meat patties also began to be manufactured and sold in South Africa. Chopped hams, viennas and smoked ostrich meat (Lambrechts & Swart, 1998) are also produced from ostriches and they have been found to be highly acceptable. The manufacture of two kinds of ostrich liver patés is a viable option, with the two products having good general quality attributes and acceptable sensory scores (Fernandez-Lopez *et al.*, 2004 as cited by Hoffman, 2005).

Apart from all these products, ostrich carcasses are also used to manufacture a few by-products. The stomach can be consumed and is regarded as a delicacy in some Eastern cultures. Culled breeding ostriches that weigh between 130 – 160kg can yield about 25kg of fatty tissue, which can be used to supplement human and animal diets (Horbanczuk *et al.*, 2003 as cited by Hoffman, 2005). According to Brand (2010, T.S. Brand, Pers. Comm., Elsenburg Animal Production Institute, Department of Agriculture: Western Cape, Private Bag X1, Elsenburg, 7607), this fat is currently mainly used in the petfood industry. The fat can also be rendered to produce ostrich oil, which is claimed to have therapeutic value in the treatment of skin complaints (Adams & Revell, 2003).

According to Brand (2010, T.S. Brand, Pers. Comm., Elsenburg Animal Production Institute, Department of Agriculture: Western Cape, Private Bag X1, Elsenburg, 7607), ostrich carcasses and other by-products from the meat industry are also used in the petfood industry. Those ostrich eggs which are unacceptable for hatching can be used for human consumption. The fat content of ostrich eggs is slightly lower than that of the domestic chicken egg and the total proportion of essential amino acids is also higher than that of the chicken. The cholesterol content and the levels of saturated fatty acids are, however, higher in ostrich eggs than in the eggs of other fowls (Sales, 1999).

Extremely attractive ornaments such as lamp-holders and jewellery boxes are produced from intricately carved and decorated ostrich egg shells (Adams & Revell, 2003).

2.3 The economics of the production of slaughter birds

Since up to 75 – 80% of the total costs of an intensive ostrich production system can currently be attributed to nutrition, any lowering of feed costs will have a major impact on the profitability of a commercial ostrich production system. The use of properly formulated and balanced least-cost diets, the utilization of locally available raw materials and pastures and the use of feed additives, are only some of the ways in which feeding costs can be reduced. Other methods of cost savings include mixing, milling and pelleting own rations on-farm, as well as improving the feed conversion ratios of the birds (Brand & Jordaan, 2004).

In a study by Cilliers (2005), feed cost between a complete feed in a feedlot system and a pasture-based system with a suitable supplement, was compared with each other. For birds aged 4 – 10 months, feed cost on the pasture-based system amounted to R363 and the feed cost of the same aged birds on a complete feed in a feedlot system was R435. This means a saving in feed cost of about 17%. For birds aged 4 – 12 months, feed cost on the pasture-based system amounted to R443 and the feed cost of the same aged birds on a complete feed in a feedlot was R607. A saving of 27% in feed cost was accomplished with this trial. For birds aged 4 – 14 months, feed cost on the pasture-based system was R513 and the feed cost of the same aged birds on a complete feed in a feedlot was R780, which implies a saving of 34% in feeding costs. It was therefore concluded with this study that a saving of 17 – 34% could be achieved by producers raising slaughter birds on pasture with a suitable supplement. Champion & Weatherley (2000) also found that by using a pasture-based system together with a correctly formulated supplement, feed costs can be reduced by 10% of the feed costs of an intensive system.

Improving the feed conversion ratio (FCR) of the birds will ultimately also improve the margin above feed cost for both an average production system (where the FCR of the birds is 8kg feed/kg weight gain) and an above-average production system (where the FCR is 25% better). This effect of improving FCR of the birds and its effect on the resultant margin above feed cost was studied by Brand & Jordaan (2004), in which they compared margins above feed costs of the average and above-average production systems. The combined income (leather, feathers and meat) from a slaughter bird (90kg) in March 2004 was R11.39/kg. The average feed cost was R775.74 per slaughter bird (based on an FCR of 8:1 and an average feed price between 0 – 51 weeks of age of R1,436.55/tonne), leading to a margin above feed cost of R249.89/slaughter bird for the average producer. For the more efficient producer (25% better FCR), feeding cost decreased to R581.77, leading to an increased margin above feed cost of R443.87. A sensitivity analysis done on these findings revealed that for a decrease of 10% in product prices and a 10% increase in feed prices, the margin above feed cost for the average producer decreased with 72% to R69.76, while for the above-average producer the negative effect will be less severe, resulting in a 36% decrease in the margin above feed cost to R283.11.

These studies emphasize the importance of efficiency in an ostrich production system as a means to absorb rising feed prices or decreased product prices (Brand & Jordaan, 2004).

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Chapter 3

Literature Review

For us to understand the nutritional needs of any species of animal, it is important to first understand the natural diet of the animal, as well as the physical and functional properties of its gastro-intestinal tract (Cilliers & Angel, 1999).

3.1 Feeding behaviour of ostriches

Ostriches are highly selective in their eating habits and free-ranging desert ostriches are able to select a diet surprisingly high in nutritive value considering the environment (Williams *et al.*, 1993). In their natural habitat, ostriches are adaptable grazers and browsers (Nitzan *et al.*, 2002). They prefer open plains offering short herbage and pasture species for foraging (Champion & Weatherley, 2000).

Ostriches will consume a wide variety of vegetation and will vary their diet according to the plant life available in the habitat (Deeming & Bubier, 1999). The natural diet of ostriches is mainly green annual grasses, new leaves and shoots from shrubs and trees, forbs, berries, seeds, succulent plants and small insects (Nitzan *et al.*, 2002). When these are not available, ostriches will feed on leaves, flowers and fruits from succulents and woody plants. Dead or woody material and animal matter (other than bones) will not be eaten by ostriches (Cilliers & Angel, 1999).

Ostriches tend to select for fibre and against phenolics in forbs. They will select plants containing 70% water, 35.2% crude fibre, 11.2% crude protein (CP), 16% ash, 4.2% lipids and those with a metabolizable energy (ME) value of 8.87 MJ/kg on a dry matter (DM) basis (Cilliers & Angel, 1999). Williams *et al.* (1993) also studied the feeding behaviour of ostriches in the Namibian desert and found that they also selected plants containing 35.2% crude fibre, 11.2% CP and 4.2% lipids. It is clear from these two studies that ostriches select a diet with an excess of 24% crude fibre and containing less than 12% CP. When ostriches are confined and stocked at high densities, they can be destructive to pasture or natural veld because of their high mobility and their selectivity (Milton *et al.*, 1994).

If ostriches are farmed, they will prefer lucerne or natural pasture over barley and Bermuda grass. This indicates that forbs are more suitable to serve as pasture for ostriches than grasses (Nitzan *et al.*, 2002). Like horses, ostriches will spend 70 to 80% of daylight hours feeding in the wild with continuous ingestion and movement being important in their digestive physiology. This long period of time spent foraging is probably because they need 5 – 6kg fresh material mass daily for maintenance (containing 70% water) when feeding on natural forage (Milton *et al.*, 1994). As it is important for ostriches to have a continuous intake of food, feed should be made continuously available to them (*ad libitum*), rather than fed as meals (Aganga *et al.*, 2003).

3.2 Anatomy & function of the gastro-intestinal tract of the ostrich

Ostriches, like pigs, poultry and horses are mono-gastric, herbivorous animals, which prefer to eat plants (Brand, 2003). Figure 3.1 shows the anatomy of the digestive system of the ostrich.

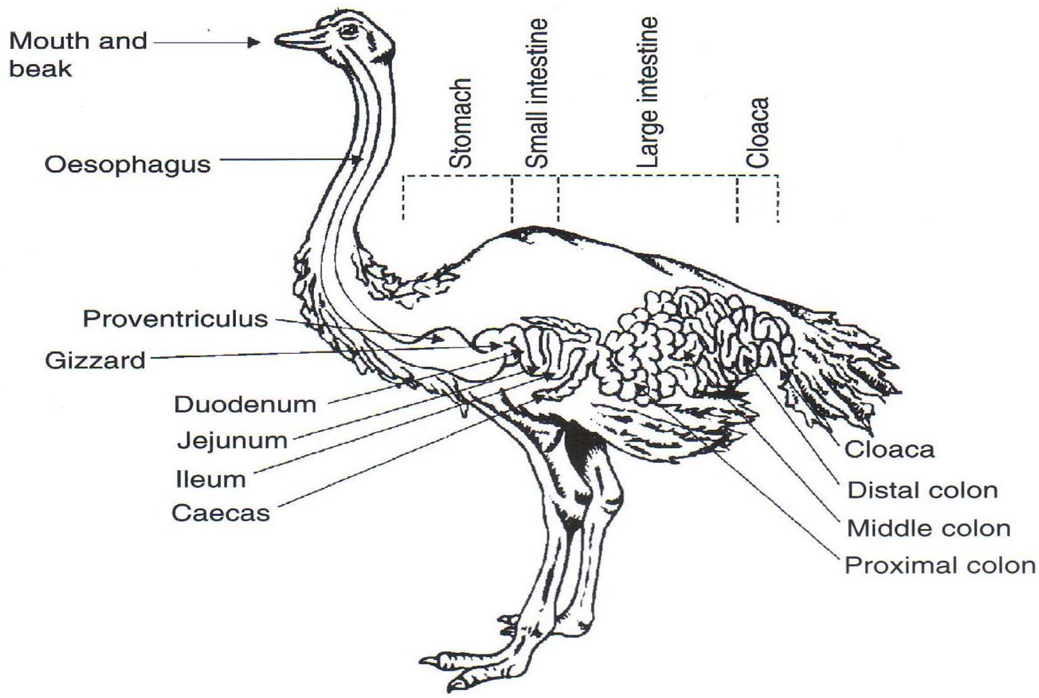

Figure 3.1 The anatomy of the digestive system of the ostrich (Brand & Gous, 2006).

The ostrich is a bird and therefore producers have always relied on poultry nutritionists to recommend appropriate ration formulations. It is now recognized that the ostrich cannot be classified as poultry, and that it utilizes nutrients very differently from poultry (Adams & Revell, 2003). This is due to the fact that the gastro-intestinal tract of the ostrich differs considerably from that of most non-ruminant animals or poultry (Cooper & Mahroze, 2004).

The digestive tracts of birds differ from that of mammals in many respects. Birds have no teeth, which are replaced functionally by a muscular stomach where mechanical food reduction takes place. The digestive tract of birds is shorter than that of mammals and it also shows less differentiation between the different parts of the intestinal tract (Gussekloo, 2006).

The digestive tract of the ostrich consists of a beak and mouth, oesophagus, proventriculus (glandular stomach), ventriculus (gizzard), small intestine, large intestine and a cloaca (Gussekloo, 2006).

The beak of the ostrich is relatively large and its function is to tear off plant material and to pick up food. Like other ratites, the ostrich has no crop in which to store ingested food (Scheideler & Sell, 1997). This means that ostriches need to consume their feed over an extended period each day, and in small quantities at a time (Van Niekerk, 1995). They do, however, have a relatively large true stomach and gizzard. These two organs have considerable food storage capacity (Scheideler & Sell, 1997). The oesophagus is also wide in its cranial part and can serve as a storage area for food (Glatz & Miao, 2006).

The proventriculus (glandular stomach) is a large thin-walled glandular stomach where bulky food and water are stored, softened and mixed with digestive enzymes (Sales, 2006). The digestive process will start here with the secretion of gastric acid (hydrochloric acid) and certain enzymes like pepsin, which breaks down protein (Gussekloo, 2006). In contrast to other birds, in which the entire surface of the proventriculus secretes digestive enzymes, enzyme and acid secretion in the proventriculus of the ostrich is restricted to an area of only 25% of the total inner surface of this organ (Cooper & Mahroze, 2004). This fact indicates that enzyme activities are low for ostriches at young ages (Glatz & Miao, 2006). Iji *et al.* (2003) found no trypsin activity in newly hatched ostrich chicks, but trypsin was active from 27 days of age. Amylase activity is also low and relatively unchanged from hatching to 27 days of age. The proventriculus will reduce the feed into more digestible fractions. This process is rapid and therefore minimal digestion occurs here (Champion & Weatherley, 2000). Volatile fatty acids are produced in the proventriculus and gizzard and this suggests that microbial fermentation occurs in these organs (Van Niekerk, 1995).

The gizzard of the ostrich has thick muscular walls and a horny interior epithelium. The function of the gizzard is to grind the ingested plant material mechanically to a finer form or paste before it is passed to the small intestine. This is done by means of the contractions of the gizzard wall, and with the help of ingested stones and pebbles. This process will expose a larger surface area for enzymic working. Digestion in the gizzard and proventriculus are also helped by a strong acid environment of about pH 2.2 (Brand & Gous, 2006). This strong acid environment assists with the enzymic digestion of the hemicellulose backbone of plant material, and this process can be compared to the increased surface area caused by rumination in ruminants (Swart *et al.*, 1993a).

The small intestine of the ostrich is relatively short and straight (Cooper & Mahroze, 2004). The small intestine consists of the duodenum, jejunum and ileum (Gussekloo, 2006). The length of the duodenum is 0.8m, whereas the jejunum and ileum are 1.6m and 4m respectively (Bezuidenhout, 1986). The duodenum forms a loop, which encloses the pancreas. The pancreas and liver both have ducts that end in the duodenum. The pancreas secretes the majority of digestive enzymes through this duct into the small intestine, while the liver secretes bile into the small intestine (Gussekloo, 2006). Some of the enzymes secreted in the small intestine include trypsin, chymotrypsinogen, lipase and amylase (Champion & Weatherley, 2000). There is a rapid increase in pH from around two to three in the proventriculus and gizzard to between seven and eight in the small intestine (Sales, 2006). Partially digested food from the gizzard and proventriculus will be digested in the alkaline environment of the small intestine and the absorption of digested nutrients will start here (Brand & Gous, 2006). The small intestine is the site where the majority of amino acids, fats, soluble carbohydrates, fat-soluble vitamins and minerals are absorbed (Champion & Weatherley, 2000). The villi of the small intestine are long and branched profusely to facilitate the absorption of nutrients (Cooper & Mahroze, 2004).

The ability of ostriches to utilize fibrous material is due to the exceptional anatomy and function of its large intestine. Compared to the small intestine, the large intestine of the ostrich is long and large to enable the digestion of bulky food and to facilitate fluid absorption. The large intestine is three times as long as the small intestine (Cooper & Mahroze, 2004) and consists of the two paired caeca and the colon (Brand & Gous, 2006). Each caecum is 0.95m in length and the colon is 16m in length. As proportions of the entire length of the gastro-intestinal tract, the duodenum makes up 3.3%, the jejunum 6.6%, the ileum 16.5%, the caeca 7.4% and the rectum 66% (Bezuidenhout, 1986). The twin caeca and colon make up about two-thirds of the length of the digestive tract of the ostrich and this allows extensive digestion of dietary fibre, as well as the synthesis of significant amounts of microbial protein and B vitamins (Glatz & Miao, 2006).

The ability of ostriches to digest fibre distinguishes them from other mono-gastric herbivores (Brand *et al.*, 2000). The capacity of the digestive tract of three common farm animals (chicken, pig & ostrich) is shown in Figure 3.2.

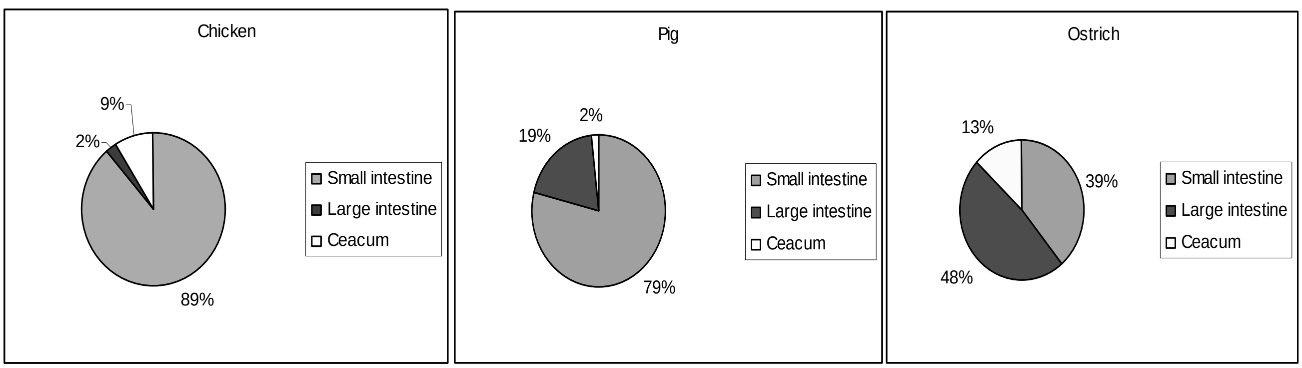

Figure 3.2 Comparative lengths of the small intestine, large intestine, and caecum of the chicken, pig, and ostrich (Swart, 1988).

From this figure, it can be demonstrated that the lower digestive tract of an ostrich is much larger than that of poultry or pigs in relation to the total digestive tract. The ability of an animal to digest fibrous material is directly related to this larger lower digestive tract. The colon plus the caeca of poultry, pigs and ostriches constitute about 11%, 21% and 61% respectively of the total digestive tract of the different species (Swart, 1988). This trend was further confirmed in a study done by Swart *et al.*, (1993b) in which it was found that the total length of the ostrich colon accounts for 52% of the entire length of the intestinal tract. In comparison with this, the small intestine, caeca, and rectum of the adult domestic chicken comprise 90%, 7% and 3% respectively of the total intestinal tract (Cilliers & Angel, 1999 *cite* Calhoun, 1954). Swart *et al.* (1993b) found that the digesta content of the small intestine represented only 11% of the total wet digesta contents of the entire intestinal tract, while the hind-gut (colon and caeca) contained 58%.

3.3 The ability of ostriches to utilize fibrous material

Ostriches lack the enzyme cellulase to digest plant fibre components. Therefore the ostrich has to rely on plant fibre fermentation, which occurs in the colon and caeca of the animal. The caeca and colon are huge fermentation chambers inhabited by large populations of bacteria that can digest hemicellulose and cellulose material (Swart *et al.*, 1993b). The caeca and colon of the ostrich have a pH of 6.9 – 7.3 and this provides a suitable environment for micro-organisms to ferment dietary fibre (Champion & Weatherley, 2000). In the alkaline environment of the colon the micro-organisms will break down the insoluble fraction of carbohydrates into short-chain fatty acids (Swart *et al.*, 1993a), ammonia, carbon dioxide and methane (Józefiak *et al.*, 2004). The volatile fatty acids produced by microbial fermentation are utilized for metabolism in addition to glucose (Nheta *et al.*, 2005). These volatile fatty acids can be absorbed and metabolized by the ostrich as an energy source (Aganga *et al.*, 2003). In a study done by Swart *et al.* in 1993b, it was shown that the energy contribution of volatile fatty acids can be as high as 76% of the ME requirements of the growing ostrich. The ostrich is also endowed with a high capacity mechanism to transport the products of fermentative digestion of plant fibre into the systemic circulation (Musara *et al.*, 2003). This, together with the gross anatomical adaptations of the hind-gut, means that the ostrich can utilize fibre efficiently (Sales, 2006). Several behavioural studies have found that wild ostriches select a diet that contains up to 24% crude fibre and that ostriches can digest up to 60% of the plant cell wall material in their diet (Scheideler & Sell, 1997).

This anatomical adaptation of the ostrich plays a similar role to the rumen in ruminant animals (Champion & Weatherley, 2000). Ruminant animals like sheep and cattle have a pre-gastric adaptation, called the rumen, which allows microbes to colonize and digest fibre within the gastro-intestinal tract. Apart from an area in the gastro-intestinal tract where microbes can colonize and reproduce without being swept away by the passage of digesta, fibre fermentation also requires a slow rate of passage of the digesta through the gastro-intestinal tract. The passage rate of digesta in the rumen is very slow (38 – 50 hours), allowing maximum fermentation (Cilliers & Angel, 1999).

A study was done by Brand *et al.*, (2000) involving ostriches, pigs and chickens. Nine diets with various crude fibre levels were fed to these three animal species and the ME contents of the diets were determined. The *in vitro* digestible organic matter content of the diets was also determined and the values were converted to ruminant ME values for comparison. This study showed that ostriches have significantly higher ME values than both pigs and ruminants for all three types of diets (low fibre, medium fibre, and high fibre). Ostriches will utilize about 25% more energy than pigs on the same feeds. They will also have a 30% higher ME value for high-fibre feeds compared to other poultry. With the low fibre diet (high concentrate diet) there was no difference between the ME values for ostriches and poultry, but the ME values for ostriches were higher than for poultry for both the medium and high fibre diets. In a study done by Cilliers *et al.* in 1994, it was also found that ostriches are capable of digesting a high starch diet to the same extent as adult roosters, but ostriches are capable of digesting a high fibre ingredient such as lucerne-meal much more efficiently than roosters. These studies confirmed that ostriches have the exceptional ability to utilize lower quality raw materials better than is the case with pigs and chickens (Brand *et al.*, 2000). In terms of nutritional requirements, the ostrich has more in common with ruminant animals than with poultry (Adams & Revell, 2003). In a study done by Salih *et al.* (1998a) it was found that the amount of cellulolytic bacteria found in the large intestine of ostriches was twofold lower than the amounts found in the intestines of ruminants. Since the ME values of roughages were significantly higher for ostriches than for poultry, this factor account for the incidence of obesity, which is still common in slaughter birds where extensive rearing systems, based on grazing lucerne and other pasture plants, are employed to a large extent (Adams & Revell, 2003).

Keys & De Barthe (1974) fed pigs a diet containing 50% lucerne to study their digestion. They found significant digestion of hemicellulose in the gastro-intestinal tract anterior to the caecum. Up to 43% of hemicellulose was digested by the pigs, but no significant digestion of cellulose took place. The reason for the good digestibility of hemicellulose is the acid in the stomach of the pig that may modify the structure of hemicellulose to make it more degradable (Keys & De Barthe, 1974). Swart *et al*.,(1993c) did a similar study on ostriches. They fed ostriches diets containing 50% lucerne and found conclusive proof that ostriches efficiently digest plant fibre, more specifically hemicellulose (66%) and cellulose (38%). This could make a positive contribution to the apparent metabolizable energy (AME) of the diet. In this study it was concluded that the low rates of the passage of digesta through the gastro-intestinal tract of ostriches (40 hours) are associated with increased digestion, increased fermentative microbial activity, and increased water and electrolyte absorption. This long retention time in the gastro-intestinal tract, together with advantageous pH values, provides a suitable environment for fermentative micro-flora, especially in the hind-gut of ostriches. Also, the way in which ostriches subject diet particles to gastric grinding and digestion in a strong acid environment in the proventriculus and gizzard, plays an important role in the exposure of fibre fractions to microbial fermentation in the hind-gut. The digestibility of hemicellulose is twice as high as cellulose digestibility, and this is due to microbial digestion in the well developed hind-gut of ostriches. This trend of higher hemicellulose digestibility in the hind-gut compared to cellulose digestibility, is the same for several vertebrates (Van Gylswyk & Schwartz, 1984). For example, it has been observed by Ulyatt *et al.* (1975) in ruminants. They found that hemicellulose digestibility is greater in the hind-gut, and cellulose digestibility is greater in the rumen of these animals.
A study was done in Australia by Farrell *et al.* in August 2000 to gain information on the nutrition and dietary needs of ostriches, as well as their ability to utilize fibre sources and pastures. The experiment was conducted to measure the AME of diets high in fibre for ostriches. A conventional basal diet was used together with four other diets in which 200g/kg of the basal diet was replaced by raw materials with different fibre levels. Wheat pollard, milled lucerne-meal, milled rhodes grass, and milled wheat straw, were used as fibre sources. These diets were given to five emus of two different ages, five adult roosters, and five ostriches. There was no significant difference in the AME of the diets between the two emu age groups, or the adult roosters. The AME declined as the fibre content of the diets increased. In contrast to these findings, the mean AME, as well as the

dry matter digestibility (DMD) for ostriches was higher than for the roosters and emus.

In a study by Salih *et al.* (1998b), it was found that ostriches of 42 – 50kg can digest 45.6% of neutral detergent fibre (NDF) and 29.3% of acid detergent fibre (ADF). Ostriches can obtain between 12 and 76% of their energy in the form of volatile fatty acids, while the chicken can digest only 6 – 9% of the fibre (Brand, 2003).

As shown by Cilliers (1998), more fibrous materials like saltbush, common reed and wheat bran as well as protein concentrates like fishmeal, are better utilized by ostriches than poultry. These results confirmed the importance of evaluating feedstuffs for ostriches by using ostriches, rather than relying on values derived from poultry. Due to the fact that the end-products of fibre fermentation can contribute to the ostrich's ME requirements, the use of ME values derived from poultry in the formulation of diets for ostriches results in an under-estimation of the true ME content of ingredients for ostriches (Cilliers & Angel, 1999). Twelve percent of the total ME in the diet disappears in the hind-gut of the ostrich. Therefore, the advantage that ostriches utilizing high fibre diets enjoy is due partly to the adaption of the large intestine (Brand, 2003). The ostrich is therefore 40% more efficient than poultry in deriving energy from its feed when the feed is of fibrous nature (Cooper & Horbanczuk, 2004). This can make a positive contribution to the AME of the diet consumed (Swart *et al.*, 1993a). In contrast to ostriches, the supply of energy in the form of volatile fatty acids from the lower digestive tract of pigs can contribute 10 – 30% of energy to the total energy requirements of pigs, which are also able to digest fibre fractions to a certain extent. The lower digestive tract of chickens, however, does not supply them with energy (Cooper *et al.*, 2004).

This hind-gut fermentation function in ostriches also resembles the digestive physiology of horses (Skadhauge, 1998), donkeys, and rabbits, and birds like grouse and ptarmigans, which all make use of post-gastric adaptations of the hind-gut, which enables them to ferment fibrous feedstuffs. Of these birds, ostriches are the best post-gastric fibre fermenters (Cilliers & Angel, 1999).

3.4 Factors affecting fibre utilization in ostriches

The two most important factors that influence the digestion of fibre by ostriches are the age of the ostrich and the retention time of the feed or rate of passage of the digesta (Brand, 2003).

Age has an effect on the length of the large intestine and also on the capacity of the large intestine for fibre utilization. The colon (as a proportion of the digestive tract) increases with age. For example, a hatching chick will have a colon to small intestine ratio of 1:1, while at three months of age, the ratio will be 1.5:1. The adult ratio at six months of age will be 2:1 (Bezuidenhout, 1986). In a study done by Salih *et al.* (1998b), it was found that feeding a high fibre diet at a young age (4 – 12 weeks), did not lead to a significant increase in the relative weight and length of the large intestine, but at the age of 52 weeks the large intestine was 27% larger in the birds consuming a high fibre diet, than in those birds consuming a low fibre diet during the same period. Therefore it can be deducted that the type of diet offered affects the relative size of the lower digestive tract, as well as the ability of the animal to obtain more of its nutrients from the diet. The study showed that fibre-rich feeds increased the capacity of the colon. Due to the fact that the ostrich is a hind-gut fermenter, it is essential that their intestines are inhabited by useful bacteria as early as possible (Aganga *et al.*, 2003). Law-Brown *et al.* (2004) found that the type and number of gut bacteria present in ostriches was largely affected by the composition of the diet.

Through a study done by Angel in 1993 it has been found that three week old ostriches can digest 6.5% of the NDF in their diet, while mature animals (at around 30 months of age) can digest 61.5%. The reason juvenile ostriches cannot digest fibre as well as more mature ostriches is that young birds lack the stones in the gizzard that are able to grind fibrous feed to a paste and also lack the necessary bacteria in the hind-gut to digest cellulose and hemicellulose. The ingestion of stones and pebbles (Milton *et al.*, 1994), as well as the faeces of adult birds (Smith, 1964), will prepare the digestive system of the juvenile for a high-fibre diet. As a result, ostriches are able to digest fibre as early as the age of 10 weeks (two-and-a-half months of age) at which stage they can digest more than 50% of dietary NDF (Cooper *et al.*, 2004). They can therefore digest NDF almost as efficiently as mature birds (Swart, 1988). Fibre digestibility has been shown to increase with the age of the bird to about 17 weeks of age after which there is no further increase (Angel, 1993). In another study done by Cilliers *et al.* (1998), it was found that immature ostriches (six months old) obtained 9.16 MJ/kg ME from lucerne, and 13.94 MJ/kg from barley, while mature ostriches (< 105kg) obtained 9.26 MJ/kg from lucerne and 13.92 MJ/kg from barley. This study concluded that the same true metabolizable energy (corrected for zero nitrogen) (TMEn) values would be suitable for ostrich diet formulation for age groups older than six months. Again, this also illustrates the fact that, in comparison to poultry, ostriches have the unique ability to digest high fibre feedstuffs and grains with anti-nutritional characteristics in comparison to poultry.

The study by Salih *et al.* (1998b) also found that the use of high fibre diets significantly reduces the production performance of birds during the starter phase, but during the grower and finisher phases, it seems that the gradual morphological adaptation of the intestinal tract in birds fed a high fibre diet, allows for better utilization of the available nutrients from these diets. This study used high-quality roughage (lucerne hay) to show that the feed conversion of the birds was not negatively affected by the high roughage levels during the growing phase of the birds (Salih *et al.*, 1998b). During the first 210 days of their lives, ostriches have a very efficient feed conversion rate. After 330 days of age, they become inefficient, and their feed conversion worsens (Aganga *et al.*, 2003).

The long retention time in the gastro-intestinal tract of the ostrich, together with the advantageous pH, provides a suitable environment for fermentative micro-flora, especially in the hind-gut of ostriches (Champion & Weatherley, 2000). The retention time is the time it takes for feed to move through the digestive tract of the animal. The longer it takes the food to pass through the digestive tract, the more time there is for the actions of digestive enzymes and microbes to digest such feed, and the more material will be digested. The retention time in hours for chickens is approximately 7, for geese 6, for turkeys 10, for pigs 30 and for ostriches approximately

40 (Swart, 1988). Due to the fact that chickens have a short retention time, it is generally agreed that they do not digest plant fibre (especially cellulose) to any significant extent. Hay-fed sheep, goats, and horses all have retention times of up to 38 hours, while kangaroos have retention times of 41 hours. In contrast to this, the Australian emu, which also has significant fibre digestion like the ostrich, only has a retention time of 5.5 hours. Ostriches tend to void more faeces in the morning than at other times of the day. Throughout the night, they tend to squat and the first faeces are usually voided in large quantities after they have risen in the morning, especially after the first feeding. This may suggest that digesta may be retained in the hind-gut overnight, providing an environment suitable for anaerobic microbial fermentation, and the absorption of water together with volatile fatty acids (Swart *et al.*, 1993a).

3.5 Problems associated with too little roughage in the diet of ostriches

With these studies it is concluded that ostriches are mono-gastric herbivores, which must, when managed intensively, be provided with an adequate, balanced ration containing optimal fibre levels (Aganga *et al.*, 2003). It is also evident from these studies that ostriches maintain higher ME values than poultry and pigs when they consume high fibre diets (Brand *et al.*, 2000). The end-products of fibre fermentation can contribute up to 12 - 76% of the ME requirement for the maintenance of growing birds (Cooper *et al.*, 2004). The inclusion of fibre in the diet of ostriches is therefore very important and it should be from a high quality source like chopped lucerne, otherwise it may lead to the danger of compaction (Cooper & Horbanczuk, 2004). Gastro-intestinal abnormalities like diarrhea, prolapse of the rectum, constipation, and ulcers can be prevented by supplying enough roughage and the correctly sized stones or pebbles (which act as grinding stones in the gizzard). Ostriches will ingest foreign material such as wood shavings, large bones and sharp sticks when the diet is not balanced or if the diet is insufficient in roughage. These substances can penetrate the proventriculus and result in the death of birds up to the age of six months. This is why the supply of a balanced diet together with adequate roughage and correctly sized stones is essential to prevent the ingestion of foreign material (Mellett, 1993). The outstanding ability of ostriches to utilize high fibre diets can therefore be applied to optimize the use of pastures as feedstuff for ostriches – especially mature birds (Brand *et al.*, 2003).

All of the fibre utilization experiments done to date show that the current practice of using poultry ME values for the formulation of ostrich diets, can lead to a gross under-estimation of the true ME value of ostrich feeds. This discrepancy will not be nearly as great when low fibre diets are used, but it can have a great influence in the case of older birds, which are generally fed highly fibrous feeds. In practice, the discrepancy will be even greater because the fibre content of feeds does not remain constant and is increased by the use of even higher levels of fibre as the birds grow older and heavier (Van Niekerk, 1995).

3.6 The benefits of pasture as a food source for animals

Natural and cultivated grazing provides most of the feed eaten by our livestock, and because it is also the cheapest form of feed for animals, grazing is and will always be very important (Williams, 1981).

As human population pressures grow and food suitable for humans become less readily available to animals, grazing will become increasingly important. Much agricultural land in South Africa can be used economically and practically only through grazing animals, and these animals will contribute to the production of food for human use (Williams, 1981). There is a need to increase the productivity of each hectare of grazing land without degrading the natural resources of the country. This is because of an increased demand for meat and other animal protein sources. Such demand can be met by increasing the production of our cultivated pastures (Aganga & Tshwenyane, 2003).

There are many advantages in using grazing forages for animal production systems, including lowering feeding costs, allowing animals to exercise (with the potential for better meat quality), the provision of extra nutrients to the animals, lower initial capital investment, the better use of land less suitable for cropping, decreased antagonistic behaviour among animals, improved animal welfare and favourable environmental perception (Rachuonyo *et al.*, 2005).

In most mono-gastric animal production systems, some kind of grain is the main energy ingredient in the formulated diet. In future, it is possible that such animal production systems (like intensive pig and ostrich systems) will compete directly with humans for cereal grains and high-quality protein supplements. These pressures on grain supplies may force producers in the future to utilize significant quantities of feedstuffs that are unacceptable for human consumption. These feedstuffs include hull or bran fractions of seeds, as well as legume and grass pastures, all of which can potentially be used to feed reproducing swine and ostriches (Varel & Yen, 1997). Scientists suggest that the use of foraging could lead to less grain use, which would decrease feed resource needs, expense and storage; and hence would decrease production costs (Rachuonyo *et al.*, 2005).

Another benefit of highly palatable forages with high intake potentials (like lucerne), is that they can decrease the proportion of concentrates in the diet, thereby minimizing the importation of feed, lowering feeding costs and reducing the nutrient (manure) load on the environment (Rachuonyo *et al.*, 2005).

3.7 The benefits of lucerne as a grazing commodity in the Western Cape

Lucerne (*Medicago sativa*) is a hardy, drought-resistant, summer-growing, temperate, perennial legume species (Durand, 1993). In the winter rainfall region of South Africa, lucerne is by far the most important grazing and forage crop. Lucerne is generally known as the “king of the forage crops” and the reason lucerne is such a popular forage crop is not only that it has the highest nutritive value and therefore supplies very high quality forage, but also that it has the highest yield potential of all legume species that are cultivated in South Africa (Oberholzer *et al.*, 1996). The perennial nature of lucerne also causes it to be more popular than various annual species. This is because it does not have to be established each year and can remain productive for many years, if well managed (Donaldson, 2001). Lucerne is the basis of sustainable, rotational cropping and animal production systems in the Southern Cape. Lucerne can be used to produce hay for animal feeding and it can also be used as a pasture for grazing by animals (Oberholzer *et al.*, 1996). Lucerne can be used for grazing, silage or zero-grazing supplementation and in times of feed scarcity, lucerne hay can be stored efficiently for long periods (De Kock & Birch, 1978).

As a nutritive food and a forage crop, the value of lucerne has been recognized for thousands of years (Donaldson, 2001). The reason for world-wide renewed interest in leguminous crops is the current high price of nitrogen fertilization and the prospect of further rapid price increases. Legumes do not require nitrogen and can, without nitrogen fertilization, produce large quantities of valuable protein, which is indispensable in the diet of man and beast. Legumes have the singular characteristic that they form nodules on their roots. These nodules contain bacteria that distinguish legumes from other crops. These bacteria have the ability to use atmospheric nitrogen for their own growth and they show their gratitude towards the legume for the protection that they enjoy in the root nodule, and for nutrients that they receive from the plant, by converting large amounts of atmospheric nitrogen (which they do not use themselves) to a form that can be absorbed by the legume. When such a legume decays or is ploughed into the soil, the nitrogen that has been built up in the plant also becomes available to other crops. Lucerne has the ability to fix 130 – 350kg nitrogen per hectare per year while the average clover fixes between 100 and 160kg nitrogen per hectare per year (Strijdom & Wassermann, 1980).

Interest in lucerne is growing because of its wide adaptability and high yield, palatability, nutritional value and financial advantages under different environmental conditions (Keftasa & Tuvesson, 1993). Lucerne has the ability to increase stocking rates and therefore to reduce supplementation by feed. All of this results in financial benefits for the producer. Also, the cultivation of lucerne has a considerable stabilizing effect on livestock farming, apart from being easy to establish. It is particularly suitable for mechanization and therefore requires little labour. Lucerne can also be integrated easily into a large variety of rotational cropping systems (De Kock & Birch, 1978).

The main advantages of having legume (such as lucerne) pastures as grazing are:

* Legumes have a higher protein (amino acid) and calcium content than all common grasses and forage plants (Donaldson, 2001). Instead of a protein supplement having to be purchased, home-grown lucerne pastures can be used to provide supplementary protein to grazing animals (Aganga & Tshwenyane, 2003).
* Legumes can retain their high feed value for a relatively longer time than grasses and therefore they can lengthen the grazing season.
* Legumes can maintain the supply of nitrogen in the soil and they can increase the yield of succeeding crops by rendering the soil nitrogen more active and available. Legumes therefore play an important role in soil fertility (Donaldson, 2001). Lucerne also reduces soil erosion. They do this by reducing the amount of cultivation necessary, by holding soil in place through their extensive root system, by

providing vigorous above-ground canopy and by improving water penetration (Putnam *et al.*, 2001).

* Legumes result in an increased intake of herbage, which leads to increased animal production. This is because legumes are more palatable and more rapidly digested than grasses.
* Legumes have the capacity to obtain their full nitrogen requirements from the atmosphere. Therefore they can still produce protein-rich foliage and seed, even in nitrogen-impoverished soils. Nitrogen fertilization is therefore not necessary, which implies a cost saving to the producer. Legumes can undeniably have a major impact on the net income of the farm and every effort should be made to make use of this potential (Donaldson, 2001).

3.8 Lucerne as a grazing commodity for ostriches

The most common cultivated pasture used for grazing ostriches is lucerne (Brand & Gous, 2006). It was found in numerous studies done on pigs, horses, sheep and heifers that animals will usually select for legume stands against grasses (Rachuonyo *et al.*, 2005). In comparison to other feedstuffs, lucerne is by far the most important and sometimes the only dietary component in ostrich production systems. Lucerne hay is a popular source of roughage in ostrich diets and most ratite feeds are lucerne-based with supplements of maize, wheat middling, oats, soybean hulls and brewers' dried grains (Cooper & Horbanczuk, 2004). In the irrigated regions of southern Africa (like the winter rainfall region of the Western Cape), lucerne often forms the staple diet of ostriches (Swart & Kemm, 1985). Uses of lucerne include putting ostriches out to graze lucerne pastures in the third phase of rearing, which is the grow-out phase. The birds will spend around 7 – 8 months grazing on lucerne or natural veld plus a variable amount of supplementation. Alternatively, juvenile ostriches can be reared in feedlots, which are devoid of vegetation (zero-grazing) and here they are provided with a grower ration and chopped lucerne (Verwoerd *et al.*, 1999).

3.9 Nutritive value of lucerne

Lucerne is one of the most palatable forage crops to livestock and because of its exceptional palatability, animals will take in larger amounts of lucerne per day than of grass hay (Zeeman, 1980). Since animal production is closely related to daily intake, animals will achieve good production and growth rates on lucerne, even higher than on any other forage crop or natural grazing. A unique characteristic of lucerne is that, when circumstances demand, it can be used as the only ration for cattle, horses and sheep without any harmful results. It must be kept in mind, however, that in spite of being able to use lucerne as the only ration, lucerne as such, is not a balanced diet (Zeeman, 1980). The digestible protein content of lucerne is high and it can produce more protein per hectare than any other crop. Lucerne is by far the most important source of protein available to the local livestock industry and up to 50% of the protein supplementation in rations is in the form of lucerne (De Kock & Birch, 1978). The digestible energy of lucerne is, however, relatively low. If an animal is allowed to graze lucerne only, and receives no supplementary feed, that animal will take in enough of the lucerne to satisfy its energy requirements, but this high intake of lucerne will lead to its protein requirements being far exceeded. If supplemented by a feed rich in energy, but low in protein (such as molasses or maize), the lucerne will be utilized more effectively (Zeeman, 1980).

Green forage lucerne has a CP content of 10 – 27%, a crude fibre content of 24.8 – 43.9%, an AME content of 8.6 MJ/kg (pasture) and 8.9 MJ/kg (hay), as well as 50.1% DMD (Glatz *et al.*, 2003). Cilliers *et al.* (1998) found that the AME value for lucerne is 8.6 MJ/kg for ostriches, while it is only 4.0 MJ/kg for roosters. The digestibility of NDF in lucerne is 36.5% (Swart *et al.*, 1993c). Lucerne leaf meal has a high CP content, while the stems have a low CP content and higher fibre content (Glatz & Miao, 2006). In 100g of lucerne plant material, different components contribute differing amounts of energy to the total digestible nutrients of the plant. For example, the non-fibrous carbohydrates (NFC), or cell solubles of the lucerne plant contribute 100% towards energy, or the total digestible nutrients, while the cell wall (NDF and ADF) contributes 20 – 60% towards energy, or the total digestible nutrients. Most of the proteins contribute 100% to the total digestible nutrients and lipids contribute 100% towards energy, although fat is present in very small amounts in forages and grass. Minerals contribute nothing towards total digestible nutrients and can range between 6 – 12% in lucerne hay (Putnam, 2002). Whole plant analysis reveals that 25 – 35% of the plant consists of NFC (sugars and starch), 30 – 50% of the plant consists of structural carbohydrates (including NDF and ADF), 15 – 25% of the plant consists of proteins (soluble and bound) and 2 – 3% of the plant contains oils (Ball *et al.*, 2001). The structural components of a lucerne plant are tabulated in Table 3.1 (adapted from Ball *et al.*, 2001).

Table 3.1 Structural components of the lucerne plant (DM basis) (adapted from Ball *et al.*, 2001)

Plant part	**NDF content (%)**	**ADF content (%)**	**CP content (%)**
Leaves	18 – 28	12 – 20	22 – 35
Stems	35 – 70	30 – 55	10 – 20

Grazing animals in South Africa often have a deficiency of vitamin A during droughts. This can lead to the animals being more susceptible to bacterial infections. Due to the fact that the main function of vitamin A in the animal's body is growth and the maintenance of cells, a deficiency in vitamin A will also retard growth. Animals can synthesize vitamin A in their digestive tracts and liver, but they need carotene that comes from green plants and good hay to do this. Since the carotene content of lucerne is high, this will not be a problem in animals grazing lucerne. Lucerne is also rich in calcium and vitamins D and E (Zeeman, 1980). These high levels of nutrients are advantageous to ostriches, as the production of feathers requires high levels of carotene (Maree, 1979). Lucerne contains 6.24g B-carotene per 100g, 0.15g thiamine, 0.46g riboflavin, 1.81g niacin and 0.46g tocopherol. Pantothenic acid, biotin, folic acid, choline, inositol, pyridoxine, vitamin B12 and vitamin K, are also present. Fresh lucerne is rich in vitamin C and contains about 1.78mg/g, but can lose up to 80% of this during the hay-making process and drying (Aganga & Tshwenyane, 2003).

3.10 Supplementation of lucerne pastures

Efficient growth and optimal weight gain cannot be attained without a nutritionally balanced diet. The essential nutrients in the diet of ostriches include energy, protein, amino acids (e.g. lysine, methionine), vitamins (e.g. vitamins A,D,E and K) and minerals (e.g. calcium, phosphorus, potassium, magnesium). This must be presented to the bird in a palatable, digestible form each day of its life to achieve the desired production goals (Scheideler & Sell, 1997). As with any grazing animal, the body condition of the animal must be assessed continually and the provision of supplemental energy as needed must be made to attain growth and production goals (Gegner, 2001). When cultivated pastures are used, it is preferable to supply the ostriches with supplementary feed to prevent any nutrient deficiencies that can occur (Brand *et al.*, 2004).

Although lucerne is the most suitable feedstuff for ostriches on its own it is not a completely balanced diet for ostriches. Lucerne has a relative low energy value for ostriches and this will impair the ability of the ostrich to utilize the lucerne protein efficiently (Swart & Kemm, 1985). Lucerne pasture must therefore be supplemented with energy to satisfy the ostrich's energy requirements (Champion & Weatherley, 2000). Some disadvantages to grain-based high energy supplements are that they can lead to a decline in fibre digestion and this can in turn lead to lower pasture intake. Too much high energy supplementary feed can lead to some of it being substituted for the cultivated pasture, but according to Wallace (1956) this substitution effect is much smaller on legume pastures (as cited by Dickenson *et al.*, 1993). If an ostrich is fed a completely balanced diet it is assumed that the diet supplies all nutrients. Among ostrich farmers it is common practice to feed ostriches on pasture, but this will dilute the balanced diet, which is also supplied. This can cause impaired growth and feed conversion. This is not only true for ostriches, but for pigs as well. This was confirmed by a study done by Varel & Yen in 1997, where they found that a diet containing more than 7 – 10% fibre has an inhibitory effect on pig growth. However, pastures can make a substantial contribution to the nutrient requirements of ostriches if supplemented by a concentrate suitable for a specific pasture type and certain stage of the year. The formulation of pasture concentrates that take the nutrient contribution of pastures into account can result in good growth rates as compared to birds receiving complete diets in feedlots. Cilliers (1998) stated that the formulation of concentrates that took into account the nutrient contribution of lucerne pastures, will give superior results and growth rates, and this compared favourably to birds receiving complete diets under feedlot conditions.

The intake of pasture by grazing animals (particularly pasture of high quality) will be depressed where concentrates are fed (Meissner *et al.*, 2000). Supplementary feed must lead to an increase in the intake of pasture feed, or must increase the efficiency of utilization of digested nutrients, or it must do both. Only then will supplementary feed provide an economic advantage (Allden, 1981). The intake amount and selection of plants or plant-parts by ostriches raised on cultivated pastures is currently unknown to producers. It is also unknown to what extent the ostriches will substitute the supplemented feed for the pasture. According to Brand & Gous (2006) the assumed intake of pasture if birds are provided with a supplementary feed is 0% in the pre-starter phase, 30% in the starter phase, 50% in the grower phase and 70% in the finishing phase.

Grazing ostriches initially have high nutrient requirements and this will mean that the composition of pasture concentrates should comprise a minimum of 67% of the total feed requirements for growing ostriches from 4 – 6 months old (45 – 70kg). The nutrient supply from pastures can gradually be increased to about 50 – 55% for birds between 6 and 10 months old (70 – 95kg), while the nutrient intake from pastures for birds above 95kg can comprise 60% of the total ingredients (Cilliers, 1998).

In a study done by Champion & Weatherley in 2000, on the other hand, it was found that high-quality Australian pasture (where clover content in the sward was managed and maintained) met most of the nutrient requirements of young growing ostriches. They concluded that supplements on these pastures should focus on the supplementation of macro and micro-minerals, rather than act as either a protein and/or energy supplement. They concluded that careful management of both pasture and husbandry can achieve improved growth rates at little or no cost.

A second experiment was undertaken by the same researchers to determine the effect of different supplements on the growth rate of the ostriches grazing pastures. Two supplements were used in combination with two pasture types. Although this experiment was abandoned due to adverse external factors, they observed that ostriches will usually utilize the supplement provided in a grazing system very soon and the methods of supplementation need to be more evenly delivered over time. According to Dean *et al.*, 1994 (as cited by Deeming & Bubier, 1999), ostriches will consume concentrated rations when provided, but they will always consume natural vegetation whenever available and it seems that they prefer natural vegetation.

In a study done by Farell *et al.* (2000), it was found that if the level of supplementation of grazing ostriches is below 70% of the total diet, it will have a negative effect on the growth of slaughter ostriches. Although the growth rate was lower, higher feed conversion ratios compared to those birds on the 100% commercial diet, were found. This study was, however, done on low quality pastures. The researchers concluded that pasture can only contribute significantly to the nutrition of ostriches if the pasture is of good quality.

Nitzan *et al.* (2002) also conducted a grazing trial where different levels of supplementary feed were provided for ostriches. These researchers concluded that ostriches will maintain higher intakes of lush, green lucerne pasture if they are supplied with less supplementary feed, thereby indicating that ostriches will adapt to a limited allowance of concentrate by increasing their intake at pasture.

Another grazing and supplementation study done with ostriches was by Glatz *et al.* (2005). Ostriches received a commercial grower diet and then walked daily from a feedlot paddock to another paddock, which had lucerne pasture available with some clover and ryegrass. These birds were allowed to graze the pasture for three to five hours per day. The researchers concluded that better quality pasture (i.e. lucerne) can contribute significantly to the nutritional requirements of growing ostriches and can be combined with a suitable commercial diet supplement for maximum production of ostriches at reduced cost.

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Chapter 4

The effect of feed supplementation to irrigated lucerne pastures on the production of finishing ostriches, their pasture intake and pasture production

Abstract

Two hundred and fifty ostriches (± six months old) were randomly allocated to five groups of fifty ostriches each. Four of these groups rotationally grazed irrigated lucerne pastures and the fifth group was put in a feedlot and received a complete finisher diet (zero grazing). The lucerne pasture was divided into 16 paddocks of approximately 0.85 ha each and grazed at a stocking rate of 15 birds/ha. Four paddocks were randomly allocated to each group of grazing ostriches. Three of the four grazing groups received supplementary feed at 1500g/bird/day, 1000g/bird/day and 500g/bird/day respectively, while the fourth group received no supplementary feed (0g/bird/day). The ostriches were weighed every 14 days and moved to a new paddock after each grazing. Five exclosure cages were put in each paddock before the ostriches were allowed to graze the paddock. Pasture dry matter (DM) production, intake, availability and residual DM were determined by cutting and collecting 0.166 m^2 sized samples at ground level inside and outside these cages just before the ostriches and cages were moved to the next paddock. The cut material was then manually divided into lucerne, grass, broad-leaf weed, clover and dry/dead material fractions before washing to remove soil and dirt. The fractions were then dried to a constant dry mass at 59°C. An analysis of variance was applied to the data. Ostriches receiving 1500g/bird/day showed the best growth, closely followed by the ostriches receiving the complete finisher in the feedlot. Ostriches receiving 0g/bird/day showed the slowest growth. There was no difference ($P > 0.05$) between the end mean live weights of the feedlot ostriches and those two grazing groups receiving 1500 or 1000g supplementation. The average daily gain (ADG) of the group receiving 1000g supplementation was lower ($P < 0.05$) than the ADG of the group receiving 1500g supplementation, but all three groups reached a mean target slaughter weight of 95kg within the 154 days of the study. It can be concluded that ostriches can be finished on a high quality pasture like lucerne while receiving the correct supplementation and that they will reach slaughter weight at approximately the same time as feedlot-raised ostriches. Plant material was composed mainly of lucerne, with only very small quantities of clover, grass, broad-leaved weeds and dry/dead material. Ostriches consumed mainly lucerne. There was no interaction between the level of supplementary feed and time (months) in respect of lucerne production, intake, availability or residual lucerne. There was no difference ($P > 0.05$) in the amount of lucerne produced, ingested and available due to the level of supplementary feed supplied, but there were significant changes in lucerne production and ingestion over time. Since lucerne production declined inexplicably during December and January, which may have been due to irrigation problems, these two months were removed from the data set, and a quadratic function was applied to the remaining data. For lucerne intake, a quadratic relationship ($P < 0.01$) was applied between pasture DM intake (g/bird/day) and supplementary feed intake (g/bird/day). From this function, it could be deducted that the maximum lucerne intake level (1692.8 g/bird/day) was achieved at 619.6 g supplementary feed/bird/day. Increasing levels of supplementary feed to grazing ostriches seemed to have had a gradually elevating effect on residual lucerne DM.

Keywords: mean live weight, ADG, FCR, lucerne intake, lucerne production, supplementary feeding

Introduction

Approximately 550 000 slaughter ostriches are produced annually all over the world. According to Kruger (2010, A. Kruger, Pers. Comm., South African Ostrich Business Chamber, P.O. Box 952, Oudtshoorn, 6620), ostrich farming has increased in popularity in South Africa with at least 220 000 birds being slaughtered in the country each year. Ostrich meat has become an increasingly important product over the last 10 – 15 years due to the worldwide shift in consumer demand for healthier red meat and the outbreak of cattle diseases like BSE and foot-and-mouth disease in Europe in 2000 (Van Zyl, 2001). Since ostrich meat is low in fat and high in poly-unsaturated fatty acids, it is now considered a more suitable and healthier alternative to beef and lamb (Cooper & Horbanczuk, 2002, as cited by Glatz & Miao, 2006).

Traditionally, slaughter ostriches are fed commercially produced high energy and high protein complete-pellet diets in an intensive management system (Baltmanis *et al.*, 1997). These diets are consumed at amounts close to maximum intake. This is despite the ostrich's ability to live in arid environments and thrive by foraging for food in the wild. By feeding only high concentrate diets in intensive farming systems, the fermentation capacity of the ostrich to utilize fibrous materials is not utilized. These high concentrate diets increase production costs and can reduce the profitability of ostrich farming (Champion & Weatherley, 2000). In consequence, the interest in raising ostriches extensively on pastures has increased recently (Baltmanis *et al.*, 1997). If the ostrich industry is to survive in the long-term, the development of cost-effective feeding methods in different areas of the world must be a primary focus of research (Cilliers & Angel, 1999). The expanded use of low-cost feed sources such as pastures has the potential to play a significant role in the further development and sustainability of the ostrich industry. One way of keeping the high production costs of ostrich farming to a minimum is to use pastures as a predominant food source along with a low-cost supplement (Champion & Weatherley, 2000). Since ostriches have the outstanding ability to utilize high fibre diets, the ensuing production of volatile fatty acids and the absorption of these fatty acids can be used to optimize the use of pastures as feedstuffs for ostriches, especially mature birds (Brand, 2003).

Efficient ostrich growth and optimal weight gain cannot, however, be attained without supplying a nutritionally balanced ration (Allden, 1981). For this reason, if pastures are being used, the correct supplementation is still essential to ensure that the animals ingest a complete and balanced ration. The ultimate goal of supplementation is two-fold. Supplementation of pastures must lead to an increase in the intake of pasture feed and/or must increase the efficiency in the utilization of digested nutrients. Only then will supplementary feed provide an economic advantage (Morley, 1981).

In the winter rainfall region of South Africa, lucerne is by far the most important grazing and forage crop. Lucerne (*Medicago sativa*) is generally known as the "king of the forage crops", because not only does it have the highest nutritive value and therefore supplies very high quality forage, but it also has the highest yield potential of all the legume species that are cultivated in South Africa (Oberholzer *et al.*, 1996). Lucerne also has a high persistence in pasture stands (Lacefield, 2004). The perennial nature of lucerne also causes it to be more popular than annual species, because it does not have to be re-established each year and can remain productive for many years, if well managed (Donaldson, 2001). All these factors are essential if an ostrich producer wants to maximize ostrich production on lucerne pastures (Lusse *et al.*, 1996). The digestible energy level and amino acid content of lucerne alone is, however, too low to support the nutrient requirements of growing ostriches. Growing ostriches grazing lucerne pasture, therefore, need to be supplemented (Zeeman, 1980).

In order to maintain high animal production on pastures, it is essential to maintain plant production and longevity in the sward while being grazed by animals (Lusse *et al.*, 1996). Grazing animals have a marked effect on pasture growth and one of the ecological indices that can be measured to assess livestock impact on pasture is biomass production (Palmer & Ainslie, 2006). Defoliation by grazing animals removes the younger leaves at the top of the canopy and it is usually those young leaves that are the most efficient in promoting further shoot growth in both grasses and legumes (Vickery, 1981). To maintain forage quality in a pasture, it is essential to maintain a young, actively growing forage canopy. This can be achieved by regular grazing or clipping. If a pasture is, however, grazed too closely or frequently, forage production and availability will be reduced. This will eventually cause a decrease in animal production due to lower DM availability and intake. If a pasture is not grazed short enough, however, some plants will be avoided and become mature, which will result in an overall decline in forage quality, lower forage DM intake and lower DM production (Rayburn *et al.*, 2007). Herbage availability and sward production can be matched with animal management by changing the number of animals per unit area (see Chapter 6 of this thesis), or by changing the time allotted to graze a pasture, or by supplying the animals with supplementary feed (as done in this study) (Belesky *et al.*, 2007).

Limited information, however, exists with respect to the nutritional management of ostriches in a grazing environment (Champion & Weatherley, 2000). The production of ostriches on different types of pastures and/or grazing systems and the science of providing supplementary feed to birds grazing pasture, are limited (Brand & Gous, 2003). Most data available on ostriches detail the results of experiments where birds are being fed prepared rations in an intensively managed or feedlot system (Champion & Weatherley, 2000). Very little research has been done to date on grazing ostriches that receive different levels of supplementary feeding.

Only a few studies on grazing ostriches have been done. Champion & Weatherley (2000) evaluated the growth of starter ostriches (80 – 105 days old) in a predominantly grazed environment. Although these researchers concluded that the grazing environment did not support growth rates equal to those seen under intensive management systems, they could not evaluate the effect of different levels of supplementary feed on the growth of grazing ostriches due to a number of experimental problems. They concluded that supplementation should not be used as a protein and energy source, but should rather supply those macro and micro-nutrients which is deficient in the pasture.

According to Farrell *et al.* (2000) the focus of ostrich production has changed from more intensive production systems, with the emphasis on meat production and rapid growth, to more extensive, slower-growing systems producing good quality hides. Due to this, grazing has become a more attractive option. Although these researchers recorded pasture DM on offer, pasture intake by the ostriches and pasture growth, it was done on low quality pasture, lacking in crude protein (CP) during unseasonal weather and record rainfall, all of which could have influenced the grazing behavior and performance of the ostriches negatively. It was also not stated if the supplements which were provided, complemented the type of pasture the ostriches were grazing to ensure a balanced diet. They concluded that ostriches given smaller amounts of concentrate feed consume more DM per day. Pastures can therefore contribute significantly to the nutrition of ostriches, but then they must be of good quality.

Nitzan *et al.* (2002) conducted a grazing trial with different levels of supplementary feeding on eight-week old ostrich chicks, which were slaughtered at 31 weeks of age. Once again, it is not known if the concentrate supplied was formulated to complement the pasture type that was grazed by ostrich chicks. This study also concentrated more on young birds and on which type of pasture is more suitable for their growth than on evaluating the effect of supplementation. Although the researchers measured the pasture intake by the chicks, they did not evaluate the effect the ostriches had on the future pasture production of the pasture. As in the previous study, they also found higher intakes of lush green pasture for groups of ostriches receiving less concentrate, indicating that ostriches adapted to a limited concentrate allowance by increasing their pasture intake.

In a recent grazing study by Glatz *et al.* (2005), ostrich growers (49 – 78kg live weight) received different levels of a commercial grower diet in a feedlot paddock and were then allowed to graze a lucerne pasture mixed with some clover and ryegrass. These birds grazed the pasture for three to five hours per day. The researchers did not measure pasture intake or pasture production and concentrated only on the growth of the ostriches. They subsequently found that better quality pasture (i.e. lucerne) can significantly contribute to the nutritional requirements of growing ostriches and can be combined with a suitable commercial grower diet supplement for the maximum production of ostriches at a reduced cost.

Grazing studies done with other mono-gastric animals such as pigs and broilers, generally found the following:

a) A reduction in the level of supplementary feed supplied with *ad libitum* fresh roughage leads to a significant increase of roughage intake, a decline in the gain of the animals and improved feed utilization (Danielsen *et al.*, 1999; Gustafson & Stern, 2003; both experiments with pigs; Ponte *et al.*, 2008; with broilers).
b) Grazing animals need supplementation to match the weight gain of animals fed a complete diet in a feedlot (Honeyman & Roush, 1999; with pigs)

The aforementioned studies done on mono-gastric animals grazing pastures and receiving a supplement showed that pastures can contribute significantly to the nutrient requirements of these animals and also that pasture intake can, in some cases, promote animal performance.

Glatz *et al.* (2005) stated in their study that their results needed to be verified on a larger scale through using a crop and pasture rotation system that allows ostriches to utilize cheaper forage sources.

The aim of this study, therefore, was firstly to evaluate the effect of different levels of supplementary feed on the production results of finishing ostriches grazing irrigated lucerne pastures. Secondly, due to the fact that animal production is not only influenced by the level of supplementary feeding, but also by plant production and stand longevity of the pasture itself, the effect that the supplementation of the diet of ostriches grazing irrigated lucerne pastures on the yield of lucerne pastures was also investigated.

Materials and methods

Experimental site:

The study was conducted at the Kromme Rhee Experimental Farm (18º50' East and latitude 33º51' South) in the Western Cape Province near Stellenbosch. Kromme Rhee lies 177m above sea level and has a typically Mediterranean climate, with a cool, wet autumn, winter and spring, and dry summer. The mean annual rainfall is 622.7mm (30-year average) and 84% of this rainfall occurs during the months of April/May to September/October (Labuschagne, 2005). The soil of the trial site is classified as a Hutton (McVicar *et al.*, 1977). The study commenced in September 2005 and was concluded in April 2006.

Experimental design:

a) Ostrich data

The experiment was completely randomized with four feed treatments in which the birds grazed lucerne pastures while receiving 0, 500, 1000, 1500g/bird/day respectively and with a fifth zero-grazing treatment, with the birds receiving an *ad libitum* complete finisher feed.

b) Pasture data

The experiment was completely randomized with four levels of feeding, i.e. 0, 500, 1000 and 1500g/bird/day, replicated four times.

Experimental animals and management:

The experimental birds used in this study were African Black ostriches (*Struthio camelus* var. *domesticus*) and they were obtained from different ostrich producers in the Oudtshoorn area of the Western Cape. A total of 250 birds with an average age of six months were used in the study. Birds were randomly allocated to five treatment groups of 50 ostriches each to obtain a stocking density of 15 ostriches per hectare grazing. Individual ostriches were identified by means of the attachment of a neck tag. Standard management practices for ostriches as applied by the Ostrich Research Unit of the Elsenburg Research Centre were implemented.

Pasture:

Lucerne (*Medicago sativa*) pastures (cv. SA Standard) had been established two years prior to the experiment. Prior to establishment the soil was analyzed and the pH, Phosphorus and Potassium levels adjusted by fertilization. The lucerne was established in the autumn by broadcasting at 12kg seed/ha. Before sowing, the seed was inoculated with the appropriate *Rhizobium* nodule bacteria. The lucerne pasture was fenced into 16 treatment paddocks of approximately 0.85 ha each. Fences were 1.5m high and consisted of wooden poles and smooth wire strands. The pastures were also irrigated on a weekly basis during the summer using an overhead sprinkler system. Irrigation after the establishment phase was restricted to once a week, if no ostriches were occupying the paddocks. While occupied by ostriches no irrigation of the paddocks was applied so as to minimize any trampling of the wet pasture by the ostriches. In each paddock drinking water was provided in rectangular 25L water troughs, each with an automatic refill apparatus attached.

Treatments:

Before the experiment started on 7 September 2005 four of the five ostrich groups were allowed to graze lucerne paddocks for 14 days without receiving any supplementation. This was done to allow the digestive systems of the ostriches to adapt to the lucerne grazing after which the four groups grazing the lucerne were put into four lucerne paddocks to start the trial. The fifth group was randomly divided into three groups and kept in three feedlot paddocks of 30m x 40m each, consisting of wooden poles and smooth wire strands in order to minimize skin damage.

The feedlot ostriches received a complete finisher diet (with zero lucerne grazing) supplied in two ostrich feeders per feedlot paddock. The birds had free access to clean drinking water supplied in rectangular 25L water troughs, each with an automatic refill apparatus attached. New feed was weighed out every two days and put into the feeding troughs. When the ostriches were weighed, the feed left in the feeding troughs was weighed again to determine the feed intake of the ostriches. The formulation of the complete finisher diet was based on the chemical composition of ingredients and ostrich nutritional requirements as proposed by Brand (2006). The ingredient and nutrient composition of the complete finisher diet is presented in Table 4.1.

Table 4.1 Ingredient (kg) and nutrient (%) composition of the complete finisher diet fed as pellets to the feedlot ostriches (values given on an *as fed* basis).

Ingredients (kg/ton feed):	
Lucerne-meal	610
Yellow maize	300
Soybean seeds meal (44% CP)	50
Molasses powder (Calorie 3000®)	12
Monocalciumphosphate	11
Limestone, ground	9
Common salt	4
Ratite Finisher Vitamin & Mineral Premix	4
Nutrients (%):	
TMEostrich (MJ/kg), calculated	10.7
CP	15.2
Lysine	0.66
Methionine & Cystine	0.44
Threonine	0.59
Tryptophan	0.19
Arginine	0.69

The four groups grazing the lucerne pastures received 0, 500, 1000 and 1500g/bird/day of a pelleted supplementary feed (treatments). This was offered to them in three low, rectangular feeding troughs per day, while they had free access to the pasture and clean drinking water. The formulation of the supplementary feed supplied was according to the nutrient requirements of the ostriches for this growth stage, i.e. at a level of 1000g supplementary feed plus 1500g lucerne pasture/bird/day (Brand & Gous, 2006). The ingredient and nutrient composition of the supplementary feed is presented in Table 4.2.

Table 4.2 Ingredient (kg) and nutrient (%) composition of the supplementary feed supplied to the ostriches grazing lucerne pastures (values given on an *as fed* basis):

Ingredients (kg/ton feed):	
Yellow maize	758
Soybean seeds meal (44% CP)	127
Molasses powder (Calorie 3000®)	30
Monocalciumphosphate	27
Limestone, ground	23
Common salt	25
Ratite Finisher Vitamin & Mineral Premix	10
Nutrients (%):	
TMEostrich (MJ/kg)	13.5
CP	12.2
Lysine	0.54
Methionine & Cystine	0.44
Threonine	0.44
Tryptophan	0.14
Arginine	0.69

The complete finisher diet and the supplementary feed were formulated using the computer programme MIXIT-2™ (1982).

Grazing management:

Four lucerne paddocks were randomly allocated to each treatment group. The ostriches were allowed to graze each paddock for a period of two weeks before the group was rotated to the next paddock in the allocated four paddocks system. The lucerne pastures were therefore subjected to a four-paddock rotational grazing system.

Observations and measurements:

a) Ostrich data

At the onset of the experiment, the ostriches in each group were weighed individually by means of a mobile electric scale (Rudweigh 200®, Contry) and their starting weights recorded. Each bird was individually weighed to an accuracy of 0.1kg to enable the determination of current live weight and also to determine growth rate. Standard methods for handling ostriches were used with a hood being placed over each individual ostrich head, which allowed easier handling of the ostriches. Since the lucerne paddocks were alike in all respects and each bird had equal access to the supplementary feed and pasture, each bird was considered a replicate. Before rotating each group of ostriches to their next paddock, each ostrich was weighed and their weights recorded, i.e. every two weeks. Together with moving and weighing the four treatment groups, the individual feedlot ostriches were also weighed and put back into their respective feedlots. There were four paddocks per treatment group and each ostrich group grazed each paddock four times in a rotational grazing system. Pasture intake of the birds were calculated as mean pasture intake per paddock (four cycles within a four-paddock rotational system). Feed conversion ratio was calculated by dividing intake of the birds by the mass change with no replications per treatment group.

b) Pasture data

Both pasture production and pasture intake by the ostriches were measured by placing five exclosure cages randomly in each treatment paddock before grazing started and sampling the available pasture DM in and outside each cage every 14 days after grazing when the ostriches were moved to a new paddock. Five readings were taken within and outside each cage and pasture production (kg/ha/day) was calculated as the difference between the amount of plant material outside the cages in the previous measurement and the amount of plant material inside the cages in the current measurement. This was then divided by the number of days between the two measurements. The pasture intake by the ostriches was calculated as the difference between the amount of plant material within the cages and the amount of plant material outside the cages at the end of each grazing period. The cages consisted of welded mesh used to form circular cages of approximately 0.45m^2 in area. The cages were tied to iron stakes which were hammered into the ground. The available and residual pasture DM was determined inside and outside the exclosure cages by cutting the pastures to ground level within 0.166m^2 quadrants using hand shears. These pasture samples were subsequently collected in plastic bags, manually fractionated into dry material, lucerne, other legume, grass and broad-leafed weed fractions. The samples were, after washing with water to remove soil, dried to a constant mass at 59°C, immediately weighed and used for the determination of the DM yield. This data was then used to estimate pasture DM production, pasture DM intake, pasture DM availability before grazing and residual pasture DM after grazing. After determining DM yield, the samples were milled through a 1mm sieve (C & N Laboratory Mill Size 8", Christy & Norris Ltd., Chelmsford, England) and stored in plastic jars pending chemical analyses. Forage samples were analyzed for concentrations of ash, CP, crude fibre, neutral detergent fibre (NDF), and acid detergent fibre (ADF). Ash concentration was determined according to the AOAC (method 942.05). NDF and crude fibre concentrations were both determined by using the Velp FIWE Raw Fibre Extractor (Velp Scientifica, Via Stazione 16, 20040 Usmate (Milano), Italy). NDF was analyzed according to the method of Robertson & Van Soest (1981) and crude fibre was analyzed according to AOAC (method 978.10). The concentration of ADF was determinted according to the method of Goering & Van Soest (1970) using the Dosi Fibre system (Labex (Pty) Ltd, P.O. Box 46009, Orange Grove, 2119). Total nitrogen was determined by using the Dumas Combustion method according to the AOAC (method 968.06) with a Leco FP-428 Nitrogen Determinator (Leco Corporation, St. Joseph, MI, USA). Crude protein concentration was then estimated as 6.25 x N concentration. The chemical composition (%) of the pasture as grazed by the ostriches during the experimental period is presented in Table 4.3.

Table 4.3 The average nutrient composition (%) on DM basis of the lucerne pastures during January to April 2006, while being grazed by finisher ostriches. Values presented as mean ± se.

Month	**CP**	**Crude fibre**	**ADF**	**NDF**
January	9.9 ± 0.7	48.3 ± 1.9	55.5 ± 2.0	67.6 ± 1.5
February	12.9 ± 0.9	41.7 ± 1.7	49.3 ± 2.1	58.9 ± 2.4
March	13.9 ± 1.3	42.7 ± 2.1	51.6 ± 2.3	58.9 ± 2.4
April	15.1 ± 2.1	41.9 ± 4.0	51.3 ± 3.8	56.4 ± 5.0

Statistical analysis:

a) Ostrich data

For the purpose of this study, total DM intake, final weight at 50 weeks of age (about 12 months), ADG and FCR were recorded. The effect of supplementary feed level (five levels) on the weight of the ostriches (Y) was analyzed by applying a simple linear regression model (y = a + b*age). A one-way ANOVA was used to analyze the effect of supplementary level (five levels) on total DM intake, final live weight at 50 weeks of age and ADG. The level of significance was calculated at a 5% confidence level. An effect with a probability smaller than 5% (P <0.05) was considered to be significant. All data were analyzed according to the experimental design with SAS 9.1.3. for Windows (2002 - 2003).

b) Pasture data

For the purpose of this study, pasture production and intake, as well as available and residual pasture were recorded. The Proc GLM (SAS 9.1.3 for Windows, 2002 - 2003) was used to analyze if there was an interaction between supplementary level and months. Proc GLM was also used to analyze the effect of supplementary level (four levels) and months (five months) on the level of pasture production, intake, availability and residual pasture after grazing. The level of significance was similarly calculated at a 5% confidence level. An effect with a probability lower than 5% ($P < 0.05$) was considered to be significant. The variables were tested by the Shapiro-Wilk test for non-normality (Shapiro & Wilk, 1965). Normality for variable residuals in the lucerne production and intake data, as well as the available and residual lucerne data, was established, and thus the results of the ANOVA were reliable and valid. The variable residuals of the other plant material fractions did not show normality and therefore this data was not analyzed statistically.

Results

a) Ostrich data

The finishing ostriches in this study showed linear growth during the experimental period. The mean live weights of finishing ostriches grazing lucerne pastures and receiving different supplementary levels as recorded for every two weeks during the trial are illustrated graphically in Figure 4.1. The growth curve of the finishing ostriches receiving a complete finisher feed in a feedlot is also included in the graph.

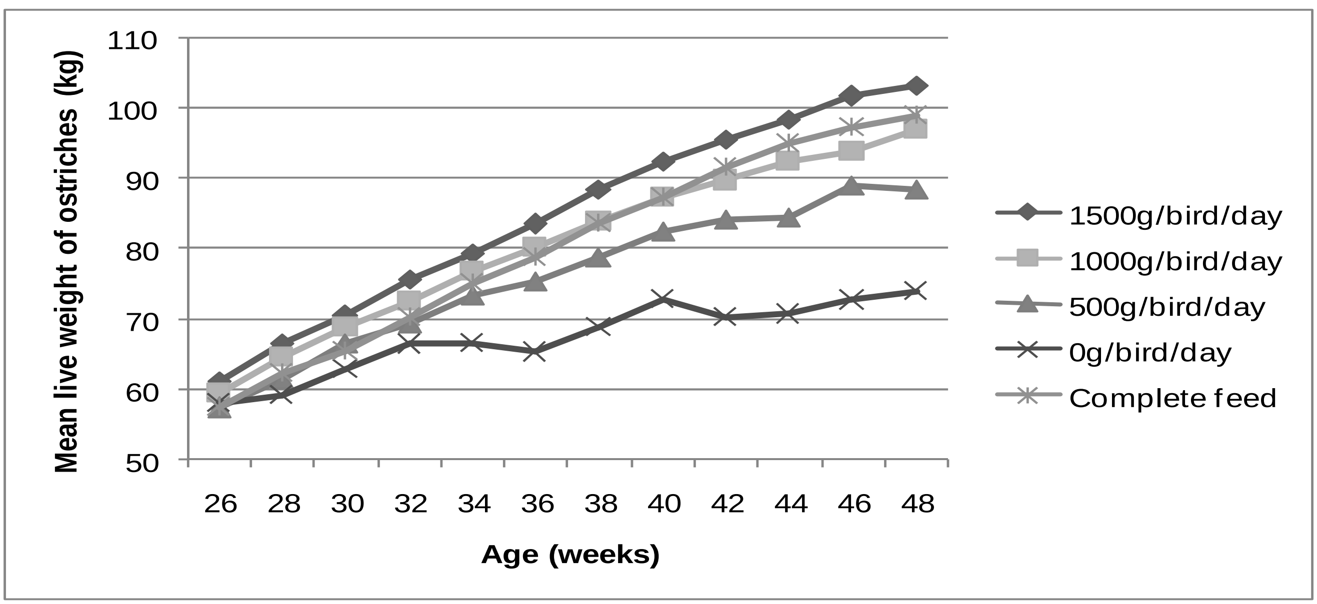

Figure 4.1 Mean live weights of finishing ostriches grazing lucerne pastures and receiving different levels of supplementary feed, and of zero-grazing ostriches receiving a complete finisher feed, as recorded every two weeks.

The linear relationships derived between age (X) and mean live weight (Y) for the different treatment groups were as follows:

0g supplementary feed/day: $y = 41.97 + 0.685X$ ($R^2 = 0.23$)

500g supplementary feed/day: $y = 22.94 + 1.432X$ ($R^2 = 0.55$)

1000g supplementary feed/day: y = 17.25 + 1.716X (R^2 = 0.68)

1500g supplementary feed/day: y = 12.33 + 1.956X (R^2 = 0.62)

Complete finisher feed (*ad libitum*): y = 7.39 + 1.969X (R^2 = 0.59)

The Least Significant Difference means were adjusted for the differences in intercepts.

The linear relationships are illustrated in Figure 4.2 below.

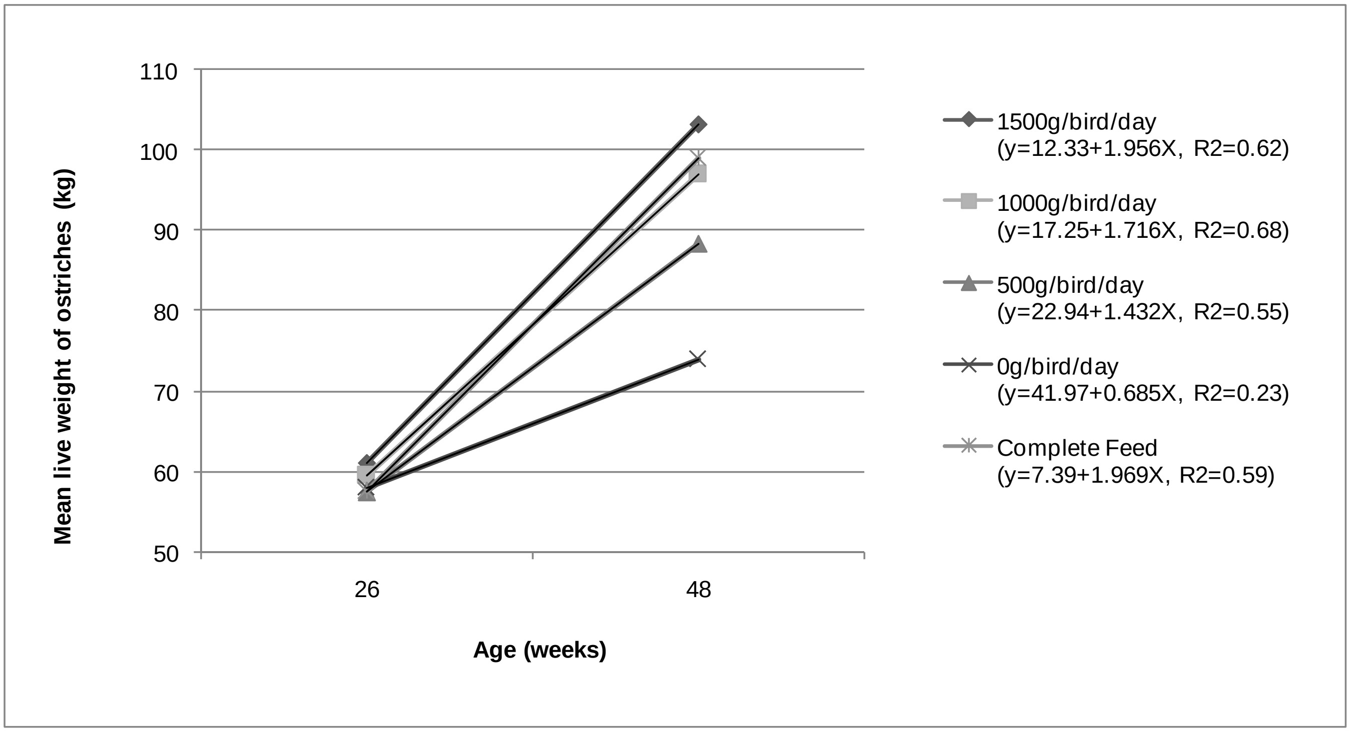

Figure 4.2 Linear relations of the mean live weights of finishing ostriches grazing lucerne pastures and receiving different levels of supplementary feed and of zero-grazing ostriches receiving a complete finisher feed.

The results of a one-way analysis of variance applied to the production data of the five different treatment groups are presented in Table 4.4.

Table 4.4 Production data of growing ostriches (± six months of age) subjected to a 154-day supplementary study on irrigated lucerne pastures. Values presented as mean ± se.

Production Parameter	**Concentrate level (g/bird/day)**				
	Zero-grazing Feedlot	**Lucerne grazing + 1500**	**Lucerne grazing + 1000**	**Lucerne grazing + 500**	**Lucerne grazing + 0**
Starting weight (kg)	$57.6^{a} \pm 1.4$	$61.1^{a} \pm 1.3$	$59.5^{a} \pm 1.3$	$57.4^{a} \pm 1.3$	$58.0^{a} \pm 1.3$
Total DM intake (g/bird/day)	$2585.2^{a} \pm 0.4$	$2114^{a} \pm 0.2$	$2284^{a} \pm 0.2$	$2135^{a} \pm 0.2$	$1073^{b} \pm 0.2$
Weight at 50 weeks of age (kg)	$99.1^{ab} \pm 1.6$	$103.2^{a} \pm 1.4$	$96.9^{b} \pm 1.5$	$88.4^{c} \pm 1.5$	$73.9^{d} \pm 1.5$
ADG (g/bird/day)	$269.6^{ab} \pm 7.4$	$273.2^{a} \pm 6.6$	$243.3^{b} \pm 6.7$	$201.6^{c} \pm 6.9$	$103.4^{d} \pm 6.7$

$^{a, b, c}$ Row means with common superscripts do not differ (P >0.05).

The one-way analysis of variance showed that there were differences in total DM intake (P <0.001), mean live weight at 50 weeks of age (P <0.001) and growth rate (ADG) (P <0.001) between the five different treatment groups. The starting weight of the birds did not differ (P >0.05) from each other (P =0.21).

The total DM intake of the birds in the feedlot and those grazing lucerne and receiving respectively 1500, 1000 and 500g supplementary feed/bird/day did not differ (P >0.05) between each other. The ostriches grazing lucerne and receiving no supplementation had lower (P <0.05) total DM feed intakes when compared to the other groups.

The mean live weights of ostriches in the feedlot did not differ from those ostriches grazing lucerne and receiving either 1500g or 1000g supplementary feed/bird/day. The ostriches receiving 1500g/bird/day had significantly heavier body weights compared to ostriches receiving 1000g/bird/day (96.9kg), 500g/bird/day (88.4kg), and 0g/bird/day (73.9kg). The mean live weights of the complete fed group were, however, significantly higher than those of the two groups receiving respectively 500g/bird/day and 0g/bird/day. Within 154 days of the start of the experiment, the birds receiving the complete finisher feed *ad libitum* in the feedlot and those groups grazing lucerne and receiving 1500g and 1000g supplementary feed/bird/day, reached a mean slaughter weight of approximately 95kg. As these three groups were, therefore, ready for slaughter at the same time, they were removed from the experiment and sent to the abattoir in Malmesbury for slaughtering. For the purposes of this study, it was necessary to perform a one-way analysis of variance on the growth data of the ostriches from the age of 26 weeks up to 48 weeks of age, i.e. a 154 day period. Data collection for the other two groups continued until they also reached a mean slaughter weight of 95kg, but was not analyzed statistically after the cut-off point of 48 weeks. The birds receiving 500g supplementary feed per day reached the target weight of approximately

95kg after 205 days, while the ostriches receiving no supplementary feed took 224 days to reach target slaughter weight.

Grazing ostriches receiving 1500g/bird/day and those receiving the complete feed, grew significantly faster than the groups grazing pasture and receiving 500 or 0g supplementary feed/bird/day, but the feedlot ostriches did not grow significantly faster than the birds receiving 1000g supplementary feed/bird/day. Birds receiving 1500g supplementary feed/bird/day did grow significantly faster than birds receiving 1000g supplementary feed/bird/day. The ADGs of birds receiving supplementation while grazing lucerne pasture steadily declined significantly with declining levels of supplementary feed from 1500g/bird/day to 0g/bird/day.

The mean FCR (kg feed/kg weight gain) of the different groups of ostriches were respectively 9.6 (feedlot ostriches), 7.7 (lucerne grazing and 1500g supplementary feed/bird/day), 9.4 (lucerne grazing and 1000g supplementary feed/bird/day), 10.6 (lucerne grazing and 500g supplementary feed/bird/day) and 10.4 (lucerne grazing only). The absolute values are graphically illustrated in Figure 4.3 below as well as the regression, which was fitted between the FCR of each group of birds and level of supplementary feed. There tended to be a relationship ($P = 0.09$ and $R^2 = 0.82$) between the FCR of each group and level of supplementation.

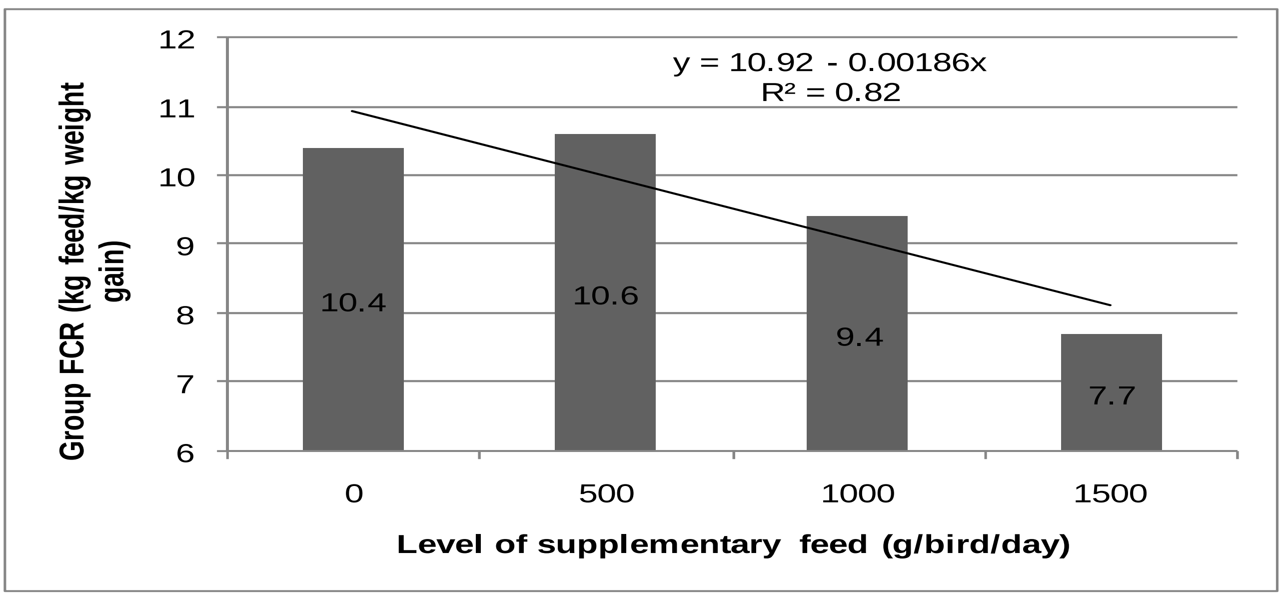

Figure 4.3 The relationship between the FCR (kg feed/kg weight gain) attained by each group of birds and level of supplementary feed (g/bird/day) by ostriches grazing irrigated lucerne pasture while receiving supplementary feed.

b) Pasture data

Collected pasture samples were composed mainly of lucerne, with only negligible quantities of clover, grass, broad-leaved weeds and dry/dead material. The ostriches, therefore, consumed mainly lucerne.

No interaction (P >0.05) was found between the level of supplementary feed supplied and elapsed time (months) for the percentage of lucerne intake (P =0.97). Data is therefore provided as the two main effects of the level of supplementary feed and the months. The percentage of lucerne ingested did not differ (P >0.05) from one another due to the different levels of supplementary feed supplied (P =0.73), and ranged from 86.4% for the 0g/bird/day group, 93.3% for the 500g/bird/day group, 85.1% for the 1000g/bird/day group, and 87.7% for the 1500g/bird/day group. There was also no difference (P >0.05) in the percentage of lucerne ingested during the period October 2005 to February 2006 (P =0.13), and the percentage of lucerne intake ranged between 78.2% (October), 85.6% (November), 94.9% (December), 89.4% (January) and 92.4% (February).

No interaction (P >0.05) was found between the level of supplementary feed and elapsed time (months) regarding either lucerne production (P =0.94) or lucerne intake (P =0.78). Data is therefore provided as the two main effects of the level of supplementary feed and the month. Lucerne production was not influenced (P <0.05) by level of supplementary feeding (P =0.55). The production of lucerne did, however, differ (P =0.02) from month to month. It declined inexplicably during December and January, which may have been due to problems with irrigation. This was most probably the reason why there also was no difference (P >0.05) in the amount of lucerne the ostriches ingested at different levels of supplementary feeding (P =0.17), while the amount of lucerne ingested did differ month by month (P =0.03). Even when the data of December and January were removed from the data set and the intake and production data again analyzed statistically over the whole period, supplementary feeding still had no influence (P >0.05) on lucerne production (P =0.25) and intake (P =0.06). Using this data, an attempt was made to apply quadratic functions to the level of supplementary feeding and lucerne production and intake. In the case of lucerne production, it was once again not possible to apply a significant (P =0.13) quadratic model to the data. For the intake data, a quadratic relationship (P =0.02; R^2 = 0.44) was found (Figure 4.4). It was deducted from the applied function ($Y = 1133.63 + 1.805X – 0.002X^2$), that the maximum lucerne intake level1692.8g/bird/day) was achieved at 619.6g supplementary feed/bird/day.

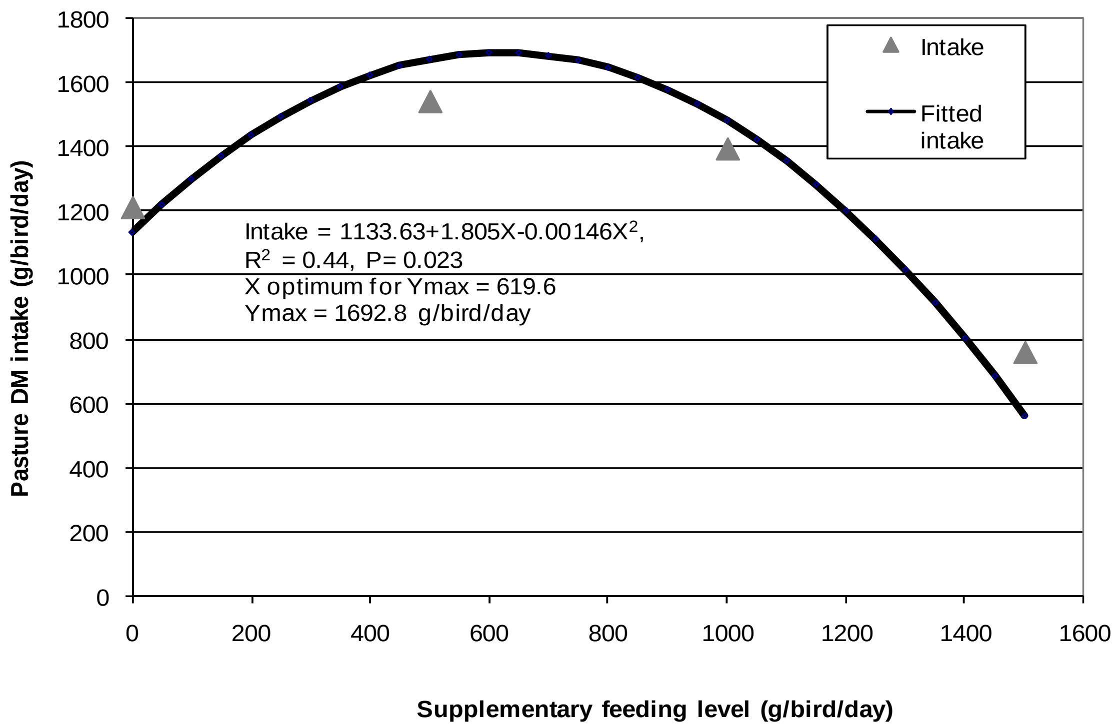

Figure 4.4 Relationship between pasture DM intake (g/bird/day) on irrigated lucerne pastures and the level of supplementary feeding (g/bird/day) by ostriches

The significant differences in the amounts of lucerne produced and ingested over the five month period are illustrated in Table 4.5.

Table 4.5 The amount of lucerne (kg/ha/day) produced and ingested by ostriches grazing irrigated lucerne pasture and receiving different levels of supplementary feed during October 2005 to February 2006. Values presented as mean ± se.

Month	Lucerne production (kg/ha/day)	Lucerne intake (kg/ha/day)
October	21.0^{ab} ± 3.4	16.5^{ab} ± 2.9
November	24.0^{a} ± 2.7	17.7^{ab} ± 2.8
December	15.7^{bc} ± 2.8	10.2^{c} ± 1.6
January	9.6^{c} ± 2.2	12.7^{bc} ± 1.8
February	16.7^{b} ± 3.8	20.3^{a} ± 3.0
P-value	0.02	0.03

$^{a, b, c}$ Column means with common superscripts do not differ (P >0.05).

The yield of lucerne being grazed by ostriches receiving different amounts of supplementary feed was highest during November and lowest during January. During the month of December ostriches ingested the lowest amount of lucerne. This did not differ significantly from the amount ingested in January, but it did differ significantly from the amounts ingested during the other months.

There was no interaction (P >0.05) between the level of supplementary feed and elapsed time (months) in respect of both the available (before grazing) and residual (after grazing) lucerne. The two main effects of the level of supplementary feed and the months are therefore provided. There was no difference (P >0.05) in the amount of available lucerne due either to the level of supplementary feed supplied (P =0.49) or due to months (P =0.13). There tended (P =0.10) to be a difference in the residual lucerne after grazing attributable to the level of supplementary feed supplied. This is tabulated in Table 4.6. The residual lucerne after grazing did not differ between months (P =0.16).

Table 4.6 The amount of residual lucerne (kg/ha) after being grazed by ostriches receiving different levels of supplementary feed. Values presented as mean ± se.

Level of supplementary feeding (g/bird/day)	Residual lucerne pasture (kg/ha)
0	894.5[b] ± 84.0
500	1087.4[ab] ± 134.5
1000	1161.4[ab] ± 111.2
1500	1391.2[a] ± 130.7
P-value	0.10

[a, b, c] Column means with common superscripts do not differ (P >0.05).

Although, according to Table 4.6, the level of residual lucerne clearly declined with increased level of supplementary feed, this decline was only significant between 1500g/bird/day and 0g/bird/day.

Discussion

a) Ostrich data

According to a study done by Swart & Kemm (1985), the ADG for feedlot-raised ostriches weighing between 60 – 110kg (aged 7 – 15 months) ranged from 129 – 240g/day, with an average of 189g/day and the FCR of the same group of birds ranged from 10 to 15.4, with an average of 12.8. These researchers concluded that a diet that contained about 35% lucerne led to the best FCR of 10kg feed/kg gain for these birds. The complete finisher diet supplied in the current trial contained 61% lucerne and these birds showed better ADGs (269.6g/day) than those of Swart & Kemm (1985). The FCR reached by the group of ostriches of the current trial for the feedlot treatment was better (9.6kg feed/kg weight gain) than those of Swart & Kemm's study (12.8kg feed/kg weight gain), which indicated that a larger quantity of a high quality forage source like lucerne can lead to better FCRs for finisher ostriches in a feedlot. It must, however, be kept in mind that the diets used in Swart & Kemm's study were meals, whereas the diets in the current study were pelleted, which could have had an effect on intake and digestibility due to particle size.

In a study done by Brand *et al.* (2000), three complete finisher diets containing respectively 94, 54 and 15% high quality lucerne hay was fed to ostriches aged from 20 – 56 weeks. The birds on the high fibre diet consumed less feed per day than birds on the other two diets, and therefore had lower ADG than birds on the low fibre diet. The ADG attained by the birds on the high fibre diet was 228g/bird/day, compared to 279g/bird/day for the birds on the low fibre diet. This could also be seen in the current trial, where birds having access only to lucerne pasture (similar to a high fibre diet), consumed 1073g/bird/day and grew at 103.4g/bird/day, whereas the birds in the feedlot (similar to a low fibre diet), consumed 2585g/bird/day and grew at 269.6g/bird/day. The FCR attained by the three groups of birds in the study of Brand *et al*., were respectively 10.1, 11.1, and 10.1kg feed/kg weight gain and did not differ significantly from one another. The mean live weights of the birds on the three diets also did not differ significantly from one another. These researchers concluded that the FCR of birds aged 12 to 52 weeks will not be influenced negatively if birds consume a diet containing a high percentage of a good quality fibre in the form of lucerne hay. The mean ADG reached by the feedlot birds (269.6g/day) in the current study was very similar to the mean ADG reached by the birds in Brand *et al.*'s study (279g/bird/day), but the mean FCR reached by the feedlot group of birds in the current study (9.6kg feed/kg weight gain) was better than the mean FCR reached by the birds in Brand *et al.*'s study (11.1kg feed/kg weight gain). According to Brand (2010, T.S. Brand, Pers. Comm., Elsenburg Animal Production Institute, Department of Agriculture: Western Cape, Private Bag X1, Elsenburg, 7607), this could be due to various factors, e.g. genetic differences, season of the year, exposure to sickness in earlier growth phases, energy and forage composition of diets and also due to the fact that individual DM intakes in the current study could not be determined.

In a grazing study of Farrell *et al.* (2000), ostriches weighing approximately 50kg (grower phase) had access to a mixed species pasture, containing mainly Rhodes grass, kikuyu and white clover. In this study, the grazing birds were supplied with different levels of the same mash (i.e. 100%, 80%, 70% and 60% of intake). The mean ADGs and FCRs were 299g/day and 4.7 (100% of intake), 254g/day and 4.4 (80% of intake), 279g/day and 3.6 (70% of intake) and 248g/day and 3.5 (60% of intake) respectively. In a second study by the same researchers, ostriches weighing approximately 37kg (beginner phase) were used in the same way as in the first experiment, except that the mash was supplied as 100%, 75% and 50% of intake. The ADGs and FCRs reached in this study were 377g/day and 5.3 (100% of intake), 299g/day and 5.4 (75% of intake) and 196g/day and 6.1 (50% of intake) respectively. The grazing ostriches receiving the mash at 100% of their intake reached a mean slaughter weight of 95kg in 140 days. The ostriches receiving mash at 60 and 70% of total intake in these two studies showed better ADGs and FCRs than the birds in our study receiving supplementary feed at 62% (i.e. 1000g supplementary feed/bird/day) and 76% (i.e. 1500g supplementary feed/bird/day) of total feed intake. This is mainly because the birds in our study were older (weighing approximately 59kg at the start of the experiment), leading to their naturally having worse ADGs and FCRs. The grazing ostriches receiving 1500g and 1000g supplementary feed/bird/day in our study reached their target weight of 95kg in 154 days, which compares very well with the 140 days taken by the younger ostriches in the study of Farrell *et al.* (2000). The mash provided together with the mixed species grazing in Farrell *et al.* (2000)'s study contained 200g/kg CP and 12.1 MJ AME/kg mash. The CP content is slightly higher than required by either beginner or grower birds, which probably enabled these birds to still show good ADGs and FCRs even if the mixed species pasture was of a very low quality (mean CP content of 4%). However, although the ADG and FCR reached in the study of Farrell *et al.* (2000) were higher than the results of this study, these studies showed the same trend as in this study. As the level of supplementation increased, ADG also increased. In the first study of these researchers, it was found that the FCR increased (became worse) when increasing the amount of mash provided and in their second study, the reverse trend was observed, i.e. the FCR became better when increasing the amount of mash provided.

Figure 4.1 depicts clearly that the ostriches receiving supplementation at 1500g/bird/day showed the best growth, closely followed by the ostriches receiving the complete finisher diet in the feedlot. The ostriches receiving 0g/bird/day showed the slowest growth. Birds grazing lucerne and receiving supplementation at respectively 1500g, 1000 and 500g/bird/day grew 164%, 135% and 94% faster than birds receiving no supplementation while grazing. This linear growth of ostriches during the finisher period is in accordance with the linear growth found by Nitzan *et al.* (2002) for beginner ostriches aged 10 weeks. These beginner ostriches received either two different levels of concentrate while grazing lush green pastures for 4 – 6 hours per day, or a concentrate without access to grazing. They found no significant differences in the mean live weights of ostriches receiving either 20 or 30g concentrate/bird/day while grazing, and those being fed 40g concentrate/bird/day without access to grazing. This contrasts to the findings of our study, in which significant differences were found between the grazing birds receiving 1500g, 1000g, 500g and 0g supplementary feed/bird/day. However, in our study the mean live weights of the group receiving a complete finisher diet *ad libitum* also did not differ (P >0.05) from the groups receiving 1500g or 1000g supplementary feed/bird/day. The mean ADG and FCR found for the beginner ostriches were 347g/day and 3.1kg feed/kg weight gain respectively. These values are much higher than the values found in our study, but this could be explained by the fact that the ostriches used in the study of Nitzan *et al.* (2002) were much younger (beginner phase) than the birds used in our study (finisher phase). This is because during their first 210 days ostriches have a very efficient FCR, but after 330 days they become less efficient and their FCR drops (Aganga *et al.*, 2003).

The findings of this study are in accordance with the study of Glatz *et al.* (2005), who found that the growth of ostriches (49 – 78kg live weight) receiving a commercial grower diet at 80% of intake and allowed to graze lucerne for 3 – 5 hours per day, was not negatively affected in comparison with the growth of ostriches receiving a completely balanced diet with zero grazing. They had similar weight gains to the ostriches raised in the feedlot. The researchers concluded that lucerne pastures can replace 20% of the grower diet without any negative effect on the growth of the ostriches.

b) Pasture data

According to Brand *et al.* (2005) feed intake will increase significantly with a decrease in the dietary energy level during the growing and finishing phases of slaughter ostriches. This decrease in feed energy content will lead to an increase in the amount of feed consumed per kg weight gain leading to an increase in FCR. Farrell *et al.* (2000) found that the DM pasture intake of grazing ostriches in the grower phase increased with the decreasing level of supplementation supplied (703g pasture/bird/day for birds receiving the mash at 100% of intake to 858g pasture/bird/day for birds receiving the mash at 70% of intake). This trend was observed up to the point where the ostriches received the mash at only 60% of their intake. After this point the lucerne intake by the ostriches declined. These findings are in accordance with the findings of the current study. According to Figure 4.4, DM pasture intake increased with increasing levels of supplementation, but only up to a certain level of supplementation, which was 619.6g supplementary feed/bird/day. The maximum pasture intake was 1692.8g lucerne pasture/bird/day. After this level of supplementation, pasture intake started to decline. According to Figure 4.4, from relatively low levels of supplementary feed, the DM pasture intake is positively influenced with increasing levels of supplementation. However, above a certain level of supplementation, substitution occurred and DM pasture intake decreased. A different trend was found by Nitzan *et al.* (2002) for ostrich chicks aged 10 – 30 weeks. These researchers found higher intakes of pasture DM for the groups of ostriches receiving the lowest amount of concentrate. Ostriches receiving only 20g/bird/day of supplementary feed and allowed to graze lush lucerne pastures for 4 – 6 hours per day had a mean pasture DM intake of 390g/bird/day, while the group receiving 30g/bird/day of supplementary feed had a mean pasture DM intake of 260g/bird/day. These researchers concluded that ostrich chicks grazing lush green pasture can reduce their concentrate intake by up to 40% without having a detrimental effect on the growth performance of the birds. Another study by Glatz *et al.* (2005) confirmed that 20% of the concentrate diet can be replaced with lucerne-based pastures without a negative effect on ostrich growth. Supplementary feeding can therefore allow higher stocking rates per hectare of pasture and a decrease in high cost supplementary feeding.

According to Durand (1993) the DM production of irrigated lucerne pastures in the Boland area of the Western Cape follows a seasonal growth pattern with peak production during the summer months, with the lowest production during the winter months. The highest production of SA Standard lucerne being grazed by sheep in a four-paddock rotational system at the Elsenburg Research Centre near Stellenbosch in his study was between November and January of each year (25 – 40kg DM/ha/day), and the lowest yield between May and July each year (5 – 10kg DM/ha/day). The highest yield period of SA Standard lucerne in Durand's study was not in accordance with our study, where the highest yield of lucerne being grazed by ostriches receiving different amounts of supplementary feed was in October to November (late spring)(21 – 24kg DM/ha/day). In our study lucerne production was uncharacteristically low during the peak production time of lucerne for this area and time (December having production of 15.7 and January having a very low production of 9.6kg/ha/day). This is why these two months were omitted from the analysis of variance. During February, lucerne production was again higher at 16.7kg/ha/day. The average lucerne that was produced from October 2005 to February 2006 during our study was 17.4kg DM/ha/day, which is in accordance with the average lucerne that was produced over a period of two years (17.39kg DM/ha/day) in Durand's study. This researcher also found a sharp decline in lucerne production during December and January, which could indicate too little irrigation during this time, paralleling the irrigation problems experienced in the current trial during these two months. According to Durand (1993), the irrigation of lucerne pastures can lead to the pasture growing actively for a longer period of time. This is evident in the original lucerne production data in the current study. In addition to the peak production in October to November, lucerne production increased again after January. Van Heerden *et al.* (1993) found a mean yearly production of 30kg DM/ha/day for the same cultivar being subjected to a four-weekly cutting system. This is higher than the values found in our study (17.4kg DM/ha/day), possibly indicating that the trampling and continuous grazing of pasture by livestock was an additional factor in production.

From the analysis of variance done on the original data (without the months of December and January omitted) and Table 4.5, it is clear that the lucerne intake by ostriches during October to December tended to be less than the amounts of lucerne produced during this time. From January onwards, lucerne DM intake by the ostriches was higher than the amount of lucerne DM produced. Pasture could have been under-grazed from October to December, but over-grazed from January onwards. During the month of December, the ostriches ingested the lowest amount of lucerne. This was significantly lower than the amounts ingested in the other months, except January. Although the amount of lucerne ingested in January was also low, it was not significantly lower than in October to December. These lower intakes during December and January were most probably because the production of lucerne during these two months was also lower than expected, and this is why the data of these two months were omitted from the analysis of variance. The lower intakes of lucerne during these two months were experienced despite the fact that the amount of available lucerne did not differ significantly during the five months of the trial. According to Bargo *et al.* (2003) the DM intake of pastures will be affected by pre-grazing pasture mass. This is emphasized by Allden & Whittaker (1970), who stated that there is a close relationship between the rate of intake of pasture and pasture availability. Since the pregrazing amount of available lucerne DM in our study did not differ significantly between treatments, the intake of lucerne by the ostriches could not have been influenced by the pregrazing level of lucerne available. This is in contrast to studies done by Popp *et al.* (1997a & b) in which it was found that the amounts of pasture ingested by cattle will gradually decline because the availability of pasture declines as the study progressed.

Supplying increasing levels of supplementary feed to grazing ostriches did however tend to have a gradual elevating effect on residual lucerne DM (Table 4.6). Karnezos *et al.* (1994) did a study with lambs grazing lucerne, which received different amounts of a maize supplement and also found that lucerne disappearance decreased linearly with increasing levels of maize supplementation. The greatest amount of lucerne residue was associated with the lowest forage disappearance and greatest level of supplementation, which is in accordance with our study.

Conclusion

The mean live weights reached during the 154-day trial did not differ significantly between ostriches receiving a complete finisher diet *ad libitum* in a feedlot and those ostriches receiving either 1500g or 1000g supplementary feed/bird/day and all three these groups reached a mean target slaughter weight of 95kg within the time of the study. It can be concluded that finisher ostriches allowed to graze a high quality pasture like lucerne can reach slaughter weight at approximately the same time as feedlot raised ostriches if they are supplied with a complementary supplement of at least 1000g/bird/day. Although the ADG of the group receiving 1000g supplementary feed/bird/day was significantly lower than the ADG of the 1500g supplementary feed/bird/day group, these ostriches still reached a mean target slaughter weight of approximately 95kg at the same time as the ostriches receiving 1500g supplementary feed/bird/day and the feedlot ostriches. This leads to the conclusion that pastures, when combined with the correct supplementation, can replace complete feeds in the finishing phase of slaughter ostriches. This re-enforces the fact that pasture of high quality can play an important role in the production of slaughter ostriches. This study concludes, therefore, that finisher ostriches can grow as satisfactorily while grazing a high quality pasture like lucerne and receiving the correct formulation and amount of supplementary feed, as ostriches raised on a complete finisher diet in a feedlot situation.

According to Cilliers (2003), feed intake is the single most important factor determining the growth of an animal. When feed intake is restricted, it leads to slower growth, lower FCR and longer periods needed for finishing. It can be concluded from Figure 4.4 that moderate levels of supplementary feeding will increase pasture intake by ostriches. This increase in pasture intake occurred up to a certain point of supplementation (619.6g/bird/day), after which the pasture intake started to decline. The conclusion reached with this study is that when finishing ostriches grazing lucerne pastures are supplied with 619.6g supplementary feed/bird/day, their pasture intake will be at a maximum of 1692.8g pasture/bird/day.

When having no supplementary feed available to them, ostriches consumed less pasture than when having 619.6g supplementary feed per day available to them. This underlines the fact that supplementary feed plays an important role in grazing and can lead to an increase in the intake of pasture by ostriches. Moderate levels of feed supplementation (619.6g/bird/day) may therefore increase efficiency by promoting pasture intake. Moderate supplementation should therefore make it possible to increase the stocking rate. This should result in higher production per hectare pasture without additional costs as more animals can be carried per hectare. This trial was, however, conducted at only one stocking rate and further research needs to be done at a range of stocking rates to test this theory.

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Chapter 5

A study of the substitution effect of fresh lucerne by concentrates in the diets of ostriches as well as the digestibility values of these selected diets for ostriches and roosters

Abstract

A digestibility trial was conducted with ostriches (aged 6.5 – 10.5 months) to determine the digestibility of diets when ostriches are fed fresh lucerne pasture together with different levels of supplementary feed. The substitution effect of supplementary feed on pasture utilization was also investigated. Dry matter (DM), crude protein (CP), lysine, methionine and threonine digestibilities, as well as apparent metabolizable energy (AME) and apparent metabolizable energy, corrected for zero nitrogen (AMEn), values were determined by the balance method for diets containing a forage source (lucerne pasture) and different amounts of a supplementary feed (mash) formulated to complement the pasture. The ostrich basal diet contained *ad libitum* fresh lucerne pasture, and the other diets *ad libitum* fresh lucerne pasture with supplementary feed supplied at respectively 50, 62, 76, 81 and 100% of total feed intake. The same diets were then fed to roosters to obtain energy values for these diets for roosters. These energy values were used to obtain a regression equation whereby ostrich energy values can be predicted from rooster energy values. Six roosters received maize as the sole dietary component, while the remaining 36 roosters received similar diets as the ostriches, except that lucerne-meal was used instead of fresh lucerne pasture and each diet was diluted with 50% maize to prevent digestive disorders. The diets of the roosters were pelleted. Food and excreta collection were carried out over a period of five days after the ostriches and roosters had adapted to the respective diets for seven and 12 days respectively. A significant substitution effect was established between DM supplementary feed intake (g/bird/day) and amount of pasture intake (%). According to the linear equation, for each 100g increase in supplementary feed intake, pasture intake declined by 4.9%. An analysis of variance revealed that the pasture DM intake of ostriches started to decline when supplementation was supplied at levels higher than 62% of total feed intake (levels higher than 1000g/bird/day). This indicate that ostriches grazing irrigated lucerne pastures substituted supplementary feed for pasture at concentrate levels higher than 62% of total feed intake. After an initial effect of promoting pasture intake, concentrate supplementation at levels higher than 62% of total feed intake led to a decline in pasture intake. Significantly higher total DM feed intakes were reached by ostriches if they grazed lucerne pastures and received some supplementary feed than if they grazed lucerne pasture alone. Dry matter digestibility (DMD) as well as AME and AMEn values increased at higher levels of supplementary feed for both ostriches and roosters. Dry matter digestibility, AME and AMEn values were also significantly higher for the diets containing supplementary feed as compared to the diet containing only the forage source (fresh pasture for ostriches and lucerne-meal for roosters). Retention of CP, lysine, methionine and threonine increased with increasing levels of supplementary feed provided to ostriches grazing lucerne pastures. A significant stepwise regression could not be computed for ostrich AME values predicted from rooster AME values.

Keywords: ostriches, poultry, lucerne, supplementary feed, pasture intake, total feed intake, dry matter digestibility, crude protein, amino acids, metabolizable energy, retention

Introduction

In order to produce high quality products from ostrich farming it is essential to ensure that nutrient supply matches the nutrient requirements of growing ostriches. In order to achieve this, it is essential to obtain information on the feed utilization efficiency and the nutrient requirements of ostriches at different growth stages. Data from other poultry species such as turkeys and chickens were initially used by ostrich farmers as a guideline for the formulation of ostrich feed. In recent years, more data concerning feed utilization by ostriches has become available (Miao & Glatz, 2003).

In one of the first metabolism studies done on ostriches, Swart (1988) demonstrated that ostriches can effectively digest plant fibre and more specifically hemicelluloses (66%) and cellulose (38%) due to the presence of cellulose bacteria in the hind-gut of the ostrich. Swart *et al.* (1993b) showed that these end-products of fibre fermentation can contribute as much as 76% of the metabolizable energy (ME) requirement for maintenance in the growing ostrich. Cilliers *et al.* (1994) did a comparative study between ostriches and poultry and found that ostriches had an AMEn value of 8.9 MJ/kg for lucerne, whereas poultry had AMEn values of 4.5 and 4.1 MJ/kg for diets containing 250 and 500g/kg lucerne-meal respectively. These researchers concluded that ostriches were capable of digesting a high fibre ingredient such as lucerne-meal more efficiently. Ostriches therefore have the ability to metabolize gross energy of fibrous feedstuffs more efficiently than poultry (Miao & Glatz, 2003). Cilliers *et al.* (1997b) also confirmed that the true retention of dietary protein is higher for ostriches (64.6%) than roosters (60.9%). It was shown in further studies that fatty acids in raw materials like full-fat canola, canola oil cake (Brand *et al.*, 2000a) and lupins (Cilliers, 1994) are also utilized more efficiently by ostriches. Cilliers (1994) also found that ostriches show more efficient digestibilities for dietary fat in diets than poultry. Ostriches have a longer average food transit time (approximately 40 hours) in their gastro-intestinal tracts (Swart, 1988). This, together with the fact that ostriches have better feed utilization efficiencies and larger capacities for using high fibre diets (such as pastures) than poultry (Miao & Glatz, 2003), make the use of nutritive values (which have been reported for chickens) invalid (Nizza & Di Meo, 2000). Therefore, the normal practice of using the feed digestibility values derived from poultry or pig diet formulations for ostriches will under-estimate the true contents of these nutrients in raw materials for ostriches (Cilliers, 1994). This can lead to an oversupply of nutrients, which can lead to nutrition-related problems (Miao & Glatz, 2003). Digestibility trials done specifically for ostriches are therefore needed to provide accurate tables of nutritional value of ingredients for ostriches (Nizza & Di Meo, 2000). Due to a current lack of such values, regression equations including energy and fibre levels of the ingredients may also be used to predict such values (Brand & Gous, 2006).

The objective of feeding supplements to grazing animals is to increase total DM and metabolizable energy (ME) intakes compared to those achieved on pasture alone, but animals will generally substitute the supplement for some of the pasture that they would otherwise have eaten (Stockdale, 2000). Therefore, pasture DM intake usually decreases when grazing animals are fed supplements and this is known as the substitution effect (Faverdin *et al.*, 1991). The substitution rate is therefore the reduction in pasture DM intake per kg of supplement supplied. No work has been done concerning the substitution effect of mono-gastric animals on grazing (especially not in the case of ostriches) and therefore ruminant studies were used for comparison purposes. The substitution effect was illustrated by a study of Bargo *et al.* (2003) on dairy cows. Pasture DM intake decreased with the increasing amounts of concentrates fed, but the total DM intake of the cows increased. High substitution rates will lead to pasture that is not used as effectively (unless stocking rates are also increased) and this can ultimately lead to reduced profitability (Stockdale, 2000).

Due to the fact that concentrates are usually higher in digestibility than pastures, it can also be expected that as the inclusion of concentrates in the diet of grazing animals increase, so an increase in total digestibility will occur. No mono-gastric animal studies of this nature could be found, but according to a study done on sheep by Blaxter & Wilson (1963), the digestibility of the energy of hay was higher if it was fed together with a concentrate. This can possibly be due to the presence of concentrated food, which possibly promotes a more efficient digestion of the fibrous materials. These researchers also recorded that the total DM intake increased when concentrates were given together with hay. After the initial effect of promoting roughage intake, concentrate supplementation given at higher levels caused the intake of roughage to decline.

The aim of the current study is, firstly, to determine the digestibility of the diets of grazing ostriches receiving supplements. Secondly, to determine how the digestibility of the diets of grazing ostriches receiving supplementation differ from those of grazing ostriches receiving no supplementation. The third aim of the study was to determine if substitution of pasture with supplementary feed takes place in the case of grazing ostriches. The primary objective of feeding supplements to grazing animals is to increase total DM and nutrient intake and this chapter aims to determine if this is indeed the case with ostriches. Literature on the accompanying level of the substitution of supplementary feed for pasture is also non-existent (Brand, 2003). The same diets as were fed to the ostriches will be fed to roosters to obtain energy values for roosters. These energy values will be used to obtain a regression equation whereby ostrich energy values can be calculated from rooster energy values.

Materials and methods

Experimental site:

The ostrich digestibility study was conducted at the Kromme Rhee Experimental Farm in the Western Cape Province near Stellenbosch. The study commenced in April 2008 and was concluded in May 2008. The experimental site is situated at longitude 18º50’ East and latitude 33º51’ South in the Southern Hemisphere. The altitude at Kromme Rhee is 177m above sea level with a climate that is typically Mediterranean. The mean annual rainfall is 622.7mm (for a 30-year average) and 84% of this rainfall is received between the months of April and October (Labuschagne, 2005). The type of soil is classified as a Hutton (McVicar *et al.*, 1977). The rooster digestibility study was conducted at the Mariendal Experimental Farm in the Western Cape Province, which is situated adjacent to the Kromme Rhee Experimental Farm near Stellenbosch. This study commenced in November 2008 and was concluded in December 2008.

Diets:

a) Ostriches

Freshly cut lucerne forage served as the basal diet for the experimental ostriches. The fresh lucerne for each ostrich was cut with hand shears every day. This was produced at the existing irrigated lucerne pastures (cv. SA Standard) which were established six years earlier and used in the first supplementation study of this thesis (Chapter 4). Each ostrich received this fresh lucerne pasture *ad libitum*. In addition to the fresh lucerne forage, each ostrich received increasing amounts of supplementary feed. The supplementary feed was supplied as a mash (8mm sieve) and formulated to complement the nutrients that are lacking in the lucerne pasture according to the nutrient requirements of ostriches. The ingredient and nutrient composition of the supplementary feed is presented in Table 5.1.

Table 5.1 Ingredient (kg) and nutrient (%) composition of the supplementary feed supplied to finishing ostriches during the digestibility trial (values are *as fed* values).

Ingredients (kg/ton feed):	
Yellow maize	758
Soybean seeds meal (44% CP)	127
Molasses powder (Calorie 3000®)	30
Monocalciumphosphate	27
Limestone, ground	23
Common salt	25
Ratite Finisher Vitamin & Mineral Premix	10
Nutrients (%):	
TMEostrich (MJ/kg)	13.5
CP	12.2
Lysine	0.54
Methionine & Cystine	0.44
Threonine	0.44
Tryptophan	0.14
Arginine	0.69

The supplementary feed was formulated using the computer programme MIXIT-2™ (1982) and the composition of the supplementary feed supplied was formulated according to the nutrient requirements of the ostriches for this growth stage at a level of 1000g of supplementary feed/bird/day plus 1500g lucerne pasture/bird/day (Brand & Gous, 2006).

As a result, the ostriches received the following feed treatments:

Treatment 1: Freshly cut *ad libitum* lucerne pasture as a basal diet (100% lucerne).
Treatment 2: Freshly cut *ad libitum* lucerne pasture and 500g supplementary feed/bird/day.
Treatment 3: Freshly cut *ad libitum* lucerne pasture and 1000g supplementary feed/bird/day.
Treatment 4: Freshly cut *ad libitum* lucerne pasture and 1500g supplementary feed/bird/day.
Treatment 5: Freshly cut *ad libitum* lucerne pasture and 2000g supplementary feed/bird/day.
Treatment 6: 3000g supplementary feed/bird/day (100% supplementary feed).

Since the fresh lucerne forage intake and the supplementary feed intake of each bird were calculated each day, it was established that the ostriches consumed supplementary feed at the following percentages:

Treatment 1: No supplementary feed intake (0%)
Treatment 2: 50% of total feed intake originating from supplementary feed
Treatment 3: 62% of total feed intake originating from supplementary feed
Treatment 4: 76% of total feed intake originating from supplementary feed
Treatment 5: 81% of total feed intake originating from supplementary feed
Treatment 6: 100% of total feed intake was supplementary feed

The chemical compositions of the rations selected by the ostriches are shown in Table 5.2 below:

Table 5.2 Chemical composition of the total diets (pasture plus supplementary feed) fed to finishing ostriches during the digestibility trial (Values are expressed on a DM-basis).

Lucerne pasture + Supplementary feed	**Supplementary feeding level (%)**					
	0	**50**	**62**	**76**	**81**	**100**
Energy content (MJ/kg)	17.6	17.2	17.2	17.1	17.1	16.9
CP (%)	24.5	18.6	17.9	16.2	15.6	13.5
NDF (%)	33.6	20.1	19.3	15.6	14.9	10.5
ADF (%)	29.4	15.2	14.2	10.4	9.7	4.6
Fat (%)	3.83	3.78	3.79	3.76	3.77	3.79
Lysine (%)	1.2	0.82	0.79	0.65	0.63	0.49
Methionine (%)	0.07	0.11	0.11	0.12	0.13	0.14
Threonine (%)	0.73	0.56	0.55	0.52	0.49	0.43

b) Roosters

To create exactly the same diet treatments for the roosters as was consumed by the ostriches without causing digestive disorders, maize was mixed as a basal feed ingredient (at 50%) with the same quantities of supplementary feed and/or lucerne as was used in the digestibility trial for ostriches. Lucerne-meal was used instead of fresh lucerne to compile the complete diets for the roosters. By using the same percentage supplementary feed intakes reached by the ostriches (i.e. 0, 50, 62, 76, 81 and 100%), the supplementary feed was mixed with the maize in these concentrations to obtain the same diet treatments for the roosters. The digestibility values of the basal maize diet (Diet 7) were used to calculate the digestibility values of the diets containing lucerne-meal and supplementary feed in the other diets. As a result, the diets of the roosters were composed as in Table 5.3 below.

Table 5.3 Ingredient (%) composition of the diets as fed to the roosters during the digestibility trial.

Supplementary feeding level (%)	Maize	Lucerne-meal	Supplementary feed
0	50	50	0
50	50	25	25
62	50	19	31
76	50	12	38
81	50	9.5	40.5
100	50	0	50
Control diet (100% maize)	100	0	0

The chemical compositions of the diets fed to the roosters (without the 50% inclusion of maize) are illustrated in Table 5.4 below.

Table 5.4 Chemical composition of the diets (without 50% maize) fed to roosters during the digestibility trial (Values are expressed on a DM-basis).

	Supplementary feeding level (%)					
	0	**50**	**62**	**76**	**81**	**100**
Energy content (MJ/kg)	17.5	17.3	17.3	16.9	17.2	17.4
CP (%)	18.1	16.6	16.9	15.2	15.2	13.8
Lysine (%)	1.1	0.79	0.70	0.64	0.51	0.47
Methionine (%)	0.02	0.04	0.04	0.15	0.11	0.16
Threonine (%)	0.62	0.58	0.53	0.51	0.40	0.43

Experimental animals and animal husbandry:

a) Ostriches

Twelve African Black ostriches (*Struthio camelus* var *domesticus*) aged 6.5 – 10.5 months (60 – 90kg) were used as experimental animals. The ostriches were individually housed in a single wooden metabolism crate (110cm x 210cm x 240cm), each equipped with its own water trough. Each metabolism crate was also equipped with two feeding troughs, one for the freshly cut lucerne and one for the supplementary feed. Twelve crates in an open-sided building were available for the experiment. A harness was attached to each bird, which allowed the ostrich free movement in the cage. A canvas bag, lined on the inside with a plastic bag, was attached to each harness by means of Velcro and used to collect daily excreta from the birds. Each canvas bag fitted snugly over the entire tail region of each bird.

Prior to the start of each digestibility trial, the ostriches were adapted to their respective diets, harnesses and metabolism crates for a week. During the adaptation period, the canvas bags were not attached to the harnesses of the ostriches, and therefore no excreta was collected during the adaptation period. Each of the six diets was randomly subjected to two ostriches per trial run. The trial runs were repeated twice, giving four observations per dietary treatment. The birds were fed the diets once a day while the consumption of supplementary feed and fresh lucerne forage was recorded daily.

At the end of the adaptation period, each ostrich received its allocated test diet, i.e. either 0, 500, 1000, 1500 and 2000g supplementary feed together with *ad libitum* fresh lucerne forage and 3000g supplementary feed without lucerne forage. The supplementary feed and lucerne forage intakes were calculated for each day and the excreta were collected from the canvas bags, which were connected to the harnesses. These canvas bags were emptied twice a day to prevent excreta losses during squatting. Excreta collection continued until a total of four days' excreta could be collected from each bird. The daily excreta for each bird were weighed immediately after collection, after which the excreta were thoroughly blended in a Waring Commercial Heavy Duty Blender (Waring Products Division, New Hartford, Conn., U.S.A.) before drying in a forced draught oven at 60ºC to constant weight. After drying, the oven was switched off and the excreta were allowed to reach equilibrium with atmospheric moisture for 24 hours before being weighed again. They were then milled through a 1mm sieve (C & N Laboratory Mill Size 8", Christy & Norris Ltd., Chelmsford, England) and the excreta of individual birds were pooled over the days and stored in plastic jars pending chemical analyses.

b) Roosters

Forty-eight Lohmann Brown roosters (*Gallus gallus* var *domesticus*) (1.8 – 2.3 kg) (20 weeks of age) were used for the rooster digestibility study. The roosters were housed in rows of individual wire cages (40.6cm x 50.8cm x 30.5cm) with raised floors. A collection tray was situated underneath each cage for the collection of excreta. Water was provided by a nipple system and feed was available in a trough running the full length of each row of cages. Room temperature was controlled with a fan system and ranged between 22 and 25ºC. Minimum ventilation was set to six air changes per hour. A 16-hour lighting regime was applied. Seven diets were randomly allocated to forty-two roosters, therefore leading to six replications. Roosters were allowed *ad libitum* intake of the test diets for 12 days prior to the start of the trial in order to adapt their digestive tracts properly to the higher fibre diets. After the adaptation period, a 24 hour fasting period to empty their digestive tracts followed. After the fasting period, the roosters were offered the test diets for four days, and their food intakes and excreta outputs were recorded during these four days. The birds were fed once a day and food intake was recorded for each individual. The daily excreta of each bird were collected twice daily from the collection trays and weighed before the daily droppings of each bird were pooled over four days. The excreta were then dried in a forced draught oven at 60ºC to constant weight. After drying, the oven was switched off and the excreta were allowed to reach equilibrium with atmospheric moisture for 24 hours, before being weighed again. They were then milled through a 1mm sieve (C & N Laboratory Mill Size 8", Christy & Norris Ltd., Chelmsford, England) and stored in plastic jars pending chemical analyses.

Chemical analysis:

A representative sample of the lucerne forage, supplementary feed and excreta was collected daily for ostriches. These samples, in addition to the faeces samples, were analyzed for concentrations of gross energy, ash, fat, crude fibre, NDF, ADF, CP, and amino acids. Gross energy was analyzed in a solid state bomb calorimeter (Modular Calorimeter MC-1000, Gallenkamp, England). Ash concentration was determined according to the AOAC Official Method 942.05 and fat was determined according to the AOAC Official Method 920.39. Crude fibre and NDF concentrations were both determined by using the Velp FIWE Raw Fibre Extractor (Velp Scientifica, Via Stazione 16, 20040 Usmate (Milano), Italy). Neutral detergent fibre was analyzed according to the method of Robertson & Van Soest (1981) and crude fibre was analyzed according to AOAC Official Method 978.10. The concentration of ADF was determinted according to the method of Goering & Van Soest (1970) using the Dosi Fibre system (Labex (Pty) Ltd, P.O. Box 46009, Orange Grove, 2119). Total nitrogen was determined by using the Dumas Combustion method according to the AOAC Official Method 968.06 with a Leco FP-428 Nitrogen Determinator (Leco Corporation, St. Joseph, MI, USA). Crude protein concentration was then estimated as 6.25 x N concentration. Amino acids were separated on a Dionex High-Performance Liquid Chromatography amino acid analyzer (Dionex Softron, Dornierstrabe 4, D-82110 Germering, Germany) using column Grom-Sil OPA-3, 3 µm (length 125.0mm x 4.0mm) (Grace Division Discovery Sciences, Brandstraat 12, B-9160, Lokeren, Belgium) after 6 N HCl and 1.5% phenol hydrolysis in a sealed tube for 24 hours at 110ºC using a RF 2000 Fluorescence Detector (Godel *et al.*, 1984; Graser *et al.*, 1985).

For each day that the roosters were fed and excreta collected, a representative sample of the feed was collected. These samples, in addition to the faeces samples, were analyzed for concentrations of gross energy, ash, CP, and amino acids. Gross energy was analyzed in a solid state bomb calorimeter (Modular Calorimeter MC-1000, Gallenkamp, England). Ash concentration was determined according to the AOAC Official Method 942.05. Total nitrogen was determined by using the Dumas Combustion method according to the AOAC Official Method 968.06 with a Leco FP-428 Nitrogen Determinator (Leco Corporation, St. Joseph, MI, USA). Crude protein concentration was then estimated as 6.25 x N concentration. Amino acids were also separated on a Dionex High-Performance Liquid Chromatography amino acid analyzer (Dionex Softron, Dornierstrabe 4, D-82110 Germering, Germany) using column Grom-Sil OPA-3, 3 µm (length 125.0mm x 4.0mm) (Grace Division Discovery Sciences, Brandstraat 12, B-9160, Lokeren, Belgium) after 6 N HCl and 1.5% phenol hydrolysis in a sealed tube for 24 hours at 110ºC using a RF 2000 Fluorescence Detector (Godel *et al.*, 1984; Graser *et al.*, 1985).

Calculation and statistical analysis of results

For the ostriches, DMD was calculated by averaging individual measurements for the various diets by using the following formula:

DMD (%) = [(DM intake (g) – DM excreted (g))/DM intake (g)] x 100

Crude protein, NDF, ADF and fat digestibilities were calculated in the same way respectively as DMD, using the following formula:

Nutrient (%) = [(Total nutrient intake (g) – total nutrient excreted (g))/ total nutrient intake (g)] x 100

According to Harris (1966), AME is the term that indicates the difference between gross energy (GE) intake and energy excreted as faeces and urine when feed is consumed. Apparent metabolizable energy was calculated by averaging individual measurements for the various diets by using the following formula:

AME (MJ/kg) = $(F_i \times GEf) - (E \times GE_e)/F_i$,

where F_i is the feed intake (g); E is the excreta output (g); GE_f is the gross energy/g of feed; and GE_e is the gross energy/g of excreta (Sibbald, 1989).

Apparent metabolizable energy (corrected for zero nitrogen) was calculated according to the following formula:

AMEn (MJ/kg) = $[(F_i \times GEf) - (E \times GE_e)] - (NR \times K)/F_i$,

where NR = $(F_i \times N_f - (E \times N_e)$; N_f is the nitrogen/g of feed (g); N_e is the nitrogen/g of excreta (g); and K is a constant, usually 36.5 kJ (Sibbald, 1989).

The same calculations were used for the roosters, except that the estimate for the test diet was calculated indirectly by the replacement method (Hill *et al.*, 1960). The AMEn values were calculated according to the formula AMEn = 0.009 + (0.948*AME), as suggested by Sibbald (1989).

For the retention of nutrients, the following formula was used:

Nutrient retention = Nutrient intake – Nutrient excreted (Sibbald, 1989).

The statistical analyses were performed by using the GLM procedures of Statistical Analysis System 9.1.3. for Windows (2002 - 2003) and a linear regression between DM supplementary feed intake and percentage lucerne pasture intake was performed on the data to determine if substitution by the ostriches had occurred. A stepwise regression was used to compute the relationship between rooster AME values of the diets and ostrich AME values of the same diets.

Results

a) Feed intake

Average intake (DM-basis) of lucerne forage and supplementary feed intakes of ostriches as recorded during this trial are illustrated in Table 5.5.

Table 5.5 Actual average DM-basis lucerne forage and supplementary feed intake of ostriches during the digestibility trial (Values presented as mean ± s.e.).

Supplementary feeding level (g/bird/day)	Lucerne forage intake		Supplementary feed intake		Total feed intake (DM)
	%	g DM/bird/day	%	g DM/bird/day	G DM/bird/day
0	100	467.3^{a} ± 39.9	0	-	467.3^{d} ± 75.9
500	50	485.2^{a} ± 45.0	50	448.1^{d} ± 68.6	933.4^{c} ± 85.7
1000	38	529.9^{a} ± 36.2	62	805.3^{c} ± 55.2	1335.2^{b} ± 68.9
1500	24	291.8^{b} ± 37.3	76	1107.9^{b} ± 56.9	1399.8^{b} ± 71.1
2000	19	374.9^{ab} ± 36.2	81	1536.7^{a} ± 55.2	1911.6^{a} ± 68.9
3000	0	-	100	1120.3^{b} ± 58.8	1120.3^{bc} ± 73.4
P-value		<.001		<.001	<.001

$^{a, b, c}$ Column means with common superscripts do not differ ($P > 0.05$).

The lucerne (DM-basis) intake of ostriches receiving different levels of supplementation while provided with freshly cut lucerne pasture differed ($P < 0.05$) from one another. The highest lucerne intakes (DM-basis) were reached by ostriches receiving 0, 50 or 62% of their total feed intake as supplementary feed (467.3, 485.2 and 529.9g DM/bird/day respectively). When the ostriches received supplementation at 76% of their total feed intake, lucerne DM intake declined and was lower ($P < 0.05$) than at the 0, 50 or 62% supplementation level (291.8g DM/bird/day).

While ostriches had access to freshly cut lucerne pasture, their supplementary feed intakes increased ($P < 0.05$) with increasing levels of supplementation. The highest supplementary feed intake (1536g DM/bird/day) was reached by ostriches receiving 81% of their total feed intake as supplementary feed. When ostriches received supplementation at 100% of their total feed intake, their supplementary feed intakes were lower ($P < 0.05$) than the supplementary feed intakes of the birds receiving supplementation at 81%, but were the same as the intake reached by birds receiving supplementation at 76%.

The total DM feed intakes of grazing ostriches receiving different levels of supplementation differed (P <0.05) from one another. The total DM feed intake of grazing ostriches receiving different levels of supplementation increased as the level of supplementation increased. Ostriches receiving no supplementation had the lowest (P <0.05) total DM intake (467.3g DM/bird/day). The total DM intake of this group was lower (P <0.05) than the total DM intake of all the other groups. The grazing ostriches which received the highest level of supplementation (81% of total feed intake), had the highest total DM intake (1911.6g DM/bird/day). This intake was higher (P <0.05) than the intakes of all the other groups. Ostriches receiving supplementation at 100% of their total feed intake had total DM intakes (1120.3g DM/bird/day) that did not differ (P >0.05) from the groups receiving supplementation at 50 (933.4g DM/bird/day), 62 (1335.2g DM/bird/day) or 76% (1399.8g DM/bird/day) of their total feed intake. This group did, however, have lower (P <0.05) intakes than the group receiving supplementation at 81% of its total feed intake.

Average DM feed intakes of roosters as recorded during this trial are illustrated in Table 5.6.

Table 5.6 Average DM feed intake of roosters during the digestibility trial (Values presented as mean ± s.e.).

Supplementary feeding level (%)	**Total DM feed intake (g/bird/day)**
0	84.9^{a} ± 13.3
50	70.2^{a} ± 10.7
62	73.2^{a} ± 7.9
76	89.2^{a} ± 9.9
81	81.6^{a} ± 8.9
100	62.9^{a} ± 8.8
P-value	0.46

$^{a, b, c}$ Column means with common superscripts do not differ (P >0.05).

The total DM feed intake of the roosters did not differ (P >0.05) between the dietary treatments.

b) Dry matter and apparent faecal CP digestibility

Dry matter and apparent faecal CP digestibility of ostriches and roosters subjected to the same diet treatments are illustrated in Table 5.7.

Table 5.7 Average DM and faecal CP digestibility of diets provided to ostriches and roosters during the digestibility trial (Values presented as mean ± s.e.).

Supplementary feeding level (%)	DMD (%)		CP digestibility (%)	
	Ostriches	Roosters	Ostriches	Roosters
0	$45.7^{b} \pm 2.6$	$37.2^{d} \pm 1.6$	$54.9^{a} \pm 4.6$	$54.1^{a} \pm 4.9$
50	$72.0^{a} \pm 2.8$	$63.7^{c} \pm 1.6$	$69.4^{a} \pm 4.6$	$56.4^{a} \pm 4.6$
62	$70.0^{a} \pm 2.6$	$63.8^{c} \pm 1.6$	$57.6^{a} \pm 3.5$	$62.7^{a} \pm 4.9$
76	$77.5^{a} \pm 2.6$	$70.3^{bc} \pm 1.6$	$59.8^{a} \pm 3.5$	$61.1^{a} \pm 4.9$
81	$77.1^{a} \pm 2.6$	$71.5^{b} \pm 1.6$	$60.5^{a} \pm 3.5$	$59.7^{a} \pm 4.6$
100	$76.8^{a} \pm 2.4$	$82.3^{a} \pm 1.6$	$70.7^{a} \pm 3.6$	$56.9^{a} \pm 4.6$
P-value	<.001	<.001	0.03	0.82

$^{a, b, c}$ Column means with common superscripts do not differ (P >0.05).

The DMD of the ostriches receiving no supplementation was lower (P <0.05) than the DMD of the other diets. In the case of the roosters, DMD differed (P <0.05) between the diet treatments. Roosters receiving supplementary feed at 100% of their intake had the highest DMD and this was higher (P <0.05) than the DMD of the other diet treatments. The DMD of the roosters receiving no supplementation was lower (P <0.05) than the DMD of the other diet treatments.

The CP digestibility of the dietary treatments did not differ (P <0.05) between each other for both ostriches and roosters.

c) Apparent faecal amino acid digestibility

Average apparent faecal lysine, methionine and threonine digestibility of ostriches and roosters subjected to the same diet treatments are illustrated in Table 5.8.

Table 5.8 Average apparent faecal lysine, methionine and threonine digestibilities for ostriches and roosters determined during the digestibility trial (Values presented as mean ± s.e.).

Supplementary feeding level (%)	**Lysine digestibility (%)**		**Methionine digestibility (%)**		**Threonine digestibility (%)**	
	Ostrich	**Rooster**	**Ostrich**	**Rooster**	**Ostrich**	**Rooster**
0	$79.4^{b} \pm 1.9$	$85.9^{a} \pm 3.3$	$58.3^{c} \pm 3.5$	$86.2^{b} \pm 1.6$	$76.6^{b} \pm 2.5$	$79.6^{a} \pm 3.2$
50	$87.0^{ab} \pm 2.1$	$84.5^{a} \pm 3.3$	$77.8^{b} \pm 3.9$	$88.2^{ab} \pm 1.6$	$82.9^{ab} \pm 2.8$	$81.7^{a} \pm 3.2$
62	$86.4^{ab} \pm 1.8$	$78.9^{a} \pm 3.3$	$81.6^{ab} \pm 3.3$	$87.1^{b} \pm 1.6$	$85.1^{ab} \pm 2.3$	$78.9^{a} \pm 3.2$
76	$88.8^{a} \pm 1.8$	$79.5^{a} \pm 3.3$	$92.3^{ab} \pm 3.3$	$93.4^{ab} \pm 1.6$	$88.3^{a} \pm 2.3$	$83.4^{a} \pm 3.2$
81	$90.7^{a} \pm 2.0$	$75.5^{a} \pm 3.3$	$93.5^{a} \pm 3.8$	$92.9^{ab} \pm 1.6$	$88.3^{a} \pm 2.3$	$77.7^{a} \pm 3.5$
100	$84.8^{ab} \pm 1.8$	$83.5^{a} \pm 3.6$	$80.4^{ab} \pm 3.5$	$94.8^{a} \pm 1.6$	$83.9^{ab} \pm 2.4$	$80.9^{a} \pm 3.5$
P-value	0.002	0.24	<.001	0.002	0.009	0.85

$^{a, b, c}$ Column means with common superscripts do not differ (P >0.05).

Lysine, methionine and threonine digestibilities increased with increasing level of supplementation for ostriches grazing lucerne. The methionine digestibility of the diet containing 0% supplementation (58.3%) was (P <0.05) lower than the methionine digestibility of the other diet treatments (range 77.8 – 93.5%) for ostriches. For ostriches, the diet containing 0% supplementation had lower (P <0.05) lysine and threonine digestibilities (79.4 and 76.6% respectively) than the diets containing 76 (88.8 and 88.3% respectively) and 81% supplementation (90.7 and 88.3% respectively).

For roosters, the apparent faecal digestibilities of lysine and threonine did not differ (P >0.05) between the diet treatments. Lysine digestibility ranged from 85.9% for the diet containing 0% supplementation to 83.5% for the diet containing 100% supplementation. Threonine digestibility ranged from 79.6% for the diet containing 0% supplementation to 80.9% for the diet containing 100% supplementation. For methionine, however, a difference (P <0.05) was found between the diet treatments. The diet containing zero supplementation had lower (P <0.05) methionine digestibility (86.2%) than the diet containing 100% supplementation (94.8%).

d) AME and AMEn values

The average ostrich and rooster AME and AMEn values for the same diet treatments are illustrated in Table 5.9.

Table 5.9 Average AME and AMEn ostrich and rooster values for the same diet treatments as observed during the digestibility trial (Values presented as mean ± s.e.).

Supplementary feeding level (%)	AME (MJ/kg)		AMEn (MJ/kg)	
	Ostriches	**Roosters**	**Ostriches**	**Roosters**
0	9.7^{b} ± 0.4	7.8^{c} ± 0.5	9.3^{c} ± 0.6	7.4^{d} ± 0.6
50	13.2^{a} ± 0.5	11.6^{b} ± 0.5	12.4^{b} ± 0.4	11.0^{c} ± 0.6
62	13.6^{a} ± 0.4	11.8^{b} ± 0.5	12.9^{ab} ± 0.3	11.2^{c} ± 0.6
76	14.2^{a} ± 0.4	12.6^{b} ± 0.5	13.6^{ab} ± 0.2	11.9^{c} ± 0.6
81	14.5^{a} ± 0.4	13.1^{ab} ± 0.5	13.9^{a} ± 0.2	12.4^{bc} ± 0.6
100	14.6^{a} ± 0.4	15.0^{a} ± 0.5	14.0^{a} ± 0.3	14.2^{ab} ± 0.6
P-value	<.001	<.001	<.001	<.001

[a, b, c] Column means with common superscripts do not differ (P >0.05).

Apparent metabolizable energy and AMEn values differed (P <0.05) between the diets for both ostriches and roosters. In the case of ostriches, the AME and AMEn values for ostriches receiving no supplementation while grazing lucerne were lower (P <0.05) than the AME and AMEn values for ostriches grazing lucerne and receiving different levels of supplementation or receiving only supplementary feed. The same was true for roosters, where the diets containing no supplementary feed had AME and AMEn values, which were lower (P <0.05) than the AME and AMEn values of the other diets.

e) NDF, ADF, and fat digestibility for ostriches

The NDF, ADF, and fat digestibilities obtained by the ostriches consuming the same diet treatments are illustrated in Table 5.10.

Table 5.10 Average NDF, ADF and fat digestibilities of ostriches during the digestibility trial (Values presented as mean ± s.e.).

Supplementary feeding level (%)	**NDF digestibility (%)**	**ADF digestibility (%)**	**Fat digestibility (%)**
0	$38.9^{a} \pm 4.4$	$42.2^{a} \pm 5.9$	$49.8^{c} \pm 2.6$
50	$52.8^{a} \pm 4.4$	$50.1^{a} \pm 4.7$	$71.9^{b} \pm 2.6$
62	$53.1^{a} \pm 3.6$	$44.8^{a} \pm 4.3$	$74.1^{b} \pm 2.1$
76	$54.8^{a} \pm 3.6$	$44.9^{a} \pm 4.0$	$84.2^{a} \pm 2.1$
81	$55.2^{a} \pm 3.6$	$51.7^{a} \pm 4.0$	$84.5^{a} \pm 2.1$
100	$50.9^{a} \pm 4.0$	$48.3^{a} \pm 6.9$	$91.3^{a} \pm 2.2$
P-value	0.08	0.70	<.001

$^{a, b, c}$ Column means with common superscripts do not differ (P >0.05).

There was no difference (P >0.05) in either the NDF or ADF digestibility between the diets for the ostriches. The fat digestibility of the diets did, however, differ (P <0.05) from one another for the ostriches. Ostriches receiving no supplementary feed had lower (P <0.05) fat digestibility for this diet than for the diets containing any level of supplementary feed. The diets containing supplementation at 76, 81 and 100% of the total feed intake of the ostriches had higher (P <0.05) fat digestibilities than all the other diets.

f) Species differences

Dry matter, apparent faecal CP, apparent faecal lysine, methionine and threonine digestibilities as well as the AME and AMEn values of the diets for the two species are illustrated in Table 5.11.

Table 5.11 Average DM, apparent faecal CP, apparent faecal lysine, methionine and threonine digestibilities as well as AME and AMEn values of the diets for the two species during the digestibility trial (Values presented as mean ± s.e.).

	Ostrich	**Rooster**	**P-value**
0 % concentrate			
DM digestibility (%)	45.7[a] ± 3.8	37.2[a] ± 5.7	0.23
CP digestibility (%)	54.9[a] ± 5.2	54.1[a] ± 7.0	0.99
Lysine digestibility (%)	79.4[a] ± 3.0	85.9[a] ± 4.6	0.25
Methionine digestibility (%)	58.3[b] ± 3.8	86.2[a] ± 5.8	0.01
Threonine digestibility (%)	76.6[a] ± 4.5	79.6[a] ± 6.8	0.71
AME value	9.7[a] ± 0.7	7.8[a] ± 1.1	0.16
AMEn value	9.3[a] ± 0.6	7.4[a] ± 0.9	0.11
50 % concentrate			
DM digestibility (%)	72.0[a] ± 2.5	63.7[a] ± 3.4	0.06
CP digestibility (%)	69.4[a] ± 2.7	56.4[b] ± 3.5	0.01
Lysine digestibility (%)	87.0[a] ± 1.8	84.5[a] ± 2.4	0.41
Methionine digestibility (%)	77.8[b] ± 2.7	88.2[a] ± 3.7	0.04
Threonine digestibility (%)	82.9[a] ± 1.9	81.7[a] ± 2.7	0.73
AME value	13.2[a] ± 0.4	11.6[b] ± 0.6	0.04
AMEn value	12.4[a] ± 0.4	11.0[b] ± 0.5	0.04
62 % concentrate			
DM digestibility (%)	70.0[a] ± 1.6	63.8[a] ± 2.6	0.05
CP digestibility (%)	57.6[a] ± 3.0	62.7[a] ± 5.5	0.43
Lysine digestibility (%)	86.4[a] ± 1.2	78.9[b] ± 1.9	0.01
Methionine digestibility (%)	81.6[a] ± 2.1	87.1[a] ± 3.5	0.19
Threonine digestibility (%)	85.1[a] ± 1.4	78.9[b] ± 2.2	0.03
AME value	13.6[a] ± 0.3	11.8[b] ± 0.5	0.01
AMEn value	12.9[a] ± 0.3	11.2[b] ± 0.4	0.01

76 % concentrate			
DM digestibility (%)	77.5[a] ± 1.4	70.3[b] ± 2.3	0.01
CP digestibility (%)	59.8[a] ± 3.1	61.1[a] ± 5.5	0.84
Lysine digestibility (%)	88.8[a] ± 1.1	79.5[b] ± 1.9	0.01
Methionine digestibility (%)	92.3[a] ± 0.7	93.4[a] ± 1.1	0.42
Threonine digestibility (%)	88.3[a] ± 1.5	83.4[a] ± 2.5	0.11
AME value	14.2[a] ± 0.2	12.6[b] ± 0.3	0.01
AMEn value	13.6[a] ± 0.2	11.9[b] ± 0.3	<.001
81 % concentrate			
DM digestibility (%)	77.1[a] ± 1.1	71.5[b] ± 1.7	0.01
CP digestibility (%)	60.5[a] ± 2.7	59.7[a] ± 4.3	0.87
Lysine digestibility (%)	90.7[a] ± 2.5	75.5[b] ± 3.5	0.003
Methionine digestibility (%)	93.5[a] ± 0.5	92.9[a] ± 0.7	0.57
Threonine digestibility (%)	88.3[a] ± 1.3	77.7[b] ± 2.3	0.01
AME value	14.5[a] ± 0.2	13.1[b] ± 0.4	0.003
AMEn value	13.9[a] ± 0.2	12.4[b] ± 0.3	0.01
100 % concentrate			
DM digestibility (%)	76.8[a] ± 2.4	82.3[a] ± 3.8	0.23
CP digestibility (%)	70.7[a] ± 4.5	56.9[a] ± 7.2	0.12
Lysine digestibility (%)	84.8[a] ± 1.8	83.5[a] ± 3.1	0.72
Methionine digestibility (%)	80.4[a] ± 5.4	94.8[a] ± 8.3	0.16
Threonine digestibility (%)	83.9[a] ± 1.9	80.9[a] ± 3.4	0.45
AME value	14.6[a] ± 0.3	15.0[a] ± 0.5	0.52
AMEn value	14.0[a] ± 0.3	14.2[a] ± 0.4	0.68

[a, b, c] Row means with common superscripts do not differ (P >0.05).

Dry matter digestibility of the diets where supplementation was provided at 76 and 81% of total feed intake was higher (P <0.05) for ostriches than roosters.

Regarding CP digestibility, ostriches showed higher (P <0.05) digestibility than roosters only for the diet containing 50% supplementation.

Ostriches showed lower (P <0.05) methionine digestibilities for diets containing 0 and 50% supplementation. Ostriches maintained higher (P <0.05) threonine digestibilities than roosters for the diets containing 62 and 81% supplementation.

For all the diets, apart from the diet containing no supplementary feed and the diet containing 100% supplementary feed, ostriches had higher (P <0.05) AME and AMEn values than roosters.

The stepwise regression computed between rooster AME values of the diets and ostrich AME values of the same diets was not significant (P >0.05).

g) Retention of energy, CP, lysine, methionine and threonine by ostriches

Energy, CP, lysine, methionine and threonine retention of the diets for ostriches are illustrated in Table 5.12.

Table 5.12 Average energy (MJ), CP (g/day), lysine (g/day), methionine (g/day) and threonine (g/day) retention values of the diets for ostriches during the digestibility trial (Values presented as mean ± s.e.).

Supplementary feeding level (%)	Energy (MJ)	CP (g/day)*	Lysine (g/day)*	Methionine (g/day)*	Threonine (g/day)*
0	$4.5^{d} \pm 1.1$	$61.7^{c} \pm 14.4$	$4.1^{c} \pm 1.1$	$0.2^{e} \pm 0.1$	$2.7^{d} \pm 0.4$
50	$12.4^{c} \pm 1.3$	$134.1^{ab} \pm 13.7$	$7.6^{abc} \pm 1.2$	$0.8^{d} \pm 0.1$	$4.7^{bc} \pm 0.5$
62	$17.3^{b} \pm 1.1$	$137.2^{ab} \pm 11.4$	$9.2^{ab} \pm 0.9$	$1.2^{c} \pm 0.1$	$6.1^{bc} \pm 0.4$
76	$20.2^{b} \pm 1.1$	$132.9^{ab} \pm 11.8$	$8.0^{abc} \pm 1.0$	$1.6^{b} \pm 0.1$	$6.2^{b} \pm 0.4$
81	$28.4^{a} \pm 1.1$	$184.8^{a} \pm 11.4$	$11.5^{a} \pm 1.1$	$2.3^{a} \pm 0.1$	$8.7^{a} \pm 0.4$
100	$16.5^{bc} \pm 1.1$	$109.6^{bc} \pm 11.7$	$4.8^{bc} \pm 1.0$	$1.3^{bc} \pm 0.1$	$4.2^{cd} \pm 0.4$
P-value	<.001	<.001	<.001	<.001	<.001

[a, b, c] Column means with common superscripts do not differ (P >0.05).
* Apparent feacal retention values.

For ostriches having access to pasture and receiving supplementary feed, the retention of all nutrients increased as the level of supplementary feeding increased. For birds receiving 100% supplementary feeding, the retentions were all lower (P <0.05) than the retentions on the 81% supplementary feeding level. The energy retention of the diet containing 0% supplementary feed was lower (P <0.05) than the energy retention of all the other diets.

h) Substitution effect by grazing ostriches

The mean supplementary feed intake (g/bird/day) and the corresponding percentage of lucerne pasture ingested by ostriches per treatment, are tabulated in Table 5.13.

Table 5.13 Average supplementary feed intake (g/bird/day) with the corresponding percentage of lucerne pasture intake (%) for ostriches in the digestibility trial (Values presented as mean ± s.e.).

Supplementary feeding level (%)	**Lucerne pasture intake as percentage of total DM intake**	**Supplementary feed intake (g DM/bird/day)**
0	100^{a} ± 0.0	0^{e} ± 0.0
50	50.3^{b} ± 2.8	448.1^{d} ± 68.6
62	38.7^{c} ± 1.9	805.3^{c} ± 55.2
76	21.6^{d} ± 3.1	1107.9^{b} ± 56.9
81	19.8^{d} ± 1.8	1536.7^{a} ± 55.2
100	0^{e} ± 0.0	1120.3^{b} ± 58.8
P-value	<.001	<.001

[a, b, c] Column means with common superscripts do not differ (P >0.05).

A regression analysis was done between DM supplementary feed intake (g DM/bird/day) and percentage lucerne pasture intake. The quadratic regression equation fitted the data the best, with a R^2-value of 0.87. The regression equation was $Y = 99.21 – 0.127X + 0.00005X^2$ (Figure 5.1).

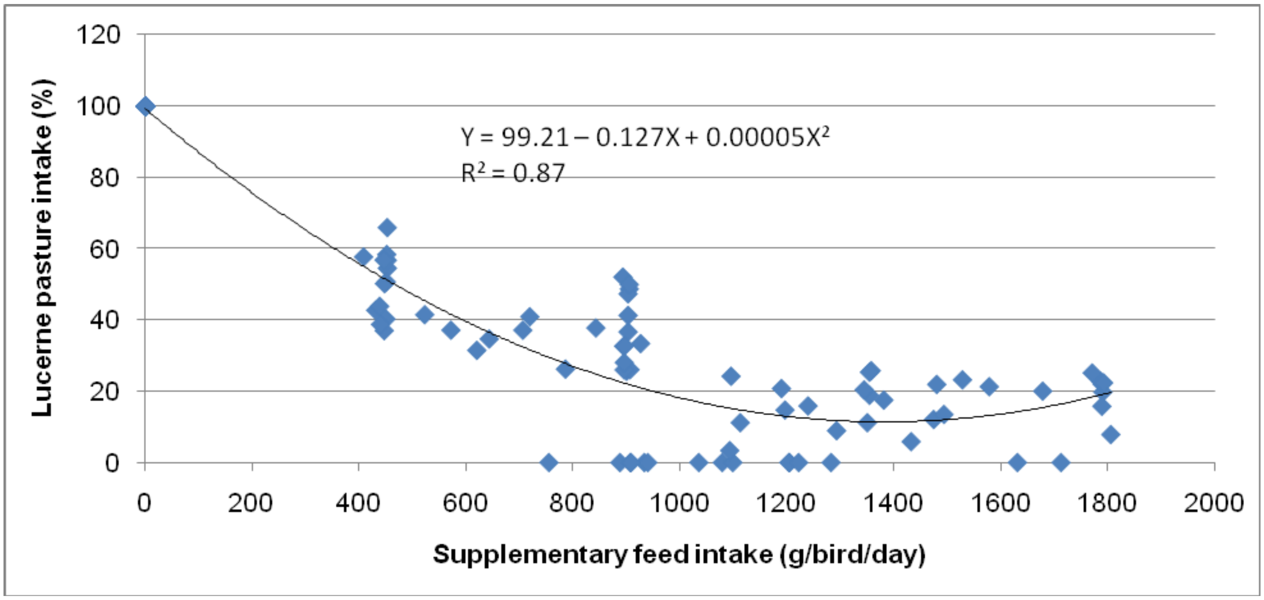

Figure 5.1 The quadratic relationship between lucerne pasture intake (%) of grazing ostriches on irrigated lucerne pastures, and the level of supplementary feeding (g/bird/day).

This figure indicates that as the level of supplementary feed intake increased, the pasture intake decreased up to a certain point, and then the pasture intake increased again slightly. Although the quadratic regression fitted the data the best, it does not make biological sense for birds to consume more pasture when they receive increasing levels of supplementary feed. Therefore, a normal linear regression was also applied to the same data. The significant ($P < 0.05$) linear regression computed between DM supplementary feed intake (g/bird/day) and lucerne pasture intake (%) by the ostriches receiving different levels of supplementary feed, showed an R^2-value of 0.68 and a P-value of $P < .001$. The corresponding equation was $Y = 79.41 – 0.049X$, which can be used to compute the percentage of lucerne pasture birds will consume when they receive a certain amount of supplementary feed. Figure 5.2 indicates that the more supplementary feed the ostriches received, the less pasture they consumed. Therefore, according to the linear regression equation, the pasture was substituted at a rate of 4.9% for each increase of 100g in supplementary feed intake by the ostriches.

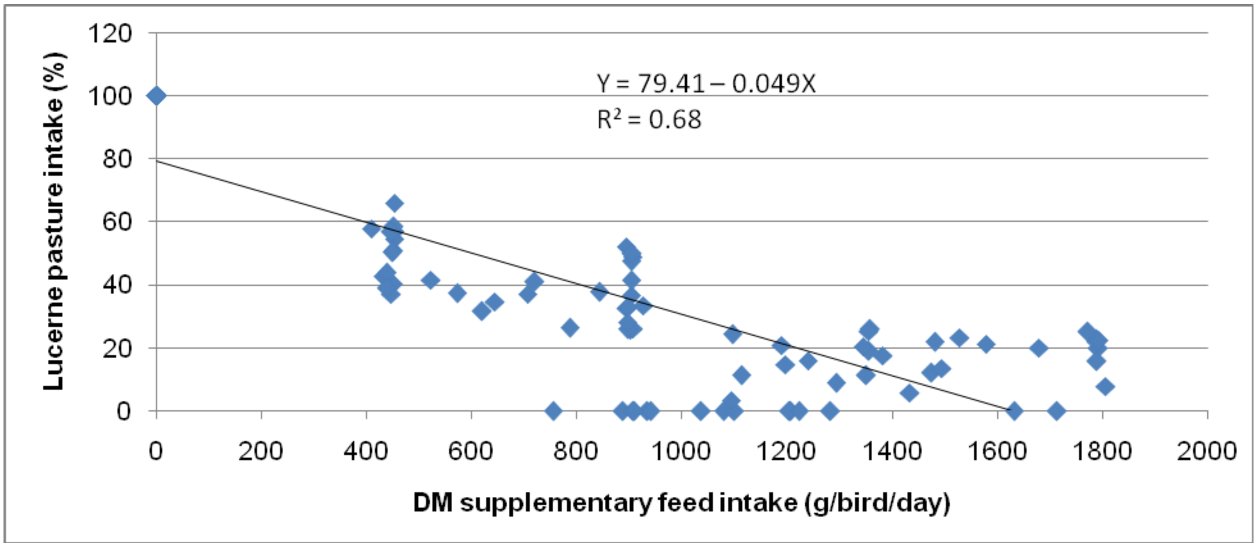

Figure 5.2 The linear relationship between lucerne pasture intake (%) of grazing ostriches on irrigated lucerne pastures and the level of supplementary feeding (g/bird/day).

Discussion

a) Feed intakes

Farrell *et al.* (2000) found that pasture intake by grazing ostriches in the grower phase increased with decreasing level of supplementation supplied (703g pasture/bird/day for birds receiving mash at 100% of intake to 858g pasture/bird/day for birds receiving mash at 70% of intake). This trend was observed up to the point where ostriches received mash at only 60% of their appetite. After this point the lucerne intake by the ostriches declined. The same trend was also found by Nitzan *et al.* (2002) for ostrich chicks aged 10 – 30 weeks. These researchers found higher intakes of pasture DM for the groups of ostriches receiving the lowest amount of concentrate. Ostriches receiving supplementary feed of only 20g/bird/day and allowed to graze lush lucerne pastures for 4 – 6 hours per day had a mean pasture DM intake of 390g/bird/day, while the group receiving supplementary feed of 30g/bird/day had a mean pasture DM intake of 260g/bird/day. Therefore, the group receiving concentrate of only 20g/bird/day adapted to this limited concentrate by increasing its pasture intake. These researchers also found that ostriches consumed more pasture when grazing on lucerne or natural pasture, than on barley or Sulla. Glatz *et al.* (2005) also confirmed that 20% of the concentrate diet can be replaced with lucerne-based pastures without a negative effect on ostrich growth. Supplementary feeding can therefore allow higher stocking rates per hectare of pasture and a decrease in high cost supplementary feeding, with the prerequisite that animal production is maintained.

Although pasture intake increased with increasing level of supplementation (467.3g pasture DM/bird/day for the group receiving 0% supplementation, 485.2g pasture DM/bird/day for ostriches receiving supplementation at 50% of intake and 529.9g pasture DM/bird/day for ostriches receiving supplementation at 62% of intake) in the current study, no significant difference in pasture intake up to a level of 62% supplementation was found. Several factors such as the bulkiness of the pasture, palatability of the supplementary feed may have played a role in these results. After this level of supplementation pasture intake declined. Therefore, levels of supplementation that are too high (76%) can lead to a reduction in pasture intake. According to Abou El-Nasr *et al.* (1994), supplementary feeding should, in addition to promoting animal performance, also add to pasture intake and not limit it, therefore increasing total DM intake. This was observed in the current trial up to the 62% supplementation level.

Ponte *et al.* (2008) conducted a study in which broilers received cereal-based feed at 50, 75 and 100% of intake while grazing subterranean clover pastures. These researchers found that as the level of cereal-based feed is decreased, the amount of pasture ingested by the broilers increased.

Roosters subjected to the different diet treatments maintained the same DM feed intakes. This is in contrast to what was found by Cilliers (1994). He found that feed intake of roosters decreased as the level of lucerne in the diet increased, which may be ascribed to the fibre contents and bulkiness of these diets. This is due to the fact that if the energy level of the diet increases, intake by birds will decrease and vice versa. This will happen up to a certain point, whereafter the bird basically cannot compensate anymore due to the bulkiness of the feed (Brand & Gous, 2006). Average daily intakes of 87, 77 and 68g were measured for birds receiving the basal diet (100% maize), test diet 2 (50% maize & 50% lucerne), and test diet 1 (75% maize & 25% lucerne) respectively. Cilliers *et al.* (1997a) found that roosters had lower food intakes of the higher fibre ingredients like oats and barley as opposed to intakes of maize and triticale.

b) Digestibilities

Dry matter digestibility for ostriches receiving no supplementation while grazing irrigated lucerne pastures was significantly lower (45.7%) than the DMD of the ostriches grazing lucerne and receiving supplementation (70 – 77.5%). This is in accordance with what Cilliers (1994) found. The DMD for ostriches was improved from 49 to 73% as the dietary levels of maize increased from 0 to 75% in his experimental diets. Cilliers (1994) estimated a DMD of 49% for ostriches consuming only lucerne, which compares well with the value of 45.7 % found in the current study.

Nheta *et al.* (1997) compared the effect of three different sources of roughage included in ostrich finishing rations on their growth, body composition and digestibility. The birds were fed a concentrate with either veld hay, katambora Rhodes grass hay, or maize stover, all of which are relatively poor quality roughages. Each of the treatment diets contained a specially formulated concentrate (500g/kg), maize (250g/kg), and roughage (250g/kg). This was compared to a control diet of concentrate and legume hay (*Silverleaf desmodium*) (seven parts of ostrich grower mash mixed with five parts of legume hay). Dry matter digestibility ranged from 65.9 to 80.3% for the different diets, which is higher than the values calculated in the current study (45.7 – 77.5%). Due to the fact that these diets contained only 25% roughage and the rest was concentrate and maize, they can be compared only to the DMD of the current trial for the diets containing 19% lucerne pasture (81% supplementary feed) and 24% lucerne pasture (76% supplementary feed). The DMD for these two diets were respectively 77.1 and 77.5%, which compares well with the study of Nheta *et al.,* where 25% of the diet contained Rhodes grass (73.2%) and maize stover (80.3%). The control diet in the study of Nheta *et al.* also contained a legume pasture, but this pasture was of very low quality, leading to a lower DMD of 65.9%.

Cilliers *et al.* (1998) found DMD values of 53% for mature ostriches consuming a diet containing only lucerne. This value is slightly higher than the value found in the current trial for ostriches grazing lucerne pastures (45.7%). These differences may probably be ascribed to differences in the fibre content of the two diets.

Nizza & Di Meo (2000) fed ostriches aged 12 and 18 weeks (3 – 6 months old) diets containing respectively a commercially available concentrate and lucerne in a 4:1 ratio. This diet therefore contained 75% concentrate and 25% lucerne grass. They found a DMD value of 57% for both groups of ostriches, which can be compared to the DMD of our diet containing 76% of supplementary feed (77.5 %). The lower DMD values found by Nizza & Di Meo can be ascribed to the fact that a young ostriches have a much smaller caecum and colon as compared to a mature ostrich. Therefore, younger ostriches will have less microbial fermentation and lower retention time in the hind-gut compared to mature ostriches. Therefore, young ostriches will have a lower DMD.
Geese, which are also hind-gut fermenters, showed a DMD of only 25.8% for lucerne chaff (Marriott & Forbes, 1970). This low DMD is probably due to the fact that geese have very high transit times for food through their gastro-intestinal tracts.

Dry matter digestibility between the different diets consumed by roosters showed similar trends as observed with the ostriches. Roosters consuming only lucerne showed significantly worse DMD (37.2%) than roosters consuming a combination of lucerne and supplementary feed (63.7 – 82.3%). This is in accordance with Cilliers (1994) who found that digestibility increased linearly from 47.3 to 82.8% as dietary levels of lucerne was reduced from 50% to zero. The DMD of diets containing different levels of lucerne was calculated in the study of Cilliers and amounted to 11.8 and 7.2%, which is much lower than the values found in our study.

Crude protein digestibilities between the different diet treatments for ostriches and roosters did not differ significantly from one another. For ostriches, CP digestibilities ranged from 54.9 to 70.7% and for the roosters the CP digestiblities ranged from 54.1 to 62.7%. These values compare well with those found by Cilliers *et al.* (1997b), in which true retention of dietary protein was 64.6% for ostriches and 60.9% for poultry. Geese digested the CP in lucerne chaff very well (76.4%) (Marriott & Forbes, 1970), which compares well with the CP digestibility values of ostriches in the current trial.
In the study of Nheta *et al.* (1997), CP appeared to be equally well digested, irrespective of the source of the roughage component. Crude protein digestiblility differed significantly among the diets, with the maize stover diet having the highest CP digestibility of 95%. The digestibilities of these diets were much higher (91.7 – 95 %)

than the figures found in the current trial (54.9 – 70.7%).

In a study by Nizza & Di Meo (2000), CP digestibility of 75% was calculated for the two ostrich groups aged 12 and 18 weeks respectively receiving a diet that consisted of 75% concentrate and 25% lucerne grass.

Cilliers (1994) and Cilliers *et al.* (1997b) tested a diet containing 39% lucerne and having a high CP value of 209.9 g/kg on seven-month old ostriches and mature roosters. This diet can be compared to the diet in the current trial containing 62% supplementation as this diet contained 38% lucerne. Cilliers found apparent faecal lysine, methionine and threonine digestibilities of 83.2, 81.6 and 83.1% respectively for seven-month old ostriches, while the current trial found apparent faecal lysine, methionine and threonine digestibilities for ostriches of respectively 86.4, 81.6 and 85.1%. For roosters, the same research study revealed apparent faecal lysine, methionine and threonine digestibilities of 76.8, 78.2 and 77.4% respectively for mature roosters, while the current study revealed values of 78.9, 87.1 and 78.9% respectively. The methionine digestibility of the current study was slightly higher than found by Cilliers (1994) and Cilliers *et al.* (1997b). This could be due to feed source differences or experimental variation between the trials. Buchanan *et al.* (2007) tested a diet containing 100% forage (Kentucky bluegrass, tall fescue and white and red clover) on 16-week old roosters. They found lysine, methionine and threonine digestibilities of 80.0, 88.3 and 82.8% respectively. This compares well with the values found in the current trial for roosters consuming a diet containing 100% lucerne meal (i.e. 85.9, 86.2 and 79.6% respectively).

Cilliers (1994) found AME and AMEn values of lucerne determined for ostriches of 9.3 MJ/kg and 8.9 MJ/kg respectively. This compares well with the values found in the current study (9.7 and 9.3 MJ/kg). He also found that AME values of lucerne in roosters amounted to 4.44 and 5.06 MJ/kg at the 50 and 25% levels of substitution. Apparent metabolizable energy values (corrected for zero nitrogen) were 4.05 and 4.49 MJ/kg for roosters, as opposed to 8.9 MJ/kg for ostriches (Cilliers, 1994). Swart *et al.* (1993a) found an AMEn value of 8.99 MJ/kg for lucerne for ostrich chicks. In this study, the basal diet of ostriches was diluted by adding 33% lucerne meal. This meant that the diet had lower energy content and higher crude fibre content than the basal diet. Since a higher crude fibre content in the diet will lead to a slower rate of passage of digesta through the gastro-intestinal tract, it is more likely that a large proportion of protein and carbohydrates will be fermented to ammonia, amines and volatile fatty acids in the hind-gut. The contribution of energy to the animal due to fermentative digestion in the hind-gut will thus be higher. In addition, since ostriches are successful hind-gut fermenters, a large proportion of nutrients can also be fermented to volatile fatty acids by the micro-flora. This could have a lower metabolic efficiency as compared to carbohydrates absorbed from the small intestine. Therefore, supplementation of dietary energy at an increased concentration of crude fibre tends to have a negative effect on the utilization of ME in growing ostriches. Not only did the efficiency of nutrient utilization deteriorate, but it also had a depressive effect on energy metabolizability (Swart *et al.*, 1993a). This was reflected in the current trial, where DMD as well as AME and AMEn values decreased as the level of supplementation decreased. Cilliers *et al.* (1998) found an AMEn value of 8.97 MJ/kg for mature ostriches consuming a diet consisting only of lucerne, which compares well with the value of 9.3 MJ/kg found in the current study.

Swart *et al.* (1993a) calculated the NDF digestibility for ostrich chicks (33 weeks old) as 45.1% if they consume a high fibre diet containing 33% lucerne. The ostriches in the current study were 6.5 – 10.5 months old and therefore had higher NDF digestibilities of 53.1% for diets containing 38% lucerne. In the study by Nheta *et al.* (1997) NDF digestibility of finishing ostriches consuming different diets ranged from 59.8 – 76.4%. These values are higher than those found in the current trial (38.9 – 55.2%), probably due to differences in NDF/ADF analyses between different laboratories. The ADF digestibility ranged from 33.6 – 56.7% in the study of Nheta *et al.* These figures compare well with the ADF digestiblities calculated in the current trial (42.2 – 51.7%). Nizza & Di Meo (2000) found NDF digestibilities of 46 – 47% and ADF digestibilities of 39 – 40% for the two ostrich groups aged 12 and 18 weeks respectively. These values also compare well with the values found in the current trial.

Cilliers (1994) and Cilliers *et al.* (1997b) found fat digestibility values for seven-month old ostriches consuming a high protein diet containing 209.9g/kg protein and 39% lucerne of 87 and 85.7% respectively. This can be compared to the fat digestibility of the diet containing 62% supplementary feed in the current trial as this diet contained 38% lucerne. The fat digestibility for this diet was 74.1% for ostriches. The fat digestibility values found by the two studies by Cilliers are higher than the value obtained for the same diet in the current trial, probably due to the fact that feed sources differed.

c) Species differences

Although ostriches demonstrated higher DMD than roosters for diets containing lucerne pasture, this was only significantly higher for the diets containing supplementation at 76 and 81% of total intake. Ostriches maintained higher AME and AMEn values for all diets and this was significantly higher for all the diets, except for the diet containing 0% supplementation. The higher digestibility values maintained by ostriches for DM, AME and AMEn could highlight the fact that ostriches are better able to digest diets higher in fibre than roosters, as are found by Cilliers *et al.* (1994). Brand *et al.* (2000b) also stated that there was no significant difference between the ME values for ostriches and poultry with low fibre diets tested in their trial, but in the case of the high fibre diets, ostriches demonstrated significantly higher ME values than poultry. This is related to the ability of ostriches to digest fibre. Farrell *et al.* (2000) also confirmed that the mean AME values for diets containing 200g/kg of four different roughage sources were higher for ostriches than for cockerels and emu. These researchers concluded that such a difference between species is not surprising, due to the fact that ostriches have large chambers in their hind-guts. These chambers ensure a longer exposure to microbial digestion.

In studies conducted by Cilliers (1994) and Cilliers *et al.* (1997b) the digestibility of all amino acids was higher in ostriches than in roosters. This was observed only for some amino acids in some of the diet treatments in the current trial. For example, the lysine and threonine digestibilities for ostriches of the diets containing 62 and

81% supplementation were significantly higher than those of the roosters and in the diet containing 76% supplementation, only lysine digestibility was significantly higher than that of the roosters. It could therefore not be concluded beyond doubt with this trial that ostriches digest amino acids more efficiently than roosters. This is due to the fact that microbial breakdown of amino acids occur in the hind-gut of the ostrich.

Due to the fact that too few animals were used per treatment in the digestibility study (i.e eight ostriches per treatment and six roosters per treatment) and the high within-group variation, it was not possible to obtain consistently significant differences between all nutrient digestibilities for the two species. The high standard errors computed for the DM, CP, lysine, methionine and threonine digestibilities (especially in the case of the roosters) reflects this high within-group variance. Due to this fact very low R^2 values were obtained (ranging from 0.0007 to 0.49). It could therefore not be established that ostriches maintain higher digestibilities for certain nutrients than roosters as was shown in previous studies (Brand *et al.*, 2000b; Cilliers, 1994; Cilliers *et al.*, 1997b).

d) Retention of nutrients by ostriches

According to Smith *et al.* (1995) the true metabolizable energy (corrected for zero nitrogen) (TMEn) requirement for finisher ostriches is approximately 18.6 MJ per day. According to the same researchers, the CP, lysine, methionine and threonine requirements of finisher ostriches (60 – 90kg live weight) are 232.6, 14.2, 4.4 and 4.9 g/day respectively. This indicated that only the diets provided at 76, 81 and 100% of supplementation supplied enough energy for these birds. Crude protein supplied was adequate only from the diets containing 62 and 81% of supplementation. No diet supplied enough lysine or methionine to the birds in the current trial. Threonine was supplied adequately only in the diets containing 50, 62, 76 and 81% supplementation. The requirements of the ostriches as well as the nutrients supplied in the different diet treatments are illustrated in Table 5.14 below.

Table 5.14 Daily nutrient requirements of finisher ostriches as well as nutrients supplied in the metabolism trial.

Daily nutrient requirement for finisher ostriches**		Nutrients supplied in diet treatments					
		Level of supplementary feeding (%)					
		0	**50**	**62**	**76**	**81**	**100**
Dietary ME value (MJ/kg)		9.7	13.2	13.6	14.2	14.5	14.6
DMI (g)	1758.3	467.3	933.4	1335.2	1399.8	1911.6	1120.3
*Energy (MJ)	18.6	4.5	12.3	18.1	19.8	27.7	16.4
CP (g)	232.6	114	174	239	227	298	151
Lysine (g)	14.2	5.6	7.7	10.6	9.1	12.0	5.5
Methionine (g)	4.4	0.33	1.0	1.5	1.7	2.5	1.6
Threonine (g)	4.9	1.5	5.2	7.3	7.3	9.4	4.8

* TMEn for daily nutrient requirement and AMEn for nutrients supplied in diet treatments
** Based on values presented by Smith *et al.* (1995).

In a study by Cilliers (1994), ostriches aged seven months were fed a complete diet containing 39% lucerne-meal. He recorded energy, CP, lysine, methionine and threonine retentions of 8.2 MJ/day, 75, 7.1, 2.1 and 3.9g/day respectively for this diet. These values were lower than the values found in the current trial for the group of ostriches grazing lucerne and receiving 62% supplementary feed (18.1 MJ/day, 239g CP/day, 10.6g lysine/day, 1.5g methionine/day and 7.3g threonine/day). Values between studies are, however, difficult to compare due to differences in laboratory techniques. This is especially true in the case of amino acid analyses.
As can be seen from Table 5.14, the total DM intake of the ostriches receiving fresh lucerne pasture and supplementation at 0, 50, 62, 76 and 100% of total feed intake was much lower than the daily DM intake expected for ostriches during this stage of their production cycle. These lower DM feed intakes is due to the fact that the feeding and keeping of ostriches in metabolism crates for an extended period of time is an unnatural procedure. This may lead to excessive stress in ostriches and therefore they may not ingest appropriate amounts of feed. In Table 5.15, the nutrients supplied with the different diet treatments were used to calculate the same scenario, but using typical feed intake values for birds aged approximately 8 months from the model of Brand & Jordaan (2009). These intakes are therefore, more normal intakes for ostriches receiving diets of approximately the same energy value as in the current trial.

Table 5.15 Daily nutrient requirements of finisher ostriches as well as nutrients supplied extrapolated to feed intake volumes determined in the model from Brand & Jordaan (2009).

Daily nutrient requirement for finisher ostriches		**Nutrients supplied in diet treatments**				
		Level of supplementary feeding (%)				
		0	**50**	**62**	**76**	**100**
Dietary ME value (MJ/kg)		9.7	13.2	13.6	14.2	14.6
*DMI (g)	1758.3	2600	1911	1855	1777	1728
*Energy (MJ)	18.6	25.2	25.2	25.2	25.2	25.2
CP (g)	232.6	637	355	332	288	233
Lysine (g)	14.2	31.2	15.7	14.7	14.0	8.5
Methionine (g)	4.4	1.8	2.1	2.0	2.1	2.4
Threonine (g)	4.9	18.9	10.7	10.2	9.2	7.4

*Predicted by the model from Brand & Jordaan (2009) using $ME_{ostrich}$ values of an ostrich of 8 months of age

Therefore, if ostriches in the current trial maintained expected DM feed intakes, all nutrients would have been supplied adequately, except for lysine at the 76 and 100% supplementation level and the methionine, which would not have been adequate for any diet treatment. This low methionine supply can possibly be explained by the very low methionine content of lucerne pastures at the experimental site at Elsenburg and/or differences in amino acid analysis methods. Table values (Wiseman, 1987) amounts to 0.26% of methionine in lucerne compared to our experimental value of only 0.11%. A proper study on the amino acid composition of South African lucerne is also needed.

e) Substitution of grazing by ostriches

No other substitution studies done on mono-gastric animals could be found in the literature and the substitution of grazing by supplementary feed of ruminants are discussed. According to Stockdale (2000), substitution increased by 0.16kg DM/kg feed for each increment of grass-dominant pasture intake, while for each additional kg DM of supplement consumed, substitution increased by 0.03kg DM/kg feed offered to grazing dairy cows. In the current study grazing ostriches decreased their lucerne intake by 4.9% for each additional 100g supplementary feed ingested.

Conclusion

Pasture intake of ostriches started to decline when supplementation was provided at levels higher than 62% of total feed intake (levels higher than 1000 g/bird/day). After an initial effect of promoting pasture intake, concentrate supplementation supplied at higher amounts than 1000g/bird/day caused the intake of pasture to decline. It is therefore recommended that 500 – 1000g/bird/day of supplementary feed should be supplied to finishing ostriches grazing irrigated lucerne pastures, because this will lead to better pasture utilization, more satisfactory bird performance and lower feeding costs for the producer. However, the regression between supplementary feed intake (g/bird/day) and percentage pasture intake showed that pasture intake declined with the increasing levels of supplementary feed provided. For each increase of 100g in the supplementary feed intake by ostriches, pasture was substituted at a rate of 4.9%.

The current trial reflects the same results as obtained by many other researchers (Blaxter & Wilson, 1963; Swart *et al.*, 1993b; Bargo *et al.*, 2003), namely that digestibilities will increase with an increase in concentrate in the diet. Increasing levels of supplementation increased the DMD of the diets for both ostriches and roosters and also increased the AME and AMEn values of the diets for both ostriches and roosters. The current trial also showed that pasture grazing alone resulted in significantly lower DMD and AMEn values than if pasture was complemented with supplementary feed in the case of both ostriches and roosters. The digestibility of fat in the diets of the ostriches also increased as the level of supplementation increased.

The effect of the level of supplementation was not significant for CP digestibility for either ostriches or roosters. The only significant result that could be determined was that methionine digestibility for ostriches consuming only lucerne pasture was lower than the methionine digestibility of the other diets.

An increase in the level of supplementation did not lead to an increase in the NDF or ADF digestibilities of ostriches. The fibre digestibility of the diets containing only lucerne pasture did not differ significantly from all the other diets, reinforcing the fact that ostriches can digest high fibre diets very well.

It is important to evaluate feedstuffs for ostriches using ostriches and not simply to rely on values established with poultry (Cilliers, 1994). This was reflected in the current study where higher DMD, AME and AMEn values (although not significant in every case) were observed for ostriches utilizing diets containing 0, 50, 62, 76, and 81% of supplementary feed. Higher DMD for the diet containing only high quality forage like lucerne explains the higher metabolizability of this diet (9.7 MJ/kg) for ostriches, as compared to 7.8 MJ/kg for poultry. A substantially higher degree of variation was observed for all digestibility values in ostriches and roosters. This can probably be explained by a high variation between the birds within each group.

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Chapter 6

The effect of supplementation to irrigated lucerne pastures and stocking rate on the production of finishing ostriches, their pasture dry matter intake and the dry matter production of the lucerne pasture

Abstract

A lucerne pasture was divided into 16 paddocks of approximately 0.85 ha each. Two hundred ostriches (± six months old) were randomly allocated to five groups. Four of the five groups grazed lucerne pasture rotationally at a stocking rate of either 15 birds/ha or 10 birds/ha, receiving either 0g or 800g supplementary feed/day. The fifth group received a complete finisher ration in a feedlot. Four lucerne paddocks were randomly allocated to each group of grazing ostriches. The ostriches were weighed every 14 days, or as soon as the pasture became depleted and subsequently moved to a new paddock after each grazing. Five exclosure cages were put in each paddock before the ostriches were allowed to graze the paddock. When the ostriches and cages were moved to the next paddock immediately after each grazing cycle, pasture dry matter (DM) production, intake and residual DM were determined by cutting (at ground level) and collecting 0.166m^2 size samples inside and outside these cages. The DM material was then manually separated into lucerne, grass, broad-leaf weed, clover and dry/dead material fractions, before washing to remove soil and dirt and drying to a constant dry mass at 59°C. The plant material was composed mainly of lucerne and contained only very small quantities of clover, grass, broad-leaved weeds and dry/dead material. Data were subjected to an analysis of variance, using the four paddocks as replicates at two supplementary feed levels and two stocking rates. Ostriches receiving supplementary feed at 800g/bird/day had higher ($P<0.05$) mean live weights at 54 weeks of age than ostriches receiving no supplementation. Ostriches receiving 800g of supplementary feed/bird/day reached the target weight (± 95kg) within the period of the trial (30 weeks), while ostriches receiving no supplementation did not reach slaughter weight. Stocking rate did not have an effect ($P>0.05$) on mean live weight at 54 weeks of age. An interaction ($P<0.05$) was, however, found between the level of supplementary feed and stocking rate in respect of average daily gain (ADG) of the birds. Stocking rate influenced ADG only for birds receiving no supplementary feed, while stocking rate had no effect on ADG where birds received supplementary feed at 800g/bird/day. As stocking rate increased, the ADG of birds receiving no supplementary feed declined. At the low stocking rate of 10 birds/ha, supplementary feeding in the beginning of the trial had no effect ($P>0.05$) on pasture intake. The pasture intake of ostriches receiving no supplementation gradually became higher ($P<0.05$) than the intake of ostriches receiving supplementation. The trend that was observed here is one of decreasing pasture intake by birds receiving supplementation of 800g/bird/day and increased pasture intake by birds receiving no supplementation. At the high stocking rate of 15 birds/ha, lucerne DM intake tended to be higher for birds receiving no supplementation than for birds receiving supplementation of 800g/bird/day. The effect of feeding level, therefore, tended to be more pronounced at this high stocking rate of 15 birds/ha over most of the trial period. These results indicate an increasing level of replacement of grazed lucerne DM by supplementary feeding as the trial progressed and this was more pronounced at the higher stocking rate of 15 birds/ha. The higher stocking rate stimulated the production of lucerne DM in the beginning of the trial, but it also eventually resulted in over-utilization of the pasture. Therefore, later in the trial, the higher stocking rate led to lower ($P<0.05$) lucerne DM production when compared to lucerne DM production at the lower stocking rate of 10 birds/ha. The high stocking rate of 15 birds/ha, therefore, seems to have had a gradual depressing effect on lucerne DM production, while the less severe levels of defoliation at the low stocking rate possibly eventually promoted lucerne DM production. Pasture grazing by ostriches did not lead to a decline in pasture quality during this trial.

Keywords: ostriches, pasture, mean live weight, ADG, FCR, lucerne intake, lucerne production, supplementary feeding

Introduction

Some of the factors affecting the growth of ostriches include diet, rearing environment, genetic potential, management and the health status of the birds (Verwoerd *et al.*, 1999). In Chapter 4 of this thesis, it was shown that the level of supplementary feed had a significant effect on the production of grazing finishing ostriches. As the level of supplementary feed to ostriches grazing irrigated lucerne pastures increased, the ostriches grew at a faster rate compared to ostriches receiving no supplementation. It was found (Chapter 4) that ostriches grazing irrigated lucerne pasture and receiving 1500g of supplementary feed per day grew faster ($P < 0.05$) than ostriches that received 1000g, 500g or 0g supplementary feed/bird/day and it was clear that the birds grew according to the amount of feed used to supplement the lucerne pasture. The level of supplementary feed supplied to the grazing ostriches also had an effect on the amount of residual lucerne after such grazings. As the level of supplementary feed supplied to the grazing ostriches increased, the amount of residual lucerne also increased. Therefore, it was evident that the level of supplementary feed supplied to grazing ostriches is an important factor, which will not only influence the production of the ostriches, but will also have an effect on the lucerne production and quality.

Another important factor in the successful production of ostriches on lucerne pastures is stocking rate (Brand, 1996). Stocking rate is an important driver in grazed systems as it is the most important grazing management factor and influences the efficiency of pasture utilization by grazing animals (Davies & Southey, 2001). This is mainly due to its influence on herbage availability (De Villiers *et al.*, 1994). The application of the correct stocking rate will ensure the maintenance of a balance between the rate of any new herbage and its rate of harvesting by the ostriches. At such a stocking rate, the ostriches will theoretically be presented with a constant supply of young and nutritious herbage (McDonald *et al.*, 2002). Increasing grazing pressure until the optimum stocking rate is exceeded results in a decrease in yield per animal (Brand, 1996). A too high stocking rate restricts the forage mass available to the animals and also restricts the selection of the highest quality plant parts by the animals and ultimately leads to a reduction in the quality of available forage (Chong *et al.*, 1997). Stocking rate not only influences animal performance, it also affects pasture growth and availability (Davies & Southey, 2001). When the stocking rate is too high the animals will graze the pasture too frequently or prematurely. This results in a too low leaf area index and ultimately the depletion of the organic root and other regrowth reserves of the plants. This ultimately leads to lower production, a poor stand and low pasture quality (Donaldson, 2001). Achieving the optimum balance between the number of animals and pasture production must therefore be the main objective of any grazing system (Cloete *et al.*, 1992).

Stocking rate as a management factor is also vital for the preservation of a lucerne pasture as ostriches have the ability to damage pastures extensively (Sales & Horbanczuk, 1998). Ostriches graze by stripping shrubs or pastures of their leaves by running the branches through their beaks (Van Niekerk, 1995) and also by plucking out small plants whole. The locally used lucerne cultivar, SA Standard is extremely grazing tolerant and is damaged much less by heavy grazing than the newer aphid-resistant cultivars like Cuf 101, Granada and Baronet (Van Heerden & Hardy, 2000).

Ostriches are currently reared under a wide range of stocking densities ranging from 16 – 40m^2 per bird (Verwoerd *et al.*, 1999). Smit (1964) estimated that one ostrich can be kept on five hectares of good Karoo veld, while on bad Karoo veld, 10 – 12 hectares are required per bird. Smit (1964) also stated that lucerne can be grazed at a stocking rate of 8 – 12 ostriches per hectare, depending on rainfall. Under irrigation, 10 birds per hectare are allowed. According to Maree (1979) 0.43ha lucerne under irrigation can carry five ostriches. This will depend on the quality of the pasture as well as the age of the birds. Nel (1993) stated that birds on lucerne pastures can be stocked at a rate of 6.5 birds per hectare. According to Mellett (1993) the carrying capacity of lucerne pastures is eight ostriches per hectare when a system of alternative grazing is applied.

Although many studies have been conducted which investigated the effect of different stocking rates on the performance of animals and the subsequent effect thereof on pastures itself, no information is available on the effect of stocking rate of finishing ostriches on grazed lucerne (Holmes, 1975). The only previous study done with ostriches allowed to graze pastures at different stocking rates was done by Cornetto *et al.* (2003). This study was, however, done on starter ostriches (21 – 98 days old) and the researchers did not study the effect of stocking rate on the condition of the pasture. The starter ostriches grazed paddocks with mixed clover and ryegrass at low, medium and high stocking rates. The ostriches also received a commercial starter diet three times a day. In this study it was found that the stocking rate had significant effects on the body weight of the birds. Birds at the high stocking rate had a lower average body weight than birds grazed at the low or medium stocking rates. The stocking rates did not have an effect on the FCR of the birds. The researchers concluded that stocking rate can influence ostrich performance and that a stocking rate of 16m^2 per bird was found to maximize the ostriches' performance.

In a study done on pigs, Imura *et al.* (2005) found that pigs stocked at low and medium stocking rates showed higher daily gains and lower concentrate requirements than those pigs at the high stocking rate. In the paddock grazed by a high density of pig, almost all vegetation cover disappeared, whereas vegetation mostly or partly remained in the low and medium rate paddocks.

Many other studies have been done concerning stocking rates with grazing ruminants. These studies all confirmed that increased stocking rates will lead to lower live weights and lower ADGs. This trend was illustrated by De Villiers *et al.* (1993), Chong *et al.* (1997), Davies & Southey (2001), Animut *et al.* (2005) and

Van Niekerk *et al.* (2006b) in respect of sheep.

Blanc & Theriez (1998) found that deer hinds grew faster at a lower stocking rate, while a high stocking density also induced social stress that adversely affected grazing patterns and growth rates, especially in subordinate individuals, which bring in another completely and hitherto not studied dimension. The ADG was also significantly lower at the high stocking rate than at the low stocking rate.

According to Relling *et al.* (2001), high stocking rates on a pasture will depress individual animal performance, because the animals do not have the opportunity to select the most nutritious plant parts, while animal production per unit area will increase as the pasture is utilized more uniformly. A lower stocking rate will, in contrast, increase individual animal performance because the animal is able to select more nutritious plant parts and the unlimited availability of grazing (Hodgson & Illius, 1996 as cited by Van Niekerk *et al.*, 2006a). Animal production per unit area declines at low stocking rates due to the fact that low stocking rates lead to wastage of forage due to low forage utilization and an eventual decline in forage quality.

De Villiers *et al.* (1993) and Davies & Southey (2001) found that pasture availability will decrease with an increase in stocking rate. Animut *et al.* (2005) found that the residual forage mass after grazing decreased with an increase in stocking rate. The percentage of grass in the pasture sward also increased and the overall nutritive value of the available forage decreased with increasing stocking rates. The decrease in the nutritive value of available pasture with increasing stocking rates was also recorded by Van Niekerk *et al.* (2006a). Van Heerden & Tainton (1987) found that increasing the stocking rate of Merino ewes led to a curvi-linear decrease in available green material of lucerne and medic pastures and in both pastures the legume content of the pasture also decreased rapidly as stocking rate increased. They concluded that pasture production will increase with increasing stocking rate, but only up to a certain point, after which pasture production will decrease due to overgrazing. Overgrazing leads to excessive defoliation of pasture plants as well as to a reduction in photosynthetic capacity and ultimately to the disappearance of species favoured by animals (Van Soest, 1982). The condition and production of the pasture will therefore be greatly affected by stocking rate (Donaldson, 2001).

Huston *et al.* (1993) did a study with beef cattle in which high stocking rates were combined with high levels of supplementary feeding. Feeding level did not interact with stocking rate. These researchers confirmed that beef cattle lost more weight at a high stocking rate than at a low stocking rate. They also found that at the high stocking rate, supplemental feeding tended only to decrease body weight loss. Greater body weight losses tended to occur at high stocking rates with increased energy feeding. The high supplementation led to a higher intake of forage by the cattle.
From these studies it is therefore evident that it is essential to determine the carrying capacity of pasture and then to utilize it with the correct number of animals for the appropriate period of time. This is important for pasture maintenance and improving animal performance.

The aim of this experiment was to measure the effects of two stocking rates on the production of grazing ostriches, as well as the effect they have on pasture production. Improved survivability and growth of ostriches is possible if research focuses on adequate space requirements as this may lead to management changes that could help diminish stress (Cornetto *et al.*, 2003). Due to the fact that not only the stocking rate, but also the level of supplementation can have an effect on ostrich and pasture production, two different levels of supplementation were also applied.

Materials and methods

Experimental site:

The study was conducted at the Kromme Rhee Experimental Farm near Stellenbosch in the Western Cape Province. The study commenced in January 2007 and was concluded in June 2007. The experimental site was situated at longitude 18º50' Easterly and latitude 33º51' Southerly in the southern hemisphere. Kromme Rhee lies 177m above sea level and has a typically Mediterranean climate with a cool, wet autumn, winter and spring, and dry summers. The mean annual rainfall is 622.7mm (for a 30-year average) and 84% of this rainfall occurs during the months of April/May to September/October (Labuschagne, 2005). The type of soil is classified as a Hutton (McVicar *et al.*, 1977).

Experimental design:

a) *Ostrich data*

For the ostrich data, the experiment had two main treatments factors namely two levels of supplementary feeding (0 and 800g/bird/day) and two stocking rates (10 and 15 birds/ha) with individual birds used as replicates.

b) *Pasture data*

For the pasture data, the experiment was completely randomized in design with six months (January, February, March, April, May and June) as split plots and two main factors namely level of supplementary feeding and stocking rates, which were replicated four times.

Experimental animals and management:

The experimental birds used in this study were African Black ostriches (*Struthio camelus* var *domesticus*). In December 2006, ostriches (n = 200) of mixed gender were obtained from different ostrich producers in the Oudtshoorn area of the Western Cape. All of the birds were six months old at the time of purchase. The birds were randomly allocated to five treatment groups. There were two groups of 50 ostriches each, two groups of 35 ostriches each and one group of 30 ostriches. The group of 30 ostriches was divided into three groups of 10 ostriches each and kept in three equally sized feedlot paddocks of 30m x 40m each, which consisted of wooden poles and smooth wire strands (in order to minimize skin damage). These birds served as reserve birds to replace any ostriches lost from the four grazing groups. This was done as a precautionary measure in order to maintain the correct stocking rate in each paddock.

The other four groups of ostriches were allowed to graze irrigated lucerne pastures. There were two groups of 50 ostriches each (the 15 birds/ha stocking rate) and two groups of 35 ostriches each (the 10 birds/ha stocking rate). Individual ostriches were identified through the attachment of a neck tag. Standard management practices for ostriches as applied by the Ostrich Research Unit of Elsenburg Research Centre for rearing ostriches were implemented.

Pasture:

Lucerne (*Medicago sativa*) pastures (cv. SA Standard) had been established four years prior to the experiment. Prior to establishment the soil was analyzed and the pH and P and K levels adjusted by fertilization. The lucerne was established in the autumn by broadcasting at 12kg seed/ha. Before sowing, the seed was inoculated with the appropriate *Rhizobium* nodule bacteria. The lucerne pasture was fenced into 16 treatment paddocks of approximately 0.85 ha each. Fences were 1.5m high and consisted of wooden poles and smooth wire strands. The pastures were also irrigated on a weekly basis during the summer, using an overhead sprinkler system. Irrigation after the establishment phase was restricted to once a week if no ostriches were occupying the paddocks. While the paddocks were occupied with ostriches no irrigation was applied so as to minimize any trampling of the wet pasture by the ostriches. In each paddock water was provided in rectangular 25L water troughs, each with an automatic refill apparatus attached.

Treatments:

Before the experiment began in January 2007, all the ostrich groups except those in the feedlots were allowed to graze four of the 16 lucerne paddocks for a few days, without receiving any supplementation. This was done as a precautionary measure to allow the digestive systems of the ostriches to adapt to the lucerne grazing, after which period the four groups were put into four new lucerne paddocks to start the trial.

The feedlot ostriches received a complete finisher diet (with zero lucerne grazing) supplied in two ostrich feeders per feedlot paddock. The birds had free access to clean drinking water supplied in rectangular 25L water troughs, each with automatic refill apparatus attached. New feed was weighed out every two days and put into the feeding troughs. When ostriches were weighed, the feed left in the feeding troughs was weighed again to determine the feed intake of the ostriches. The formulation of the complete finisher diet was based on the chemical composition of ingredients and ostrich nutritional requirements as proposed by Brand (2006). The ingredient and nutrient composition of the complete finisher diet is presented in Table 6.1.

Table 6.1 Ingredient (kg) and nutrient (%) composition of the complete finisher diet fed as pellets to the feedlot ostriches (values given on *as fed* basis).

Ingredients (kg/ton feed):	
Lucerne-meal	610
Yellow maize	300
Soybean seeds meal (44% CP)	50
Molasses powder (Calorie 3000®)	12
Monocalciumphosphate	11
Limestone, ground	9
Common salt	4
Ratite Finisher Vitamin & Mineral Premix	4
Nutrients (%):	
TMEostrich (MJ/kg)	10.7
CP	15.2
Lysine	0.66
Methionine & Cystine	0.44
Threonine	0.59
Tryptophan	0.19
Arginine	0.69

Of the four groups grazing the lucerne pastures two groups (10 and 15 birds/ha respectively) received 0g/bird/day of a pelleted supplementary feed and two groups (10 and 15 birds/ha respectively) received 800g/bird/day of a pelleted supplementary feed. This was offered to them daily in three low, rectangular feeding troughs. They had free access to the pasture and clean drinking water. The composition of the supplementary feed supplied was formulated according to the nutrient requirements of the ostriches for this growth stage at a level of 1000g supplementary feed/bird/day plus 1500g lucerne pasture/bird/day (Brand & Gous, 2006). The ingredient and nutrient composition of the supplementary feed is presented in Table 6.2.

Table 6.2 Ingredient (kg) and nutrient (%) composition of the supplementary feed supplied to the ostriches grazing lucerne pastures (values given on *as fed* basis).

Ingredients (kg/ton feed):	
Yellow maize	758
Soybean seeds meal (44% CP)	127
Molasses powder (Calorie 3000®)	30
Monocalciumphosphate	27
Limestone, ground	23
Common salt	25
Ratite Finisher Vitamin & Mineral Premix	10
Nutrients (%):	
TMEostrich (MJ/kg)	13.5
CP	12.2
Lysine	0.54
Methionine & Cystine	0.44
Threonine	0.44
Tryptophan	0.14
Arginine	0.69

The complete finisher diet and the supplementary feed were formulated using the computer programme MIXIT-2^{TM} (1982).

Grazing management:

Four lucerne paddocks were randomly allocated to each treatment group. The ostriches were allowed to graze each paddock for a period of two weeks, or until the pasture became depleted, whichever came first. The group was then moved to the next paddock in the group of four paddocks allotted. The lucerne pastures were therefore subjected to a four-paddock rotational system.

Observations and measurements:

a) *Ostrich data*

At the onset of the experiment the ostriches in each group were weighed individually by means of a mobile electric scale (Rudweigh 200®, Contry) and their starting weights recorded. Each bird was individually weighed to within an accuracy of 0.1kg to enable the determination of live weight and also to determine growth rate. Standard methods for handling ostriches were used with a hood being placed over each individual ostrich head, which allowed easier handling of the ostriches. All the lucerne paddocks were alike in all respects and each bird had equal access to the diets, therefore individual birds were considered as a replicate. Before moving each group of ostriches to the next paddock at the end of every two weeks, they were individually weighed and their weights recorded. In cases when the pastures became depleted earlier, the ostriches were moved and weighed more frequently. When the four grazing groups were weighed and moved, the feedlot ostriches were also weighed. There were four paddocks per treatment group and each ostrich group grazed each paddock four times in a rotational grazing system. Pasture intake of the birds were calculated as mean pasture intake per paddock (four cycles within a four-paddock rotational system). Feed conversion ratio was calculated by dividing intake of the birds by the mass change with no replications per treatment group.

b) *Pasture data*

Pasture production and pasture intake by the ostriches were both measured by placing five exclosure cages randomly in each paddock before grazing started and sampling the available pasture DM inside and outside each cage every time the ostriches were moved to a new paddock. Samples were taken within and outside each cage by cutting the pasture to ground level within 0.166m^2 quadrants using hand shears. The pasture production (kg/ha/day) was calculated as the difference between the amount of plant material outside the cages at the previous measurement, and the amount of plant material inside the cages during the current measurement. The pasture intake by the ostriches was calculated as the difference between the amount of plant material within the cages and the amount of plant material outside the cages at the end of each grazing period. The cages were constructed of 1200mm x 50mm x 100mm welded mesh cut into 3000mm lengths and used to form circular cages of approximately 0.45m^2 in area. The cages were tied to iron stakes, which were hammered into the ground. The cut pasture samples were subsequently collected in plastic bags and manually fractionated into dry material, lucerne, other legume, grass and broad-leaved weed fractions. The samples were dried to constant mass at 59°C, after washing to remove soil and weighed to determine the DM yield. These data were then used to estimate pasture DM production, pasture DM intake and residual pasture DM after grazing. After determining the DM yield of the pasture samples, the samples were milled through a 1mm sieve (C & N Laboratory Mill Size 8", Christy & Norris Ltd., Chelmsford, England) and stored in plastic jars pending chemical analyses. Forage samples were analyzed for concentrations of ash, CP, crude fibre, neutral-detergent fibre (NDF) and acid-detergent fibre (ADF). Ash concentration was determined according to the AOAC (method 942.05). Neutral-detergent fibre and crude fibre concentrations were both determined by using the Velp FIWE Raw Fibre Extractor (Velp Scientifica, Via Stazione 16, 20040 Usmate (Milano), Italy). Neutral-detergent fibre was analyzed according to the method of Robertson & Van Soest (1981) and crude fibre was analyzed according to AOAC (method 978.10). The concentration of ADF was determinted according to the method of Goering & Van Soest (1970), using the Dosi Fibre system (Labex (Pty) Ltd, P.O. Box 46009, Orange Grove, 2119). Total nitrogen was determined by using the Dumas Combustion method according to the AOAC (method 968.06), with a Leco FP-428 Nitrogen Determinator (Leco Corporation, St. Joseph, MI, USA). Crude protein concentration was then estimated as 6.25 x N concentration. The mean chemical composition (%) of the pasture as grazed by the ostriches during the experimental period is given in Table 6.3.

Table 6.3 The average nutrient composition (%) on a DM basis of the lucerne pastures during January to June 2007 while being grazed by finisher ostriches. Values presented as mean ± s.e.

Month	**CP**	**Crude fibre**	**ADF**	**NDF**
January	11.5 ± 0.89	49.4 ± 1.62	57.8 ± 2.25	66.3 ± 2.70
February	14.0 ± 0.65	44.1 ± 1.22	54.8 ± 2.59	60.3 ± 1.63
March	13.2 ± 0.44	43.3 ± 0.71	50.8 ± 0.78	58.3 ± 1.21
April	17.1 ± 0.96	39.0 ± 1.15	49.4 ± 2.48	54.4 ± 1.55
May	21.8 ± 0.95	34.3 ± 0.95	42.9 ± 0.87	49.2 ± 1.07
June	23.6 ± 1.28	32.6 ± 1.42	40.9 ± 1.27	46.2 ± 1.56

Statistical analysis:

a) Ostrich data

The final weight of the ostriches at the age of 54 weeks, their ADGs and the groups' FCRs were recorded. The effect of the supplementary feed level and stocking rate on the weight of the ostriches was analyzed by fitting a simple linear regression, y = a + b*age. The Proc GLM (SAS 9.1.3 for Windows, 2002 – 2003) program was used for the statistical analyses of the data. Analysis of variance on animal performance was used to test for significance of the treatments. The level of significance was calculated at a 5% confidence level.

b) Pasture data

The Proc GLM (SAS 9.1.3 for Windows, 2002 - 2003) was used for statistical analyses. The level of significance was calculated at a 5% confidence level. Normality for variable residuals for lucerne production, intake and residual lucerne were found and thus the results of the ANOVA were found to be reliable and valid. The variable residuals for the other plant material fractions were not distributed normally and were therefore not analyzed statistically.

Results

a) *Ostrich data*

The mean live weights of the different groups of birds at the start of the experiment did not differ (P >0.05) between each other. There was no interaction (P >0.05) between level of supplementary feed and the stocking rate for total DM intake of the birds (P =0.81) and mean live weight at 54 weeks (P =0.16). Data was therefore presented as the two main effects, the level of supplementary feed and the stocking rate. Supplementary feeding level had a noticeable effect (P <0.001) on both the total DM intake of the birds and mean live weight at 54 weeks. The growth curves of ostriches subjected to two different levels of supplementary feed is shown in Figure 6.1.

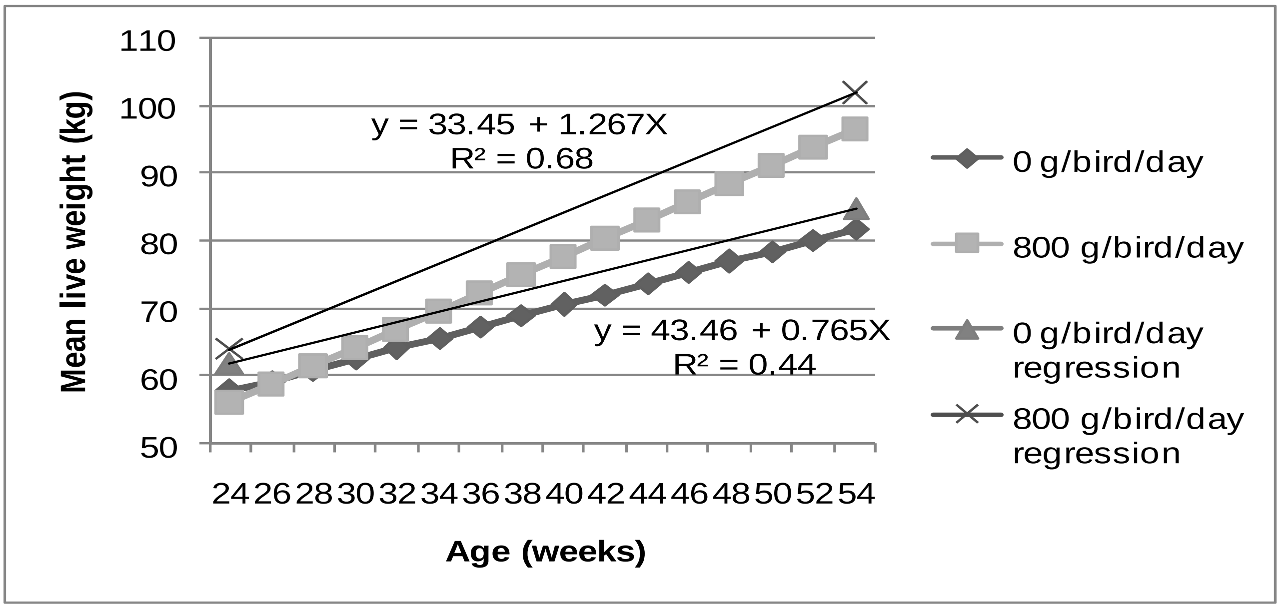

Figure 6.1 Mean live weights (kg) of grazing finishing ostriches subjected to two different levels of supplementary feed.

The linear relations for age (X) and mean live weight (Y) for the different treatment groups were as follows:

0g supplementary feed/day: $y = 43.46 + 0.765X$ ($R^2 = 0.44$)

800g supplementary feed/day: $y = 33.45 + 1.267X$ ($R^2 = 0.68$)

Ostriches receiving supplementation of 800g/bird/day had higher (P <0.05) total DM intakes (1736g/bird/day) than ostriches receiving no supplementary feed (1166g/bird/day). Ostriches receiving 800g of supplementary feed/bird/day reached the target weight (± 95kg) within the period of the trial, but the ostriches receiving no supplementary feed while grazing lucerne did not reach target slaughter weight in this period. Ostriches receiving 800g supplementary feed/bird/day reached a final higher (P <0.05) mean live weight of 98.9kg, while the ostriches receiving no supplementary feed reached a mean final live weight of 82.7kg only. The group of ostriches receiving 800g supplementary feed/bird/day had a FCR of 9.6kg feed/kg weight gain per group, while the group of ostriches receiving no supplementary feeding had an FCR of 10.9kg feed/kg weight gain per group.

Stocking rate did not have a significant effect ($P > 0.05$) on total DM intake of the birds and mean live weight at 54 weeks. Linear relations for age (X) and mean live weight (Y) for the different treatment groups, were as follows:

10 birds/ha: $y = 38.24 + 1.008X$ ($R^2 = 0.51$)

15 birds/ha: $y = 37.98 + 1.021X$ ($R^2 = 0.48$)

Total DM intake of the ostriches at a stocking rate of 10 birds/ha was 1475g/bird/day, while the total DM intake reached by the ostriches stocked at 15 birds/ha was 1426g/bird/day. Ostriches subjected to a stocking rate of 10 birds/ha achieved an average live weight of 91.5kg at 54 weeks, while the ostriches subjected to a stocking rate of 15 birds/ha reached a live weight of 90.0kg. Feed conversion ratio for the group of ostriches stocked at 10 birds/ha was 9.9kg feed/kg weight gain and it was 10.3kg feed/kg weight gain for the group of birds stocked at 15 birds/ha. Production results as obtained from the analysis of variance are presented in Tables 6.4 and 6.5.

Table 6.4 Total DM intake (g/bird/day) and mean live weight (kg) of ostriches subjected to two different levels of supplementary feed and two stocking rates. Values are mean ± s.e.

Supplementary feeding level	**Total DM intake (g/bird/day)**	**Mean live weight at 54 weeks (kg)**
0 g/bird/day	$1166^{b} \pm 0.09$	$82.7^{b} \pm 0.84$
800 g/bird/day	$1736^{a} \pm 0.09$	$98.9^{a} \pm 0.88$
Stocking rate		
10 birds/ha	$1475^{a} \pm 0.09$	$91.5^{a} \pm 1.29$
15 birds/ha	$1426^{a} \pm 0.09$	$90.9^{a} \pm 1.21$

$^{a,\ b,\ c}$ within supplementary feeding level and stocking rate columns, means with a different superscript differ significantly ($P < 0.05$).

A significant interaction was, however, found between the level of supplementary feed and stocking rate in respect of average daily gain (ADG) of the birds. The ADGs of the birds was analyzed using linear regression.

Table 6.5 Average daily gains (ADG) reached by ostriches subjected to two different levels of supplementary feed and two stocking rates. Values are mean ± s.e.

	Stocking rate			
	10 birds/ha		**15 birds/ha**	
	0 g/bird/day	**800 g/bird/day**	**0 g/bird/day**	**800 g/bird/day**
ADG (g/day)	131.8[b] ± 5.79	194.7[a] ± 5.69	107.8[c] ± 5.02	195.3[a] ± 6.02

[a, b, c] within rows, means with a different superscript differ significantly ($P < 0.05$).

It is clear that supplementary feeding of 800g/bird/day at each stocking rate led to significantly higher ADGs of ostriches as compared to no supplementary feeding. Also, if no supplementary feeding is supplied, birds grew at a faster rate ($P < 0.05$) at the lower stocking rate. The Proc GLM indicated an interaction ($P < 0.05$) between level of supplementary feed and stocking rate ($P = 0.04$) for ADG. This is illustrated in Figure 6.2.

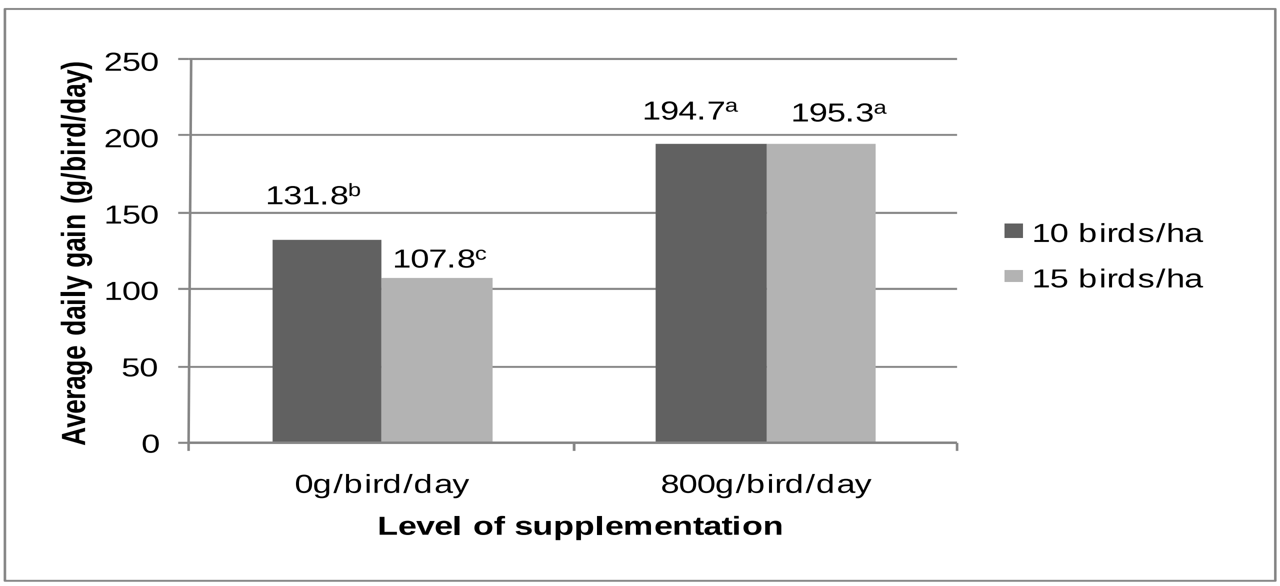

Figure 6.2 The ADGs (g/day) of ostriches subjected to two levels of supplementary feed, and two stocking rates.

Stocking rate had no significant effect on the ADGs of the ostriches that received 800g supplementary feed/bird/day. In the case of the ostriches receiving no supplementation, the ADGs were, however, significantly higher at 10 birds/ha than at the 15 birds/ha stocking rate. Therefore it can be concluded that stocking rate only influenced ADG of the birds when they did not receive any supplementary feed, while stocking rate did not influence the ADG of the birds which received 800g supplementary feed/bird/day. As stocking rate increased, the ADGs of birds receiving no supplementary feed therefore declined.

b) Pasture data

The pasture samples were composed mainly of lucerne with only negligible quantities of clover, grass, broad-leaf weeds and dry/dead material. The ostriches therefore consumed mainly lucerne.

An interaction (P <0.05) was found for lucerne intake between the level of supplementary feeding, stocking rate and months (P =0.03). This is illustrated in Figures 6.3 and 6.4.

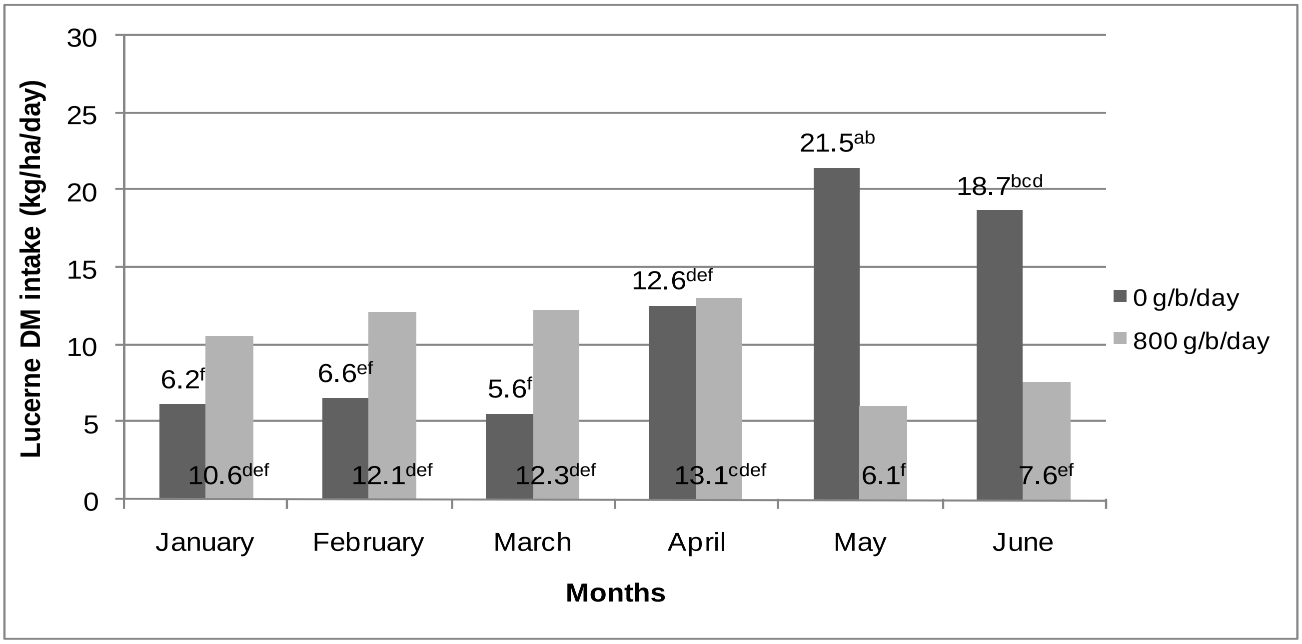

Figure 6.3 Mean lucerne DM intake (kg/ha/day) from January to June 2007, as influenced by two different levels of supplementation for ostriches grazing irrigated lucerne pastures and subjected to a stocking rate of 10 birds/ha. ^{a,b,c,d} means with a different superscript differ significantly (P <0.05) between levels of supplementation.

At the lower stocking rate of 10 birds/ha, supplementation did not influence (P >0.05) lucerne DM intakes during January to April. From May to June, the ostriches receiving no supplementation had higher (P <0.05) lucerne DM intakes than birds receiving 800g/bird/day supplementation. Supplementation of ostriches grazing irrigated lucerne pastures therefore resulted in birds grazing less lucerne DM during May and June at the lower stocking rate of 10 birds/ha.

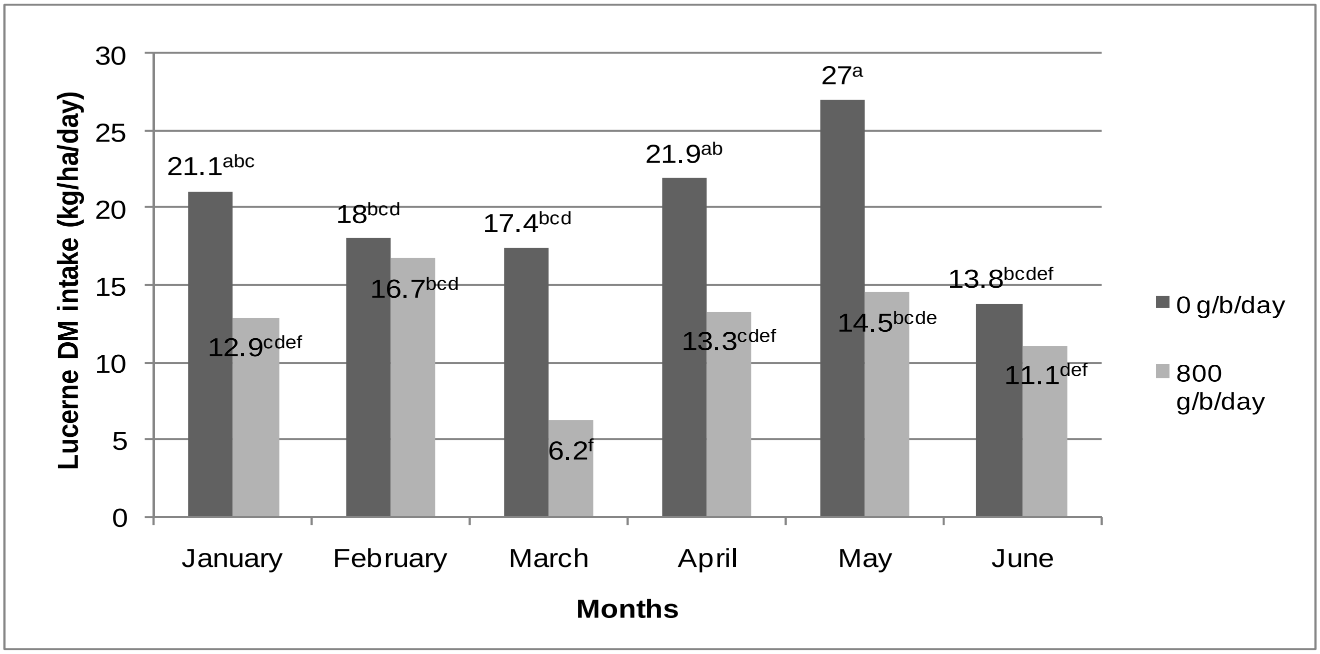

Figure 6.4 Mean lucerne DM intake (kg/ha/day) from January to June 2007, as influenced by two different levels of supplementation for ostriches grazing irrigated lucerne pastures and subjected to a stocking rate of 15 birds/ha. [a,b,c,d] means with a different superscript differ significantly (P <0.05) between levels of supplementation.

At the higher stocking rate of 15 birds/ha, birds receiving no supplementation had (P <0.05) higher lucerne DM intakes during March, April and May than the birds receiving supplementation of 800g/bird/day. During January, February and June, lucerne DM intake for ostriches receiving no supplementation tended (P >0.05) to be higher than lucerne DM intakes of ostriches receiving 800g supplementary feed/bird/day. It was unexpected that during the month of June lucerne DM intake of ostriches receiving no supplementation was very close to the intake of ostriches receiving supplementary feed at 800g/bird/day.

In the case of lucerne DM production, an interaction (P <0.05) was found between stocking rate and month (P <0.001). This is shown in Figure 6.5.

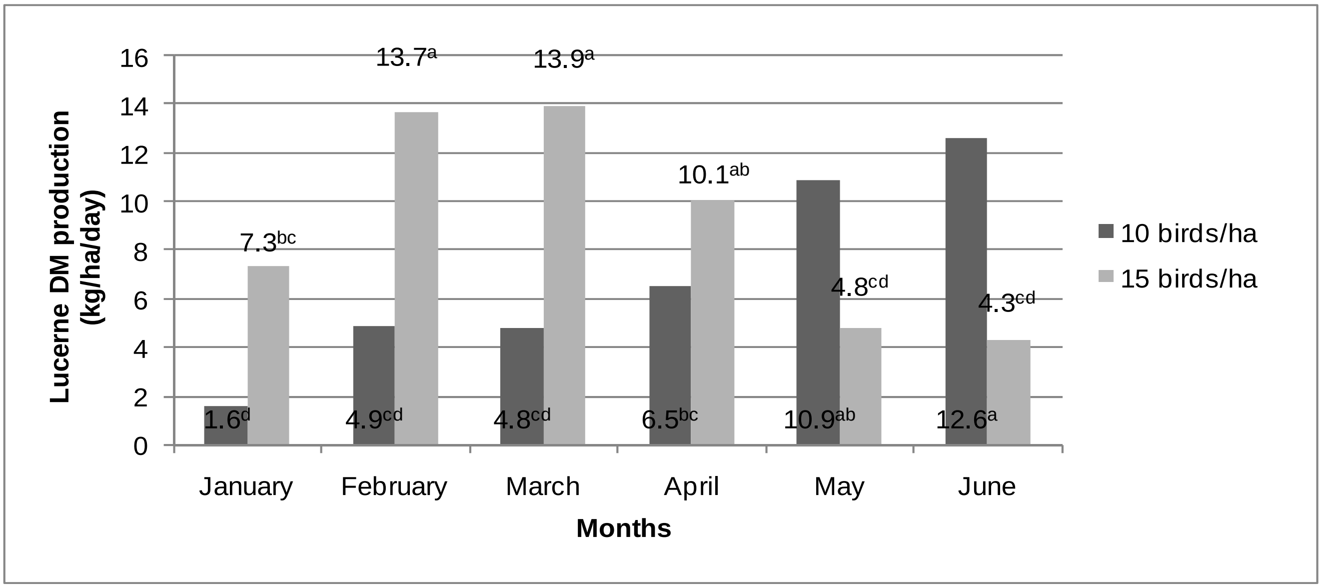

Figure 6.5 Mean lucerne DM production (kg/ha/day) during January to June 2007, as influenced by grazing ostriches at two stocking rates. [a,b,c,d] means with a different superscript differ significantly (P <0.05) between different stocking rates.

During January, February and March, lucerne DM production was higher (P <0.01) at the 15 birds/ha stocking rate than at 10 birds/ha, while there was no difference (P >0.05) between the lucerne DM production in April. Lucerne DM production was, however, higher (P <0.01) at 10 than at 15 birds/ha in May and June, probably due to overgrazing at the stocking rate of 15 birds/ha.

The nutrient contents of the available (pre-grazing) and residual (post-grazing) lucerne pasture are tabulated in Table 6.6.

Table 6.6 Average (%) (± s.e.) chemical composition of the available and residual lucerne pastures from January to June 2007.

Available DM lucerne pasture (pre-grazing)	January	February	March	April	May	June
Crude Protein (CP) (%)	10.4[d] ± 0.81	12.7[cd] ± 0.57	11.9[cd] ± 0.38	15.4[bc] ± 0.84	19.7[ab] ± 0.87	21.4[a] ± 1.15
ADF (%)	52.1[a] ± 2.10	49.7[ab] ± 2.40	45.9[ab] ± 0.79	44.6[bc] ± 2.26	38.7[cd] ± 0.78	36.9[de] ± 1.17
NDF (%)	59.7[a] ± 2.46	54.7[ab] ± 1.53	52.8[bc] ± 1.13	49.1[cd] ± 1.46	44.4[de] ± 0.99	41.8[ef] ± 1.43
Residual DM lucerne pasture (post-grazing)						
CP (%)	8.2[d] ± 0.63	9.9[cd] ± 0.75	10.6[cd] ± 0.28	12.1[c] ± 0.45	17.1[b] ± 0.86	19.5[a] ± 0.70
ADF (%)	55.8[a] ± 1.78	53.1[ab] ± 1.77	51.3[ab] ± 0.58	50.9[bc] ± 1.89	46.3[cd] ± 1.11	44.4[d] ± 1.19
NDF (%)	64.9[a] ± 1.83	60.3[b] ± 1.61	60.7[ab] ± 0.55	57.9[bc] ± 0.84	54.5[cd] ± 1.25	50.8[d] ± 1.35

[a, b, c] within rows, means with a different superscript differ significantly (P <0.05).

There was no interaction (P >0.05) between level of supplementary feed and stocking rate in respect of the nutrient contents of available and residual lucerne pasture. The percentage of the CP, ADF and NDF of the lucerne pasture did not vary between before and after grazing. No decrease in the nutritive value of the pasture was observed in successive grazing cycles due either to the level of the supplementary feed or the stocking rate of ostriches. The nutrient content of the available and residual lucerne pasture varied (P <0.05) between months. As the trial progressed, the percentage of CP in the available and residual lucerne pasture increased, while the percentage of fibre (ADF and NDF) decreased.

No effect (P >0.05) of either level of supplementation or of stocking rate was observed on residual (after grazing) lucerne DM in this trial.

Discussion

a) Ostrich data

Two of the most important management practices that influence the body weight changes of animals grazing pasture are the level of supplementary feeding and the stocking rate (Huston *et al.*, 1993). No other studies with grazing finishing ostriches at different stocking rates and receiving different levels of supplementary feeding have thus far been reported on. The only study involving the stocking rate of ostriches was done by Cornetto *et al.* (2003) and was done with starter ostrich chicks aged 21 to 98 days. Furthermore, this study did not include different levels of supplementary feeding. In Chapter 4 of this thesis, different levels of supplementary feeding were provided to finishing ostriches grazing irrigated lucerne pastures. Four groups of ostriches in that study were stocked at a stocking rate of 15 birds/ha and they received respectively 0, 500, 1000 and 1500g of supplementary feed/bird/day respectively. In the current study ostriches grazed irrigated lucerne pastures at either 10 or 15 birds/ha and received either 0 or 800g supplementary feed/bird/day. As mentioned in the results of this study, no significant interaction was found between the level of supplementary feeding and stocking rate in respect of the mean live weight of the ostriches. Stocking rate also did not have a significant effect on the mean live weight of the ostriches. This is in contrast to what was found by Cornetto *et al.* (2003). They found that as the stocking rate increased, so the final live body weights of ostrich chicks declined. The level of supplementary feeding in the current study had a significant effect on the final live weight of the birds at 54 weeks of age. Birds subjected to a stocking rate of 15 birds/ha and receiving 500g supplementary feed/bird/day in the previous study reached a mean live weight of 88.4kg within 205 days of the trial and the group had a FCR of 10.6kg. Birds receiving 1000g of supplementary feed/bird/day reached a mean live weight of 96.9kg within 154 days and their FCR was 9.4kg. This compared very well with the groups of ostriches in the current study, which received 800g supplementary feed/bird/day and reached a mean live weight of 98.9kg within 201 days and had a FCR of 9.6kg. In the previous study, birds receiving no supplementation reached a mean live weight of 73.9kg at 48 weeks of age and had an FCR of 10.4. This is comparable to the current study's ostriches which received no supplementation. They reached mean live weights of 82.7kg at 54 weeks of age and had a mean FCR of 10.9. In the current study the mean live weights of the ostriches which received no supplementation were better than in the previous study, due to the fact that they were kept longer on the pasture before slaughter.

In the current study there was significant interaction between the level of supplementary feed and the stocking rate in respect of the ADG of the birds. At high levels of supplementation (800g/bird/day), the ADG of the birds for both stocking rates were very similar (194.7g/day for the 10 birds/ha group and 195.3g/day for the 15 birds/ha group). However, in the treatment where birds were not supplied with supplementary feeding while grazing, there was a significant decrease in ADG from the low stocking rate (131.8g/day) to the high stocking rate (107.8g/day). This decline in ADG with increased stocking rate, where animals received no supplementation, agrees with numerous other studies done on grazing ruminants. Jones (1974) showed this trend with yearling cattle in Australia; Van Heerden & Tainton (1987) with sheep on lucerne and medic pastures in South Africa; De Villiers *et al.* (1994) with lambs on kikuyu grass; Relling *et al.* (2001) with sheep on tropical pastures; Animut *et al.* (2005) with sheep and goats on a grass/forbs mixed pasture; and Van Niekerk *et al.* (2006b) with lambs on a perennial irrigated pasture. This is mainly due to the fact that at high stocking rates the feed intake of grazing animals are restricted due to limited pasture availability and limited opportunity to select the more nutritious plant parts in the pasture. The performance of the animals will therefore deteriorate (Van Niekerk *et al.*, 2006b). This will be even more so in the case of ostriches because of the manner in which they graze the pasture, which is by stripping the stems of their leaves. The leaves are the most nutritious parts of the plants (Van Niekerk, 1995).

b) *Pasture data*

The replacement of pasture with supplementary feed, which is evident in Figure 6.3 and Figure 6.4 of the current study (where birds receiving supplementation of 800g/bird/day took in significantly less lucerne DM during the last two months of the trial than birds receiving no supplementation), agrees with studies done by various researchers, who all stated that when grazing dairy cows are fed increasing amounts of supplements, the pasture DM intake will usually decrease (Grainger & Mathews, 1989; Stockdale, 2000; and Bargo *et al.*, 2003). This process is known as roughage-concentrate substitution (Faverdin *et al.*, 1991). Stockdale (2000) found a significant interaction between the level of substitution and unsupplemented pasture intake when concentrates are fed. The substitution of pasture increased for each additional kg of concentrate fed. This high substitution may reduce profitability because pasture is not used as effectively (unless stocking rates are also increased). According to a study done by Huston *et al.* (1993), a high stocking rate will lead to a lower feed intake by beef cows on native rangelands. The same trend was found by Van Niekerk *et al.* (2006b) for lambs grazing perennial irrigated pastures. This was also found in the present study where birds receiving supplementation of 800g/bird/day while on the higher stocking rate of 15 birds/ha showed increased levels of substitution of pasture with supplementary feeding and had significantly lower lucerne DM intakes during the months of March, April and May of the trial.

Animals need to maintain feed intakes to maintain good ADGs and reduction in feed intake will ultimately lead to a decline in animal performance (Relling *et al.*, 2001). Stocking rate usually affects animal performance through its influence on the pasture availability (De Villiers *et al.*, 1994). According to the study of Van Niekerk *et al.* (2006b), increasing stocking rates will lead to a decrease in pasture availability. Animals which receive no supplementation on pasture are dependant on pasture availability. The decline in the ADG of birds receiving no supplementation with increased stocking rate (Figure 6.2) is therefore due to reduced intake at this higher stocking rate and in accordance with these studies.

The production of lucerne DM was at first stimulated by a higher stocking rate of 15 birds/ha, but after March the production of lucerne DM started to decline at the high stocking rate. In contrast to this, lucerne DM production gradually increased at the lower stocking rate of 10 birds/ha until it was significantly higher than the lucerne DM produced under the high stocking rate during the last two months of the trial. The higher production of lucerne DM under the high stocking rate of 15 birds/ha is in accordance with a study of Cid *et al.* (2008), in which it was found that two higher stocking rates in pastures resulted in the pasture re-growth being 61% higher than the re-growth of pastures at two lower stocking rates. This is due to the fact that the young leaves of recently defoliated pasture tend to have a higher capacity for photosynthesis than undefoliated pasture. Although a higher stocking rate will initially lead to a higher regrowth of the pasture, this can lead to degradation of the pasture if it is too high. This is probably what happened during the last three months at the higher stocking rate of 15 birds/ha in our study. A decline in lucerne DM production was observed during this period as opposed to an increase in lucerne DM production at the lower stocking rate of 10 birds/ha during the same period. This decline in the production of lucerne pasture from increasing the stocking rate is in accordance with a study done by Jones (1974) on a legume-based pasture in Australia.

Animut *et al.* (2005) found that the concentration of nitrogen in residual pasture DM declined as stocking rate was increased. This was not found in the current study and there was also no difference in the nutrient content of the pasture before and after being grazed by ostriches. In the study of Animut *et al.* (2005), the stocking rate did not affect the concentration of NDF in the pasture before and after grazing, which is in accordance with the current study. Popp *et al.* (1997) however, found that the NDF and ADF were sometimes greater in pastures being stocked at heavy levels.

As the current study progressed, the percentage of CP in the available and residual lucerne pasture increased, while the percentage of fibre (ADF and NDF) decreased. This is in stark contrast with what was found in other studies involving grazing cattle. Popp *et al.* (1997) found seasonal declines in grazed lucerne-grass herbage CP for all his grazing treatments (i.e. continuous or rotational systems), confirming that CP content declines as forage matured. Also, the NDF and ADF content of the pastures in the study by Popp *et al.*(1997) increased as the season progressed, which again is in contrast to what was found in the current study with ostriches.

Animut *et al.* (2005) also found that as stocking rates increased, the amount of residual forage declined linearly, as opposed to pastures being stocked at a lighter rate. This was also found by Davies & Southey (2001), but was not found in the current trial, since neither stocking rate, nor level of supplementation influenced the residual forage mass. This could be due to the fact that an additional factor (i.e. level of supplementary feeding) in the current study also had an influence on the results and not just the stocking rate.

Conclusion

In this study stocking rate (10 vs. 15 birds/ha) did not have a significant effect on the total DM feed intake and the mean live weight of finishing ostriches grazing irrigated lucerne pastures while receiving supplementation or not. This can be investigated further in future studies, where the two stocking rates chosen can be higher than the stocking rates used in the current trial. Supplementary feeding, however, did have a significant effect on total DM feed intake and mean live weight of the birds at 54 weeks of age. Those birds receiving 800g supplementary feed/bird/day reached the target slaughter weight of ± 95kg within the period of the trial, whereas the birds receiving no supplementation did not reach this weight. This seems to reinforce the fact that lucerne pasture *per se* is not a balanced diet and cannot supply all the necessary nutrients needed by grazing finishing ostriches. Stocking rate only influenced the ADG significantly when the ostriches did not receive any supplementation; but when they received 800g/bird/day, the stocking rate had no influence on the ADGs of the birds. When no feed supplementation was given, an increase in the stocking rate from 10 to 15 birds/ha leads to a decrease in the ADGs of the birds.

From the results of this study, it can be concluded that at the low stocking rate of 10 birds/ha, supplementary feeding in the beginning of the trial had no significant effect on pasture intake. The pasture intake of ostriches receiving no supplementation gradually became higher than the intake of ostriches receiving supplementation. The trend that was observed here is one of decreasing pasture intake by birds receiving supplementation of 800g/bird/day and increased pasture intake by birds receiving no supplementation.

At the high stocking rate of 15 birds/ha, lucerne DM intake tended to be higher for birds receiving no supplementation than for birds receiving supplementation of 800g/bird/day. The effect of feeding level, therefore, tended to be more pronounced at this high stocking rate of 15 birds/ha over most of the trial period. These results seem to indicate an increasing level of replacement of grazed lucerne DM by supplementary feeding as the trial progressed and this was more pronounced at the higher stocking rate of 15 birds/ha.

Stocking rate seems to have had a cumulative effect on lucerne DM production in this trial. Lucerne DM production was higher at the higher stocking rate of 15 birds/ha in the beginning of the trial. Therefore, the higher stocking rate stimulated the production of lucerne DM, but this higher stocking rate also eventually resulted in over-utilization of the pasture. Therefore, in the later months of the trial, the higher stocking rate of 15 birds/ha led to lower lucerne DM production when compared to the lucerne DM production at the lower stocking rate of 10 birds/ha. The high stocking rate of 15 birds/ha, therefore, seems to have had a gradual depressing effect on lucerne DM production, while the less severe levels of defoliation at the low stocking rate possibly eventually promoted lucerne DM production.

Stocking rate and supplementary feeding influenced lucerne DM intake, while only stocking rate influenced lucerne production. Supplementary feeding depressed lucerne intake at both the high and low stocking rate. Since there was no difference in the nutrient content of the pasture either before or after being grazed by ostriches, it can be concluded that such grazing did not lead to a decline in pasture quality in this trial.

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Chapter 7

The economics of supplying different levels of supplementary feed for finishing off ostriches on irrigated lucerne pastures

Abstract

Since feeding costs contribute 70 – 80% of the total costs of an intensive ostrich production system, it has an important financial impact on the profitability of such an enterprise. One option to reduce feeding costs when finishing ostriches is to convert from a conventional intensive feedlot system to a pasture-based system with supplementary feed. This study investigated the performance of slaughter ostriches kept on irrigated lucerne pasture at different levels of supplementation and no supplementation, in comparison to ostriches kept in a feedlot fed on complete finisher diets. The economics of the different feeding systems were evaluated. Two hundred and fifty ostriches (± six months old) were randomly allocated to five groups of fifty ostriches each. Four of these groups grazed irrigated lucerne pastures on a rotational basis, and the fifth group was put in a feedlot and received a complete finisher diet (zero-grazing). Three of the four grazing groups received supplementary feed at respectively 1500g/bird/day, 1000g/bird/day, and 500g/bird/day while the fourth group received no supplementary feed (0g/bird/day). Pasture dry matter (DM) production, intake, availability, and residual DM were determined by cutting samples and data were used to calculate the feed cost per unit of DM pasture. A margin above feed cost analysis was performed to evaluate the economic viability of the different feeding systems. Ostriches grazing lucerne and receiving 1000g supplementary feed/bird/day showed the highest margin above feed cost, closely followed by the ostriches receiving 1500g supplementary feed/bird/day, with ostriches raised in a feedlot showing the lowest margin above feed cost. Birds finished on lucerne pasture with 1000g supplementary feed/bird/day led to a saving of 57% in feeding costs if compared to a feedlot system. The economics of the different feeding systems over the entire six year productive lifespan of lucerne pastures were assessed with a Present Value (PV) analysis for a 100-bird unit. This revealed a higher total margin above feed cost for the feedlot system as compared to the pasture-based system. This is due to the fact that only one batch of ostriches can be finished off from pastures within a given year, as compared to two batches of ostriches in a feedlot system. The PV of the margin above feed cost for the pasture-based system with 1000g/bird/day supplementation was, however, only 8.3% lower than that of the feedlot system over six years, while the PV of the cost of the same pasture-based system was 78.4% lower than that of the feedlot system. A sensitivity analysis of the margin above feed cost for possible changes in product prices and feed prices revealed that the pasture-based system was also less sensitive to changes in feeding costs than the feedlot system. Although the unique circumstances of each ostrich producer will play a role in the decision whether to produce ostriches in a feedlot or on pastures, the results of this study may be of value in terms of determining long-term economic viability.

Keywords: ostrich production, pasture-based system, feedlot system, margin above feed cost, sensitivity analysis, present value

Introduction

Some of the most important factors that influence the profitability of an ostrich production unit are feeding costs and the number of chicks per breeding hen (Van Zyl, 2001). To gain competitiveness, the ostrich industry must focus on the satisfactory growth of the birds while reducing costs associated with feeding. Feed costs are by far the biggest element in an intensive ostrich production system (Adams & Revell, 2003). According to Farrell *et al.* (2000), feed costs for growing birds are as high as 70% of the total production costs and for the ostrich industry to remain viable, it is necessary to reduce these feeding costs. In South Africa alone, approximately 250 000 tons of ostrich feed is used annually at a cost of about R494 million. If the industry could save only 10% in feeding costs, this would result in a total saving of R49.4 million per year for the local industry (Brand & Gous, 2003). This can have a major impact on the profitability of a commercial ostrich production unit (Farrell *et al.*, 2000).

According to Brand (2001), birds consume about 70kg of feed during the pre-starter and starter phase. This is 14% of their total feed intake up to slaughter. Therefore, feed cost during these phases has only a minor effect on the total cost of raising the birds. However, birds in the grower and finisher phase consume respectively about 150 and 280kg of feed, which amounts to 86% of the total feed intake needed from hatch to slaughter (Brand, 2001). According to results from a study by Cilliers (1998), the nutrient supply from pastures for birds between 6 – 10 months of age may contribute up to 50 – 55% without a decrease in production. Therefore, it is of economic importance to investigate the feeding costs associated with these two phases of the production cycle of the ostrich. Typically, management systems for the production of ostriches rely on significant inputs of commercially formulated complete feeds or pellets in a feedlot system (Champion & Weatherley, 2000). According to these researchers, an extensive production system for the growth of young slaughter birds from 4 – 14 months of age could be critical to the success of a sustainable future for the ostrich industry. This is due to the fact that grazing systems are low-cost management systems, which can produce high-quality hide, skin and feather products. These researchers found that although ostrich growth on pastures is not as rapid as in an intensive system, grazing systems provides a number of cost, welfare and marketing benefits for the industry. The study of Champion & Weatherley (2000) found that total feed intake for an intensive system amounted to 600kg per bird, whereas a pasture-based system with a correctly formulated supplement, only needed 200kg of supplement per bird. Even when the establishment and maintenance costs of the pasture are taken into account, total feed costs decline by 10% when a pasture-based system is used instead of commercial complete feeds in an intensive system.

Increasing the use of pastures as a low-cost feed source therefore can have the potential of playing an important role in the long-term sustainability of the ostrich industry (Brand & Gous, 2006). It is possible for an ostrich producer, who is able to grow his own pasture, to buy a supplement to complement this pasture and then produce marketable slaughter birds at much lower feeding cost than farmers making use of complete feeds in feedlot systems (Adams & Revell, 2003).

In Chapter 4 of this thesis, the results of a study were reported on the growth of finisher ostriches receiving a complete finisher diet in a traditional feedlot as compared to finisher ostriches allowed to graze lucerne pastures while they received respectively 1500, 1000, 500 and 0g supplementary feed/bird/day. This study revealed that feedlot ostriches as well as ostriches grazing lucerne pastures supplemented with 1500 or 1000g feed/bird/day respectively, reached a mean target live weight of 95kg within the same timespan (which was 154 days from the start of the trial), while the ostriches grazing lucerne supplied with either 500 or 0g supplementary feed/bird/day did not reach a mean target live weight of 95kg by then. An ANOVA revealed that feedlot-raised ostriches and ostriches grazing lucerne supplemented with 1500g feed/bird/day showed mean live weights of respectively 99.1 and 103.2kg, which were not significantly different from each other. The ostriches grazing lucerne and supplied with 1000g supplementary feed/bird/day reached a mean live weight of 96.9kg, which was significantly lower than the mean live weights reached by the ostriches receiving 1500g supplementary feed/bird/day, but not significantly lower than the mean live weights of the feedlot-raised ostriches. For the purposes of the economic study, the mean live weights at 154 days were used, although the average daily gains and feed conversion ratios were also recorded. The aim of this study was to determine which of these three feeding systems were the most viable option for ostrich producers in the Little Karoo district of the Western Cape. This chapter firstly performs a cost calculation on lucerne pasture, followed by an assessment of the margin above feed cost of each feeding system. This was followed by a sensitivity analysis to determine the effect of changes in feed costs on the margins of the different feeding systems. The chapter concludes with a comparison of the profitability of the different feeding systems. A PV analysis over a six-year time horizon, which is the productive lifespan of lucerne pasture, was applied.

Theoretical background

To assist farmers in assessing the economic viability of a certain production system in the farm business, the gross margin of the production system can be calculated (Bhiya, 2006). A projection of the average annual costs, and returns for an enterprise will be made, and this is referred to as the gross margin calculation for the enterprise (Boehlje & Eidman, 1984). The difference between the estimated gross production value and the directly allocatable variable costs of a specific enterprise, is defined as the gross margin. The potential contribution of an individual production system to the fixed and non-directly allocatable variable costs, and therefore also to the eventual profit of the whole farming enterprise, will therefore be represented by the gross margin (Barnard & Nix, 1979).

The gross production value of a farm business can be defined as the total value of saleable production of the farm business in a particular year (Van Zyl *et al.*, 1999). In an ostrich enterprise, this will include the meat, leather, and feather sales generated from slaughter ostriches.

For most economic analyses, costs can be categorized in various ways, but division into two broad categories is appropriate (Van Zyl *et al.*, 1999). Fixed costs are those costs that do not change with the level of output of the production system. Therefore, these costs remain the same whether there is any production, and will also remain the same in high-income as well as in low-income years. Examples of costs that are usually fixed include: depreciation on buildings; taxes on the farm; insurance; cash rent; and the interest payments on loans. Variable costs, on the other hand, change with the level of output of the production system and they are a function of the amount of product generated. These costs do not occur unless the farmer attempts production. Examples of variable costs include: seed; fuel; pesticides; harvesting; drying; and labor hired on a daily or weekly basis. Examples of variable costs could also be money spent to purchase feed and medication and to pay for transport and marketing expenses. Variable costs can be managed more easily in the short term and they are divided into directly allocated variable costs, indirectly allocated variable costs, and non-allocated variable costs. In the short-term, only variable costs should be considered when deciding what to produce, how to produce it, and how much to produce. Fixed costs will remain the same regardless of these decisions (Boehlje & Eidman, 1984). According to Van Zyl *et al.* (1999), it can be difficult to allocate the total costs of a farm business amongst different enterprises accurately, but the general practice in applying profitability analyses to individual enterprises is to allocate all possible costs that can be assigned to a particular production system with reasonable accuracy, hence the term directly allocatable variable cost.

This study is about feeding costs and the margin above feeding costs has been used to assess which feeding system is the most viable option in the Little Karoo. Subtracting feeding costs from the gross production value of the production system then gives the margin above feed cost.

Since the profitability of an enterprise can be sensitive to various macro-economic factors (over which the ostrich producer has no control), a sensitivity analysis can be performed to account for the effect that possible fluctuations in product prices and input costs may have on the margin (Barnard & Nix, 1979). The most critical variables that affect the ostrich industry are the prices of end-products and the overall increase in the prices of inputs like feed that have to be purchased. This may mean that the price realized by the farmer may be higher or lower than the price envisaged during the planning process (Bhiya, 2006). With a sensitivity analysis, the producer can, to some degree, quantify the effect of future risk and uncertainty on the margins of a particular production system.

The availability of ostrich chicks at any given time, the length of the period until slaughtering, the frequency of cash flow, and the fixed cost structure, are all factors that need to be taken into account when the profitability of different feeding systems are to be compared. The feedlot system of raising slaughter ostriches cannot simply be compared to a feeding system where ostriches graze lucerne pasture and receive different amounts of supplementary feed. This is because it is technically possible to raise two batches of feedlot ostriches within a production year, whereas only one batch of grazing ostriches receiving supplementary feed can be raised per year due to the production cycle of lucerne. Ideally then, a comparison between the different feeding systems needs to be done over a specific time horizon, preferably six years so as to match the lifespan of lucerne pastures. Comparing the different feeding systems over a period stretching beyond the current production year, will mean that cash flows will also occur over such a period of time in the future. It is for this reason that the time value of money needs to be taken into account. The basic concept of time value is that a rand in a farmer's hand today is worth more than a rand received sometime in the future (Bhiya, 2006).

To determine the value of money today when its value at some future date is known, future value (FV) can be discounted to find present value (PV) (Castle *et al*., 1987; Kay & Edwards, 1999). Present value is more appropriate to make decisions <u>now</u>. To evaluate the profitability of different systems over a period of time in the future, the PV analysis can therefore be used (Boehlje & Eidman, 1984). The alternative with the highest PV of net cash flow, is the most desirable. According to Barry *et al.* (1996), the formula by which the PV can be calculated, is as follows:

$$PV = FV/(1 + i)^n$$

where PV is present value, FV is future value and i is the current interest rate.

The net present value (NPV) of cash flows is a summation of the PV of all future cash flows and can be calculated as follows:

$$NPV = -INV + \frac{P_1}{(1+i)^1} + \frac{P_2}{(1+i)^2} + \ldots\ldots + \frac{P_N}{(1+i)^N} + \frac{V_N}{(1+i)^N}$$

where *INV* is the initial investment, P_N is the measure of net cash flows each year, *N* is the planning horizon, V_N is the salvage or terminal investment value, and *i* is the interest rate or discount rate (Barry *et al.*, 1995).

The discount rate is used to adjust the expected future net cash flow to its PV (Boehlje & Eidman, 1984) and is often the more difficult value to estimate. The discount rate is described by Kay & Edwards (1999) as the opportunity cost of capital, suggesting that if funds are to be borrowed to finance an investment, the discount rate can be set equal to the cost of borrowed capital (the interest rate).

According to Van Reenen & Marais (1992), the following steps are necessary for the application of NPV analysis:

1. Determination of the discount rate;
2. Calculation of the present value of the cash outlay required to launch the capital projects or to produce the assets;
3. Calculation of the annual net cash flow of the projects over their lifetime;
4. Calculation of the PV of the annual net cash flow;
5. Calculation of the NPV of the projects;
6. Acceptance or rejection of the project, or selection of the most advantageous project.

The materials and methods of this study are based on the aforementioned theoretical background. It was used to determine the cost of lucerne pastures, the margin above feed cost and the present value of the different feeding systems over a six year timespan.

Materials and methods

Experimental site:

The study was conducted at the Kromme Rhee Experimental Farm in the Western Cape Province near Stellenbosch. Kromme Rhee is situated at longitude 18º50' East and latitude 33º51' South in the Southern Hemisphere and lies 177m above sea level. The climate is typically Mediterranean, with cool, wet autumn, winter and spring, and dry summers. The mean annual rainfall is 622.7mm (for a 30-year average) and 84% of this rainfall occurs during the months of April/May to September/October (Labuschagne, 2005). The type of soil is classified as a Hutton (McVicar *et al.*, 1977). The study commenced in September 2005 and was concluded in April 2006.

Experimental animals and management:

The experimental birds used in this study were African Black ostriches (*Struthio camelus* var. *domesticus*) and they were obtained from different ostrich producers in the Oudtshoorn area of the Western Cape. A total of 250 birds of average age of six months were used in the study. Birds were randomly allocated to five treatment groups of 50 ostriches each to obtain a stocking density of 15 ostriches per hectare (in the case of the grazing groups). Individual ostriches were identified through the attachment of a neck tag. Standard management practices for ostriches, as applied by the Ostrich Research Unit of Elsenburg Research Centre, were implemented.

Pasture:

Lucerne (*Medicago sativa*) pastures (cv. SA Standard) had been established two years prior to the experiment. Prior to establishment, the soil was analyzed and the pH and Phosphorus and Potassium levels adjusted by fertilization. The lucerne was established in the autumn by broadcasting at 12kg seed/ha. Before sowing, the seed was inoculated with the appropriate *Rhizobium* nodule bacteria. The lucerne pasture was fenced into 16 treatment paddocks of approximately 0.85 ha each. Fences were 1.5m high and consisted of wooden poles and smooth wire strands. The pastures were also irrigated on a weekly basis during the summer using an overhead sprinkler system. Irrigation after the establishment phase was restricted to once a week, if no ostriches were occupying the paddocks. While the paddocks were occupied, no irrigation was applied so as to minimize any trampling of the wet pasture by the ostriches. In each paddock water was provided in rectangular 25L water troughs, each with an automatic refill apparatus attached.

Treatments:

Before the experiment began on 7 September 2005 four of the five ostrich groups were allowed to graze lucerne paddocks for a few days, without receiving any supplementation. This was done to allow the digestive systems of the ostriches to adapt to the lucerne grazing, after which period, the four groups grazing the lucerne were put into four lucerne paddocks to start the trial. The fifth group was randomly divided into three groups and kept in three feedlot paddocks of 30m x 40m each, also fenced with wooden poles and smooth wire strands in order to minimize skin damage.

The feedlot ostriches received a balanced, self-mixed complete finisher diet supplied in two ostrich feeders per feedlot paddock (15% crude protein (CP), 0.66% lysine and 10.7 MJ metabolizable energy (ME)/kg feed). This complete finisher diet was formulated according to the chemical composition of ingredients and ostrich nutritional requirements as proposed by Brand (2006). The birds had free access to clean drinking water supplied in rectangular 25L water troughs, each with automatic refill apparatus attached. New feed was weighed out every two days and put into the feeding troughs. When ostriches were weighed the feed left in the feeding troughs was weighed again to determine the feed intake of the ostriches.

The four groups grazing the lucerne pastures received respectively 0, 500, 1000 and 1500g/bird/day of a self-mixed pelleted supplementary feed (treatments) (12% CP, 0.54% lysine, and 13.5 MJ ME/kg feed). The supplementary feed was formulated according to the nutrient requirements of the ostriches for this growth stage at a level of 1000g of supplementary feed plus 1500g lucerne pasture/bird/day (Brand & Gous, 2006). Rations were fed in three low, rectangular feeding troughs per day, while the birds also had free access to the pasture and clean drinking water.

The complete finisher diet and the supplementary feed were formulated using the computer programme MIXIT-2™ (1982).

Grazing management:

Four lucerne paddocks were randomly allocated to each treatment group. The ostriches were allowed to graze each paddock for a period of two weeks before the group was rotated to the next paddock in the allocated four paddocks system. The lucerne pastures were therefore subjected to a four-paddock rotational system per treatment.

Observations and measurements:

a) Ostrich data

At the onset of the experiment, the ostriches in each group were weighed individually by means of a mobile electric scale (Rudweigh 200®, Contry) and their starting weights recorded. Each bird was individually weighed within an accuracy of 0.1kg to enable the determination of current live weight and also to determine growth rate. Standard methods for handling ostriches were used with a hood being placed over each individual ostrich head, which allowed easier handling of the ostriches. Since all the lucerne paddocks are alike in all respects and each bird had equal access to the diets, each bird was considered as a replicate. Before rotating each group of ostriches to their next paddock, each ostrich was weighed and their weights recorded, thereby ensuring that weights were obtained every two weeks. Together with moving and weighing the four treatment groups, the individual feedlot ostriches were also weighed and put back into their respective feedlots. There were four paddocks per treatment group and each ostrich group grazed each paddock four times in a rotational grazing system. Pasture intake of the birds were calculated as mean pasture intake per paddock (four cycles within a four-paddock rotational system).

b) Pasture data

Pasture production and pasture intake by the ostriches were measured by placing five exclosure cages randomly in each treatment paddock before grazing started and sampling the available pasture DM in and outside each cage every 14 days after grazing when the ostriches were moved to a new paddock. Five readings were taken within and outside each cage and pasture production (kg/ha/day) was calculated as the difference between the amount of plant material outside the cages in the previous measurement, and the amount of plant material inside the cages in the current measurement. This was then divided by the number of days between the two measurements. The pasture intake by the ostriches was calculated as the difference between the amount of plant material within the cages, and the amount of plant material outside the cages, at the end of each grazing period. The cages consisted of welded mesh used to form circular cages of approximately 0.45m^2 in area. The cages were tied to iron stakes, which were hammered into the ground. The available and residual pasture dry matter (DM) measurements were determined both inside and outside the exclosure cages by cutting the pastures to ground level within 0.166m^2 quadrants, using hand shears. These pasture samples were subsequently collected in plastic bags, manually fractionated into dry material, lucerne, other legume, grass, and broad-leaved weed fractions. The samples were, after washing with water to remove soil, dried to constant mass at 59°C, immediately weighed and used for the determination of the DM yield. These data were then used to estimate pasture DM production and pasture DM intake.

Profitability analysis

The gross production value of ostriches consists of three components, namely meat, skins and feathers.
The gross production value of the meat is based on mean carcass weights per treatment group, multiplied by current market prices for May, 2010 (Klein Karoo Group of Companies, P.O. Box 241, Oudtshoorn, 6620). Experimental values for the mean slaughter weight of each treatment group were converted to mean carcass weight with an average dressing percentage of 45% (Brand, 2006).

For skins, the model of Brand & Jordaan (2009) was used for predicting skin size. Based on the linear relationship between the slaughter mass of a bird and its potential skin size yield, the mean skin size per treatment group was determined by applying the following equation:

$Y = 82.01 + 0.628X$ ($P = <.001$ and $R^2 = 0.99$), where

Y = Skin size (dm^2) and
X = Slaughter mass of bird (kg)

Linking skin grading norms (Brand & Jordaan, 2009) to skin size, the gross production value was determined using current market-related prices for May, 2010 (Klein Karoo Group of Companies, P.O. Box 241, Oudtshoorn, 6620).

Based on the linear relationship between slaughter mass and feather yield (Brand & Jordaan, 2009), the mean feather yield per treatment group was determined by applying the following equation:

$Y = -1.03 + 0.026X$ ($P = 0.002$ and $R^2 = 0.78$), where

Y = Feather yield (kg) and
X = Slaughter mass of bird (kg)

The latest market prices (October 2009) for feathers were then used to calculate the gross production value of the feather yield in the present study (2010, A. Muller, Pers. Comm., Klein Karoo Group of Companies, P.O. Box 241, Oudtshoorn, 6620).

The price of the lucerne pasture was based on the on-farm production costs. These on-farm production costs consisted of the cost to establish lucerne pasture (in the first year) as well as the cost of maintaining this pasture for the next five years. According to Burger (2010, W. Burger, Pers. Comm., Department of Agriculture: Western Cape, P.O. Box 249, George, 6530) lucerne stands in the Little Karoo area of the Western Cape have a production lifespan of six years. Production costs included all directly allocatable variable costs associated with establishment and maintenance for a total period of six years. The costs per kg were determined by dividing the total production cost by the total DM production over six years. The DM production of the lucerne stand over six years was determined by adding the actual lucerne intake by the grazing ostriches (thereby taking into account wastage and trampling caused by the ostriches) plus the DM equivalent of two cuttings of hay during the winter season when lucerne production is not sufficient for raising ostriches (March and May of each year). This DM equivalent of two hay cuttings was added to pasture production for the following reason. It is very difficult to obtain the cost of lucerne pasture due to the fact that it is not a commodity which can be sold (e.g. lucerne bales sold at R50 per bale). To calculate the cost of lucerne pasture, the total DM yield (pasture intake by the birds) and the costs of establishment and maintenance must be calculated. This gives the total cost per kg DM. In the case of this study, the pasture-based system used dictates that additional hay can be produced during the season when the birds are not grazing the lucerne. Therefore it needs to be added to the DM yield to calculate the total yield of the pasture per unit (for e.g. per hectare). This influences the cost of the pasture in terms of R/kg DM and therefore it also influences feeding costs (2010, J. Jordaan, Pers. Comm., Nelson Mandela Metropolitan University, Private Bag X6531, George, 6530).

All the market-related current prices of raw materials used in the formulation of the complete finisher diet and the supplementary feed, were obtained from the local Coop (2010, A. Tredoux, Pers. Comm., Klein Karoo Group of Companies, P.O. Box 241, Oudtshoorn, 6620). A 10% milling and mixing fee (2010, T.S. Brand, Pers. Comm., Elsenburg Animal Production Institute, Department of Agriculture: Western Cape, Private Bag X1, Elsenburg, 7607) was added to take into account on-farm milling and mixing costs.

Subtracting the total feed costs from the gross production value, yielded the margin above feed cost per bird.

A sensitivity analysis was performed on the margins above feed cost to test the effect of marginal changes in both the value of production and feed costs, on the margins. Sensitivity of the margins was tested for both increases and decreases of 5, 10, 15 and 20% respectively for both feed costs and the value of production.

In order to compare the profitability of the different feeding systems, the projected cash flows of a 100-bird unit over six years (the lifespan of lucerne pasture) for three of the different feeding systems were estimated and converted to present values. The discount rate was assumed to be equal to the prime interest rate.

The following assumptions have been made in the profitability analyses:

1. For this study, the production year was taken to be from September to August. This is because the established lucerne pasture was ready for grazing in September, and six-month old ostriches were available to start the finishing phase. For the purpose therefore of comparing the present value (PV) of the margins above feed cost over a six-year period, the different production systems commenced in September, employing an all-in, all-out batch processing system.

2. The annual reproduction cycle of ostriches in South Africa occurs over an eight-month breeding season, which starts in June and lasts until January each year (Lambrechts, 2004). According to Engelbrecht (2010, A. Engelbrecht, Pers. Comm., Department of Agriculture, P.O. Box 313, Oudtshoorn, 6620), the first chicks are born in July and the last chicks are born in April. For the purpose of the PV value analysis in this study, it was assumed that six-month old ostriches would be available to start the finisher period between January and October. Therefore, it was assumed that the ostriches were six months old at purchase.

3. The economic analyses in this study were performed per bird, and each bird was assumed to be a representative of a batch in a specific feeding system, and was proportional to the inputs and yield. It should be kept in mind, however, that flock variables can influence the profitability of an ostrich enterprise in a specific feeding system.

4. Feed costs were the only directly allocatable variable costs considered.

5. The cost of harvesting hay includes only the variable costs of machinery, implements, and labour.

6. It was assumed that a farmer would be in possession of a farm with the required feedlot infrastructure and/or arable land for finishing off slaughter birds. Capital outlay for the ostrich production unit was therefore not considered in this study.

7. Current market prices for meat, skin and feathers were obtained from the Klein Karoo Group of Companies in Oudtshoorn (Klein Karoo Group of Companies, P.O. Box 241, Oudtshoorn, 6620).

8. The current bank lending rate of 10% was used as the discount rate (South African Reserve Bank, July 2010).

9. For the PV analysis, income and costs were adjusted annually to take into account inflationary effects. Income was adjusted on the basis of the index of producer prices for animal products, while costs were adjusted on the basis of the price index of intermediate goods from the Abstract for Agricultural Statistics (National Department of Agriculture, 2010). For both income and costs, the assumed annual percentage change was based on indices (with the year 2005 = 100) averaged over the latest five years (2005 – 2009).

It should be noted that financial viability calculations are case-specific and may vary between producers, depending on their individual management practices, production systems, and cost structures, as well as on any assumptions made.

Results and discussion

The cost of production of the establishment and maintenance of lucerne pasture is illustrated in Table 7.1 below.

Table 7.1 Lucerne establishment and maintenance cost budget for six years (per hectare)

Lucerne establishment costs: First year					
Directly allocatable variable costs				**Price**	**Total**
Input	**Product**	**Unit**	**Amount**	**R/unit**	**R/ha**
Lucerne seed	S.A. Standard	Kg	25	60.00	1,500.00
Lucerne seed treatment	*Rhizobium* innoculant	Unit	1	214.50	214.50
Fertilizers:					
Gypsum	Gypsum	Ton	2.5	700.00	1,750.00
Phosphate	Double supers	Ton	0.2	4,240.00	848.00
Minerals	Mb	Litre	0.13	119.13	15.49
Pest Control:					
Pest control	Dimet	litre	1	50.38	50.38
Weed control:					
Weed control	Cysure	litre	1.2	301.68	362.02
Weed control	Immiboost	litre	6	13.32	79.92
Total					**4,820.30**
Non-directly allocatable costs					
Input					**R/ha**
Diesel					838.59
Maintenance					499.16
Water					218.00
Electricity					638.00
Total					**2,193.75**
Labour costs					91.28
Total production cost of establishment					**7,105.32**
Annual lucerne maintenance costs: Year 2 – 6					
Directly allocatable variable costs				**Price**	**Total**

Input	Product	Unit	Amount	R/unit	R/ha
Fertilizers:					
Phosphate	Double supers	ton	0.075	4,240.00	318.00
Potassium sulphate	Potassium sulphate	ton	0.1	6,460.00	646.00
Minerals	Mb	litre	0.13	119.13	15.49
Pest Control:					
Pest control	Dimet	litre	0.5	50.38	25.19
Pest control	Methomyl	litre	1	43.89	43.89
Weed control:					
Weed control	Gramaxone	litre	4	41.64	166.56
Total					**1,215.13**
Non-directly allocatable costs					
Input					**R/ha**
Diesel					54.52
Maintenance					111.60
Water					218.00
Electricity					638.00
Total					**1,022.12**
Labour costs					77.30
Total production cost per year for maintenance					**2,314.54**
Harvesting costs per hay cutting (R/ha):					940.04

(Adapted from Burger, 2010)

According to Table 7.1, the estimated cost to establish lucerne pasture during the first year was R7,105.32/ha. The estimated annual cost to maintain this pasture was R2,314.54/ha. The total production cost for pasture for a six-year period was calculated as R18,678.02/ha, relating to an average pasture cost of R3,113.00/ha/year. Burger (2010) drew up a budget for lucerne pastures in the Little Karoo district of the Western Cape. This lucerne was not used for grazing, but only for hay cuttings. The establishment cost for this pasture that yields six cuttings of hay per year, amounted to R12,575/ha, while the annual maintenance cost for a further five years amounted to R9,635/ha. Therefore, a total production cost of R10,125/ha/year was determined. This cost is much higher than the production costs of the current trial, but this can be readily accounted for, since six cuttings of hay are made annually, while in the current study only two cuttings were made annually, and the rest was grazed by the ostriches. This means that the pasture used in the study of Burger (2010) was much more labour and equipment intensive. In 2005, Cilliers determined the establishment cost of dryland lucerne in the Little Karoo to be R2,000/ha. He assumed that the pasture had a lifespan of 4 – 5 years, and therefore the total production cost of the lucerne pasture was estimated as R500/ha/year. This is significantly lower than the figures found in the current trial, due to the fact that no irrigation was used on the dryland lucerne pastures, no hay cuttings were made, and only grazing by ostriches was allowed. Costs in 2005 would also be much less than today.

The total yield of the lucerne pasture was taken as the amount of lucerne the ostriches ingested during their five-month grazing period plus the hay yield that the pasture can deliver during the time that the ostriches are not grazing it. According to Roux (2010, P. Roux, Department of Agriculture, P.O. Box 313, Oudtshoorn, 6620), a lucerne pasture can be established in March (first year of the lucerne production cycle) in the Little Karoo district of the Western Cape, if irrigation is available. This pasture must be cut clean of weeds during June and will be ready for the ostriches to start grazing in September. If ostriches graze this pasture for a five-month (154 day) period, two hay cuttings can be taken from the pasture in the second and subsequent years (end of March; and May) before the next batch of ostriches can be allowed to graze again in September each year. Table 7.2 illustrates the potential yield from the lucerne pasture if ostriches are allowed to graze it, while receiving different levels of supplementary feed, and allowing for two hay cuttings per year.

The lucerne ingested by the different groups of ostriches, was respectively: 8.4 (1500g supplementation group); 16.9 (1000g supplementation group); 21.8 (500g supplementation group); and 14.4 ton DM/ha (0g supplementation group), in total during the six-year period that the lucerne can be grazed. According to these figures, ostriches receiving 1000g supplementary feed/bird/day ingested twice as much lucerne pasture as the ostriches receiving 1500g supplementation. This lower pasture intake could possibly be because the level of supplementation was too high. It is clear that ostriches substituted lucerne pasture at the high level of supplementary feed. The higher level of pasture intake in the case of the 1000g supplementation group could have been due to the fact that this amount of supplementary feed stimulated pasture intake by the birds. As the level of supplementation declined from 1000g to 500g supplementary feed/bird/day, ostriches increased their intake of pasture to accommodate the lower level of supplementation. However, ostriches receiving no supplementation had a lower pasture intake than the group receiving 500g/bird/day and this could possibly be due to overgrazing, since there was no supplementary feed available to this group. This could be because either the stocking rate for this group was too high (15 birds/ha), or that the grazing period was too long. In addition to pasture intake, two hay cuttings per year will yield a total of 22.5 tons of DM/ha for the whole production cycle of the pasture.

Table 7.2 Potential DM yield and price of irrigated lucerne pasture in the Little Karoo region

	Level of supplementary feed (g/bird/day)							
	1500 g		**1000 g**		**500 g**		**0 g**	
Lucerne pasture intake (Total DM)*:	*kg/ha/year*	*ton/ha/6 years*	*kg/ha/year*	*ton/ha/6 years*	*kg/ha/year*	*ton/ha/6 years*	*kg/ha/year*	*ton/ha/6 years*
	1,397.4	8.4	2,823.1	16.9	3,628.5	21.8	2,399.9	14.4
Pasture yield **	*ton/ha/year (as is)*	*ton/ha/6 years*	*ton/ha/year (as is)*	*ton/ha/6 years*	*ton/ha/year (as is)*	*ton/ha/6 years*	*ton/ha/year (as is)*	*ton/ha/6 years*
Hay cutting - March	2.5	12.5	2.5	12.5	2.5	12.5	2.5	12.5
Hay cutting - May	2.5	12.5	2.5	12.5	2.5	12.5	2.5	12.5
Total hay (ton/ha)(*as is*)	5	25	5	25	5	25	5	25
Hay converted to DM***		22.5		22.5		22.5		22.5
Total DM yield (ton/ha) (lucerne intake & hay)		30.88		39.44		44.27		36.90
Pasture price/ton (R/ton)		604.78		473.59		421.90		506.19
Pasture price/kg (R/kg)		0.60		0.47		0.42		0.51

* Estimated with the use of exclosure cages

** Predicted pasture yield according to Roux (2010, P. Roux, Department of Agriculture, P.O. Box 313, Oudtshoorn, 6620)

*** Since hay still contains 10 - 15% moisture, a factor of 0.9 was used to convert it to 100% DM

The total lucerne DM yield per hectare was therefore 30.9 (1500g supplementation group), 39.4 (1000g supplementation group), 44.3 (500g supplementation group), and 36.9 ton DM/ha (0g supplementation group) for the six-year production cycle of the pasture. This leads to a yield of respectively 5.2, 6.6, 7.4, and 6.2 tons of lucerne DM/ha/year. According to Gerstner (1980), irrigated lucerne pasture can yield up to 12 ton/ha. Lucerne under irrigation yields an average of 2 – 3 tons hay per hectare per cutting, with five to eight cuttings obtained per year. According to De Kock & Birch (1978), lucerne under irrigation can yield from 8 – 15 tons per hectare with five cuttings per year. In the Outeniqua district of the Southern Cape, Oberholzer *et al.* (1993) found that a four-weekly and six-weekly cut can respectively deliver 8.9 and 12 tons lucerne hay/ha. For irrigated S.A. Standard lucerne in the Western Cape, a four-weekly and six-weekly cut will yield 13.8 and 25.4 tons/ha respectively. These figures are much higher than the production figures found in the current study, but this is because, in the current study, ostriches were allowed to graze the lucerne in addition to two hay cuttings per year. Ostriches are very destructive to pasture and therefore a lot of pasture wastage will occur (Brand, 2008). With the cost of the pasture and the yield of the pasture as estimated in the current study, the pasture price per kg was calculated as R0.60 (1500g supplementation group), R0.47 (1000g supplementation group), R0.42 (500g supplementation group), and R0.51 (0g supplementation group). According to Burger (2010, W. Burger, Pers. Comm., Department of Agriculture: Western Cape, P.O. Box 249, George, 6530), lucerne pasture price per kg can amount to R0.30.

The ingredients and costs of the complete finisher diet and supplementary diet, is illustrated in Table 7.3 below.

Table 7.3 Ingredients and costs of the complete finisher diet and supplementary feed

Raw material used in complete finisher ration	Amount (kg)	Price/kg	Cost (R)
Lucerne hay	610	2.81	1,711.38
Yellow maize	300	78.4	470.40
Soyabean seeds meal (44% CP)	50	5.59	279.30
Molasses powder (Calorie 3000®)	12	2.38	28.58
Monocalciumphosphate	11	8.40	92.38
Limestone, ground	9	0.73	6.57
Common salt	4	1.12	4.49
Ratite Finisher vitamin & mineral premix	4	18.00	72.00
On-farm milling & mixing cost (+ 10%)			266.51
TOTAL	**1000**		**2,931.60**

Raw material used in supplementary ration	**Amount (kg)**	**Price/kg**	**Cost (R)**
Yellow maize	758	78.4	1,188.54
Soyabean seeds meal (44% CP)	127	5.59	709.42
Molasses powder (Calorie 3000®)	30	2.38	71.46
Monocalciumphosphate	27	8.40	226.74
Limestone, ground	23	0.73	16.78
Common salt	25	1.12	28.06
Ratite Finisher vitamin & mineral premix	10	18.00	180.00
On-farm milling & mixing cost (+ 10%)			242.10
TOTAL	**1000**		**2,663.10**

The cost of the complete finisher diet was calculated as R2.93/kg and the cost of the supplementary feed was calculated as R2.66/kg, which leads to R2,931.60 and R2,663.10 per ton of feed respectively.

Margin above feed cost is depicted in Table 7.4. According to this table, the ostriches grazing lucerne and receiving 1000g supplementary feed/bird/day showed the highest margin above feed cost (R1,803.18). They were closely followed by the ostriches receiving 1500g supplementary feed/bird/day. Although the 500 and 0g systems yielded margins higher than the margins of the feedlot (R1,727.24 and R1,328.16 respectively), these birds did not reach an acceptable slaughter weight of 95kg and so technically were not ready for the market. Ostriches raised in the feedlot had the lowest margin above feed cost of R1,180.83. A similar trend was found by Jordaan & Brand (2010) in calculating margin above cost for birds that are raised intensively from four months old to slaughter (12 months of age) and birds raised on pasture (dryland lucerne in the Southern Cape).

Table 7.4 Margin above feed costs per bird for feedlot finishing and pasture-based finishing at different levels of supplementation.

		Supplementation level on pastures			
Item	**Complete ration**	**1500 g**	**1000 g**	**500 g**	**0 g**
	R	**R**	**R**	**R**	**R**
Gross value of production					
Skin	530.32	541.23	530.32	502.84	485.80
Meat	1,650.02	1,718.28	1,613.39	1,400.26	824.72
Feathers	167.63	180.00	163.13	135.00	101.25
Total value of production	2,347.97	2,439.51	2,306.84	2,038.10	1,411.77
Feeding costs					
Complete finisher feed	1,167.13				
Supplementary feed		615.18	410.12	205.06	0
Pasture		57.47	93.54	105.79	83.61
Total feed costs	1,167.13	672.64	503.65	310.85	83.61
Margin above feed costs (R/bird)	1,180.83	1,766.87	1,803.18	1,727.24	1,328.16

According to Table 7.4, the total cost of feeding finisher ostriches from the age of six months to a slaughter weight of approximately 95kg, differed according to feeding system applied. The total cost to finish one bird in a feedlot on a complete finisher diet was R1,167.13, while the feeding cost of one bird finished on lucerne pasture with varying levels of supplementary feed/bird/day was respectively R672.64 (1500g supplementation), R503.65 (1000g supplementation), R310.85 (500g supplementation), and R83.61 (0g supplementation). Therefore, a saving in feed cost ranged from 42% in the case of the 1500g supplementation group to 57% in the 1000g supplementation group. In the study of Cilliers (2005), the feeding costs of a complete feed in a feedlot system vs. a pasture-based system (with a suitable supplement) were compared. For birds aged 4 – 10 months, the feeding costs on the pasture-based system amounted to R363 and the feeding costs of birds of the same age on a complete feed in a feedlot system were R435. This means a saving in feed cost of about 17%. For birds aged 4 – 12 months, feeding costs on the pasture-based system amounted to R443 and the feeding costs of the same aged birds on a complete feed in a feedlot were R607. A saving of 27% in feeding costs was accomplished with this trial. For birds aged 4 – 14 months, feeding costs on the pasture-based system were R513 and the feeding costs of birds of the same age on a complete feed in a feedlot were R780, which implies a saving of 34% in feeding costs. This study therefore concluded that a saving of 17 – 34% can be achieved by producers raising slaughter birds on pasture with a suitable supplement. Champion & Weatherley (2000) found that feed costs decreased by 10% if pasture-based systems were used instead of feedlot systems.

Due to the fact that pastures are not generally traded as a commodity, they are less prone to price fluctuations, whereas the ingredients of mixed rations (e.g. maize, soya, lucerne hay, etc.) are often subject to price movements due to changing supply and demand factors. When the prices of maize, soya and lucerne hay change, the ration price is affected and, consequently, the margin above feed cost is influenced. Table 7.5 depicts a sensitivity analysis of the margins above feed cost for both a feedlot and a pasture-based system with 1000g supplementary feed. Pasture costs were kept constant, and prices of concentrate rations allowed to increase, based on a 5, 10, 15, and 20% increase in the prices of the maize, soya, and lucerne hay ingredients of the rations. Income (gross production value) changes at 5, 10, 15 and 20% were also considered.

Table 7.5 Sensitivity analysis of margin above feeding costs for a feedlot and pasture-based (1000g supplementary feed) system

Feeding system	**Scenarios**	**Current margin**	**5%**	**10%**	**15%**	**20%**
Feedlot	A	1,180.83	1,126.94	1,073.05	1,019.16	965.28
	B	1,180.83	1,063.43	946.04	828.64	711.24
	C	1,180.83	1,298.23	1,415.63	1,533.03	1,650.43
	D	1,180.83	1,009.54	838.26	666.97	495.68
Pasture + 1000 g/bird/day	A	1,803.18	1,787.10	1,771.03	1,754.95	1,738.88
	B	1,803.18	1,687.84	1,572.50	1,457.16	1,341.81
	C	1,803.18	1,918.52	2,033.86	2,149.21	2,264.55
	D	1,803.18	1,671.76	1,540.35	1,408.93	1,277.51

A: Scenario where feed costs increase and income remains unchanged

B: Scenario where income decreases and feed costs remain unchanged

C: Scenario where income increases and feed costs remain unchanged

D: Scenario where feed costs increase and income decreases

In the feedlot scenario, the margin decreases from R1,180.83 to R965.28 if feed cost increases by 20%. This represents a decrease in the margin of 18.3%. In the pasture-based system with 1000g supplementary feed, a 20% increase in feed cost decreases the margin from R1,803.18 to R1,738.88, which represents a decrease of only 3.6%. In a worse case scenario, where feed costs increase and income both decrease by 20%, the feedlot margin decreased from R1,180.83 to R495.68, which represents a decrease of 58.0%. The margin of the pasture-based system supplied with 1000g supplementary feed decreased from R1,803.18 to R1,277.51, which represents a decrease of only 29.2%. It is clear therefore from the sensitivity analysis that the pasture-based system is less affected by changes in feeding costs than the feedlot system, therefore making this system a less risky option for the producer. Other supplementary feeding systems will portray the same trend relative to the feedlot system. According to Brand & Jordaan (2004), a 10% increase in the price of feed will lead to a decrease of 31% in the margin above feed costs. This is for an average ostrich producer, whereas for an above-average ostrich producer, the negative effect on the margins above feed cost will be less severe (13%). For a simultaneous 10% drop in product prices and a 10% increase in feed prices, the margin above feed cost for the average producer will decrease by 72%, whereas for the above-average producer, a 36% drop in margin above feed cost was calculated. Therefore, to be efficient in the production system, it is important to absorb rising feed prices or decreased product prices (Brand & Jordaan, 2004). In a study by Van Zyl (2001), ostriches from the age of three months were kept on lucerne pastures until they reached an age of six months, after which they were put in a feedlot until slaughter at 12 months. For this production system, feeding and grazing costs amounted to R329 per ostrich, and the directly allocatable costs were R798 per slaughter bird. An income of R1,657 per bird was achieved. This led to a gross margin of R859 per slaughter bird. If the average price of the purchased feed changed by 10%, a 4% change in cost per bird, and a 3.7% change in the gross margin per bird, were revealed by a sensitivity analysis. A purchased complete finisher ration would cost the producer R1.23 per kilogram, whereas if the farmer had his own lucerne pasture and the facilities to mix his own ration, it would cost him only R0.42 per bird. This leads to a saving of R810 per ton feed. It must be borne in mind that Van Zyl's study was done nine years ago, and also that he did not use the same production system as was followed in the current trial. It is not appropriate, therefore, to compare these figures to the results of the current trial.

Although from Table 7.4 it can be observed that the feeding system (where ostriches grazed lucerne pasture with 1000g of supplementation/bird/day), was the most profitable in terms of margin above feed cost (R1,803.18), from an economic perspective, it should be taken into account that a pasture-based system can yield only one batch of ostriches per year, whereas in a feedlot system, two batches of ostriches can be raised in the same year from the same area. This suggests that if the systems are to be compared over a full production year, feedlot systems may generate more profits. Due to the fact that a pasture-based system can run over a six-year period, the comparison between feedlot and pasture-based systems should ideally be done over the full six years. A comparison between the feedlot system and two pasture-based systems (1500 and 1000g supplementary feed/bird/day) of this study is illustrated in Table 7.6 below. The comparison is based on a 100-bird unit, taking into account the additional income earned annually from the two hay cuttings in the pasture-based systems. Since the timing and amount of cash flows differ between the feedlot and pasture-based systems over the full production period, cash flows were converted to PV to take into account the time value of money.

Table 7.6 Annual income, cost and present value (PV) of margin above feed cost per 100-bird unit per year over six years

Feedlot-raised ostriches							
Year	**Gross Income**	**Direct Cost**	**Margin above cost**	**Discount factor**	**PV of margin**	**Feed cost**	**PV of feed cost**
1	R 469,593.00	R 233,426.49	R 236,166.51	0.9091	R 214,696.82	R 233,426.49	R 212,205.90
2	R 525,215.99	R 268,965.27	R 256,250.72	0.8264	R 211,777.45	R 268,965.27	R 222,285.35
3	R 587,427.49	R 309,914.77	R 277,512.72	0.7513	R 208,499.41	R 309,914.77	R 232,843.55
4	R 657,007.90	R 357,098.75	R 299,909.14	0.6830	R 204,841.98	R 357,098.75	R 243,903.25
5	R 734,830.06	R 411,466.42	R 323,363.64	0.6209	R 200,783.38	R 411,466.42	R 255,488.27
6	R 821,870.21	R 474,111.47	R 347,758.74	0.5645	R 196,300.74	R 474,111.47	R 267,623.56
Total	**R3,795,944.64**	**R2,054,983.18**	**R1,740,961.46**		**R1,236,899.79**	**R2,054,983.18**	**R1,434,349.90**
1500 g/b/day supplementary feed + lucerne grazing							
Year	**Gross Income**	**Direct Cost**	**Margin above cost**	**Discount factor**	**PV of margin**	**Feed cost**	**PV of feed cost**
1	R 280,617.67	R 79,798.22	R 200,819.45	0.9091	R 182,563.13	R67,264.30	R61,149.37
2	R 313,856.65	R 91,947.36	R 221,909.29	0.8264	R 183,396.10	R77,505.18	R64,053.87
3	R 351,032.77	R 105,946.19	R 245,086.58	0.7513	R 184,137.17	R89,305.21	R67,096.32
4	R 392,612.37	R 122,076.31	R 270,536.06	0.6830	R 184,779.77	R 102,901.77	R70,283.29
5	R 439,117.06	R 140,662.22	R 298,454.84	0.6209	R 185,316.97	R118,568.39	R73,621.64
6	R 491,130.19	R 162,077.80	R 329,052.39	0.5645	R 185,741.50	R136,620.22	R77,118.55
Total	**R2,268,366.71**	**R702,508.10**	**R1,565,858.60**		**R1,105,934.65**	**R592,165.06**	**R413,323.04**
1000 g/b/day supplementary feed + lucerne grazing							
Year	**Gross Income**	**Direct Cost**	**Margin above cost**	**Discount factor**	**PV of margin**	**Feed cost**	**PV of feed cost**
1	R 267,350.17	R 62,899.35	R 204,450.81	0.9091	R 185,864.38	R 50,365.44	R 45,786.76
2	R 299,017.62	R 72,475.67	R 226,541.95	0.8264	R 187,224.75	R 58,033.49	R 47,961.56
3	R 334,436.07	R 83,509.97	R 250,926.10	0.7513	R 188,524.49	R 66,868.98	R 50,239.66
4	R 374,049.81	R 96,224.21	R 277,825.59	0.6830	R 189,758.62	R 77,049.67	R 52,625.96
5	R 418,355.76	R 110,874.18	R 307,481.58	0.6209	R 190,921.87	R 88,780.35	R 55,125.61
6	R 467,909.74	R 127,754.59	R 340,155.15	0.5645	R 192,008.71	R 102,297.00	R 57,743.99
Total	**R2,161,119.16**	**R553,737.97**	**R1,607,381.19**		**R1,134,302.83**	**R443,394.93**	**R309,483.54**

According to Table 7.6, a 100-bird feedlot system generates a higher margin above cost over the six years than the two pasture-based systems. If the PV of the total margins of the different feeding systems are compared, the feedlot generates a PV margin of R1,236,899.79, while the 1500g supplementation system generates a PV margin of R1,105,934.65 and the 1000g supplementation system generates a PV margin of R1,134,302.83. The feedlot has a very high feeding cost structure in comparison with the two pasture-based systems, with the PV of feed cost incurred by the feedlot over the six year period at R1,434,349.90, compared to feed costs of R413,323.04 and R309,483.54 for the 1500g and 1000g supplementation systems respectively. The difference in the PV margins between the feedlot and the 1000g supplementation system, is R102,596.96, whereas the PV cost difference between the same two systems is R1,124,866.36. If for instance, the availability of operating capital or cash flow is a bigger concern for the producer than ultimate profitability, the pasture-based system may be considered rather than the feedlot system. This is due to the fact that the ultimate margin above feed cost on a pasture-based system (with 1000g supplementation) is only 8.3% less than the feedlot margin, whereas the cost of the same pasture-based system is 78.4% lower than that of the feedlot system.

Conclusion

Although it was established in Chapter 4 of this thesis that the ostriches grazing lucerne pasture while receiving 1500g of supplementary feed/bird/day had the best mean live weights and average daily gains within the 154 days of the trial, the economic analyses show that the system where ostriches grazed lucerne pasture while receiving 1000g of supplementary feed/bird/day, generated higher margins above feed costs. The current study reveals that if slaughter birds are raised on lucerne pastures while they receive 1000g supplementary feed/bird/day, it can lead to a saving of 57% in feeding costs, as compared to the same birds raised in a feedlot on a complete finisher diet.

It is clear from the sensitivity analysis done on the data that the pasture-based system was less affected by changes in feeding costs than the feedlot system, therefore making this system a less risky option for the producer. If feeding costs increase and income decrease by 20%, the margin of the pasture-based system decreases by only 29.2%, whereas the margin of the feedlot decreases by 58.0%. The importance of being efficient in the production system by absorbing rising feed prices, or decreased product prices, is illustrated by this trial.

Although a PV analysis showed that the feedlot system generated a higher margin above feed cost over a six-year period than a pasture-based system (where birds received 1000g supplementary feed/bird/day), the margin of the pasture-based system was only marginally lower while the feeding cost structure of the feedlot system was found to be substantially higher.

Acknowledging the limitations of this study, i.e. restricting the study to a stocking rate of 15 birds/ha and assessing economics based on margin above feed cost only, the results of this study may be of value in terms of long-term decision making on economic viability. Ultimately, the unique circumstances of each ostrich producer with regard to cash flow and the availability of operating capital will play a role in the decision whether to raise ostriches in a feedlot or on pastures.

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Chapter 8

General Conclusion and future prospects

In this research study two grazing trials and a digestibility trial were performed in order to gain some information pertaining to the nutritional management of ostriches produced primarily under grazing production systems. Emphasis was placed especially on the effect of supplying different levels of supplementary feeding to irrigated lucerne pasture on the production of both the ostriches and the pastures. Some of the most important conclusions made from these studies are mentioned here.

Firstly, finisher ostriches can grow as satisfactorily while grazing a high quality legume pasture like lucerne and receiving the correct amount of a correctly formulated supplement as ostriches produced on a complete finisher diet in a feedlot production system. This was proved during the first grazing study where the mean live weights reached during the 154-day trial did not differ significantly between the ostriches receiving a complete finisher diet *ad libitum* in a feedlot, and those ostriches grazing lucerne and receiving either 1500 or 1000g of supplementary feed/bird/day. These three groups of ostriches reached an average slaughter weight of 95kg within 154 days. The level of supplementary feed did not have a significant effect on the lucerne production or the lucerne intake by the ostriches, but a significant quadratic relationship was found between pasture DM intake (g/bird/day) and supplementary feed intake (g/bird/day), which indicated that as supplementary feed increased, pasture intake by the birds also increased, but only up to a certain level of supplementation, after which pasture intake started to decline again. Based on the applied function, it was deducted that the maximum lucerne intake level (1692.8g/bird/day) was achieved at 619.6g supplementary feed/bird/day. Therefore, moderate levels of supplementation (619g/bird/day) increase efficiency by increasing pasture intake and should, therefore, make it possible to increase the stocking rate. This should result in higher production per hectare of pasture without additional costs. This study was, however, conducted at only one stocking rate and further research needs to be done with a range of stocking rates. It would also be interesting to conduct the same study with different types of grazing to see if the same results, as in the case of a high quality pasture like lucerne, are possible. For example, since the Little Karoo district has fluctuating and low rainfall, as well as sporadic droughts, it could be wise to examine the grazing capacity of a drought-resistant grazing commodity like salt bush (*Atriplex nummularia*). The production of slaughter ostriches in the Southern Cape (Caledon to George) on different types of grazing (medics, seradella, etc.) should also be investigated further. Also, the current study focused only on the production of slaughter ostriches. The stocking of breeding ostriches on pasture can also be investigated further with a view to saving feeding costs. The role of grazing with other species in mixed grazing systems can also be investigated further to help manipulate and manage pasture composition and quality. A mixed farming system may yield different results (Van Zyl, 2001).

The second grazing study (where two stocking rates of birds and two levels of supplementary feeding were applied) revealed that stocking rate did not influence the mean live weights of the ostriches, but it did influence the average daily gains (ADG) of the ostriches. Stocking rate influenced ADG only significantly when the ostriches did not receive any supplementation on the lucerne pastures, but when they did receive supplementation, the stocking rate had no influence on the ADGs of the ostriches. For ostriches receiving no supplementation, an increase in the stocking rate will lead to a decrease in the ADG of each bird. This study revealed that the level of supplementary feeding as well as stocking rate both influenced lucerne DM intake, but only stocking rate influenced lucerne production. Supplementary feeding depressed lucerne intake at both the high and low stocking rates, although at the high stocking rate this effect was more pronounced than at the lower stocking rate. Supplementary feeding did not influence lucerne production, but a high stocking rate eventually depressed lucerne production. Again, future research must be done on the different stocking rates for finisher ostriches, especially higher stocking rates than the 10 or 15 birds/ha that were used in the current study.

It is also very important to establish exactly how much pasture will go to waste if grazed by ostriches, since this will influence the productivity of the pasture and therefore the cost of the pasture. In this regard, it is relevant to note that ostriches are very destructive to pasture, either due to trampling or due to their feeding methods (by stripping the stems of their leaves) (Brand, 2008). Current estimates of the level of pasture wastage are about 30 – 40% when being grazed by ostriches (Burger, 2010), but this has not been proved scientifically yet.

Since a growing segment of today's consumers is requesting healthier and organic animal products, this is an area of ostrich research which can be developed further. Several studies in the beef production industry have shown that meat quality traits and shelf life can be improved when steers were finished on forage diets, as compared to steers finished on concentrates (Faucitano *et al.*, 2008 *cite* O'Sullivan *et al.*, 2002 & Gatellier *et al.*, 2005). One such study was done by Faucitano *et al.*, 2008, in which the effect of forage-finishing on the meat quality, fatty acid composition and overall palatability of the meat in Angus cross steers was compared with grain-forage finishing. They found that exclusive feeding of forages increased the proportion of n-3 fatty acids in the meat and decreased the ratio of n-6 to n-3 fatty acids as compared to supplementing grain. These higher n-3 fatty acids and the lower ratio of n-6 to n-3 fatty acids can prevent certain diseases in humans (Faucitano *et al.*, 2008 *cite* Connor, 2000).

Regarding the substitution of supplementary feed for pasture, this study revealed that if finisher ostriches graze irrigated lucerne pastures and they are supplied with supplementation at levels higher than 62% (higher therefore than 1000g supplementary feed/bird/day) of total feed intake, substitution will take place. For each increase of 100g in supplementary feed intake by ostriches, pasture was replaced at a rate of 4.9%. This study also confirmed that the digestibility of nutrients will increase with an increase in concentrate fed while birds are allowed to graze pasture. It was concluded that pasture together with a supplementary feed will lead to better feed intakes and better digestibilities of nutrients than supplying pasture alone. This study also shows that it is important to evaluate feedstuffs for ostriches by using ostriches and not simply to rely on values established with poultry. Higher dry matter digestibility, apparent metabolizable energy, and apparent metabolizable energy, corrected for zero nitrogen, were found for ostriches than roosters in the current study.

Finally, the economic analysis showed that although the feedlot system generated a higher margin above feed cost over a six year period than the pasture-based system (where the birds received 1000g supplementary feed/bird/day), the cost structure of the feedlot system was also very high. The margin above feed cost for the pasture-based system was only 8.3% lower than that of the feedlot system, while the cost of the same pasture-based system was 78.4% lower than that of the feedlot system. The current study revealed that if slaughter birds are raised on lucerne pastures while they receive 1000g supplementary feed/bird/day, it can lead to a saving of 57% in feeding costs as compared to the same birds raised in a feedlot on a complete finisher diet. The particular circumstances of each ostrich producer will therefore play a role in his decision to raise ostriches in a feedlot or on pastures. The pasture-based system was also less sensitive to changes in feeding costs than the feedlot system.

For the first time biological parameters for ostriches grazing pasture was established. These data will be incorporated in an optimization model for ostriches (Gous & Brand, 2008) and help to simulate the optimum feeding condition of birds in different production systems.

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Annexure 1

Calibration of the plate meter for measuring pasture production

Introduction

For the effective management of pasture, it is critical to estimate pasture mass accurately. This data can be used by managers to make decisions regarding stocking rates for livestock, management of wildlife, capacity to sustain recreation, and the erosion potential of their pastures. However, it is time consuming and labour intensive to determine pasture production and intake and it involves the regular clipping, bagging, oven-drying and weighing of pasture material. Alternative methods which are non-destructive have, however, been developed to estimate pasture mass before and after grazing (Fehmi & Stevens, 2009), such as the so called pasture plate or disc meter. Plate meters are popular, as they are easy to use, the measurements can be taken quickly, and also have a history of success in several rangeland vegetation types (Fehmi & Stevens, 2009). They are also inexpensive, simple to construct, easy to duplicate, and little skill is needed to use the instrument (Castle, 1976). Measurements can also be taken with minimal disturbance to the pasture (Bransby & Tainton, 1977).

Description and working of the plate meter

The plate meter consists of a central aluminium rod, which is 1.84m long with a 20mm diameter. Over this central rod is a second free-sliding aluminium tube, which is 1.2m long and with a 28mm diameter, is fitted. Connected at the end of this outer or second aluminium tube, is fitted an aluminium plate that is 1.5mm thick and 460mm in diameter. The total outer plate and rod of the meter weighs approximately 1.5kg. The central rod is further marked at 0.5mm intervals, starting at nought at the top of the free-moving pipe. To measure pasture height, the central, marked rod is held perpendicular to the ground, while the central rod placed in at ground level in the ground and the outer rod and plate then released onto the sward from a position where the upper end is level with the upper end of the central rod. This ensures that the meter is always released onto the pasture from a standard height above the ground. As soon as the plate meter settles on the sward, the height of the pasture is read from the marked inner rod (Muller & Botha, 1990).

Calibration of the plate meter

To be able to estimate the amount of pasture material per hectare with the plate meter, the plate meter has to be calibrated for the particular pasture. This is done by taking enough pasture plate meter readings and cut material samples measurements to enable a significant relationship between disc meter reading and available pasture dry matter (DM) to be developed. In the case of this study, the data was built up over time by taking ten readings and samples per paddock at each date. Five of these samples were taken inside the exclusion cages (representing the available pasture material before grazing) and five were taken outside the exclusion cages (representing the residual pasture material after grazing) when the ostriches were moved to a new paddock.

After taking a height measurement, the amount of pasture that was underneath this plate meter was cut off at ground level with a pair of hand shears. The collected pasture material was washed to remove soil and dirt, dried to a constant dry mass at 59 ºC and weighed. To calibrate the plate meter, the relationship between each height measurement of the plate meter (X), and available DM pasture material per hectare (Y) was calculated by means of the regression method for *n* samples. A total of 964 samples were used. For the development of the relationship between pasture disc meter reading and available pasture DM, the averaged of each values were used, resulting in a data set of *n* = 46 pairs of observations. Data were analyzed using the regression method in SAS 9.1.3 for Windows, 2002 – 2003.

Results

A highly significant linear relationship (P <0.001) was derived between the natural log values of the meter readings and DM lucerne (kg/ha) yield. The regression equation was y = 620.03 + 535.7ln(x). The coefficient of determination (R^2) value for the pooled data, i.e. the percentage of variation explained by the regression, was 0.62. This means that, on average, more than 62% of variation in yield is accounted for by disc height alone. This relationship is shown in Figure 1.

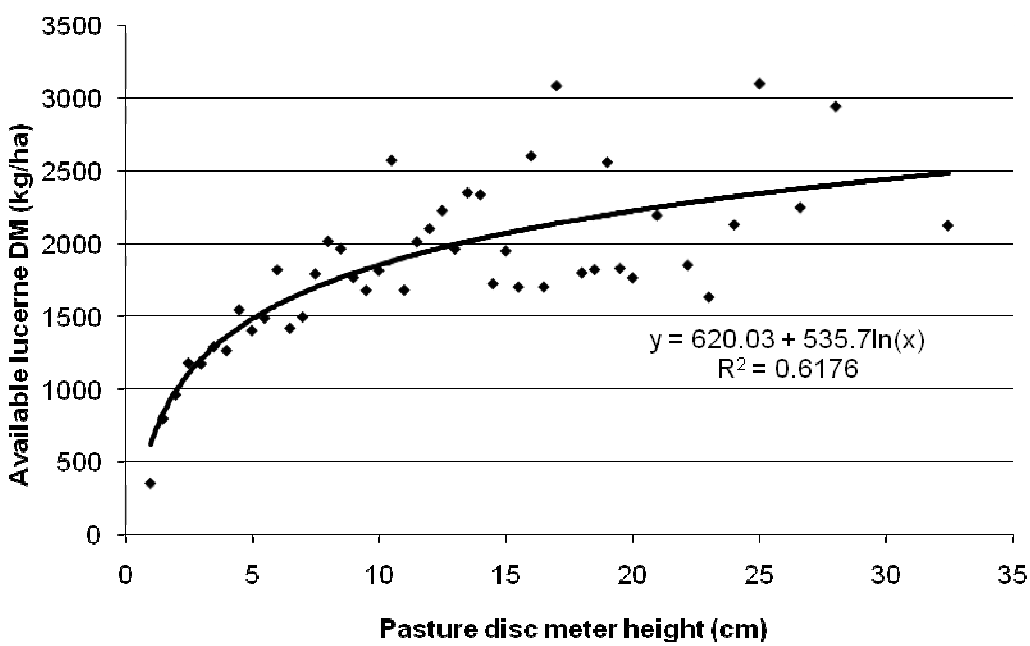

Figure 1 The relationship between pasture disc meter height (cm) and available lucerne pasture DM (kg/ha) for lucerne pastures grazed by finisher ostriches.

Practical use of the plate meter

To illustrate the potential use of the calculated regression equation Table 1 was generated and can serve as a handy reference to farmers grazing ostriches on irrigated lucerne pastures.

Table 1 Lucerne pasture (kg DM/ha) available as measured from the pasture disc meter and calculated by the regression equation $Y = 620.03 + 535.7\ln(x)$

Pasture disc meter height (cm)	**Available lucerne pasture (kg DM/ha)**
1	620
2	991
3	1209
4	1363
5	1482
6	1580
7	1662
8	1734
9	1797
10	1854
11	1905
12	1951
13	1994
14	2034
15	2071
16	2105
17	2138
18	2168
19	2197
20	2225
21	2250

22	2280
23	2300
24	2323
25	2344
27	2378
28	2405
33	2484

This table can thus be used to estimate if there is enough pasture available to the animals before grazing starts. If the available amount of pasture is known to a farmer, he can determine the correct stocking rate that he has to apply to the known amounts of available pasture before grazing and with the available pasture after grazing being known, the pasture intake of the animals can be determined (Bransby & Tainton, 1977).

Summary

It is a difficult and timely procedure to determine pasture production, and therefore, the plate meter is a practical and accurate method to solve this problem. Using a plate meter rapid yield estimations of standing forage can be made. A significant linear regression relationship between meter reading and pasture DM yield was derived in the current trial (R^2 = 0.62), which shows that the meter is accurate enough to use in practice. The meter should, however, be calibrated for each specific set of conditions and forage type in which it is to be used (Bransby & Tainton, 1977).

References

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