REPRODUCTION CRITERIA AND MEAT QUALITY OF SOUTH AFRICAN BLACK (*STRUTHIO CAMELUS* VAR. *DOMESTICUS*), ZIMBABWEAN BLUE (*STRUTHIO CAMELUS AUSTRALIS*) AND SOUTH AFRICAN BLACK X ZIMBABWEAN BLUE OSTRICHES

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DECLARATION

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

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SUMMARY

The aim of this study is to determine the effect of crossbreeding Zimbabwean Blue (ZB) and South African Black (SAB) ostriches on the morphological, physical, chemical and sensory quality of the meat. However, it is also necessary to determine the reproductive performance of these genotypes to scientifically support decisions made in the ostrich industry.

In relation to reproductive traits and body measurements influencing these traits, results from the study suggested that ZB birds are between 9 and 15% heavier than their SAB contemporaries. Regarding SAB females, egg production was 47% higher, levels of shell deaths were lower, percentage of eggs not incubated was lower (P<0.01) and 84% more (P<0.01) chicks were produced in a season compared to their ZB contemporaries. Mates of SAB males produced a higher (P≤0.05) percentage of eggs not incubated and higher shell death percentages than the mates of ZB males. It has to be conceded that ZB females had a lower reproduction than SAB females, limiting the application of this genotype as a dam line in crossbreeding systems.

With regard to morphological properties, the pure Blue genotype in comparison to the pure Black genotype differed significantly (P≤0.05), with 16 kg for live weight, 8.3 kg for carcass weight and 3.5 kg for leg weight. However, when comparing carcass yields (expressed as %) there were no significant differences (P>0.05) between genotypes. The *M. gastrocnemius*, *M. femorotibialis accessorius*, *M. iliotibialis cranialis*, *M iliotibialis lateralis*, *M. iliofibularis* and *M. iliofemoralis* showed significant genotype differences (P≤0.05) for individual muscle weight.

When comparing the physical meat quality characteristics between the pure Blue genotype and the pure Black genotype, 70% of the muscles were higher (P≤0.05) in pH_{24}, 50% of the muscles were redder (P≤0.05) and significantly less (P≤0.05) saturated in colour, 67% of the muscles had a lower (P≤0.05) percentage drip loss and 50% of the muscles had a lower (P≤0.05) percentage cooking loss. No significant (P>0.05) genotype differences were observed regarding the sensory quality of the meat.

Regarding chemical meat quality characteristics, the percentage of moisture was higher and the percentage of lipid was lower for eight of the ten muscle groups from the pure Blue genotype. No significant differences (P>0.05) were found between genotypes or between muscles regarding the percentage of protein present in the meat. The highest (P>0.05) content of soluble collagen, myoglobin and cholesterol was found in the Blue x Black genotype, whereas the lowest percentage of the latter constituents was found in the pure Blue genotype. For the pure Black genotype the concentration of saturated fatty acids in the meat was lower (P≤0.05), the concentrations of total unsaturated fatty acids and desirable fatty acids in the *M. illiofibularis* were the highest (P≤0.05), while the concentration of monounsaturated fatty acids was also higher (P≤0.05) in both muscles of this genotype compared to the other two genotypes. Regarding both fat depots, the pure Black genotype had a lower (P≤0.05) concentration of saturated fatty acids, a higher (P≤0.05) concentration of monounsaturated fatty acids and total unsaturated fatty acids and a higher (P≤0.05) polyunsaturated:saturated

fatty acid ratio. The percentage of desirable fatty acids in the abdominal fat depot was significantly higher ($P \leq 0.05$) for the pure Black and the Blue x Black genotype.

In conclusion, crossbreeding between SAB and ZB ostriches seems to be a viable option to produce larger birds with more meat, without negatively affecting the overall quality of the meat.

OPSOMMING

Die doel van die studie was om die effek van kruisteling van Zimbabwean Blue (ZB) en South African Black (SAB) volstruise op die morfologiese, fisiese, chemise en sensoriese kwaliteit van die vleis te bepaal. Dit was egter ook van belang om die reproduksie prestasie van die genotipe te bepaal om sodoende besluite in die volstruis industrie wetenskaplik te ondersteun.

Vir reproduksie eienskappe en die liggaamsmetings wat dit beïnvloed, het die interaksie van genotipe met jaar vir lewende gewig aan die begin van die broeiseisoen aangetoon dat ZB volstruise tussen 9 en 15% swaarder is as die SAB volstruise. Die SAB wyfies het 47% hoër eierproduksie getoon, die persentasie dood-in-dop kuikens was laer, die persentasie eiers nie geïnkubeer nie was laer (P<0.01) en 84% meer (P<0.01) kuikens is geproduseer in vergelyking met die ZB wyfies in ‘n broeiseisoen. Broeimaats van die SAB mannetjies het ‘n hoër (P≤0.05) persentasie eiers geproduseer wat nie geïnkubeer kon word nie, asook ‘n hoër persentasie van dood-in-dop kuikens as die broeimaats van die ZB mannetjies. Gevolglik het die ZB wyfies ‘n laer reproduksie-vermoë as die SAB wyfies en dit beperk die toepassing van eersgenoemde genotipe as ‘n moerlyn in kruisteling-sisteme.

Met die morfologiese studies is gevind dat die suiwer Blou genotipe in lewende gewig 16 kg swaarder (P≤0.05) is, in karkasmassa 8.3 kg swaarder is en die boudmassa 3.5 kg swaarder is in vergelyking met die suiwer Swart genotipe. Met bepaling van karkas opbrengs is daar egter geen betekenisvolle (P>0.05) verskille gevind tussen genotipes nie. Die *M. gastrocnemius*, *M. femorotibialis accessorius*, *M. iliotibialis cranialis*, *M iliotibialis lateralis*, *M. iliofibularis* en *M. iliofemoralis* het betekenisvolle genotipe verskille getoon (P≤0.05) betreffende individuele spiermassa.

Betreffende die fisiese eienskappe vir die suiwer Blou genotipe, was 70% van die spiergroepe hoër (P≤0.05) in pH_{24}, 50% van die spiergroepe rooier (P≤0.05) en minder (P≤0.05) versadig in kleur, 67% van die spiergroepe het ‘n laer (P≤0.05) persentasie drupverlies getoon en 50% van die spiergroepe het ‘n laer (P≤0.05) persentasie kookverlies getoon in vergelyking met die suiwer Swart volstruise. Geen betekenisvolle (P>0.05) genotipe verskille is gevind vir die sensoriese vleiskwaliteit nie.

Vir die chemiese eienskappe was die persentasie vog hoër en die persentasie vet laer vir 8 van die 10 spiergroepe van die suiwer Blou genotipe. Geen betekenisvolle (P>0.05) genotipe of spier verskille is gevind vir die persentasie proteïene van die vleis nie. Die hoogste (P>0.05) inhoud van oplosbare kollageen, mioglobien en cholesterol is gevind in die Blou x Swart genotipe, teenoor die laagste inhoud van laasgenoemde komponente in die suiwer Blou genotipe. Betreffende die suiwer Blou genotipe, was die versadigde vetsuur konsentrasie die laagste (P≤0.05), die konsentrasie totale onversadigde vetsure en die wenslike vetsure in die *M*. *illiofibularis* die hoogste (P≤0.05) en die konsentrasie mono-onversadigde vetsure die hoogste (P≤0.05) in vergelyking met die ander twee genotipes. Vir beide vet depots het die suiwer Swart genotipe ‘n laer (P≤0.05) konsentrasie versadigde vetsure, ‘n hoër (P≤0.05) konsentrasie mono-onversadigde vetsure en totale

onversadigde vetsure en ‘n laer ($P \leq 0.05$) poli-onversadigde:versadigde vetsuur verhouding getoon. Die konsentrasie van wenslike vetsure in die maagvet was betekenisvol hoër ($P \leq 0.05$) vir die suiwer Swart genotipe en die Blou x Swart genotipe.

Gevolglik wil dit blyk asof kruisteling tussen SAB en ZB volstruise ‘n moontlike opsie is om groter volstruise met meer vleis te produseer sonder om die algehele vleiskwaliteit negatief te beïnvloed.

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Lord, God for loving me and sustaining me and for giving me the ability, strength, endurance and provision all of the time. All honour and glory to Him!

LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
BHT	Butylated hydroxytoluene
CS_2	Carbon disulfide
D	Dam line
DFA	Desirable fatty acids
DFD	Dark, firm and dry meat
EtOH	Ethanol
FAME	Fatty acid methyl esters
GLC	Gas liquid chromatography
HCl	Hydrochloric acid
HDL	High-density lipoproteins
HNO_3	Nitric acid
ICP	Inductively coupled plasma spectrometry
KOH	Potassium hydroxide
LDL	Low-density lipoproteins
LSD	Least Significant Difference
M	Molar
MeOH	Methanol
m/m	Mass per mass
MUFA	Monounsaturated fatty acids
n	Number
N	Newton
NaCl	Sodium chloride
nm	Nanometer
OEF	Oudtshoorn Experimental Farm
r	Coefficient of correlation
rpm	Resolutions per minute
pH_{24}	pH 24 hours after the animal is bled
pH_f	Final or ultimate pH
P:S	Ratio of polyunsaturated fatty acids to saturated fatty acids
PUFA	Polyunsaturated fatty acids
S	Sire line
S.	*Struthio*
SAB	South African Black ostriches
SD	Standard deviation
SE	Standard error
SFA	Saturated fatty acids

TLC	Thin-layer chromatography
TUFA	Total unsaturated fatty acids
UV	Ultraviolet
v/v	Volume per volume
WHC	Water holding capacity
ZB	Zimbabwean Blue ostriches

CONTENTS

The language and style used in this thesis are in accordance with the requirements of the *International Journal of Food Science and Technology.* This thesis represents a compilation of manuscripts in which each chapter is an individual entity and some repetition between chapters has, therefore, been unavoidable.

The experimental birds used in this study were SAB (pure Black) and ZB (pure Blue) ostriches, as well as the offspring (Blue x Black) of SAB females mated to ZB males. The former two groups could be referred to as bloodlines, while the latter group was only a cross between established bloodlines. The descriptive term

applicable in both situations is genotype and the term genotype was thus used throughout this thesis, except when directly referring to published literature.

CHAPTER 1

Introduction

The ostrich industry stands on three legs: the feather, meat and leather trade. Ostrich farming has a long history in South Africa and this country is still considered the leader worldwide in ostrich production (Girolami *et al*., 2003). However, the ostrich industry has always been marked by fluctuations. Ostrich farming first started in 1863 in the Oudtshoorn area (Smit, 1964). During the early 1880s ostrich feathers were fourth in order of priority regarding export merchandise from South Africa (Smit, 1964) and therefore the feathers were the most important product derived from the ostrich. According to Smit (1964), the industry went through slumps in the period of 1883–1890, 1894–1899, as well as 1914-1945. The ostrich industry followed feather fashions and reached a peak in 1913 (Smit, 1964). Birds were imported to improve feather quality by improving the local lines through crossbreeding (Smit, 1964; Swart *et al*., 1987). The African Black or Oudtshoorn ostrich (*Struthio camelus* var. *domesticus*) resulted from this crossbreeding (Madeiros, 1995; Horbaňczuk *et al*., 1998). *Struthio* (*S*.) *camelus* var. *domesticus* has been bred since 1963, specifically for its feathers and leather (Madeiros, 1995; Horbaňczuk *et al*., 1998). Only birds exhibiting the best marketable plumage were maintained as breeders (Petitte & Davis, 1999). Selection was based only on feather quality, whereas other characteristics such as rate of gain of body weight and egg production were not taken into account (Petitte & Davis, 1999). In 1914 the industry collapsed (Smit, 1964). The population of domestic ostriches, estimated at nearly a million in 1913, was reduced to around thirty thousand by 1930 (Smit, 1964). After the slump of 1914, the feather industry remained at an insignificant level for a period of 30 years, until it recovered in 1945 (Smit, 1964).

The first ostrich abattoir was established in 1965 and in 1970 Klein Karoo Co-operative Ltd established the first tannery in South Africa (Van Zyl, 2001). In about 1975 the emphasis of ostrich production shifted in favour of the skin and meat (Van Zyl, 2001). However, the skin of the ostrich still earned the highest income for the ostrich producer in comparison to the meat and feathers (Wagner, 1986). According to Van Zyl (2001), the income from the feathers, meat and leather was divided into 8%, 27% and 65% respectively for the year 2001. Currently, ostrich meat is becoming even more important in the market as a source of income and greater emphasis is placed on the meat and the skin of the ostrich, as opposed to the feathers (Petitte & Davis, 1999; Cloete *et al*., 2002). Most recent statistics indicate that the feathers contribute only 5% to the income, whereas the leather and the meat each contribute 50% and 45% respectively (Hoffman, 2005). South Africa is still the leader in ostrich production (Girolami *et al*., 2003) and contributes up to 70% of the total ostrich meat produced worldwide (Hoffman, 2005). Since 1990 ostriches have also become an important livestock outside South Africa (Smit, 1964; Horbaňczuk *et al*., 1998). The worldwide demand for ostrich meat is still increasing (Nitzan *et al*., 2002). Therefore, it is of the utmost importance to produce the highest quality of meat. No genetic selection for meat quality has been conducted or reported in scientific literature. Genetic improvement will have to play a greater role in producing and developing birds to meet the specific future markets of meat and leather (Petitte & Davis, 1999). Selection in stock for a specific objective is essential; otherwise there will be no increase in performance from generation

to generation. However, as a result of the incidence of avian influenza in 2004, trade bans were introduced regarding ostrich and ostrich products between infected trade partners (South Africa) and influenza-free trade partners (Olivier & Ganzevoort, 2005). According to Olivier and Ganzevoort (2005), agriculture is the cornerstone of economic activities in the Western Cape and as such the ostrich industry is of strategic importance. Therefore, the socio-economic impact of the disease and the resulting control strategies and bans can be enormous in the Western Cape (Olivier & Ganzevoort, 2005).

Extensive research has been done on common domestic species (poultry, cattle, pigs and small ruminants) pertaining to the effect of breeding on meat quality and reproductive performance. No research that determines the influence of crossbreeding and genotypes on ostrich meat quality could be sourced. A limited number of related articles are available on the effect of subspecies on meat quality. In most studies the genotype of ostrich is not even mentioned. The ostrich has only recently been used for meat production (Van Zyl, 2001), therefore the influence of crossbreeding on meat quality has not yet been investigated. Several authors have suggested that the crossbreeding of different genotypes of ostriches could improve overall production and reproduction performance. Currently, there is a tendency to crossbreed Kenyan Rednecks (*S. camelus massaicus*), Zimbabwean Blues (*S. camelus australis*) and South African Blacks (*S. camelus* var. *domesticus*) without scientific evidence to guide crossbreeding decisions (Petitte & Davis, 1999). According to Van Schalkwyk and Cloete (1996), selection is mostly based on appearance and on objective criteria such as live mass. Thus far only a limited number of attempts have been made to develop long-term selection programmes and specific genotypes of birds in response to consumer markets for meat and leather (Petitte & Davis, 1999). According to Cloete *et al*. (2002), research into the crossbreeding of various lines constituting the current commercial ostrich population is urgently needed. Information is required to design scientifically based selection and breeding strategies to improve production in ostriches (Swart & Lambrechts, 1998). Bunter *et al*. (2001) stated that future reproduction gains through selection are likely in the ostrich. Later studies indicate that gains with regard to selection for egg and chick production were achieved in the ostrich (Cloete *et al*., 2004; Cloete *et al*., 2005).

Different subspecies of ostrich have different phenotypic characteristics (Duerden, 1919; Sauer, 1968; Brown *et al*., 1982; Freitag, 1992), including size of the bird and growth rate (Madeiros, 1995). Subspecies in the more traditional animal species also influence various aspects of meat quality (Lawrie, 1998). In South Africa one subspecies (*S. camelus australis*) and the genotype of ostrich, namely *S. camelus* var. *domesticus* is found. Observations made by Jarvis (1998) suggest considerable variation in mature live weight between *S. camelus australis* (125 kg) and *S. camelus* var. *domesticus* (115 kg). The chicks of *S. camelus australis* have a faster growth rate and normally reach a body weight of 95 kg earlier than chicks from the other subspecies (Jarvis, 1998). In South Africa most ostrich producers use *S. camelus* var. *domesticus*, because it is the more common ostrich found in South Africa (Madeiros, 1995). The ostrich producer will benefit from crossbreeding *S. camelus australis* and *S. camelus* var. *domesticus,* if the offspring can grow faster and be larger without affecting meat quality negatively. Larger birds will probably produce more meat and a larger skin and will therefore result in a higher income for the producer. An additional motivation is the benefits that could be obtained in lowly heritable traits such as survival, which is known to be a problem in ostriches (Pirchner, 1969). Crossbreeding improves survival in the ostrich (Pirchner, 1969).

It would be of value to the South African ostrich industry to determine what the effect of crossbreeding *S. camelus australis* and *S. camelus* var. *domesticus* would be on the morphological, physical, chemical and sensory qualities of the meat. However, it is also necessary to determine the reproductive performance of these genotypes.

In view of the above, the aim of this study is therefore to determine the morphological, physical, chemical and sensory qualities of meat (Fig. 1) derived from the four genotypes resulting from crossbreeding *S. camelus australis*, a Blue Neck subspecies, and *S. camelus* var. *domesticus*, a Black Neck genotype. The reproductive performance of these genotypes will also be evaluated (Fig. 2).

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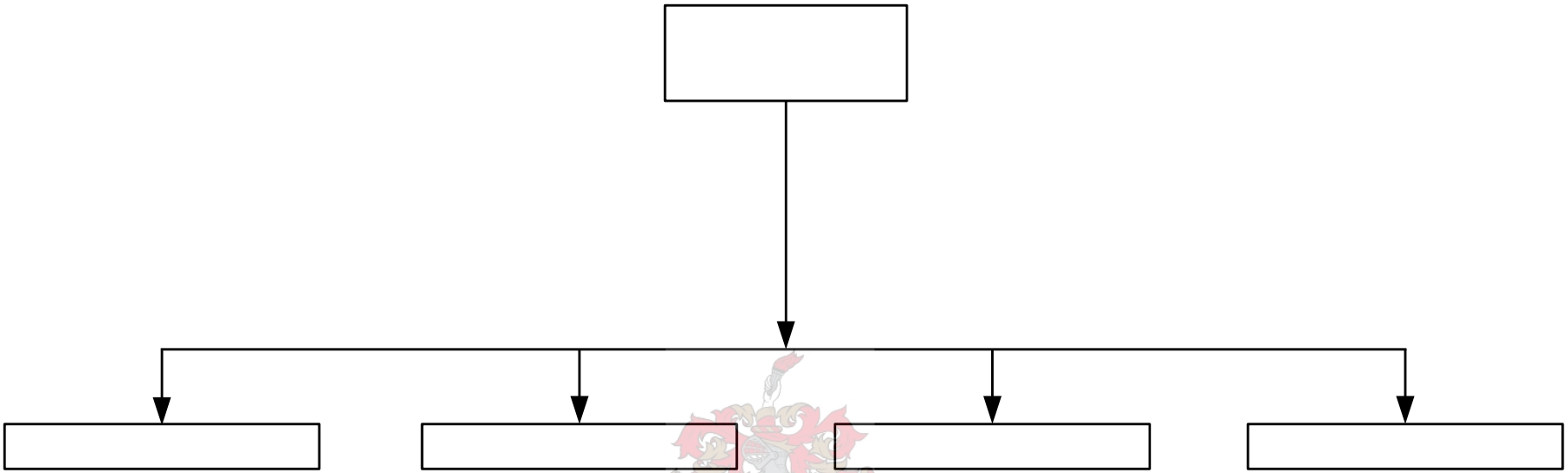

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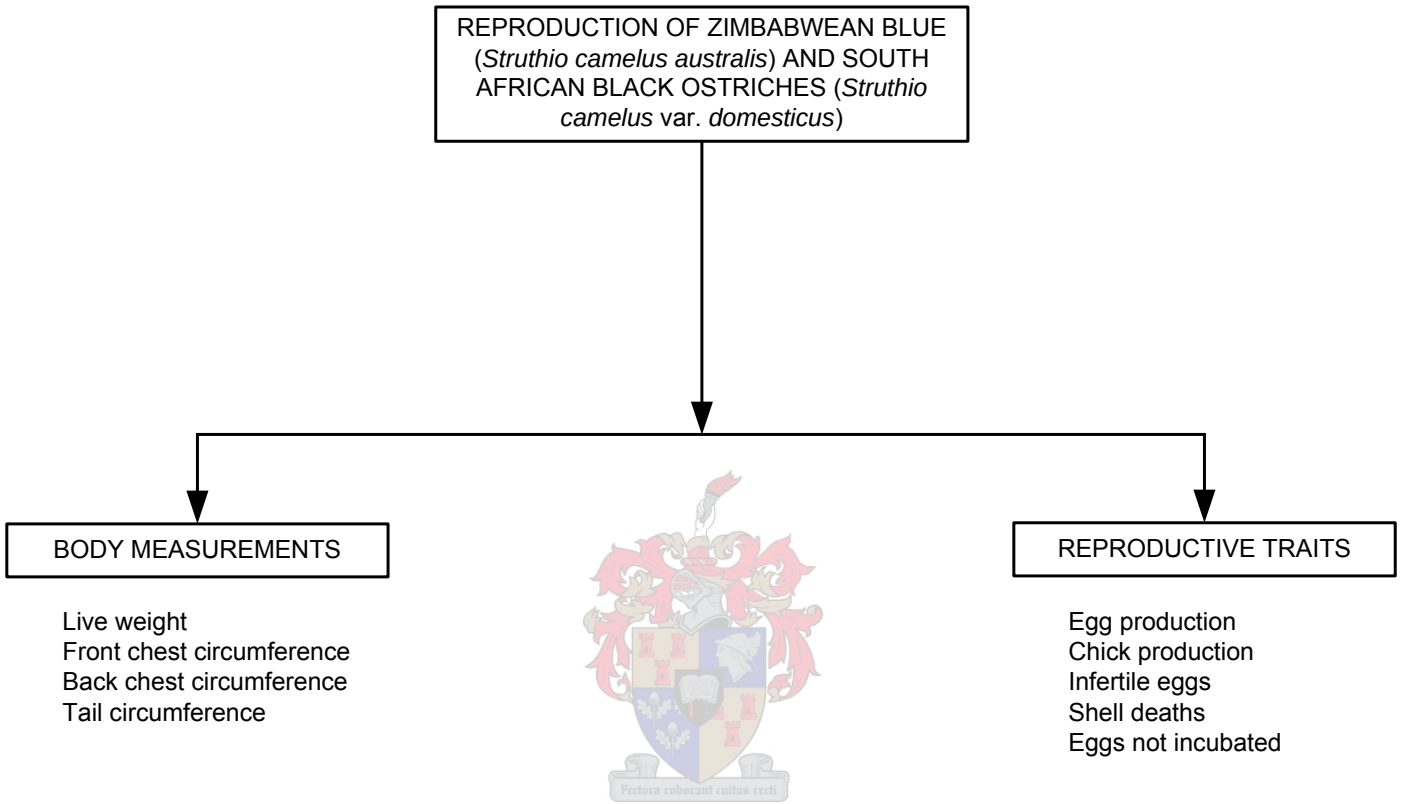

Figure 2
Research framework for determining reproductive performance of ostriches during 2003 and 2004

CHAPTER 2

Literature review

Literature review

INTRODUCTION

No research that determines the influence of crossbreeding and genotypes on ostrich meat quality could be sourced. Only a limited number of related articles are available on the effect of subspecies on meat quality. In most studies the genotype of ostrich is not even mentioned. The ostrich industry stands on three legs: the feather, meat and leather trade. Since 1975 the emphasis of ostrich production has shifted away from feathers as the most important product in favour of the skin and meat (Van Zyl, 2001). According to Van Zyl (2001), the income from the feathers, meat and leather in 2001 was divided into 8%, 27% and 65% respectively. Ostrich meat is becoming more important in the market as a source of income. Regarding the income currently derived from ostrich production, the feathers, meat and leather each contribute 5%, 45% and 50% respectively (Hoffman, 2005). In South Africa ostrich crossbreeding has been practised with ostriches to produce better quality feathers and leather (Madeiros, 1995; Horbaňczuk *et al*., 1998). The ostrich has only been used as meat animal recently (Van Zyl, 2001), so the influence of crossbreeding on meat quality has not yet been investigated. Different subspecies of ostrich have different phenotypic characteristics (Duerden, 1919; Sauer, 1968; Brown *et al*., 1982; Freitag, 1992), including size of the bird and growth rate (Madeiros, 1995). Therefore, there will be an advantage to the ostrich producer if the size and growth rate of birds can be increased through crossbreeding without affecting the skin and meat quality negatively.

This chapter provides an overview of the subspecies of ostrich, their crossbreeding and the resulting genotypes, as well as the reproduction properties and the factors that influence ostrich meat quality, including morphological properties, physical properties, chemical properties, and sensory properties.

SPECIES AND SUBSPECIES

Three types of ostriches are found in Africa, namely the Red Neck, the Blue Neck and the Black Neck (domesticated) variety (Madeiros, 1995). According to Kawka (2005) the highest genetic distance is found between Black and Red Necks, followed by the genetic distance between the Black and Blue Necks (Fig. 1). However, the smallest genetic distance is found between the Blue and Red Necks (Fig. 1). All subspecies found can be classified as one of these three.

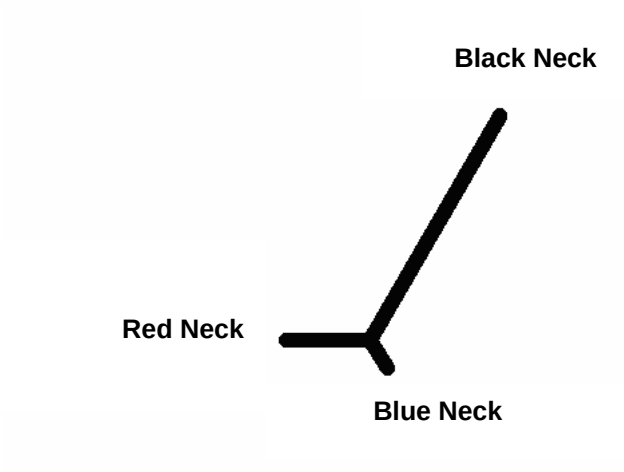

Figure 1 Neighbour-joining of ostriches as presented by Kawka (2005)

There is much controversy on whether there are in fact subspecies of ostrich. Mayr (1963) defines a species as "groups of actually or potentially interbreeding populations which are reproductively isolated from other such groups". Failure to interbreed between two or more groups that overlap in distribution qualifies them for different species status (Jarvis, 1998). Ostriches are classified into the species *Struthio (S.) camelus* (Sclater, 1906). Landsborough-Thomson (1964) defines a subspecies as "a population of which the members can be morphologically distinguished, if sometimes only on average from the members of other populations of the species to which all belong". Different subspecies will interbreed and produce viable crossbred offspring, also known as genotypes (Madeiros, 1995; Jarvis, 1998). Between subspecies there are substantial phenotypic differences such as body size, skin colour, egg size and shell porosity, the presence or absence of a bald head patch and the white band of feathers encircling the neck (Duerden, 1919; Sauer, 1968; Brown *et al*., 1982; Freitag, 1992).

Subspecies of ostrich

There are currently four extant subspecies of ostrich in Africa and one subspecies that has become extinct (Table 1). These subspecies include: *S. camelus syriacus* (extinct); *S. camelus camelus*; *S. camelus massaicus*; *S. camelus molybdophanes*; and *S. camelus australis* (Sclater, 1906; Duerden, 1919; Sauer, 1968; Brown et al., 1982; Madeiros, 1995; Jarvis, 1998; Robinson & Matthee, 1999).

Table 1 Phenotypic characteristics of ostrich genotypes

Genotypes	Neck colour	Body weight	Locality
S. camelus syriacus	Red	Extinct	Arabian deserts, Palestine, Persia, Syria
S. camelus camelus	Red	105	Northern Africa
S. camelus massaicus	Red	135	Tanzania, Kenya
S. camelus molybdophanes	Blue	105	Somalia, Ethiopia, Kenya
S. camelus australis	Blue	125	South Africa, Namibia, Botswana, Zimbabwe
S. camelus var. *domesticus*	Black	115	South Africa, Bophuthatswana (currently SA), Swaziland, Namibia

(Madeiros, 1995; Brown *et al*., 1982; Jarvis, 1998)

The Syrian ostrich (*S. camelus syriacus*) was a Red Neck subspecies which became extinct in 1941 through over-hunting for its feathers (Meinertzhagen, 1954; Brown *et al*., 1982; Madeiros, 1995). It is said to have had the most perfect of natural feathers.

The North African ostrich (*S. camelus camelus*) is a Red Neck subspecies. This subspecies is generally taller than the other subspecies, with a longer neck and legs, thicker legs and larger feet (Madeiros, 1995).

The Massai ostrich (*S. camelus massaicus*) is also a Red Neck subspecies. This subspecies has the largest body weight (Table 1) of all the subspecies and it is the tallest (Jarvis, 1998). North America, Asia and Europe are more interested in using this subspecies for its meat potential; therefore it has been domesticated in these parts (Horbańczuk *et al*., 1998).

The Somali ostrich (*S. camelus molybdophanes*) is a Blue Neck subspecies. According to Madeiros (1995), it is considered to be the tallest wild ostrich and it has a relatively low body weight compared to the other subspecies (Table 1).

The Zimbabwean ostrich (*S. camelus australis*) is a Blue Neck subspecies. This subspecies is small bodied, but has very long legs and neck and normally reaches a body weight of 95 kg earlier than the chicks from the other subspecies (Jarvis, 1998). Birds of this subspecies have a relatively high body weight in comparison to the birds of other subspecies (Table 1). This subspecies has been exported for use of its meat to North America, Asia and Europe, and is currently domesticated there (Horbańczuk *et al*., 1998).

The African Black ostrich (*S. camelus* var. *domesticus*), also known as the Oudtshoorn ostrich, is a Black Neck type of ostrich (Madeiros, 1995; Horbańczuk *et al*., 1998). It is a genotype between *S. camelus camelus* and *S. camelus autralis* (Swart *et al*., 1987). Therefore, it is a variety (genotype) and not a subspecies (Madeiros, 1995). This genotype has been bred since 1963 for its feathers and leather from imported ostriches selectively crossed with local stock (Madeiros, 1995; Horbańczuk *et al*., 1998). Only birds meeting certain criteria regarding the feathers and leather were maintained as breeders (Swart *et al.*, 1987; Madeiros, 1995). In comparison to the wild subspecies this genotype is smaller, with shorter legs and neck, broader, wider, longer bodies and a shorter bill (Madeiros, 1995).

Morphological properties

Morphological properties refer to the carcass characteristics and the meat yield of an ostrich carcass. According to Sales (1999), the highest percentage of usable meat in an ostrich carcass is situated on the legs and a lesser quantity is situated in the neck and the pair of muscles from the back (*M. obturatorius medialis*). Two thirds of the meat derived from a carcass consists of ten major muscles (*M. gastrocnemius, M. femorotibialis, M. iliotibialis cranialis, M. obturatorius medialis, M iliotibialis lateralis, M. iliofibularis, M. iliofemoralis externus, M. fibularis longus, M. iliofemoralis* and *M. flexor cruris lateralis)*, with the remaining third being classified as lean trimmings (Sales, 1999). Morphological properties have been investigated by various researchers (Morris *et al*., 1995b; Sales, 1996; Pollok *et al*., 1997b). Only Sales (1996) mentioned

the genotype used (*S. camelus* var. *domesticus*). It has been noted that, at the live weight of 80-90 kg at which most birds are slaughtered, the gender of the birds has no effect on slaughter yields or carcass characteristics (Morris *et al*., 1995a; Morris *et al*., 1995b). In the ostrich the breast amounts to only 9.56% of the total carcass, whereas the legs amount to 80.73% (Mellett, 1992). In broilers the breast amounts to 34.4% of the total carcass, whereas the legs amount to 48.8% (Mellett, 1992). Mellett (1992) studied the ostrich as a slaughter animal to provide meat. The genotype of ostrich is not mentioned. However, personal communication with Mellett (University of Stellenbosch, Stellenbosch, South Africa) confirms that the genotype used was *S. camelus* var. *domesticus*. Various aspects of growth are mentioned by Mellett (1992), including a detailed description of the muscle anatomy of the ostrich. The findings of Mellett (1992) and Mellett (1996b) are summarised in Table 2. The ostrich carcass consists of a total of 23 muscles. Figures 2 to 5 illustrate where all these muscles are situated (Mellett, 1996b). The numbers in the figures correlate with the numbers used in Table 2.

Table 2 Anatomical names, expected adult muscle mass and industrial, marketing application of ostrich hind-limb muscles (Mellett, 1992; Mellett, 1996b)

Muscle name	Mass (kg)	Application
Pre-acetabular muscles		
1. *M. iliotibialis cranialis*	1.530	Whole muscle
2. *M. ambiens*	0.540	Whole muscle
3. *M. pectineus*	0.308	Whole muscle
Acetabular muscles		
4. *M. iliofemoralis externus*	1.150	Whole muscle
5. *M. iliofemoralis internus*	0.128	Processing
6. *M. iliotrochantericus caudalis*	0.092	Processing
7. *M. iliotrochantericus cranialis*	0.148	Processing
Post-acetabular muscles		
8. *M. iliotibialis lateralis*	3.280	Whole muscle
9. *M. iliofibularis*	3.400	Whole muscle
10. *M. iliofemoralis*	1.160	Whole muscle
11. *M. flexor cruris lateralis*	1.170	Whole muscle
12. *M. flexor cruris medialis*	0.375	Whole muscle
13. *M. pubio-ischio-femoralis*	0.387	Whole muscle
14. *M. ischiofemoralis*	0.131	Processing only
15. *M. obturatorius medialis*	1.710	Whole muscle
16. *M. obturatorius lateralis*	Very small	Carcass meal
Femoral muscles		
17. *M. femorotibialis medius*	1.660	Whole muscle
18. *M. femorotibialis accessorius*	1.280	Whole muscle
19. *M. femorotibialis externus*	0.368	Whole muscle
20. *M. femorotibialis internus*	0.300	Whole muscle
Lower leg muscles		
21. *M. gastrocnemius*	5.890	Whole muscle
22. *M. fibularis longus*	1.650	Processing
23. Flexor and extensor group	3.300	Processing
Total	29.957	

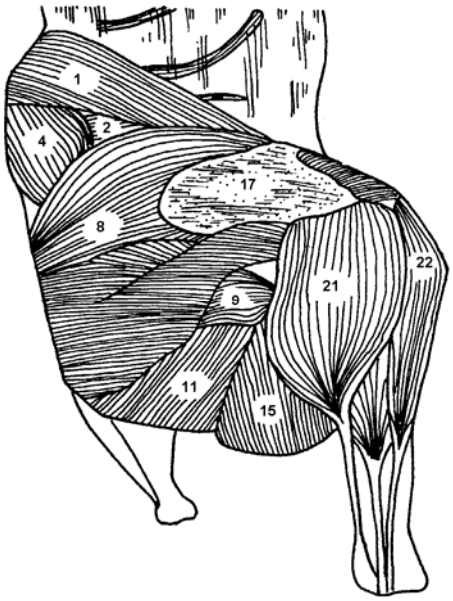

Figure 2 Superficial layer of muscles of the pelvic limb (Mellett, 1996b)

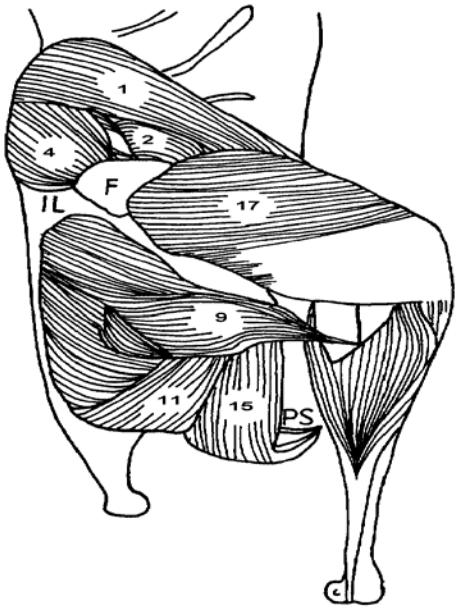

Figure 3 Second layer of muscles of the pelvic limb (Mellett, 1996b)

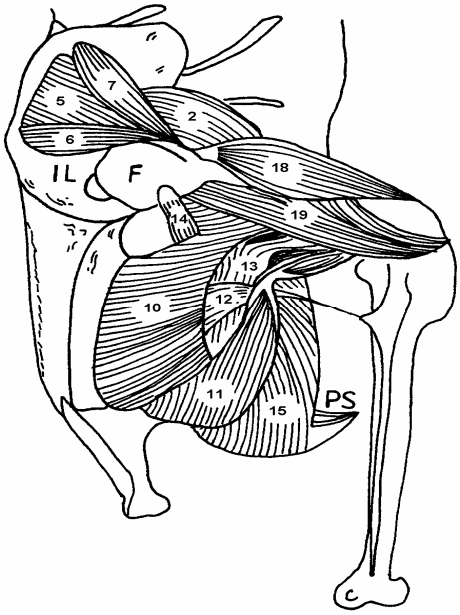

Figure 4 Third and fourth layers of muscles of the pelvic limb (Mellett, 1996b)

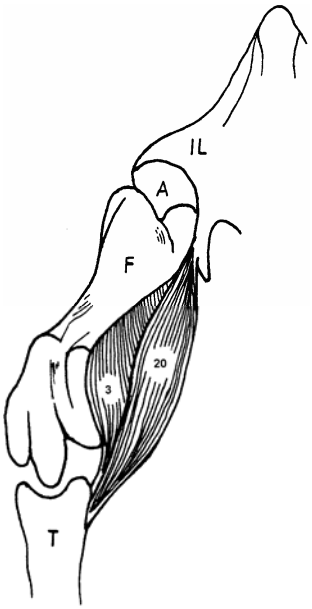

Figure 5 Medial muscles of the upper leg (Mellett, 1996b)

According to Mellett (1996a), most ostrich meat is marketed as individual muscles, for example, the fan fillet (*M. iliofibularis*), big drum (*M. gastrocnemius*), tornedo fillet (*M. ambiens*) and inside strip (*M. iliofemoralis*). Mellett (1996a) stated that the smaller muscles can only be used for processing. The muscle group no. 23 (Table 1) must be cooked for a very long period; therefore it is not of much value commercially (Mellett, 1996a). The individual muscles with the highest income include: big drum (*M. iliofibularis*), inside strip (*M. iliofemoralis*) and the round steak (*M. iliotibialis lateralis*) (Mellett, 1992). The larger muscles that are currently available on the market include: top loin (*M. iliotibialis cranialis*), outside strip (*M. flexor cruris lateralis*), tenderloin (*M. obturatorius medialis*), tip (*M. femorotibialis accessorius*) and the mid leg (*M. fibularis longus*). Other muscles that are also marketed include: tip, trimmed (*M. femorotibialis medius*), big drum (*M. gastrocnemius*) and the tornedo fillet (*M. ambiens*) (Mellett, 1992).

Physical properties

In this investigation, the pH, the instrumental colour, the water-holding capacity and the instrumental tenderness of the meat comprise the physical properties.

The pH of meat is an important characteristic, since its influence is so widespread (Joubert, 2003). It influences colour, water-holding capacity (WHC), juiciness, flavour and microbial shelf life (Lawrie, 1998). The pH of living ostrich muscles is around 7.2 (Sales, 1999). When the animal dies, glycogen is broken down by anaerobic glycolysis, producing lactic acid, which causes a drop in pH (Lawrie, 1998). Normal glycolysis is a slow process and continues until a final pH (pH_f) of approximately 5.5 is reached (Sales, 1999). However, if glycolysis takes place very quickly, meat has a light appearance and low WHC (Sales, 1999). In contrast, if a slow, slight drop in pH occurs over time, meat will have a dark colour, high WHC and limited shelf life (Sales, 1999). This dark, firm and dry meat (DFD) is associated with the depletion of glycogen in the muscle and it is common in animals that are stressed before slaughter (Lawrie, 1998). Undesirable aspects of DFD meat include less acceptable flavour, dark colour, sticky texture, high WHC (low moisture loss) and greater susceptibility to microbial growth during storage (Bailey, 1986). According to Sales and Mellett (1996), ostrich meat can be classified as an intermediate meat type, ranging anything between normal (pH_f = 5.5) and extremely dark, firm and dry (DFD, pH_f > 6.2) meat types. Post-mortem glycolysis has been investigated in several ostrich muscles, but the genotype used is not mentioned (Sales & Mellett, 1996). According to Mellett (University of Stellenbosch, Stellenbosch, South Africa, personal communication), it can be accepted that the genotype used was *S. camelus* var. *domesticus*. The *M. gastrocnemius pars interna, M. femorotibialis medius, M iliotibialis lateralis* and *M. iliofemoralis* showed the typical pattern of gradually descending pH decline (Sales & Mellett, 1996). However, the *M. ambiens* and *M. iliofibularis* showed a very rapid decline in pH until 2 h post-mortem, after which the pH again increased (Sales & Mellett, 1996).

When consumers purchase meat, colour is one of the first attributes to be evaluated. Lawrie (1998) states that meat colour in general is also affected by external factors such as species, genotype, sex, age, nutritional status and exercise. Colour is defined mathematically by the CIE formulae, where L* measures the brightness, and a* and b* define the red to green and yellow to blue axis respectively. In comparison to beef and lamb, ostrich meat is very dark in appearance (Otremba *et al*., 1999). The dark colour of meat in general is a result of the high pH_f (Lawrie, 1998), whereas the dark colour of ostrich meat specifically is also related to the pigment content (Sales, 1996). The colour of beef muscles ranges from slightly red to moderately cherry red. In contrast, ostrich muscles are slightly dark red to slightly cherry red (Morris *et al*., 1995b; Paleari *et al*., 1998). When the meat is cooked, ostrich meat is similar in appearance to beef (Paleari *et al*., 1998). Morris *et al.* (1995b) found that there are significant differences in colour, as measured by a trained sensory panel, between different muscles from the same ostrich carcass. According to Jones *et al.* (1994) and Schaefer *et al.* (1995), sex has no influence on ostrich meat colour. Meat derived from older birds has a darker colour (Mellett, 1996a; Hoffman & Fisher, 2001), most probably due to higher myoglobin content.

WHC describes the ability of meat to retain water during the presence of external forces, for example, cutting, mincing and heating. The pH and rate of pH decline influence the WHC of meat (Swatland, 1995; Warris, 2000). Numerous studies, such as that of Onyango *et al*. (1998), found a relationship between an increased pH_f, which causes an increase in the WHC of the meat, and lower moisture loss. A high WHC leads to the surface of the meat appearing dry, less moisture being lost during the cooking of the meat and hence an unfavourable impression of juiciness during mastication. The different meat proteins will denaturate during cooking of meat (Honikel, 1998), causing structural changes which result in cooking loss. Onyango *et al*. (1998) also found that high WHC results in low cooking loss. Therefore the WHC of meat affects the pre-cooking appearance, cooking ability, juiciness during chewing and the total quantity of saleable meat (Trout, 1988; Barge *et al*., 1991; Honikel, 1998; Onyango *et al*., 1998). When a muscle is cut, a red aqueous solution of proteins, known as drip or purge, oozes from the surface over time (Joubert, 2003). This affects the value of meat negatively. Drip loss is a combination of water and water-soluble proteins such as sarcoplasmic protein (Swatland, 1995). In the meat the water-soluble proteins decrease and salt-soluble proteins increase over time (Sales, 1999). Juiciness of meat is also related to the WHC of meat (Offer & Trinick, 1983).

The texture of meat determines the overall acceptability of the product (Risvik, 1994). The texture of meat includes its tenderness, which is the most important quality characteristic sought by consumers (Sales, 1999). Tenderness refers to the ease of shearing or cutting during mastication, as well as the amount of residue remaining in the mouth after chewing (Gillespie, 1960; Forrest *et al*., 1975). Lawrie (1998) notes that the tenderness of meat depends, among other factors, on the content and state of three types of protein: the connective tissue (collagen, elastin, reticulin, mucopolysaccharides of the matrix), myofibrils (actin, myosin and tropomyosin) and sarcoplasma (sarcoplasmic proteins and sarcoplasmic reticulum). Interfibre water content, the extent of the contraction of actin and myosin and the tropomyosin components of the myofibrils also play a role in tenderness (Curie & Wolfe, 1980). According to Sales (1999), connective tissue has an important effect on tenderness of meat. Tenderness can be measured instrumentally, using the Warner Bratzler shear device, or subjectively, using sensory analysis (Sales, 1999). Ostrich meat is a red meat and is similar in texture to veal and beef (Nitzan *et al*., 2002). However, numerous studies have found that ostrich meat is more tender than beef (Jones *et al*., 1994; Paleari *et al*., 1998) and similar to turkey (Paleari *et al*., 1998). Ostrich age (8, 10, 12, 14 months) was found to have no effect on Warner Bratzler shear force (Sales, 1994; Mellett & Sales, 1997; Girolami *et al*., 2003). However, in studies done by Mellett and Sales (1997) and Girolami *et al.* (2003) results from a sensory panel indicated that tenderness of ostrich meat was affected by slaughter age. Only Girolami *et al.* (2003) mention the subspecies (*S. camelus australis*) of ostrich used. Meat from 8-month-old birds was significantly more tender than meat from 10-, 12- and 14-month-old birds, and meat from 10-month-old birds more tender than that from 12- and 14-month-old birds as measured by sensory analysis (Girolami *et al*., 2003). Hoffman and Fisher (2001) compared 14-month-old and 8-year-old birds and found that age did have an effect on Warner Bratzler shear force. Again the genotype used is not mentioned. However, it can be accepted that the genotype used in studies done by Sales (1994), Mellett and Sales (1997), and Hoffman and Fisher (2001) was *S. camelus* var. *domesticus* (Mellett, University of Stellenbosch, Stellenbosch, South Africa, personal communication). Sex has no effect on instrumental or sensory analysis of tenderness in ostrich meat (Jones *et al*., 1994; Sales, 1994). Muscle type has a marked effect on tenderness of ostrich meat. Instrumental measurements and

sensory analysis ranked the *M. iliofibularis* as the most tender (*P*<0.001), the *M. gastrocnemius* as the least tender (*P*<0.001), whereas the *M. iliotibialis* showed an intermediate tenderness (Pollok *et al*., 1997a; Girolami *et al*., 2003). Similar results were obtained by Berge *et al.* (1997) in a study on emus. Ostrich meat shear values were indicative of moderately tender meat. There is no significant difference between tenderness of the *M. iliofibularis, M iliotibialis lateralis* and *M. femorotibialis medius* as measured by sensory analysis (Mellett & Sales, 1997).

Chemical composition

Chemical composition of ostrich meat refers to, amongst other factors, the content of moisture, protein, fat (including fatty acids), cholesterol, ash, collagen, myoglobin and the mineral composition of the meat.

Perceived healthiness of food is of great importance for consumer preference (Fisher *et al*., 2000) and consumers want to be informed of the nutrient composition of food (Sales & Hayes, 1996; Horbańczuk *et al*., 1998). A lack of public knowledge about the nutritive value of ostrich meat hampers its utilisation (Sales, 1995). The nutrient composition differs between muscles in the same ostrich carcass (Sales, 1996; Sales & Hayes, 1996). According to Joubert (2003), ostrich meat has traditionally been marketed as lean meat with a high protein content compared to beef, chicken and pork (Table 3).

Table 3 Mean ranges of the chemical composition of ostrich meat as noted by Joubert (2003)

Component	Content
Moisture (%)	65.8-77.7
Protein (%)	20.5-22.0
Fat (%)	0.3-3.1
Ash (%)	1.0-1.3

(Harris *et al*., 1993; Sales, 1996; Sales & Hayes, 1996; Horbańczuk *et al*., 1998; Paleari *et al*., 1998).

In the study by Sales and Hayes (1996) the *M. iliofibularis, M. femorotibialis medius* and the *M. gastrocnemius pars interna* were used for the comparison of the proximate, amino acid and mineral composition (Table 4). The genotype of ostrich was not mentioned. However, it can be accepted that the genotype used was *S. camelus* var. *domesticus* (Mellett, University of Stellenbosch, Stellenbosch, South Africa, personal communication).

Table 4 Proximate composition (g/100 g edible portion) of different ostrich muscles (mean ± SD)

Component	*M. iliofibularis*	*M. femorotibialis medius*	*M. gastrocnemius pars interna*
Water	76.24 ± 0.529	76.41 ± 0.529	76.15 ± 0.454
Protein	21.0 ± 0.576	20.81 ± 0.718	21.6 ± 0.486
Ash	1.03 ± 0.132	1.13 ± 0.040	1.04 ± 0.077

(Sales & Hayes, 1996)

As noted in Table 4, water content did not differ (*P*>0.05) between muscles (*M. iliofibularis, M. femorotibialis medius, M. gastrocnemius pars interna*) (Sales & Hayes, 1996). The moisture content values are higher than for beef, chicken and turkey (Sales & Hayes, 1996; Paleari *et al*., 1998).

Ostrich meat is similar in protein content and amino acid composition compared to meat derived from traditional livestock species (Sales & Hayes, 1996). However, Paleari *et al.* (1998) found that ostrich meat is slighter higher in protein content compared to beef and turkey, whereas Sales and Hayes, (1996) found that beef is higher in protein content. Schweigert (1987) found that the protein content as well as the amino acid composition of meat protein, irrespective of species, remains constant irrespective of cut. Sales and Hayes (1996) studied the *M. iliofibularis, M. femorotibialis medius* and the *M. gastrocnemius pars interna* to determine the protein content (Table 4) and amino acid composition of these ostrich muscles. Protein content did not differ significantly (P>0.05) between muscles (*M. iliofibularis, M. femorotibialis medius, M. gastrocnemius pars interna*) (Sales & Hayes, 1996). According to Sales (1999), the amino acid composition of meat protein of chicken, beef and ostrich remains markedly consistent. In the study by Sales and Hayes (1996) muscles showed a similar pattern in amino acid composition, except for the following few amino acids: valine and methionine were higher (P≤0.05) in the *M. iliofibularis* than in either the *M. femorotibialis medius* or the *M. gastrocnemius pars interna*, but in the latter muscle leucine was lower (P≤0.05) than in the *M. iliofibularis*. Glycine was significantly higher (P≤0.05) in the *M. gastrocnemius pars interna* than in the other two muscles.

According to Sales and Hayes (1996), the ash content for ostrich meat is higher compared to beef and chicken. However, contradicting this, Paleari *et al.* (1998) found that beef has a higher ash content. Ostrich meat is similar in mineral composition compared to other conventional meat types (Sales & Hayes, 1996). Potassium is quantitatively the most important mineral in meat derived from traditional livestock species, followed by phosphorus (Lawrie, 1998). Regarding the potassium and phosphorus content, Sales and Hayes (1996) found the same tendency in ostrich meat. The concentration of iron and zinc in ostrich muscles is the highest (P≤0.05) in the *M. femorotibialis medius*, while both phosphorus and magnesium are lower (P≤0.05) in the *M. gastrocnemius pars interna* (Sales & Hayes, 1996). Ostrich meat contains a higher concentration of iron than meat derived from chicken and beef (Sales & Hayes, 1996). Iron is the most important mineral in meat and is especially relevant in the diets of teenage and adult women (Stipanuk, 2000). Ostrich meat also has a low sodium content (Sales & Hayes, 1996) and is therefore suitable for use in a low-sodium diet (Stipanuk, 2000). Humans with hypertension on salt restriction diets will benefit from this (Stipanuk, 2000).

Fat contributes to the juiciness of meat and therefore affects the eating quality of meat. Fat has a stimulatory effect on the secretion of saliva (Lawrie, 1998). Ostrich meat has a low content of intramuscular fat (Mellett, 1992; Shanawany, 1995; Sales, 1998). A loss of sustained juiciness therefore occurs during chewing due to the absence of fat and the consumer is left with the perception of a dry product (Sales, 1999). Although the latter is true, the low intramuscular fat content, together with the low sodium content, can be used as an advantage when marketing ostrich meat as a health product.

Ostrich meat is considered a healthy product, due to its low intramuscular fat content (Mellett, 1992; Shanawany, 1995; Sales, 1998). Therefore, it is seen as a new alternative red meat (Sales, 1998). The content of intramuscular fat differs between subspecies (Horbańczuk *et al.*, 1998) and between muscle types (Sales, 1994). In a study done on Blue Neck ostriches (*S. camelus australis*), intramuscular fat content was significantly higher (P≤0.05) in the *M. iliotibialis* than in either the *M. iliofibularis* or the *M. gastrocnemius*

(Girolami *et al.*, 2003). Horbańczuk *et al.* (1998) also found similar results in Blue Neck ostriches. Red Neck (*S. camelus massaicus*) and Blue Neck (*S. camelus australis*) ostriches were used to determine the influence of subspecies on the intramuscular fat content (Horbańczuk *et al.*, 1998). Two muscles, the *M. gastrocnemius,* and *M. iliofibularis*, were analysed. There was no significant difference (P>0.05) in total lipid content in the two muscles between the subspecies (Horbańczuk *et al.*, 1998). In the same study lipid values for the *M. iliofibularis* were lower than the lipid values found for African Blacks (*S. camelus* var. *domesticus*) in a similar age range (Sales & Hayes, 1996; Horbańczuk *et al.*, 1998). Sales and Hayes (1996) found that the intramuscular fat content of the *M. iliofibularis* was higher (P≤0.05) than in both the *M. femorotibialis medius* and the *M. gastrocnemius pars interna*. The genotype of ostrich studied was not mentioned, but it can be accepted that the genotype used was *S. camelus* var. *domesticus* (Mellett, University of Stellenbosch, Stellenbosch, South Africa, personal communication). In general, the meat of younger animals also contains less fat than that of older animals (Lawrie, 1998). Contradicting this, no significant difference was observed for the content of intramuscular fat of ostrich meat between different ages at slaughter (10-11 vs. 14-15 months) (Girolami *et al.*, 2003).

Individual fatty acids are discussed first, and then the grouping of the different fatty acids, the polyunsaturated:saturated (P:S) and the *n*-6:*n*-3 ratios will be discussed. Intramuscular fat composition of all animal species consists mainly of palmitic (C16:0), stearic (C18:0), oleic (C18:1) and linoleic (C18:2) acid (Lawrie, 1998). Ostrich meat is no different (Mellett, 1996b). A high percentage of oleic acid (C18:1) is found in beef, pork, mutton, poultry and ostrich meat (Cambero *et al*., 1991; Sales, 1998). In ostrich meat oleic acid (C18:1) presents the highest concentration, followed by palmitic acid (C16:0) and then linoleic acid (C18:2) (Sales, 1994; Horbańczuk *et al*., 1998; Paleari *et al*., 1998; Sales, 1998; Hoffman & Fisher, 2001). Concentration of fatty acids differs between subspecies, muscles within a given subspecies and even within a single muscle (Lawrie, 1998; Sales, 1994). In a study conducted on African Black ostriches (*S. camelus* var. *domesticus*), it was found that the percentage of individual fatty acids differed between muscles (*M. gastrocnemius, M. femorotibialis medius, M. ambiens, M. iliotibialis lateralis, M. iliofibularis, M. iliofemoralis*) (P≤0.05) and variations were found within muscles (Sales, 1998). The *M. gastrocnemius, M. femorotibialis* and *M. iliofibularis* have the highest content of *n*-3-fatty acids (Sales, 1998). Horbańczuk *et al.* (1998) studied Red Neck (*S. camelus massaicus*) and Blue Neck (*S. camelus australis*) ostriches to determine the fatty acid composition of ostrich meat as influenced by subspecies. Two muscles, the *M. gastrocnemius,* and *M. iliofibularis,* were analysed. The percentage of some individual fatty acids differed significantly (P≤0.05) (Horbańczuk *et al*., 1998). The percentage of myristic acid (C14:0) in both muscles and palmitic acid (C16:0) in the *M. iliofibularis* were higher (P≤0.05) in the Blue necks than in the Red Necks (Horbańczuk *et al.*, 1998). There was a higher (P≤0.05) proportion of the monounsaturated palmitelaidic acid (C16:1) in the Red Necks than in the Blue Necks in the *M. gastrocnemius* (Horbańczuk *et al*., 1998). Then again, the percentage of the monounsaturated fatty acid (MUFA) gondoic acid (C20:1) was higher (P≤0.05) in the Blue Necks than in the Red Necks in both muscles (Horbańczuk *et al*., 1998). Hoffman and Fisher (2001) found differences in the fatty acid composition of birds from different ages (14-month vs. 8 years). However, it must be noted that the vast majority of commercial birds are slaughtered at an age of 9-14 months, when a body weight of 80-90 kg is reached, and not at 8 years of age (Van Zyl, 2001). Amongst other researchers, Hoffman and Fisher (2001) speculated that some of these differences could most probably be attributed to

diet. In a later study, Hoffman *et al*. (2005) indicated that the fatty acid profile of ostriches can be changed by their diet.

Fat contains 99% triglycerides and also a considerable content of phospholipids, which are a component of the cell membrane (Lawrie, 1998). In beef, fatness affects the fatty acid composition of the total lipid content because the triacylglycerols, which increase with fatness, are less unsaturated than the more constant phospholipids in muscle membranes (Enser *et al*., 1998). Ostrich meat has a very high percentage of phospholipids, because it is low in intramuscular fat. Phospholipids are a rich source of polyunsaturated fatty acids (PUFA) (Lawrie, 1998). Sales and Hayes (1996) and Paleari *et al.* (1998) reported that ostrich meat has a higher content of PUFA than beef, broilers and turkey. Ostrich meat has a favourable fatty acid profile, which presents a high content of PUFA and a lower content of saturated fatty acids (SFA) (Mellett, 1992; Sales, 1998). This increase in PUFA and decrease in SFA results in lowering of human blood cholesterol (Sinclair *et al*., 1982). Intramuscular ostrich fat contains 16.5% of the essential polyunsaturated *n*-6 fatty acid, linoleic acid, and approximately one third of the total fatty acids are MUFA (Mellett, 1996b). The ratio between the SFA and unsaturated fatty acids are also important (Paleari *et al*., 1998). Ostrich meat can be considered outstanding in terms of health characteristics, because its ratio of saturated:monounsaturated:polyunsaturated fatty acids is 1:1:1 (Sales, 1994).

In a study conducted on African Black ostriches (*S. camelus* var. *domesticus*), it was found that the percentage of total SFA, MUFA and PUFA varied between muscles (*M. gastrocnemius, M. femorotibialis medius, M. ambiens, M. iliotibialis lateralis, M. iliofibularis, M. iliofemoralis*) (Sales, 1998). The SFA, palmitic acid (C16:0) and stearic acid (C18:0) are the lowest in the *M. iliofibularis* (Sales, 1998). The highest percentage of total MUFA is found in the *M. ambiens*, followed by the *M. iliofemoralis* (Sales, 1998). The *M. iliofibularis* contains the highest ($P \leq 0.05$) percentage of total PUFA (Sales, 1998). This causes a higher ($P \leq 0.05$) P:S and a lower ($P \leq 0.05$) monounsaturated:polyunsaturated ratio in the latter muscle compared to other muscles (Sales, 1998). Horbańczuk *et al.* (1998) studied Red Neck (*S. camelus massaicus*) and Blue Neck (*S. camelus australis*) ostriches to determine the fatty acid composition of ostrich meat as influenced by subspecies. Two muscles, the *M. gastrocnemius* and *M. iliofibularis*, were analysed. The total percentage of SFA and total MUFA was similar ($P > 0.05$) between subspecies in both muscles (Horbańczuk *et al*., 1998). The total percentage of PUFA was higher ($P \leq 0.05$) in the Blue Necks than in the Red Necks in the *M. gastrocnemius,* but percentages did not differ ($P > 0.05$) between subspecies in the *M. iliofibularis* (Horbańczuk *et al*., 1998). In African Blacks higher percentages of total PUFA are found in the *M. gastrocnemius* and the *M. iliofibularis* (Sales, 1994). The study by Horbańczuk *et al.* (1998) indicates that the fatty acid composition does not differ to a large extent between the subspecies *S. camelus massaicus* and the subspecies *S. camelus australis*. Girolami *et al.* (2003) conducted research on Blue Neck ostriches (*S. camelus australis*) and found that the fatty acid profile was significantly affected by age (10-11 vs. 14-15 months) at slaughter ($P < 0.001$) and muscles (*M. iliofibularis, M. gastrocnemius, M. iliotibialis*) ($P < 0.001$). In older birds (14-15 months) an increase of total SFA ($P \leq 0.05$) and MUFA ($P < 0.001$) and a decrease of total PUFA ($P < 0.001$) were found (Girolami *et al.*, 2003). This caused an increase in the (P:S) ratio ($P < 0.001$). In general, the meat of younger animals contains a higher percentage of PUFA and less SFA than that of older animals (Lawrie, 1998). A higher content of PUFA and a lower content of MUFA are found in meat of

ostriches slaughtered at 10-11 months (Girolami *et al*., 2003). The meat from young ostriches will therefore contribute positively towards the health of consumers. The highest percentage of PUFA (P<0.001) is found in the *M. gastrocnemius*, whereas the highest content of SFA and MUFA (P<0.001) were found in the *M. iliofibularis* (Girolami *et al.*, 2003).

Girolami *et al*. (2003) conducted research on Blue Neck ostriches (*S. camelus australis*) to study the effect of age (10-11 vs. 14-15 months) and muscle (*M. iliofibularis, M. gastrocnemius, M. iliotibialis*) on the fatty acid composition of the meat. The ratios of *n*-6:*n*-3 for the three muscles (*M. iliofibularis, M. gastrocnemius, M. iliotibialis*) were 7.57 ± 0.31, 8.31 ± 0.31 and 7.77 ± 0.31 respectively (Girolami *et al*., 2003). There was no significant difference (P>0.05) for this ratio between muscles, although it was higher in the *M. gastrocnemius* (Girolami *et al*., 2003). These values are above the recommended maximum value of 4 as proposed by the British Department of Health (Girolami *et al*., 2003). Therefore, studies by Girolami *et al*. 2003 indicate an unfavourable *n*-6:*n*-3 ratio in ostrich meat. However, high contents of essential polyunsaturated linoleic (C18:2) and arachidonic (C20:4) acids are recorded (Girolami *et al*., 2003). Age at slaughter influences the mean *n*-6:*n*-3 ratio (Girolami *et al*., 2003). In the age groups of 10-11 months and 14-15 months of age, the values for the *n*-6:*n*-3 ratio were 6.82 ± 0.25 and 8.95 ± 0.25 respectively (Girolami *et al*., 2003). The *n*-6:*n*-3 ratio was significantly lower (P<0.001) for younger birds (Girolami *et al*., 2003). In a study conducted on different muscles (*M. gastrocnemius, M. femorotibialis medius, M. ambiens, M. iliotibialis lateralis, M. iliofibularis, M. iliofemoralis*) of African Black ostriches (*S. camelus* var. *domesticus*), it was found that the *n*-6:*n*-3 ratio was the highest in the *M. iliofemoralis*, but constant in all other muscles (Sales, 1998). Horbaňczuk *et al.* (1998) studied Red Neck (*S. camelus massaicus*) and Blue Neck (*S. camelus australis*) ostriches to determine the fatty acid composition of ostrich meat as influenced by subspecies. Although the mean *n*-6:*n*-3 ratio was higher in the *M. gastrocnemius* than in the *M. iliofibularis*, it did not differ (P>0.05) between subspecies within muscle (Horbaňczuk *et al*., 1998).

A high *n*-6:*n*-3 ratio, as well as a high intake of cholesterol is a risk factor for humans with coronary heart disease and atherosclerosis (Sales, 1998; Girolami *et al*., 2003). A high intake of cholesterol also results in hypercholesterolemia (Enser *et al*., 1998). Ostrich meat has a low cholesterol content and is therefore considered a healthy product (Mellett, 1992; Shanawany, 1995; Sales, 1998). The statement that ostrich meat is low in cholesterol because of its low intramuscular fat content is a myth (Sales, 1994). Intramuscular fat content is poorly correlated to cholesterol content. Cholesterol is a structural component of cell membranes and the sub-cellular distribution of cholesterol differs in muscle tissue (Sales, 1999). Therefore, its content does not increase as intramuscular fat increases. However, according to Jensen (2004), muscle fibres have approximately 75% of their cholesterol associated with membranes and the other 25% associated with their neutral lipids. Therefore, if the content of neutral lipids in the muscle increases, the content of cholesterol will also increase. It seems therefore that, as opposed to statements by Sales (1999), the cholesterol content may increase as content of intramuscular fat increases. Compared to beef (68 mg/100 g), lamb (71 mg/100 g), chicken (98 mg/100 g) and turkey (82 mg/100 g), ostrich meat has a lower cholesterol content (62 mg/100 g) (Sales, 1994). A study conducted on African Black ostriches (*S. camelus* var. *domesticus*) found that cholesterol content differed between muscles (*M. gastrocnemius, M. femorotibialis medius, M. ambiens, M. iliotibialis lateralis, M. iliofibularis, M. iliofemoralis*) (Sales, 1998). A significant difference (P≤0.05) between the cholesterol content of the *M. femortibialis medius* and the *M.*

iliofemoralis was noted. Red Neck (*S. camelus massaicus*) and Blue Neck (*S. camelus australis*) ostriches were used to determine the influence of subspecies on the cholesterol content of ostrich meat (Horbańczuk *et al.*, 1998). The *M. gastrocnemius* and the *M. iliofibularis* were analysed. A mean value of 66 mg/100 g is mentioned for both muscles in both subspecies (Horbańczuk *et al.*, 1998). Girolami *et al*. (2003) conducted research on Blue Neck ostriches (*S. camelus australis*) to study the effect of age and muscle on cholesterol content of the meat. Horbańczuk *et al.* (1998) and Girolami *et al.* (2003) observed that cholesterol content did not differ significantly ($P>0.05$) among muscles, nor between ages at slaughter.

As opposed to what occurs in broilers, fat forms a layer in the abdominal cavity of ostriches. Most of the flavour of ostrich meat is stored within this fat (Sales, 1994). This main deposition of fat in the abdominal cavity results in an exceptionally low intramuscular fat content of the meat (Sales, 1999). The breast fat is a layer of fat overlaying the sternum (Sales, 1999) and it contributes a lesser extent to the quantity of extra-muscular fat. There are very few detailed analyses of bird fats. Only one study was found on the composition of fatty acids in ostrich fat. It was done on a single ostrich and the genotype was not mentioned (Gunstone & Russell, 1954). According to this study, ostrich fat does not differ that much from other bird fats, since the major fatty acids present are palmitic (C16:0), oleic (C18:1) and linoleic (C18:2) acid (Gunstone & Russell, 1954). According to Gunstone and Russell (1954), each fatty acid contributes 24.8%, 39.8% and 17.1% respectively. These latter three fatty acids are also the major fatty acids present in other bird fats (Gunstone & Russell, 1954). Myristic (C14:0), stearic (C18:0), arachidonic (C20:4), palmitelaidic (C16:1), linolenic (C18:3) and higher unsaturated fatty acids are also present (Gunstone & Russell, 1954). Hoffman *et al.* (2005) found that extramuscular fat of the abdominal fat depots of ostriches was influenced by dietary fish oil. Characteristics that were affected include flavour and fatty acid profile. An increase in the quantity of dietary fish oil consumed was found to have no significant effect ($P>0.05$) on the sensory characteristics of ostrich meat (Hoffman *et al*., 2005). However, increased quantity of fish oil did have a significant effect ($P\leq0.05$) on the flavour of the abdominal fat depots (Hoffman *et al*., 2005). The fatty acid profile of both extramuscular fat and ostrich muscle was altered as a result of the consumption of fish oil (Hoffman *et al*., 2005).

Collagen is the principal fibrous protein in connective tissue (Tarrant, 1998). It forms a structural matrix for the cellular components of muscle, providing the muscle with form and support, as well as a means of transmitting and absorbing forces generated by muscle contraction (McCormick, 1994). The amino acid hydroxiproline is present in collagen and its presence is therefore used to determine the collagen content (Sims & Bailey, 1981). Collagen is stabilised by lysine-derived cross-links (Bailey & Sims, 1977). When collagen is exposed to heat of about 65^{o}C, it contracts to one quarter of its original length and becomes rubber-like (Bailey & Sims, 1977). This contraction causes an increase in tension and more fluid is exuded from the muscle, resulting in an increase of meat toughness (Bailey & Sims, 1977). Connective tissue is correlated with animal age and has an effect on tenderness (Sales, 1999). With increasing animal age, total collagen content decreases, but the solubility of collagen also decreases (Smith & Carpenter, 1970). This decrease in solubility is due to the greater thermal stability of the bonds, resulting from a conversion of the labile reducible cross-links to stable non-reducible bonds (Bailey & Sims, 1977). As the solubility of the collagen decreases, the toughness of the meat increases. Therefore, a distinct correlation exists between total collagen content and collagen insolubility and the toughness of meat (Young &

Braggings, 1993). In emus the tenderness of different muscles increased as the content of total collagen decreased (Berge *et al*., 1997). According to Sales (1996), ostrich meat is characterised by low connective tissue content. Ostrich muscles (*M. iliofibularis, M. gastrocnemius, M. iliotibialis*) differ on the basis of different collagen content (Girolami *et al*., 2003). For example, total collagen content is higher in the *M. gastrocnemius* and lower in the *M. iliofibularis* (Sales *et al*., 1996).

Pigment content contributes to the colour of meat (Sales, 1996). The red colour of meat is mainly the result of myoglobin, which accounts for 75% of the pigment in red meat (Lawrie, 1998). The other 25% is the result of haemoglobin (Levie, 1979; Charley & Weaver, 1998). Due to the reaction of purplish-red myoglobin with oxygen, bright red oxymyoglobin forms when the cut meat surface is exposed to air (Lawrie, 1998). In an oxidative reaction, brown metmyoglobin forms from myoglobin and oxymyoglobin (Lawrie, 1998). According to Lawrie (1998), there are various other forms of myoglobin that form under different conditions and through different reactions. All these forms will influence the colour of meat. Thus by determining the myoglobin content of meat, an indication of colour can be obtained. Activity and content of myoglobin are influenced by various factors such as species, subspecies, sex, age and muscle type (Lawrie, 1998). Sales (1996) investigated the pigment content in six different ostrich muscles (*M. gastrocnemius pars interna, M. femorotibialis medius, M. ambiens, M iliotibialis lateralis, M. iliofibularis, M. iliofemoralis*) in *S. camelus* var. *domesticus*. A mean value of 6.62 ± 1.73 mg g^{-1} haem was determined for the six muscles (Sales, 1996). In the same study it was determined that the *M iliotibialis lateralis* differs the least in pigment content (6.12 ± 0.91 mg g^{-1} haem) from the mean, while the *M. iliofemoralis* differs the most in pigment content (9.09 ± 1.33 mg g^{-1} haem) from the mean.

Sensory properties

The sensory properties of ostrich meat refer to the flavour, juiciness and tenderness of the meat. Flavour of meat is a complex sensation which consists of aroma and taste (Charley & Weaver, 1998). Taste includes the basic taste sensations (Charley & Weaver, 1998). Aroma is perceived as an odour when volatiles pass into the nasal area from the mouth, or are sniffed through the nostrils (Meilgaard *et al*., 1987). Meat flavour is influenced by texture, pH and temperature (Lawrie, 1998). Ostrich meat has a characteristic aftertaste which is seldom observed in beef (Harris *et al*., 1993; Paleari *et al*., 1995). Trained panels often consider ostrich meat to be bland. According to Lawrie (1998), blandness of meat in general may possibly result from a high pH_f and a low intramuscular fat content. Both these characteristics are evident in ostrich meat (Sales & Mellett, 1996; Sales, 1998) – therefore, it may be the reason for the blandness observed in ostrich meat. The *M. gastrocnemius* was identified as bland more frequently than the *M. iliofibularis, M. obturatorius medialis* and *M. iliotibialis lateralis* (Harris *et al*., 1993). The *M. obturatorius medialis* was described as the most intense in flavour. In contradiction to this, Pollok *et al.* (1997c) and Girolami *et al.* (2003) note that muscle type and slaughter age had no effect on the intensity of meat flavour.

Tenderness is the most important palatability attribute of meat (Lawrie, 1998), the predominant quality determinant and is probably the most important sensory characteristic of red meat (Koohmaraie, 1988). Tenderness refers to the force needed to shear, compress and ground meat during mastication and consumption (Lepetit & Culioli, 1994). Thus it refers to the ease with which the consumer disorganises the

meat structure. The sensation of tenderness is a very complicated physical process, since chewing the meat involves not only cutting and grinding, but also squeezing, shearing and tearing (Pearson, 1963). Therefore, meat tenderness is an extremely complex characteristic, as it is caused and affected by numerous factors. The variables related to tenderness include: intramuscular fat; percentage of moisture and fat; collagen content and percentage soluble collagen; level of enzymes; glycogen content; sarcomere length; and juiciness (Davis *et al*., 1979; Hawkins *et al*., 1987). Ante-mortem intrinsic factors that also influence tenderness include: species, age, sex and nutritional status; the post-mortem extrinsic factors that influence tenderness include: slaughtering methods, pre-slaughtering stress handling, processing and cooking temperatures (Lawrie, 1998). It has been found that frequently the extrinsic factors have a stronger effect than the intrinsic factors.

Juiciness, on the other hand, is related to the WHC of meat (Offer & Trinick, 1983). If analytical sensory analysis is used to measure juiciness, two sensory components are relevant (AMSA, 1978). The first component is the initial impression of juiciness. This refers to the amount of fluid exuded on the meat surface when pressed between thumb and forefinger. Sustained juiciness is the second component and refers to the impression that is formed after the first two to three bites between the molar teeth. The latter is also affected by the presence of fat, because fat stimulates the secretion of saliva and thus improves juiciness (Lawrie, 1998).

REPRODUCTION

In this investigation reproduction is inclusive of estimates for live weight, body measurements and reproductive traits including: eggs produced, infertility, chicks produced, shell deaths and eggs not incubated for ostrich males and females during two breeding seasons.

Crossbreeding and genotypes

The importance of crossbreeding and selection strategies in the ostrich industry is as follows. Concerning the history of ostrich breeding in South Africa, only birds exhibiting the best marketable plumage were initially maintained as breeders (Petitte & Davis, 1999). Selection was based only on feather quality, whereas other characteristics such as rate of body weight gain and egg production were not taken into account (Petitte & Davis, 1999). In crossbreeding controlled crosses between various subspecies is done to develop strains with improved potential for commercialisation (Jarvis, 1998). These strains are also known as genotypes. Several authors have suggested crossbreeding of different genotypes of ostriches to improve overall performance, but this far no published studies have adequately quantified differences between genotypes in their reproductive performance (Bunter, 2002). Bunter *et al.* (2001) stated that future gains through selection are likely in the ostrich. Later studies confirmed that reproduction gains with regard to selection for egg and chick production were achieved in the ostrich (Cloete *et al*., 2004; Cloete *et al*., 2005a). Improvement of a genotype is done through the selection of superior individuals as the parents of the next generation (Jarvis, 1998). In the process of crossbreeding the individuals of different subspecies are crossed to produce crossbred offspring (Jarvis, 1998). From these offspring individuals are chosen again to breed more offspring (Jarvis, 1998). Breeding with the best birds (chosen through selection) and culling the rest (Petitte

& Davis, 1999) ensures that desired characteristics are included and undesirable characteristics are eliminated (Smit, 1964; Freitag, 1992). Culling (through slaughter) prevents any chance of birds with inferior performance passing on poor genes to the population of breeders (Petitte & Davis, 1999). Bunter *et al*. (2001) state that appropriate selection and culling strategies will improve the reproductive performance of the current and future flocks.

According to Petitte and Davis (1999), the conformation or performance of an individual is determined both by its genetic make-up and the environment. If there is no selection in stock for a specific purpose, so that each generation is improved over the preceding generation, there will be no increase in performance. Currently greater emphasis is placed on the meat and the skin of the ostrich, as opposed to the feathers (Petitte & Davis, 1999; Cloete *et al*., 2002). Therefore genetic improvement will have to play a greater role in producing and developing birds to meet the specific future market for meat and leather (Petitte & Davis, 1999).

Reproductive traits

According to Petitte and Davis (1999), "a trait is any characteristic that can be visually identified or measured in a bird, such as feather colour, number of eggs, rate of gain, etc." It is frequently stated by various researchers (Bunter *et al*., 2001; Bunter, 2002; Cloete *et al*., 2002) that a limited amount of literature is available that addresses either non-genetic and/or genetic aspects of production traits in this species. There are only a few published scientific studies that provide evidence quantifying significant factors affecting reproduction in the ostrich (Bunter *et al*., 2001; Bunter, 2002; Cloete *et al*., 2002). Despite being an established commercial industry, genetic parameters for production traits such as eggs produced, infertility, chicks produced, shell deaths and eggs not incubated are practically non-existent (Cloete *et al*., 1998). Limited data are available for the estimation of these parameters and the formulation of a breeding policy for South African ostriches (Cloete *et al*., 1998). Large data bases to estimate production parameters are also practically non-existent (Cloete *et al*., 1998). At present only a few efforts have been made to develop long-term selection programmes or even specific lines of birds in response to consumer markets for meat and leather (Petitte & Davis, 1999). According to Bunter (2002), almost no knowledge has been accumulated which addresses genetic control of, or variation in, economically important traits. A significant amount of literature is available for similar reproduction traits in common domestic species such as poultry, dairy cattle and pigs (Bunter, 2002; Cloete *et al*., 2002; Cloete *et al*., 2004). Considering the marked genetic improvement in the reproduction of poultry, it is clear that similar successes could be expected from well constructed breeding programmes involving ostriches (Lambrechts, 2004). Profit from ostriches in a commercial environment is significantly influenced by reproductive success, which ultimately determines the production of slaughter progeny (Bunter *et al*., 2001). Information is urgently required to design scientifically based selection and breeding strategies to improve production and reproduction in ostriches (Swart & Lambrechts, 1998).

Feeding costs constitute more or less 80% of the total cost of ostrich production (Van Zyl, 2001). In ostriches poor reproductive performance and the high cost of maintaining breeding adults increase the value of improving traits such as fertility and hatchability in this species (Bunter, 2002). Factors such as location,

age, subspecies and/or management may influence production performance of ostriches under intensive commercial conditions (Lambrechts *et al*., 2004).

Reproduction in ostriches have been shown to be highly variable (Deeming, 1996; Van Schalkwyk *et al*., 1996; Bunter *et al*., 2001; Cloete *et al*., 2002; Lambrechts, 2004). For instance, egg production is extremely variable for individual ostriches (Deeming, 1996; Van Schalkwyk *et al*., 1996; Bunter, 2002). The major contribution to known variation in egg production is associated with breeding pair. Gene action largely controls the latter variation (Cloete *et al*., 1998). However, according to recent studies, the variation in breeding pair has recently been partitioned adequately in genetic, permanent environmental and service sire effects (Cloete *et al*., 2004; Cloete *et al*., 2006). Average egg production reported by South African researchers is usually in the vicinity of 41 to 60 eggs per season (Van Schalkwyk *et al*., 1996; Cloete *et al*., 2004; Cloete *et al*., 2005a; Cloete *et al*., 2005b; Cloete *et al*., 2006).

Following egg production, fertility is the next most limiting factor to ostrich chick production (Bunter, 2002). According to Deeming and Ar (1999), the success of ostrich farming depends mainly on the production of fertile eggs. The suitability of eggs for setting (fertility) and hatchability are usually recorded as percentage traits for the sires and dams, because male and female factors affecting fertility and hatchability cannot be recorded individually (Bunter, 2002). Average values for fertility in ostriches are low in comparison to those for poultry (Deeming & Ar, 1999).

The primary objective in ostrich breeding is the production of chicks (Cloete *et al*., 2004). Significant differences between breeding birds in embryonic mortality will affect their relative reproductive success (Bunter, 2002). Van Schalkwyk *et al*. (1996) reported variation from 0 to 55.6% embryonic deaths between breeding pairs. Average levels were around 21%, making a significant contribution towards the reduced hatchability of fertile eggs in the ostrich. Genotypes influence embryonic development and therefore also influence embryonic mortality (Bunter, 2002). There are also various reasons for eggs being rejected and not incubated, including: broken or cracked eggshells; chalky eggshells; loose air cells; and too small eggs (Lambrechts *et al*., 2004). These factors make the production of chicks even more difficult.

In poultry (chickens, ducks and turkeys) antagonistic associations exist between growth and reproductive traits and therefore hens are separated into layer or broiler populations (Bunter, 2002). Selection emphasis within genotypes is predominantly on either growth or reproductive traits. In ostriches, however, limited evidence for antagonistic associations between growth and/or body weight and reproductive success has been published (Bunter, 2002; Cloete *et al*., 2002). A recent study by Cloete *et al*. (2006) found positive genetic correlations between live weight and both egg and chick production. However, the same study indicates an antagonistic genetic association between live weight and hatchability (Cloete *et al*., 2006). Although there is limited evidence regarding this antagonistic effect in ostriches, it is known that reproductive problems resulting from high adult male body weight are the result of obesity rather than antagonistic genetic correlations between these traits (Van Schalkwyk & Cloete, 1996; Bunter, 2002). Therefore selection for growth and reproduction can be achieved in a single dual-purpose line or in specialist lines selected for either reproduction or slaughter traits (Cloete *et al*., 1998; Petitte & Davis, 1999; Cloete *et al*., 2002; Lambrechts, 2004).

Research into the crossbreeding of various lines constituting the current commercial ostrich population should be conducted (Cloete *et al*., 2002). Taking a cue from commercial poultry operations, genetic improvement should be focused on relatively few breeding flocks which provide stock for commercial producers (Cloete *et al*., 2002). Currently crossbreeding is done without scientific evidence to guide crossbreeding decisions. According to Petitte and Davis (1999), there is a tendency to crossbreed Kenyan Rednecks (*S. camelus massaicus*), Zimbabwean Blues (*S. camelus australis*) and South African Blacks (*S. camelus domesticus*) in a haphazard manner. However, by rather using a structured crossbreeding system, advantages such as heterosis and sexual dimorphism can be optimally exploited.

In this study *S. camelus australis*, a Blue Neck subspecies, will be reciprocally crossed with *S. camelus* var. *domesticus*, a Black Neck genotype (Fig. 6).

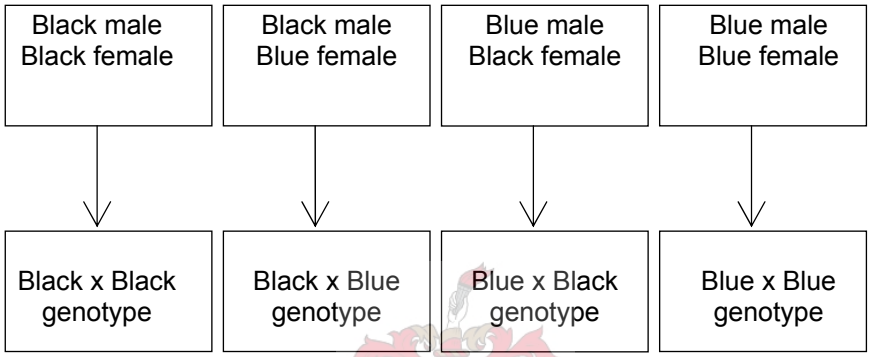

Figure 6 Crossbreeding of *S. camelus australis* (Blue Neck) and *S. camelus* var. *domesticus* (Black Neck)

CONCLUSION

South Africa contributes up to 70% of the total ostrich meat produced worldwide – 950 000 tons per annum (Hoffman, 2005). Therefore in a country such as South Africa - a leader in ostrich production - it is important to produce the highest quality of meat (Girolami *et al*., 2003).

Subspecies influence various aspects of meat quality in the more traditional meat-producing species (Lawrie, 1998). As noted in Table 1, the different genotypes of ostrich have different phenotypic characteristics. All the subspecies of ostrich are found in Africa. However, more specifically in South Africa, only one subspecies of ostrich is found, namely *S. camelus australis.* The genotype, *S. camelus* var. *domesticus*, also inhabits South Africa. The chicks of *S. camelus australis* have a faster growth rate than chicks from other subspecies (Table 1). *S. camelus australis* is also a larger subspecies because of its longer legs. According to Jarvis (1998), *S. camelus australis* has a relative high body weight in comparison to the other subspecies (Table 1). Most ostrich producers use the genotype *S. camelus* var. *domesticus*, because it is the more common ostrich found in South Africa (Madeiros, 1995).

The skin and the meat contribute respectively 50% and 45% to the income of ostrich production (Hoffman, 2005). Therefore there will be an advantage to the ostrich producer if the size and the growth rate of ostriches can be increased through crossbreeding without affecting the meat quality negatively. Larger

birds will probably produce more meat and a larger skin, and therefore will lead to a higher income for the producer per unit slaughtered.

In view of the above reasons, it is important to determine what the effect of the above mentioned subspecies and genotype, and the various genotypes resulting from crossbreeding these two, would be on the morphological, physical, chemical and sensory qualities of the meat. However, it is also necessary to determine the reproductive performance of this subspecies and genotype to support decisions made in the ostrich industry scientifically.

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CHAPTER 3

A comparison of live weights, body measurements and reproductive traits of Zimbabwean Blue (*Struthio camelus australis*) and South African Black ostriches (*Struthio camelus* var. *domesticus*)

A comparison of live weights, body measurements and reproductive traits of Zimbabwean Blue (*Struthio camelus australis*) and South African Black ostriches (*Struthio camelus* var. *domesticus*)

ABSTRACT

Data obtained from a pair-mated ostrich flock located at Oudtshoorn in South Africa were used to estimate possible line differences for live weight, body measurements and reproductive traits in sexually mature ostriches of the Zimbabwean Blue (*Struthio camelus australis*) and South African Black (*Struthio camelus* var. *domesticus*) genotypes. At the commencement of breeding, Zimbabwean Blue (ZB) males were heavier (P<0.01) than South African Black (SAB) males, the differences amounting to 9%. At the cessation of breeding ZB males tended (P=0.09) to be heavier than SAB males, the difference amounting to 4%. ZB females were also heavier (P<0.01) than SAB females, the differences amounting to 12% at the commencement of breeding and 7% at the cessation of breeding. No genotype differences were observed for front chest circumference in both sexes. At the commencement of breeding, back chest circumference of ZB males and females was higher (P≤0.05) than for their SAB contemporaries. At the cessation of breeding, mean back chest circumference of ZB males was 3% higher (P<0.01) than that of SAB males. However, in the females no significant difference (P=0.10) was found for back chest circumference at the cessation of breeding between the two genotypes. The tail circumferences of ZB males and females were higher (6% and 4% respectively; P<0.01) than those of their SAB contemporaries at the commencement of breeding. At the cessation of breeding the tail circumferences of both the ZB males and females were significantly higher (P≤0.05) than those of their SAB contemporaries. Live weight and tail circumference at the commencement of breeding was complicated by a significant (P≤0.05) interaction between sire line and year. No evidence of a dam line x year interaction was present in females for both of these variables. The interaction of genotype with year for live weight at the commencement of breeding indicated that ZB birds are between 9 and 15% heavier than their SAB contemporaries. Egg production was affected (P<0.01) by dam line, but not by sire line or the interaction between dam line and sire. Egg production of SAB females was 47% higher than that of their ZB contemporaries (49.5 ± 2.6 vs. 33.6 ± 3.2 eggs respectively). Infertility was fairly constant at 18-23% and not affected (P>0.05) by any of the independent variables considered. The percentage of shell deaths was affected (P≤0.05) by both sire and dam line. Overall SAB females sustained lower levels of shell deaths than ZB females (24.0 ± 2.2 vs. 31.5 ± 2.7% respectively), while the mates of SAB males had higher shell death percentages than the mates of ZB males (31.8 ± 2.5 vs. 23.7 ± 2.4% respectively). There was a suggestion that ZB females mated to SAB males have particularly high levels of shell deaths, resulting in an interaction between sire line and dam line that approached significance (P=0.08). This trend cannot be readily explained and further studies are indicated. The percentage of eggs not incubated was lower in SAB females than in ZB females (7.9 ± 2.2 vs. 17.7 ± 2.7% respectively; P<0.01). Mates of SAB males produced a higher percentage of eggs not incubated than mates of their ZB contemporaries (16.7 ± 2.5 vs. 8.9 ± 2.4% respectively; P≤0.05). Once again, this percentage tended to be unexpectedly higher than

anticipated in the ZB mates of SAB males. This effect is poorly understood and validates further research. Chick production was only affected by dam line; the effects of sire line and the dam line x sire line interaction were not significant (P>0.10). Overall, SAB females produced 84% more chicks than their ZB contemporaries in a season (27.0 ± 1.7 vs. 14.7 ± 2.1 chicks respectively; P<0.01). Further studies are needed to supplement this preliminary investigation, if a structured crossbreeding programme for improving production performance based on scientific principles is to be developed for the ostrich industry.

Keywords: Ostrich chick production, egg production, crossbreeding

INTRODUCTION

Extensive breeding research has been done on common domestic livestock species such as poultry, cattle, pigs and small ruminants. Genetic and crossbreeding parameters, as well as line and breed differences, for these livestock species are thus readily available. Access to this information ensures structured breeding programmes, involving line and crossbreeding, and the exploiting sexual dimorphism as well as heterosis. However, such information is severely limited or totally lacking in the ostrich industry (Cloete *et al*., 2002). It is thus impossible to provide the ostrich industry with clear-cut guidelines as far as breed or genotype differences and the structured crossbreeding of genotypes are concerned (Petitte & Davis, 1999; Cloete *et al*., 2002). Observations made by Jarvis (1998) suggest considerable variation in mature live weight of the various genotypes of ostriches that are available for commercial production. Several authors have suggested that the crossbreeding of different genotypes of ostriches could improve overall performance. However, so far no published scientific studies have adequately quantified differences between these genotypes in their reproductive performance (Bunter, 2002). According to Cloete *et al*. (2002), research into the crossbreeding of various lines constituting the current commercial ostrich population is urgently needed. There will be an advantage to the ostrich producer if the size of slaughter birds can be increased through the exploitation of dimorphism for live weight between ostrich genotypes in a structured crossbreeding programme, without affecting meat and skin quality negatively. At present there is a tendency to crossbreed Kenyan Rednecks (*Struthio camelus massaicus*), ZB (*Struthio camelus australis*) and SAB (*Struthio camelus* var. *domesticus*) ostriches without scientific evidence to guide crossbreeding decisions (Petitte & Davis, 1999). Appropriate selection and culling strategies, together with crossbreeding, has the potential to improve reproductive performance of the current and future flocks (Bunter *et al*., 2001).

According to Van Schalkwyk and Cloete (1996), selection in ostriches is mostly based on appearance and on objective criteria such as live weight. Negative correlations, although not significant, exist between male body weight and both egg production potential and productivity (Van Schalkwyk & Cloete, 1996). Similarly, tail circumference is negatively correlated (P<0.01) with egg production potential and productivity (Van Schalkwyk & Cloete, 1996).

This study provides estimates of live weight, body measurements and reproductive traits including the eggs produced, infertility, shell deaths, eggs not incubated and chicks produced for ostrich males and females consisting of one subspecies of ostrich, Zimbabwean Blues (ZB), and one genotype of ostrich, South African Blacks (SAB), for two breeding seasons.

MATERIALS AND METHODS

Experimental animals and location

Experimental birds used in the study were SAB and ZB ostriches from the commercial ostrich breeding flock at the Oudtshoorn Experimental Farm (OEF) near Oudtshoorn, South Africa. The commercial SAB population has long been available on the experimental farm (Van Schalkwyk *et al*., 1996), while a population of ZB has recently been acquired from commercial producers. A total of 34 male and 21 female ZB ostriches were obtained from the producers to complement one male and three females already present in the breeding flock. Twenty-three males were obtained from one producer and 11 from another producer. All the females were obtained from the latter producer. All these birds originated from commercial properties in the Bulawayo and Harare regions of Zimbabwe, prior to importation to South Africa. These birds were introduced to the experimental farm during March 2003, about two months prior to being joined in a pair-breeding structure on 28 May 2003. The birds were joined according to a structured breeding programme, involving the two pure genotypes and the reciprocal cross between them. Seventeen SAB breeding pairs and 12 ZB breeding pairs represented the purebred combinations. The crossbred combination involving SAB males mated to ZB females was represented by 13 breeding pairs, while 24 breeding pairs represented ZB males mated to SAB females. Breeding ceased on 27 January 2004, when the birds were taken out of the breeding paddocks. In 2004 breeding commenced on 25 May 2004 and ceased on 25 January 2005, once more making use of a pair-breeding structure. The number of breeding pairs for the purebred combinations remained constant for the second breeding season. The crossbred combination involving SAB males mated to ZB females was represented by 11 breeding pairs, while 23 breeding pairs represented ZB males mated to SAB females. Only data of individuals present at the commencement and cessation of breeding were considered for statistical analysis, while reproduction traits were only assessed in breeding pairs that were paired off for the entire season of 8 months (June to January) in both years, and where the age of the individual male or female at pairing-off exceeded two years. Pairs that were disrupted by the death of a member, and those with a first breeder as one member, were thus excluded. This precaution was prompted by the established effect of male and female age upon reproduction in ostriches (Bunter, 2002).

Management of breeding pairs

The same standard procedure was followed for the management of breeding pairs during both years. During the non-breeding season (February to May) the two different genotypes of ostriches were maintained together in single sex flocks and fed on *ad libitum* sex-specific diets of hammer-milled lucerne (*Medicago sativa*) with a

mineral-vitamin premix. The ostriches also had access to lucerne pastures. Routine management included the harvesting of the white plumage (clipping and plucking). A standard drenching, vaccination and ectoparasite treatment was applied to all breeding birds. Birds were flushed two weeks prior to the breeding season with strategic dietary supplements (Van Schalkwyk *et al*., 1996). Breeding pairs were housed in paddocks of 0.25 ha. Paddocks were situated in the same area on the OEF. The topography is rolling with isolated shrubs and a rocky surface. Foraging material in the paddocks was limited and was consumed shortly after the commencement of breeding. No artificial shelter was applied. All birds received the same breeder diet (8.5 MJ energy, 120 g protein/kg dry matter) at a level of 2.5 kg per bird per day throughout the entire breeding season, with free access to drinking water.

Management of eggs and chicks

The same procedures were followed for the management of eggs and chicks throughout the experimental period. Eggs were identified according to paddock number and date of production, and were collected in the evening on a daily basis. Egg production was recorded individually for each breeding paddock. Eggs were transferred to the incubation facilities in specially designed crates (to minimise transport and shock damage) immediately after collection. Eggs were disinfected through exposure to ultra-violet irradiation for 20 min in a UV disinfectant machine (Prohatch Incubation Systems). After sanitation eggs were stored for a maximum of 6 days in a cool room at 17°C and 75% relative humidity, and were turned once daily through an angle of 45°. As with commercial incubation, eggs were stored upright with the air cell in the uppermost position. Eggs not suitable for incubation were noted for each breeding paddock in the experiment and removed from storage. There are various reasons for eggs being rejected, including: broken/cracked eggshells; chalky eggshells; loose air cells; and too small eggs (Lambrechts *et al*., 2004). The cut-off point for too small eggs was 1-1.1 kg (Brand, Institute for Animal Production, Oudtshoorn, South Africa, personal communication). The outcome of incubation for individual eggs (infertile, hatched, or dead in shell) was known (Van Schalkwyk et al., 2000; Bunter, 2002). Buckeye®, Prohatch® and Natureform® electronic incubators were used to incubate the eggs artificially for a period of 38 days at 36°C and 28% relative humidity. Eggs were fogged weekly with F-10 (Health and Hygiene Ltd, South Africa) for sanitation. Eggs were candled on day 14 and day 21 to establish early embryonic deaths and fertility, and on day 35 to establish late embryonic deaths. Eggs showing no macroscopic development were regarded as infertile and those with embryonic development that had ceased as embryonic deaths. After 35 days of incubation eggs were transferred to the hatching unit, operated at 36°C and 28% relative humidity. Here eggs were held vertically with no turning. Internal pipping generally commenced on the 41st day of incubation, with external pipping some 6-12 h later. Eggs were transferred to separate compartments after external pipping to prevent loss of chick identity. Chicks were kept in the hatcher for 24 h after hatching to allow sufficient time for the navel to close and for the chick to dry off before being dispatched to the chick-rearing facility on the experimental farm. The number of unhatched eggs and the reasons for not hatching during incubation were recorded throughout the study. All the above data recorded were used to determine overall egg and chick production, as well as the average percentages of infertile eggs, eggs not incubated and shell deaths for individual pairs.

Data recorded

Individual live weights (kg) and body measurements (cm) were recorded for each bird at the commencement and cessation of breeding. Body measurements included front chest circumference, back chest circumference and tail circumference, and were obtained as described and motivated in the literature (Van Schalkwyk & Cloete, 1996; Lambrechts, 2004). Traits considered were overall egg and chick production, as well as the average percentages of infertile eggs, eggs not incubated and shell deaths for individual pairs. Definitions for the reproduction parameters are as follow:

- Total egg production: Total number of eggs produced per breeding pair during the production period (Lambrechts *et al*., 2004)
- Total chick production: Number of day-old chicks hatched (Lambrechts *et al*., 2004)
- Average percentage of infertile eggs for individual pairs: The number of infertile eggs expressed as percentage of eggs set in the incubator
- Average percentage of shell deaths for individual pairs: The number of shell deaths expressed as percentage of fertile eggs (eggs set – infertile eggs)
- Average percentage eggs not incubated: The number of eggs not incubated expressed as a percentage of total eggs produced

Statistical analysis

Live weight data of both sexes were assessed by least squares procedures (Harvey, 1990), with the effects of genotype (SAB or ZB), year (2003 or 2004) and the genotype x year interaction assessed. The F-test for the specific main effect was used to assess significance in the absence of a significant interaction. The effect of year was not pertinent to the outcome of this study and was therefore not reported unless it was involved in a significant interaction. Reproduction data were similarly analysed by least squares with sire line, dam line and year as main effects. Two factor interactions between sire line and dam line, as well as between dam line and year, were also computed. The effect of year was treated as specified above. Results were defined as being not significant at a level of $P>0.05$, significant at a level of $P\leq0.05$ and highly significant at a level of $P<0.01$.

RESULTS AND DISCUSSION

The means and standard errors (± SE) for live weight and body measurements of male and female ostriches of both genotypes (SAB and ZB) are presented in Table 1 and Table 2.

Table 1 Means (± SE) for live weight and body measurements of male SAB and male ZB ostriches

Traits	Genotype		Significance
	SAB	ZB	
	n = 59	n = 69	
Live weight (kg)			
Start	122.1 ± 2.0	132.8 ± 1.9	0.01
End	117.9 ± 1.8	122.1 ± 1.7	0.09
Front chest circumference (cm)			
Start	124.1 ± 0.8	125.1 ± 0.8	0.36
End	128.9 ± 0.7	127.4 ± 0.7	0.13
Back chest circumference (cm)			
Start	138.3 ± 1.1	141.6 ± 1.0	0.03
End	148.4 ± 0.8	152.8 ± 0.8	0.01
Tail circumference (cm)			
Start	112.6 ± 1.1	119.9 ± 1.1	0.01
End	108.5 ± 0.8	110.9 ± 0.7	0.02

At the commencement of breeding ZB males were heavier (P<0.01) than SAB males, the differences amounting to 9% (Table 1). At the cessation of breeding ZB males tended (P=0.09) to be heavier than SAB males (Table 1), the difference amounting to 4%. No genotype differences were observed for front chest circumference. At the commencement of breeding, back chest circumference of ZB males was 2% higher (P≤0.05) than for their SAB contemporaries. At the cessation of breeding, mean back chest circumference of ZB males was 3% higher (P<0.01) than that of SAB males. Similarly, the tail circumference of ZB males was 6% higher (P<0.01) at the commencement of breeding and only 2% higher (P≤0.05) at cessation of breeding.

Table 2 Means (± SE) for live weight and body measurements of female SAB and female ZB ostriches

Traits	Genotype		Significance
	SAB	ZB	
	n = 74	n = 47	
Live weight (kg)			
Start	114.9 ± 1.6	128.9 ± 1.9	0.01
End	108.1 ± 1.4	115.6 ± 1.7	0.01
Front chest circumference (cm)			
Start	122.2 ± 0.6	123.7 ± 0.7	0.09
End	124.3 ± 0.6	123.1 ± 0.7	0.21
Back chest circumference (cm)			
Start	140.3 ± 1.0	144.1 ± 1.3	0.02
End	148.3 ± 0.9	150.8 ± 1.2	0.10
Tail circumference (cm)			
Start	114.5 ± 0.9	119.1 ± 1.1	0.01
End	108.3 ± 0.9	109.6 ± 0.8	0.02

ZB females were heavier (P<0.01) than SAB females, the differences amounting to 12% at the commencement of breeding and 7% at the cessation of breeding (Table 2). The trends in both sexes are consistent with an argument that the body weight of ZB ostriches is higher than the body weight of SAB ostriches (Jarvis, 1998). However, Jarvis (1998) did not state the sex of ostriches used. As was the case with the male ostriches (Table 1), no genotype differences were observed for front chest circumference (Table 2). Back chest circumference of ZB females was 3% higher (P≤0.05) at the commencement of breeding than for their SAB contemporaries. At the cessation of breeding, no significant difference (P=0.10) was found for back chest circumference between the two genotypes. The tail circumference of ZB females was 4% higher (P<0.01) at the commencement of breeding and only 1% higher (P≤0.05) at cessation of breeding.

Live weight and body measurements found for purebred SAB female ostriches corresponded well with those reported by Lambrechts (2004) and Lambrechts *et al.* (1998). These include means (± SD) for live weight at the commencement (115 ± 14 kg) and cessation (111 ± 17 kg) of breeding, front chest circumference at the commencement (122 ± 6 cm) and cessation (128 ± 12 cm) of breeding, as well as tail circumference at the commencement (102 ± 10 cm) and cessation (100 ± 8 cm) of breeding (Lambrechts, 2004). In an earlier study Lambrechts *et al*. (1998) reported similar values for mean live weight (120 ± 13 kg), front chest circumference (120 ± 6 cm), back chest circumference (141 ± 7 cm), as well as tail circumference (104 ± 14 cm) at the commencement of breeding. According to results published by Bunter (2002), it can be accepted that the ostrich genotype used in the above studies was SAB. No research could be found in the literature for ZB female ostriches.

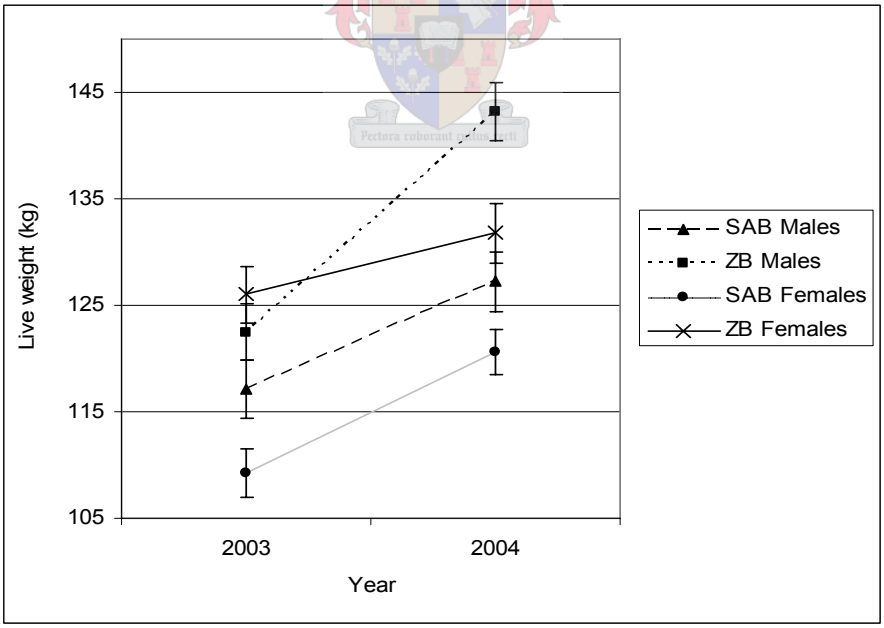

Figure 1 The interaction between sire line and year, as well as between dam line and year for live weight (kg) at the commencement of breeding. Vertical bars about the mean denote standard errors.

Live weight at the commencement of breeding was complicated by a significant (P≤0.05) interaction between sire line and year (Fig. 1). No significant difference was found between sire lines during 2003 (117.1 ±

2.7 vs. 122.5 ± 2.6 kg for SAB and ZB males respectively; $P>0.05$). However, ZB males were 13% heavier than SAB males during 2004 (127.2 ± 2.8 vs. 143.2 ± 2.7 kg for SAB and ZB males respectively; $P<0.01$). No evidence of a dam line x year interaction was present in females (Fig. 1), the superiority of ZB females relative to SAB females amounting to 15% in 2003 and to 9% in 2004 ($P<0.01$). The interaction could possibly result from the males being treated differently before being introduced to OEF, since 23 males were obtained from one producer and 11 from another producer. All the females were obtained from the latter producer. During 2004, after all birds were maintained under the same conditions for approximately 1.5 years, such differences stemming from previous differential treatment could have been eliminated. This theory is supported by the relatively constant difference in favour of the ZB genotype in females (both years) and males during 2004. It can thus be argued that mature ZB birds are between 9 and 15% heavier than their SAB contemporaries.

In general, it was clear that the live weight of mature ZB birds was somewhat higher than that of SAB. This result is supported by results provided by Jarvis (1998), stating the average live weights of ZB ostriches to be 125 kg, compared to 115 kg for SAB ostriches. These figures agree with the present results (124.85 kg for the ZB vs. 115.7 kg for the SAB genotype).

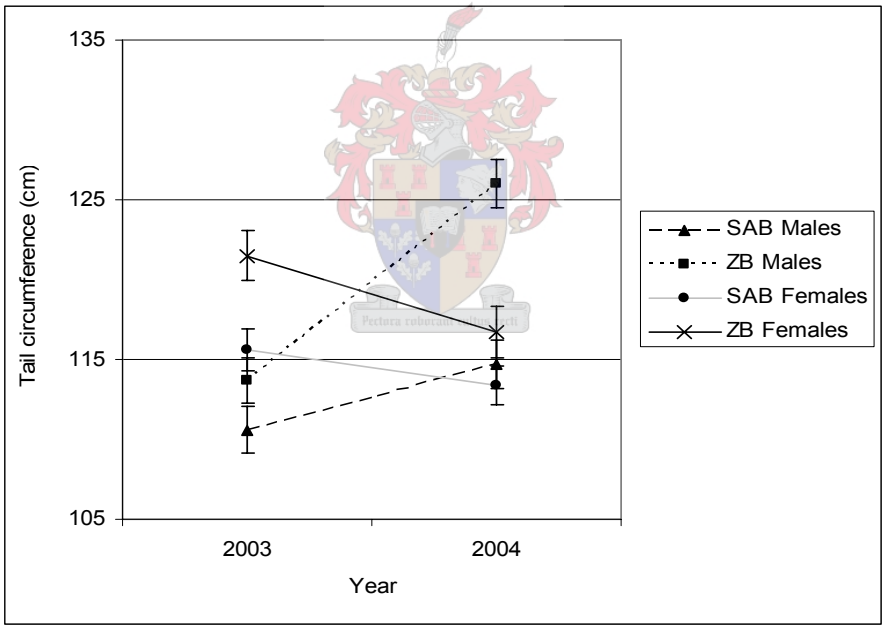

Figure 2 The interaction between sire line and year, as well as between dam line and year for tail circumference (cm) at the commencement of breeding. Vertical bars about the mean denote standard errors.

Tail circumference at the commencement of breeding also resulted in a significant ($P\leq0.05$) interaction between sire line and year (Fig. 2). A significant difference was found between sire lines during 2003 (110.6 ± 1.5 vs. 113.7 ± 1.4 cm for SAB and ZB males respectively; $P\leq0.05$). However, tail circumference of ZB males at the commencement of breeding was 10% higher than for SAB males during 2004 (114.7 ± 1.5 vs. 126.0 ± 1.5 cm for SAB and ZB males respectively; $P\leq0.05$). No evidence of a dam line x year interaction was present in females (Fig. 2). The superiority of ZB females relative to SAB females amounted to 5% in 2003 (115.6 ± 1.3 vs.

121.5 ± 1.6 cm for SAB and ZB females respectively; $P \leq 0.05$), and to 3% (113.4 ± 1.2 vs. 116.7 ± 1.6 cm for SAB and ZB females respectively; $P \leq 0.05$) in 2004.

The interactions between sire line x year and dam line x year show the same pattern as was found for live weight at commencement of breeding (Fig. 1). In both variables (live weight and tail circumference) sire line shows a significant ($P \leq 0.05$) interaction with year and dam line shows no interaction with year. The same explanation that was provided for live weight also seems applicable in this instance. Since the tail is regarded as an important depot of body fat (Van Schalkwyk & Cloete, 1996), the results presented in Fig. 1 and Fig. 2 support each other.

The patterns found in Fig. 1 and Fig. 2 suggests a positive relation between the live weight and tail circumference at commencement of breeding of the SAB and ZB males. As the live weight increased, the tail circumference also increased. Therefore, as the quantity of fat in the tail (as reflected by an increased tail diameter) increased, the live weight also increased. A recent study by Cloete *et al*. (2006) indicates positive genetic correlations between live weight and tail circumference at commencement and cessation of breeding of female ostriches. However, it is important to note that, while the body weight of the female ostriches in both genotypes increased, the tail circumference decreased (Fig. 1 and Fig. 2). This phenomenon was unexpected and requires further attention.

According to Carey (1996), nutrition plays an important role in egg production in female birds and has to be adequate to meet the nutritional requirements for the maintenance of body condition, as well as providing nutrients for egg production. The repeated removal of eggs for artificial incubation results in female birds laying several times the natural clutch of eggs in a breeding season (Brand *et al*., 2002). Brand *et al.* (2003) stated that required energy and nutrients for egg formation may be derived from daily food intake or from stored reserves. The tail is regarded as an important depot of body fat (Van Schalkwyk & Cloete, 1996). Therefore, it seems that ostrich females are utilising their stored fat reserves in order to produce eggs. This consequently results in a decrease of body condition, as reflected by a reduced tail circumference. Males, on the other hand, are not subject to the drainage of reproduction and are able to improve in body condition when provided with the same diet supplied to the females. However, further scientific investigation is needed to substantiate this hypothesis.

The least square means and standard errors (± SE) for depicting the influence of sire line (SAB or ZB) and dam line (SAB or ZB) on female reproduction traits are presented in Tables 3.

Table 3 Least square means (± SE) depicting the influence of ostrich sire (S) line (SAB or ZB) and dam (D) line (SAB or ZB) on female reproduction traits

Dam line (D)	SAB		ZB		Significance		
Sire line (S)	SAB n = 32	ZB n = 42	SAB n = 24	ZB n = 23	S	D	S x D
Traits							
Egg production (n)	53.9 ± 3.9	45.1 ± 3.4	32.7 ± 4.5	34.4 ± 4.6	0.40	0.01	0.21
Infertility (%)	18.1 ± 4.2	23.2 ± 3.6	21.1 ± 4.8	21.5 ± 4.9	0.54	0.89	0.59
Shell deaths (%)	26.6 ± 3.3	21.3 ± 2.9	37.0 ± 3.8	26.1 ± 3.9	0.02	0.03	0.08
Not incubated (%)	9.2 ± 3.3	6.5 ± 2.9	24.2 ± 3.8	11.2 ± 3.9	0.03	0.01	0.13
Chick production (n)	28.8 ± 2.6	25.1 ± 2.3	12.6 ± 3.0	16.8 ± 3.0	0.92	0.01	0.16

D – Dam line; S – Sire line

Egg production was affected (P<0.01) by dam line, but not by sire line or the interaction between dam line and sire line (Table 3). This is in accordance with studies done by Lambrechts (2004) that indicated that the influence of service sire upon egg production of females is limited. Overall, the egg production of SAB females was 47% higher than that of ZB contemporaries (49.5 ± 2.6 vs. 33.6 ± 3.2 eggs respectively). Reproduction parameters found for purebred SAB ostriches correspond very well with those reported in the literature. Previous figures for egg production per female in a breeding season were 55.5 (Van Schalkwyk *et al*., 1996), 51.1 (Bunter *et al*., 2001), 46.3 (Cloete *et al*., 2004) and 46.3 (Lambrechts, 2004). According to background information provided by Bunter (2002), it can be accepted that the ostrich genotype used in the above studies was SAB. Infertility in this investigation was fairly constant at 18-23% and not affected (P>0.05) by any of the independent variables considered. The percentage of shell deaths was affected (P≤0.05) by both sire and dam line. Overall SAB females sustained lower levels of shell deaths than ZB females (24.0 ± 2.2 vs. 31.5 ± 2.7% respectively), while the mates of SAB males had higher shell death percentages than the mates of ZB males (31.8 ± 2.5 vs. 23.7 ± 2.4% respectively). There was a suggestion for ZB females mated to SAB males to have particularly high levels of shell deaths, resulting in an interaction between sire line and dam line that approached significance (P=0.08). This trend cannot be readily explained and further studies are required. The percentage of eggs not incubated was lower in SAB females than in ZB females (7.9 ± 2.2 vs. 17.7 ± 2.7% respectively; P<0.01). Mates of SAB males produced a higher percentage of eggs not incubated than mates of their ZB contemporaries (16.7 ± 2.5 vs. 8.9 ± 2.4% respectively; P≤0.05). Once again, this percentage tended to be unexpectedly higher than anticipated in the ZB mates of SAB males. This result is poorly understood with the data presently available. Chick production was only affected by dam line, the effects of sire line and the dam line x sire line interaction being not significant (P>0.10). Overall, SAB females produced 84% more chicks than their ZB contemporaries in a breeding season (27.0 ± 1.7 vs. 14.7 ± 2.1 chicks for SAB and ZB females respectively; P<0.01). Means found in the literature for chick production were 29.1 (Van Schalkwyk *et al*., 1996), 23.8 (Bunter *et al*., 2001), 22.9 (Cloete *et al*., 2004) and 22.9 (Lambrechts, 2004). According to background information provided by Bunter (2002), the ostrich genotype used in the above studies was SAB.

No research could be found on crossbreeding of SAB and ZB ostriches, and the possible crossbreeding combinations resulting from that, to support or refute the results presented. There is a definite need for further investigations to provide producers with robust recommendations in this respect.

CONCLUSION

Live weights and body measurements of ZB ostriches were generally higher than those of SAB ostriches. Overall, egg and chick production of SAB females was higher than that of their ZB contemporaries. From these results, it seems viable to combine the relatively high live weight of ZB males with the relatively high reproduction performance of SAB females in a commercial crossbreeding operation. However, it must be noted that SAB ostriches came from a research flock where there is a natural tendency to farm scientifically and thus over the years there was an artificial selection for reproduction traits by the management. As far as could be established, this was not the case for the ZB ostriches. Therefore, there is still an opportunity for genetic improvement regarding the reproduction of the ZB birds. Studies on other populations of ZB and SAB ostriches, where there was no selection, are therefore essential and will add robustness to recommendations for the implementation of scientifically-based crossbreeding in commercial ostrich production. Productivity in the crossbred progeny may also be enhanced by heterosis for chick growth and survival.

Further studies on the relative size and reproduction performance of the two genotypes are also required to complement these preliminary findings. This study provides a preliminary framework to start the establishment of scientific crossbreeding principles in the ostrich industry. The formulation of a structured crossbreeding plan, based on scientific principles, will only become a reality when such information is available.

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CHAPTER 4

Carcass and individual muscle yield of South African Black (SAB), Zimbabwean Blue (ZB) and SAB x ZB ostriches

Carcass and individual muscle yield of South African Black (SAB), Zimbabwean Blue (ZB) and SAB x ZB ostriches

ABSTRACT

Data from three ostrich genotypes, obtained from crossbreeding SAB ostriches (*Struthio camelus* var. *domesticus*) and ZB ostriches (S*truthio camelus australis*), were used to estimate possible genotype differences for live weight (kg), carcass weight (kg), leg weight (kg), individual muscle weight (kg) and carcass yields including: dressing percentage (%); percentage bone weight relative to leg weight (%); percentage leg weight relative to live weight (%); percentage leg weight relative to carcass weight (%); as well as percentage individual muscle weight relative to leg weight (%). Ostriches reared in the same environment and of a commercially standard slaughter age of 14 months were used in this study. Significant genotype differences ($P \leq 0.05$) were observed for live weight, carcass weight and leg weight, where the pure Blue genotype had the heaviest weights and the Black X Black genotype had the lowest weights. The pure Blue genotype in comparison to the Black X Black genotype differed significantly ($P \leq 0.05$), with 16 kg for live weight, 8.3 kg for carcass weight and 3.5 kg for leg weight. However, when comparing carcass yields (dressing percentage, percentage bone weight relative to leg weight, percentage leg weight relative to live weight and percentage leg weight relative to carcass weight), there were no significant differences ($P > 0.05$) between genotypes. Dressing percentage ranged from 50.9–51.2%, percentage bone weight relative to leg weight ranged from 15.9–17.1%, percentage leg weight relative to live weight ranged from 35.8–36.4% and percentage leg weight relative to carcass weight ranged from 70.7–71.5%. Six of the ten major muscles present in the ostrich leg showed significant genotype differences ($P \leq 0.05$) for individual muscle weight, including: *M. gastrocnemius*; *M. femorotibialis accessorius*; *M. iliotibialis cranialis*; *M iliotibialis lateralis*; *M. iliofibularis*; and *M. iliofemoralis*. The individual muscles with the highest economic value including the *M. iliofibularis*, *M. iliofemoralis* and the *M. iliotibialis lateralis*, differed significantly ($P \leq 0.05$) between genotypes. The *M. gastrocnemius* (including the *M. gastrocnemius pars externa* (0.6 ± 0.10 kg) and the *M. gastrocnemius pars interna* (0.9 ± 0.14 kg)), *M. iliofibularis* (1.5 ± 0.18 kg) and *M iliotibialis lateralis* (1.1 ± 0.17 kg) were the heaviest muscles from the ostrich carcass. All the muscles of the pure Black genotype, with the exception of the *M. obturatorius medialis*, were the lightest in comparison to the corresponding muscle weights in the other two genotypes. The percentage individual muscle weight relative to leg weight (%) only showed a significant genotype difference between purebred Black and Blue genotypes ($P \leq 0.05$) for the *M. obturatorius medialis*. The *M. gastrocnemius* (including the *M. gastrocnemius pars externa* and the *M. gastrocnemius pars interna*), *M. iliofibularis* and *M iliotibialis lateralis* each made up 3.9 ± 0.63%, 5.7 ± 0.71%, 9.5 ± 1.0% and 7.4 ± 0.84% of the ostrich leg weight. The *M. femorotibialis internus* has the lowest percentage (0.8 ± 0.16%) for individual muscle weight relative to leg weight. Although the percentage carcass yields did not show significant genotype differences, larger ostriches were produced through crossbreeding.

Keywords: Ostrich morphology, carcass yield, crossbreeding, ostrich muscles

INTRODUCTION

In the ostrich industry the focus on the three major ostrich products derived from the ostrich has shifted from feathers during the early 1900s to the current situation, where the meat and the skin are of more economic importance to the ostrich producer (Petitte & Davis, 1999; Van Zyl, 2001; Cloete *et al.*, 2002). According to recent statistics, the feathers contribute only 5% to the income, whereas the leather and the meat each contribute 50% and 45% respectively (Hoffman, 2005). Therefore, ostrich meat plays an integral role in the survival and sustainability of the South African ostrich industry. In volume and value the ostrich industry is the leading South African meat exporter of all types of meat, including beef and poultry (National Agricultural Marketing Council, 2003). In 2003 South Africa had ten European Union approved abattoirs for ostrich meat compared to five export abattoirs for other types of red meat (National Agricultural Marketing Council, 2003). Because of the shift regarding the income generated by the different products, the ostrich producer is interested in ostriches that produce a larger skin and more meat.

According to various researchers, different subspecies of ostrich have different phenotypic characteristics (Duerden, 1919; Sauer, 1968; Brown *et al.*, 1982; Freitag, 1992). These differences also include the size of the bird and growth rate (Madeiros, 1995). Jarvis (1998) suggested considerable variation in mature live weight between Zimbabwean Blue (ZB) ostriches (125 kg) and South African Black (SAB) ostriches (115 kg). The chicks of ZB ostriches have a faster growth rate and normally reach a body weight of 95 kg earlier than chicks from the other subspecies (Jarvis, 1998). The SAB ostrich is the more common ostrich found in South Africa (Madeiros, 1995). The ostrich producer will benefit from crossbreeding ZB ostriches and SAB ostriches, if the offspring can grow faster and be larger without affecting skin and meat quality negatively. Larger birds will probably produce more meat and a larger skin area, which will result in a higher income for the producer. According to Engelbrecht *et al.* (2005), genetic correlations between live weight and skin area approach unity. Therefore, as the ostrich live weight increases the skin area increases (Engelbrecht *et al.*, 2005).

Although extensive research has been reported on morphological differences between and within common domestic livestock species (poultry, cattle, pigs and small ruminants), studies on morphological properties of ostriches depicting differences between genotypes could not be sourced. Several authors have suggested that the crossbreeding of different genotypes of ostriches could improve overall performance. Currently, there is a tendency to crossbreed Kenyan Rednecks (*Struthio camelus massaicus*), ZB and SAB without scientific evidence to guide crossbreeding decisions (Petitte & Davis, 1999).

Factors that determine the value of an ostrich carcass relative to market conditions include: the carcass weight; the yield of saleable meat; and the quality of lean meat (Swatland, 1995). According to Mellett (1996a), most ostrich meat is marketed as individual muscles, for example, the fan fillet (*M. iliofibularis*), big drum (*M. gastrocnemius*) and triangular fillet or inside strip (*M. iliofemoralis*). The individual muscles with the highest income include: *M. iliofibularis*, *M. iliofemoralis* and the *M. iliotibialis lateralis* (Mellett, 1992). The larger muscles that are currently available on the South African market include: *M. iliotibialis cranialis*, *M. flexor cruris lateralis*, *M. obturatorius medialis*, *M. femorotibialis accessorius*, *M. fibularis longus* and the *M. gastrocnemius* (Mellett, 1992). The importance of the carcass yield and individual

muscle yield of the bird is therefore accentuated. This study was, therefore, undertaken in an attempt to gain scientific information on the morphological properties of different genotypes of ostrich, resulting from crossbreeding between South African Blacks and Zimbabwean Blues. Morphological properties refer to the carcass composition and the carcass yield of an ostrich carcass.

MATERIALS AND METHODS

Experimental birds and location

A total of 46 ostriches (*Struthio camelus*), comprising different genotypes of ostriches, were included in this study (Fig. 1). The ostriches were slaughtered during 2005 at Klein Karoo Co-operative in Oudtshoorn, South Africa. Experimental birds used in the study consisted of genotypes resulting from crossbreeding between SAB and ZB ostriches (Fig. 1).

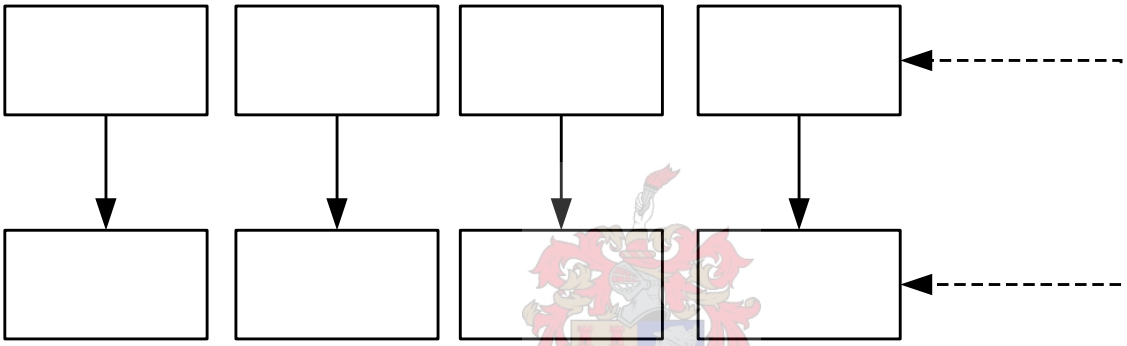

Figure 1 The distribution of ostriches slaughtered according to genotypes used for morphological studies

The same standard procedure was followed for all the birds. Ostriches were reared on the Oudtshoorn Experimental Farm near Oudtshoorn, South Africa and kept under the same conditions. The topography is rolling with isolated shrubs and a rocky surface. Birds were kept in one flock and housed in a paddock of one hectare. Foraging material in the paddocks was limited and was consumed shortly after the ostriches were introduced to the paddock. No artificial shelter was present. All birds received the same *ad libitum* diet (10.5 MJ energy, 160 g protein/kg dry matter) and had free access to drinking water. Routine management included the harvesting of the white plumage (clipping and plucking). A standard drenching, vaccination and ectoparasitic treatment was applied to all birds. Ostriches were more or less the same age (14 months) at slaughtering. This is the predominant age at which ostriches are slaughtered commercially (Sales, 1999).

Slaughtering

Ostriches were slaughtered at a commercial abattoir at Oudtshoorn, following commercial procedures, which involved lairage in roofed pens for a period of 24 h with free access to drinking water. The ostriches were electrically stunned (105–110 V, 400-800 mA, 10 s). After stunning, ostriches were suspended by both legs and bled. A high neck cut and a cut to the aortic vein (thoracic stick) were used to exsanguinate the birds. Bleeding was allowed for 10-15 min, after which plucking, skinning, evisceration and health inspection took

place. Following health inspection, legs were removed (within 45 min from stunning) and allowed to chill for 24 h at 0-4°C.

Morphological measurements

Final live weight of the birds was recorded just before the ostriches were slaughtered. Carcass weight was obtained after health inspection, before the legs were separated from the carcass. After the 24 h chilling period, the left leg was weighed, after which the legs were deboned by hand into 13 specific individual muscles (Table 3), Grade A and B trimmings and bone. These muscles were identified as described by Mellett (1996b). The large membranes and visible fat were trimmed from the individual muscles before weighing. Weights for individual muscles, trimmings and bone was determined.

Statistical analysis

The first experiment consisted of 3 genotypes with unequal replications each. An one-way analysis of variance (ANOVA) was performed on the data of the measurements (SAS, 1999). With the second experiment a two-factor factorial experiment was performed in a randomised block design with 46 block replications (carcasses). The factors were three genotypes (Black x Black, Blue x Black and Blue x Blue) and 13 muscles (flat drum, *M. femorotibialis accessorius, M. fibularis longus, M. flexor cruris lateralis, M. gastrocnemius pars externa, M. gastrocnemius pars interna, M. iliofemoralis, M. iliofemoralis externus, M. femorotibialis internus, M. iliofibularis, M. iliotibialis cranialis, M. iliotibialis lateralis* and *M. obturatorius medialis*). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an ANOVA using SAS version 9 (SAS, 1999) statistical software. With both experiments the ANOVA was performed on the full model with factors and interactions included, where as the Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 5% significance level to compare treatment means for both experiments (Ott, 1998). Results were defined as being not significant at a level of $P>0.05$ and significant at a level of $P\leq0.05$. In few cases deviations from normality were the cause of outliers, which were removed before the final analysis. Where there was still a significant evidence of non-normality, this could be ascribed to kurtosis rather than skewness. Interpretation of results was thus continued as motivated by Glass *et al.* (1972).

RESULTS AND DISCUSSION

The means and standard deviations (± SD) for live weight (kg), carcass weight (kg) and leg weight (kg), as well as the means and standard deviations (± SD) for dressing percentage, percentage bone weight relative to leg weight, percentage leg weight relative to live weight and percentage leg weight relative to carcass weight for the different genotypes of ostrich are presented in Table 1. Dressing percentage is defined as the average percentage of carcass weight on live weight (Morris *et al.,* 1995a).

Table 1 Mean live weight (± SD) and mean percentages (± SD) for carcass yields for different genotypes of ostrich

Yield parameters	Genotype			LSD (*P*=0.05)
	Black x Black n = 34	Blue x Black n = 10	Blue x Blue n = 2	
Live weight (kg)	84.9 ± 9.2[b]	96.8 ± 11.2[ab]	100.9 ± 4.2[a]	12.58
Carcass weight (kg)	43.3 ± 5.2[b]	51.1 ± 5.0[a]	51.6 ± 1.1[a]	6.90
Dressing percentage (%)	50.9 ± 2.1	51.2 ± 1.7	51.2 ± 1.0	2.79
Leg weight (kg)	14.7 ± 1.7[b]	18.0 ± 1.9[a]	18.2 ± 0.3[a]	2.24
Bone weight relative to leg weight (%)	17.1 ± 1.2	15.9 ± 0.9	16.1 ± 0.5	1.55
Leg weight relative to live weight (%)	35.8 ± 1.8	36.4 ± 1.6	36.2 ± 0.8	2.40
Leg weight relative to carcass weight (%)	71.0 ± 2.2	71.5 ± 1.6	70.7 ± 0.2	2.83

LSD, Least Significant Difference, *P*=0.05

[ab]Means in rows with different superscripts are significantly different (*P*≤0.05)

The purebred combinations (Black x Black and Blue x Blue) differed significantly (*P*≤0.05) regarding live weight (Table 1). There was a vast difference of 16 kg for live weight between the purebred Black and Blue lines (*P*≤0.05). A large difference of 11.9 kg – not significant (*P*>0.05) however – was noted between the pure Black and Blue x Black genotype (Table 1). According to Table 1, there was a much smaller difference of 4.1 kg between the Blue x Black and pure Blue genotype (*P*>0.05). The above findings are consistent with an argument that the mature live weight of ZB ostriches is heavier than that of the SAB ostriches (Jarvis, 1998). However, mature live weights reported by Jarvis (1998) were somewhat higher than the live weights obtained in this study. According to Jarvis (1998), ZB ostriches have a live weight of 125 kg in comparison to SAB ostriches with a live weight of 115 kg. However, the exact age of the ostriches used by Jarvis (1998) is not mentioned. Ostriches used in this study were slaughtered at the same age of 14 months, which is the age at which ostriches are normally slaughtered commercially (Sales, 1999). Live weight for ostriches as reported by various researchers ranges from 84 kg to 99.7 kg (Table 2). Note that the genotype of ostrich is not mentioned by any of the researchers. The live weights found in this study range from 84.9 kg to 100.9 kg and are therefore similar to results found by other researchers (Table 2).

When analysing carcass weight, only the pure Black genotype differed significantly (*P*≤0.05) from the other two genotypes (7.8 kg difference compared to the Blue x Black line and 8.3 kg difference compared to the pure Blue genotype) (Table 1). Present results for ostrich carcass weight ranged from 43.3–51.6 kg and, according to Table 2, other researchers published similar results (43.5–55.9 kg).

Regarding leg weight as noted in Table 1, only the pure Black genotype differed significantly (*P*≤0.05) from the other two genotypes (3.3 kg or 18.3% difference compared to the Blue x Black line and 3.5 kg or 19.2% difference compared to the pure Blue genotype). Swart (1981) reported a leg weight of 16.1 kg for 14-month-old birds (Table 2). The average leg weight for the three genotypes (17 kg) is somewhat higher than the results found by Swart (1981). Swart (1981) did not mention the genotype of ostrich used.

According to Table 1, no significant differences (P>0.05) between genotypes were noted for dressing percentage, percentage bone weight relative to leg weight, percentage leg weight relative to live weight and for the percentage leg weight relative to carcass weight. The dressing percentage values from this investigation (50.9–51.2%) lie in a similar range (49–60%) to those reported by other researchers (Table 2).

Table 2 Weight (kg) and percentages for ostrich carcass yields as found in literature

Traits	Percent of live weight	Weight	References
Live weight		94.8	Harris *et al.,* 1993
		84.0	Jones *et al.,* 1994
		95.5	Morris *et al.,* 1995a
		95.7	Morris *et al.,* 1995b
		99.7	Pollok *et al.,* 1997a
Carcass weight	60.0	43.5	Mellett, 1992
	57.1	55.5	Harris *et al.,* 1993
		50.0	Jones *et al.,* 1994
		55.9	Morris *et al.,* 1995a
		54.6	Morris *et al.,* 1995b
		48.8	Pollok *et al.,* 1997a
Leg weight		16.1	Swart, 1981
Dressing percentage	58.6		Harris *et al.,* 1993
	60.0		Jones *et al.,* 1994
	58.6		Morris *et al.,* 1995b
	49.0		Pollok *et al.,* 1997a

The mean weight (kg) and standard deviations (± SD) for the individual muscles derived from the three different ostrich genotypes are presented in Table 3.

Table 3 Mean weight (kg) and standard deviations for muscles derived from different genotypes of ostrich

Muscles	Black x Black n = 34	Blue x Black n = 10	Blue x Blue n = 2
Flat drum	0.51 ± 0.07^{b}	0.66 ± 0.09^{a}	0.67 ± 0.03^{a}
M. femorotibialis accessorius	0.69 ± 0.10^{b}	0.88 ± 0.12^{a}	0.88 ± 0.11^{a}
M. fibularis longus	0.29 ± 0.04	0.32 ± 0.03	0.36 ± 0.01
M. flexor cruris lateralis	0.30 ± 0.04	0.36 ± 0.05	0.35 ± 0.04
M. gastrocnemius pars externa	0.59 ± 0.08^{b}	0.63 ± 0.08^{b}	0.74 ± 0.03^{a}
M. gastrocnemius pars interna	0.84 ± 0.13^{b}	1.00 ± 0.10^{a}	1.01 ± 0.14^{a}
M. iliofemoralis	0.40 ± 0.06^{b}	0.46 ± 0.08^{ab}	0.50 ± 0.01^{a}
M. iliofemoralis externus	0.19 ± 0.03	0.22 ± 0.03	0.21 ± 0.00
M. femorotibialis internus	0.11 ± 0.02	0.14 ± 0.02	0.13 ± 0.01
M. iliofibularis	1.41 ± 0.15^{c}	1.63 ± 0.14^{b}	1.76 ± 0.15^{a}
M. iliotibialis cranialis	0.49 ± 0.07^{b}	0.60 ± 0.11^{a}	0.56 ± 0.03^{ab}
M. iliotibialis lateralis	1.08 ± 0.15^{b}	1.28 ± 0.15^{a}	1.34 ± 0.02^{a}
M. obturatorius medialis	0.55 ± 0.08	0.58 ± 0.08	0.55 ± 0.00

LSD (Least Significant Difference, P=0.05) = 0.097

^{ac}Means in rows with different superscripts are significantly different (P≤0.05)

Two thirds of the meat derived from an ostrich carcass consists of the following ten major muscles: *M. gastrocnemius*, *M. femorotibialis*, *M. iliotibialis cranialis*, *M. obturatorius medialis*, *M iliotibialis lateralis*, *M. iliofibularis*, *M. iliofemoralis externus*, *M. fibularis longus*, *M. iliofemoralis* and *M. flexor cruris lateralis* (Sales, 1999). Six of these ten major muscles showed significant genotype differences ($P \leq 0.05$) (Table 3). Concerning muscle weight for the flat drum, *M. femorotibialis accessorius*, *M. gastrocnemius pars interna* and the *M. iliotibialis lateralis*, only that of the pure Black genotype differed significantly ($P \leq 0.05$) from the other two genotypes. The weight for the *M. gastrocnemius pars externa* from the pure Blue genotype differed significantly ($P \leq 0.05$) from both the Blue x Black and pure Black genotypes. The *M. iliofemoralis* showed a significant difference ($P \leq 0.05$) between the pure Blue and pure Black genotype. All three genotypes differed significantly ($P \leq 0.05$) for the weight of the *M. iliofibularis*. The Blue x Black and pure Black genotypes differed significantly ($P \leq 0.05$) regarding the weight of the *M. iliotibialis cranialis*. According to Mellett (1992), the individual muscles with the highest income include the *M. iliofibularis, M. iliofemoralis* and the *M. iliotibialis lateralis.* Significant genotype differences ($P \leq 0.05$) were evident for these three muscles (Table 3).

There is a tendency that the weight of all the muscles, with the exception of the *M. obturatorius medialis* of the pure Black genotype, were the lightest in comparison to the weight of the corresponding muscles in the other two genotypes. For all the genotypes the heaviest and lightest weights were for the *M. iliofibularis* and the *M. femorotibialis internus*, respectively.

Various researchers have investigated the weights for individual ostrich muscles, irrespective of the effect of genotype, and their findings are summarised in Table 4. Comparison of the latter findings with the present study is also shown in Table 4.

The weight for the *M. femorotibialis accessorius, M. gastrocnemius pars externa, M. iliofemoralis externus* and *M. obturatorius medialis* were much lower than the corresponding values found in the literature (Table 4). However, in the available literature vast differences are also noted; for example, for the *M. iliotibialis lateralis* the muscle weights ranged from 0.8–3.5 kg (Table 4). According to Baltmanis *et al.* (1997), morphological properties indicated in various studies will differ due to different carcass standards used by different processing plants in the ostrich industry. This makes it difficult to draw general conclusions regarding the morphological properties of the ostrich. Results for the other muscles were more or less the same as the results found in the literature (Table 4).

Table 4 Comparison of present study to available literature regarding mean weight for different muscles of ostrich irrespective of genotype

Muscles	Industrial names	Weight (kg) [#]	Weight (kg)	References
		Present study	Literature	
-	Flat drum	0.6	0.5	Camdeboo meat processors pamphlet, 1997
M. femorotibialis accessorius	Tip	0.7	2.1	Morris *et al.,* 1995b
			2.0	Pollok *et al.,* 1997b
M. fibularis longus	Mid leg	0.3	2.6	Morris *et al.,* 1995b
			0.3	Sales, 1996
M. flexor cruris lateralis	Outside strip	0.3	1.0	Morris *et al.,* 1995b
			0.3	Sales, 1996
			0.5	Pollok *et al.,* 1997b
M. gastrocnemius pars externa	Outside leg	0.6	1.5	Pollok *et al.,* 1997b
M. gastrocnemius pars interna	Inside leg	0.9	0.7	Sales, 1996
			1.5	Pollok *et al.,* 1997b
M. iliofemoralis	Inside strip	0.4	1.0	Morris *et al.,* 1995b
			0.3	Sales, 1996
			0.5	Pollok *et al.,* 1997b
M. iliofemoralis externus	Oyster	0.2	1.5	Morris *et al.,* 1995b
			0.7	Pollok *et al.,* 1997b
M. femorotibialis internus	-	0.1	-	-
M. iliofibularis	Fan fillet	1.5	3.5	Morris *et al.,* 1995b
			1.2	Sales, 1996
			1.7	Pollok *et al.,* 1997b
M. iliotibialis cranialis	Top loin	0.5	1.4	Morris *et al.,* 1995b
			0.4	Sales, 1996
			0.7	Pollok *et al.,* 1997b
M. iliotibialis lateralis	Round	1.1	3.5	Morris *et al.,* 1995b
			0.8	Sales, 1996
			1.7	Pollok *et al.,* 1997b
M. obturatorius medialis	Tenderloin	0.6	0.9	Harris *et al.,* 1993
			0.9	Morris *et al.,* 1995a
			1.7	Morris *et al.,* 1995b
			0.8	Pollok *et al.,* 1997b

[#] Muscle weight is the average weight of the specific muscle, irrespective of genotype

The means and standard deviations (± SD) for percentage individual muscle weight relative to leg weight (%) for different genotypes of ostrich are presented in Table 5.

Table 5 Muscles expressed as mean percentage (± SD) on a leg weight basis for different genotypes of ostrich

Muscles	Black x Black n = 34	Blue x Black n = 10	Blue x Blue n = 2
Flat drum	3.5 ± 0.5	3.6 ± 0.2	3.7 ± 0.2
M. femorotibialis accessorius	4.7 ± 0.5	4.9 ± 0.4	4.8 ± 0.5
M. fibularis longus	2.0 ± 0.3	1.8 ± 0.1	2.0 ± 0.0
M. flexor cruris lateralis	2.1 ± 0.3	2.0 ± 0.3	1.9± 0.3
M. gastrocnemius pars externa	4.0 ± 0.7	3.5 ± 0.2	4.0 ± 0.2
M. gastrocnemius pars interna	5.7 ± 0.8	5.6 ± 0.3	5.5 ± 0.7
M. iliofemoralis	2.8 ± 0.4	2.6 ± 0.4	2.7 ± 0.1
M. iliofemoralis externus	1.3 ± 0.2	1.2 ± 0.1	1.1 ± 0.0
M. femorotibialis internus	0.8 ± 0.2	0.8 ± 0.1	0.7 ± 0.0
M. iliofibularis	9.6 ± 1.1	9.1 ± 0.7	9.7 ± 1.0
M. iliotibialis cranialis	3.4 ± 0.6	3.3 ± 0.4	3.1 ± 0.2
M. iliotibialis lateralis	7.5 ± 0.9	7.1 ± 0.5	7.4 ± 0.0
M. obturatorius medialis	3.8 ± 0.7[a]	3.2 ± 0.6[ab]	3.0 ± 0.0[b]

LSD (Least Significant Difference, P=0.05) = 0.64

[ab]Means in rows with different superscripts are significantly different, $P \leq 0.05$

When muscle weight was expressed as a percentage of the leg weight, only the *M. obturatorius medialis* showed a significant genotype difference. The purebred Black and Blue genotypes differed significantly ($P \leq 0.05$) from each other regarding this ratio percentage. The *M. gastrocnemius*, including the *M. gastrocnemius pars externa* (0.6 ± 0.10 kg) and the *M. gastrocnemius pars interna* (0.9 ± 0.14 kg), *M. iliofibularis* (1.5 ± 0.18 kg) and *M. iliotibialis lateralis* (1.1 ± 0.17 kg) were the heaviest muscles from the ostrich carcass (Table 3) and these muscles respectively made up 3.9 ± 0.63%, 5.7 ± 0.71%, 9.5 ± 1.0% and 7.4 ± 0.84% of the ostrich leg weight (Table 5). Results by Morris *et al.* (1995b) also found the latter three muscles to be the heaviest. It is interesting to note that the *M. femorotibialis internus* had the lightest muscle weight (0.1 ± 0.03 kg) and therefore also the lowest percentage (0.8 ± 0.16%) relative to leg weight (Table 5).

CONCLUSION

The aim of this study was to determine if crossbreeding of South African Black and Zimbabwean Blue ostriches would affect the morphological properties of an ostrich carcass. Overall, significant differences were observed for weight characteristics including the live weight, carcass weight, leg weight and individual muscle weight. In general, the pure Blue genotype was significantly larger than the pure Black genotype, and the Blue x Black genotype tended to be larger than the pure Black genotype. Percentage carcass yields, taken as a whole, did not differ significantly between genotypes.

Considering that the Black x Blue genotype had no surviving ostriches (see Chapter 3) and the pure Blue genotype was represented by only two ostriches, further studies are recommended to ensure more

reliable results. Studies on other populations of SAB and ZB ostriches will also add robustness to the present findings.

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CHAPTER 5

Physical and sensory meat quality of South African Black (SAB), Zimbabwean Blue (ZB) and SAB x ZB ostriches

Physical and sensory meat quality of South African Black (SAB), Zimbabwean Blue (ZB) and SAB x ZB ostriches

ABSTRACT

Meat derived from three genotypes of ostrich, resulting from crossbreeding with SAB ostriches (*Struthio camelus* var. *domesticus*) and ZB ostriches (S*truthio camelus australis*), was analysed to investigate the influence of crossbreeding on the physical and sensory quality of the meat. Physical quality characteristics included the final pH (pH_{24}), the colour, the water-holding capacity (WHC) and the tenderness of the ostrich meat, while the sensory quality characteristics referred to the flavour, juiciness and tenderness of the meat as perceived by a trained panel. Ostriches of a commercially standard slaughter age of 14 months were used in this study. Significant genotype differences observed for the physical characteristics included the pH_{24}, colour characteristics (excluding the hue angle), percentage drip loss and percentage cooking loss. The pH_{24} was the highest in the pure Blue genotype ($P \leq 0.05$) and therefore meat from this genotype was the darkest ($P \leq 0.05$) and the percentage drip loss ($P \leq 0.05$) and cooking loss ($P \leq 0.05$) the lowest. When comparing the pure Blue genotype to the pure Black genotype, 70% of the muscles (*M. femorotibialis accessorius*, *M. fibularis longus*, *M. gastrocnemius*, *M. iliofemoralis externus*, *M. iliofibularis*, *M. iliotibialis cranialis* and the *M. iliotibialis lateralis*) were higher ($P \leq 0.05$) in pH_{24}, 50% of the muscles (*M. femorotibialis accessorius*, *M. fibularis longus*, *M. gastrocnemius*, *M. iliofemoralis* and the *M. iliofibularis*) were redder ($P \leq 0.05$) and significantly less ($P \leq 0.05$) saturated in colour, 67% of the muscles (*M. fibularis longus*, *M. iliofibularis*, *M. iliotibialis cranialis* and the *M. obturatorius medialis*) had a lower ($P \leq 0.05$) percentage drip loss and 50% of the muscles (*M. fibularis longus*, *M. iliofibularis* and the *M. obturatorius medialis*) had a lower ($P \leq 0.05$) percentage cooking loss for the former genotype. No significant genotype differences ($P > 0.05$) were found regarding the instrumental toughness (shear force values) of the meat, nor the sensory attributes of the meat. Generally, as the pH_{24} increased the meat became darker (L* value: $P < 0.01$, r = -0.200), less red (a* value: $P < 0.01$, r = -0.309), less yellow (b* value: $P < 0.01$, r = -0.186), and less saturated in color and therefore appeared duller (chroma value: $P < 0.01$, r = -0.312), had a lower percentage drip loss ($P < 0.01$, r = -0.236) and was more tender (first bite: $P \leq 0.05$, r = 0.516 and residue: $P \leq 0.05$, r = -0.521). When the instrumental toughness (shear force) of the meat increased, the percentage cooking loss also increased ($P < 0.01$, r = 0.466) and therefore the meat was found to be less juicy (sustained juiciness: $P \leq 0.05$, r = -0.443). As the instrumental toughness (shear force) of the meat increased, the meat was also subjectively perceived to be tougher (first bite: $P < 0.01$, r = -0.701 and residue: $P < 0.01$, r = 0.650). The higher the initial juiciness of the meat, the more tender (first bite: $P < 0.01$, r = 0.621 and residue: $P < 0.01$, r = -0.568) the meat was perceived to be. As the initial impression of juiciness increased, the sustained juiciness of the meat also increased ($P < 0.01$, r = 0.726). The higher the moisture loss during the cooking period, the lower was the sustained juiciness of the meat ($P < 0.01$, r = -0.614) and the tougher the meat was perceived to be (first bite: $P \leq 0.05$, r = -0.474 and residue: $P \leq 0.05$, r = 0.503). As the amount of residue in the meat increased, the meat was less juicy (initial juiciness: $P < 0.01$, r = -0.543 and sustained juiciness: $P < 0.01$, r = -0.802). The more tender the meat was perceived to be (high first bite value), the better the

sustained juiciness of the meat (P<0.01, r = 0.848) was. Residue and first bite were highly negatively correlated (P<0.01, r = -0.944). As measured by sensory analysis, the *M*. *iliofibularis* was juicier (P≤0.05) and more tender (P≤0.05) than the *M*. *gastrocnemius*. The influence of ostrich genotype was less on the physical and sensory meat quality characteristics than was the variation between the different muscles.

Keywords: pH, colour, water-holding capacity, toughness, sensory analysis, ostrich muscles

INTRODUCTION

Recent statistics regarding the income generated from the various ostrich products state that the feathers contribute only 5% to income, whereas leather and meat contribute 50% and 45% respectively (Hoffman, 2005). As ostrich farming is shifting to meat as a primary source of income (Petitte & Davis, 1999; Van Zyl, 2001; Cloete *et al*., 2002; Hoffman, 2005), more information is needed to understand and improve the quality characteristics of ostrich meat.

Different subspecies of ostrich have different phenotypic characteristics (Duerden, 1919; Sauer, 1968; Brown *et al*., 1982; Freitag, 1992), including the size of the bird and the growth rate (Madeiros, 1995). Jarvis (1998) suggested considerable variation in mature live weight between Zimbabwean Blue (ZB) ostriches (125 kg) and South African Black (SAB) ostriches (115 kg). The chicks of ZB ostriches have a faster growth rate and normally reach a body weight of 95 kg earlier than chicks from the other subspecies (Jarvis, 1998). However, the SAB ostrich is the more common ostrich found in South Africa (Madeiros, 1995). Therefore, the ostrich producer may benefit from crossbreeding ZB ostriches and SAB ostriches, especially if the offspring grow faster, are larger and produce meat with a good eating and physical quality. These changes in size and growth rate through crossbreeding will most possibly result in a higher income for the producer per unit slaughtered.

Extensive research has been done on physical meat quality differences between and within common domestic species (poultry, cattle, pigs and small ruminants). However, no research on the influence of crossbreeding and genotypes on the physical and sensory quality of ostrich meat could be sourced. As the ostrich has only recently been used as a meat animal (Van Zyl, 2001), the influence of crossbreeding on meat quality has not yet been investigated intensively. Several authors have suggested that the crossbreeding of different genotypes of ostriches could improve overall performance. Currently, there is a tendency to crossbreed Kenyan Rednecks (*Struthio camelus massaicus*), ZB and SAB without scientific evidence to guide crossbreeding decisions (Petitte & Davis, 1999).

The quality of lean meat is one of the factors that determine the value of an animal carcass relative to market conditions (Swatland, 1995). Consumers determine meat quality according to a combination of characteristics that define the level of acceptability (Kramer & Twigg, 1962). These include the colour when the meat is purchased, aroma when the meat is cooked, and flavour, juiciness and tenderness when the meat is consumed (Smith *et al*., 1970).

Meat quality is, to a large extent, influenced by the final pH (pH_{24}) in the muscle after slaughter (Sales & Mellett, 1996). The pH of meat is an important characteristic, since it influences, amongst other factors, the colour, water-holding capacity (WHC), juiciness, flavour and microbial shelf life (Lawrie, 1998). The WHC of meat affects the pre-cooking appearance, cooking ability, juiciness during chewing and the total quantity of saleable meat (Trout, 1988; Barge *et al*., 1991). Furthermore, some researchers are of the opinion that meat tenderness is affected by juiciness (Davis *et al*., 1979; Hawkins *et al*., 1987). Other factors are also involved: genotype affects the colour of meat and the type of muscle influences the post-mortem pH of meat in general (Lawrie, 1998) and more specifically the colour of ostrich meat (Morris *et al*., 1995b) and its tenderness (Girolami *et al*., 2003).

Most ostrich meat is marketed as individual muscles, for example, the fan fillet (*M*. *iliofibularis*), big drum (*M*. *gastrocnemius*) and triangular fillet or inside strip (*M*. *iliofemoralis*) (Mellett, 1996a). The individual muscles with the highest income include the *M*. *iliofibularis*, *M*. *iliofemoralis* and the *M*. *iliotibialis lateralis* (Mellett, 1992). The larger muscles that are also currently available on the South African market include the *M*. *iliotibialis cranialis*, *M*. *flexor cruris lateralis*, *M*. *obturatorius medialis*, *M*. *femorotibialis accessorius*, *M*. *fibularis longus* and the *M*. *gastrocnemius* (Mellett, 1992).

The primary aim of this study was to determine the effect of crossbreeding ZB ostriches and SAB ostriches on the physical characteristics of the various individual muscles. The secondary aim is to determine the effect of crossbreeding on the sensory characteristics of two ostrich muscles commercially available on the meat market. Physical characteristics included the pH 24 hours after the animal is bled (pH_{24}), the instrumental colour, the WHC and the instrumental tenderness of the ostrich meat. Sensory characteristics of ostrich meat referred to the flavour, juiciness and tenderness of the meat as perceived by a descriptive sensory taste panel.

MATERIALS AND METHODS

Experimental birds and location

A total of 21 ostriches (*Struthio camelus*) of different genotypes were included in this study to determine the physical properties of the meat (Fig. 1). The pH and colour measurements were done on the following ten muscles: *M*. *femorotibialis accessorius*, *M*. *flexor cruris lateralis*, *M*. *iliofemoralis*, *M*. *iliofemoralis externus*, *M*. *gastrocnemius*, *M*. *iliofibularis*, *M iliotibialis lateralis*, *M*. *obturatorius medialis*, *M*. *iliotibialis cranialis* and the *M*. *fibularis longus*. The six muscles used to determine the drip loss, cooking loss and instrumental tenderness (shear force) of the meat were: *M*. *gastrocnemius*, *M*. *iliofibularis*, *M iliotibialis lateralis*, *M*. *obturatorius medialis*, *M*. *iliotibialis cranialis* and the *M*. *fibularis longus*.

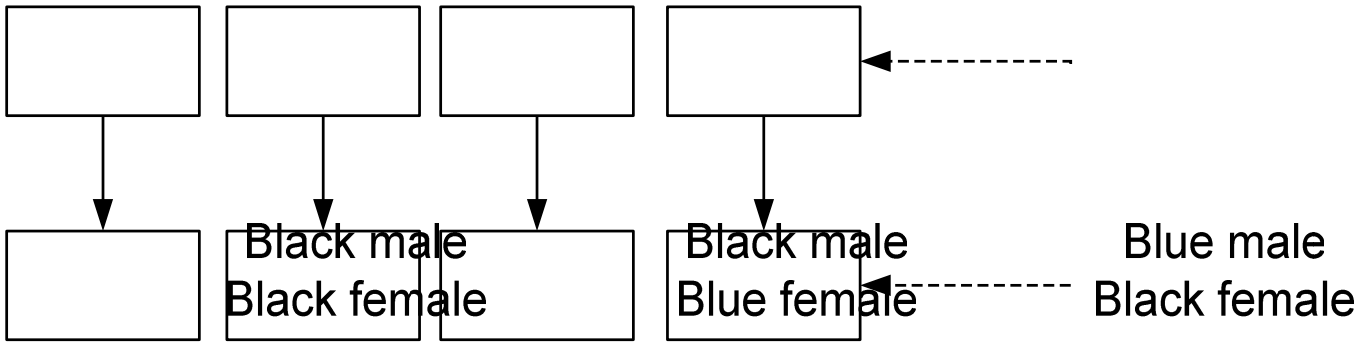

Figure 1 Genotypes and distribution of slaughtered ostriches used for the physical analysis

To determine the sensory attributes of two ostrich muscles, a total of 10 ostriches, of different genotypes, were included in this study (Fig. 2). The *M*. *gastrocnemius* (big drum) and *M*. *iliofibularis* (fan fillet) were used for this analysis, as these two muscles are commonly available on the market for consumers to purchase (Mellett, 1992). The *M*. *iliofibularis* is also described as a muscle with high economic value (Mellett, 1992).

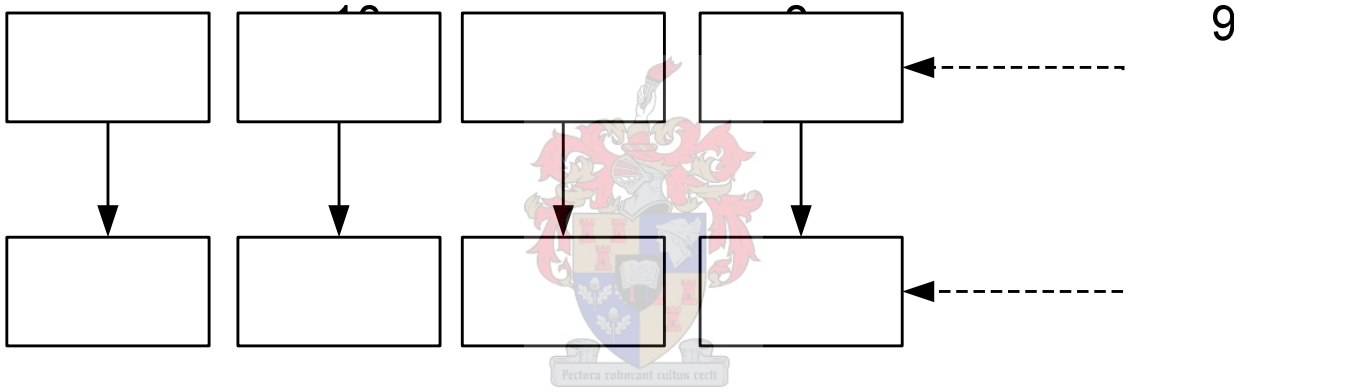

Figure 2 Genotypes and distribution of slaughtered ostriches used for the sensory analysis

The experimental birds used in this study comprised of the genotypes resulting from crossbreeding between SAB and ZB ostriches (Fig. 1 and Fig. 2). The ostriches were slaughtered in February 2005 at the Klein Karoo Co-operative in Oudtshoorn, South Africa.

The same standard procedures were followed for all the birds. Ostriches were reared on the Oudtshoorn Experimental Farm near Oudtshoorn, South Africa and kept under the same conditions. The topography is rolling with isolated shrubs and a rocky surface. Birds were kept in one flock and housed in a paddock of one hectare. Foraging material in the paddocks was limited and was consumed shortly after the ostriches were introduced to the paddock. No artificial shelter was present. All birds received the same *ad libitum* diet (10.5 MJ energy, 160 g protein/kg dry matter) and had free access to drinking water. Routine management included the harvesting of the white plumage (clipping and plucking). A standard drenching, vaccination and ectoparasiticide treatment was applied to all birds. Ostriches were more or less the same age (14 months) at slaughtering. This is the age at which ostriches are slaughtered commercially (Sales, 1999).

Slaughtering

Ostriches were slaughtered at a commercial abattoir in Oudtshoorn, following commercial procedures, which involved lairage in roofed pens for a period of 24 h with free access to drinking water. The ostriches were electrically stunned (105–110 V, 400-800 mA, 10 s). After stunning, ostriches were suspended by both legs and bled. A high neck cut and a cut to the aortic vein (thoracic stick) were used to exsanguinate the birds. Bleeding was allowed for 10-15 min, after which plucking, skinning, evisceration and health inspection took place. Following health inspection, legs (drumsticks) were removed within 45 min after stunning. Legs were allowed to chill for 24 h at 0-4°C, after which the left leg was deboned by hand into 10 specific individual muscles (Table 3). Two muscles were excised from the right leg of the carcass to be used for sensory analysis (Table 7). These muscles were identified as described by Mellett (1996b). The large membranes and visible fat were trimmed from the individual muscles before subjecting muscles to further analysis.

Physical measurements

The pH_{24} of all ten muscles was measured 24 h post-mortem. The pH was measured with a penetrating glass electrode on a portable Crison pH/mV-507 meter. The pH meter consisted of an automatic temperature compensator to ensure for the adjustment of the pH for temperature. The pH meter was re-calibrated after every fourth reading with pH 4.01 and pH 7.02 standard buffers and the electrode was cleansed with distilled water after every reading.

Whole individual muscles were cut in half for the determination of instrumental colour, drip loss and cooking loss. The cut was made perpendicular to the longitudinal axis of the muscle. Two 1.5 cm thick samples of meat were then cut from the inside of each half. The one sample was used to determine the colour, cooking loss and instrumental tenderness (shear force) of the meat; where as the other sample was used to determine the drip loss. The samples of the six muscles were weighed and then placed in netting and suspended in an inflated plastic bag to determine the drip loss. After a storage period of 24 h at 4°C, the samples were blotted with absorbent paper, weighed again and the drip loss was calculated as weight loss expressed as a percentage of the original weight of the sample (Honikel, 1998). To determine cooking loss, samples of six muscles were weighed and placed in thin-walled plastic bags in a water-bath at 80°C. After 1 h the samples were removed from the water-bath, cooled in cold water, blotted dry and weighed. Cooking loss was calculated as the difference in sample weight before and after cooking, expressed as a percentage of the initial sample weight (Honikel, 1998).

For instrumental tenderness, six cylindrical cores were cut from each cooked sample (after determining cooking loss) using a 1.27 cm diameter bore. Samples were randomly removed from the centre of each muscle. Samples were chilled at a temperature of 4-6°C to ensure temperature consistency throughout all the samples. Shear force values for ostrich meat samples were obtained using a Warner Bratzler shear force attachment, fitted to an Instron Universal Testing Machine (Model 4444). This machine works on the principle that as meat becomes tougher, more force is required to shear a core of meat (Lawrie, 1991; Honikel, 1998). Maximum Warner Bratzler shear force values required to shear a cylindrical core of

cooked muscle, perpendicular to the longitudinal orientation of the muscle fibres at a crosshead speed of 200 mm/min, were recorded for each sample and the mean was calculated for each muscle.

All ten muscles were used for the determination of fresh meat colour. Three readings were taken per sample at randomly selected positions after blooming for 20 min. Colour was evaluated according to the method described by Honikel (1998) using a Colour-guide 45°/0° colorimeter (Catalogue no: 6805; BYK-Gardner, USA) to determine L*, a* and b* values, with L* indicating lightness, a* the red-green range and b* the blue-yellow range (CIE Lab, 1978). These values were also used to calculate the hue angle and the chroma value according to the following equations (CIE Lab, 1978):

Hue angle: $h_{ab} = \tan^{-1}\left\{\frac{b*}{a*}\right\}$ Chroma: $C* = \sqrt{(a*)^2 + (b*)^2}$

Descriptive sensory analysis

The vacuum-packed meat samples taken from the leg on the right side of the ostrich carcass were thawed at a temperature of 4-6°C for a period of 48 h prior to cooking on their pre-assigned sensory analysis dates. The meat samples were roasted in cooking bags placed on a wire-rack covered in foil on an open roasting pan to an internal temperature of 72°C. The temperature changes were monitored using thermocouples connected to hand-held digital recorders until the desired internal temperature of 72°C was reached. The samples were cooked at 160°C in two Defy 835 electric ovens connected to a computerised temperature control system (Viljoen *et al*., 2001). Immediately after cooking, the samples were cut into 1 cm x 1 cm cubes, wrapped in aluminium foil, placed in preheated glass ramekins marked with random three-digit codes and placed in a preheated oven at 100°C (until evaluated 10 min later) and were served to the panel.

Descriptive sensory analysis was performed on the ostrich meat. The panellists were selected and trained in accordance with the guidelines for sensory analysis of meat of the American Meat Science Association (AMSA, 1978) and the generic descriptive analysis technique (Lawless & Heymann, 1998). The panel was tested for consistency, after which the eight-member panel analysed the ostrich samples for the following sensory attributes: ostrich meat aroma and flavour; juiciness (initial impression of juiciness and sustained juiciness); and tenderness (first bite and residue). An unstructured line scale was used to evaluate the latter sensory attributes. Table 1 depicts the definitions of the attributes used in the sensory analysis.

The panellists were seated in individual booths in a temperature-controlled (21°C) and light-controlled (artificial daylight) room (AMSA, 1978). Distilled water, apples and crackers were given to the panellists between samples to cleanse and refresh their palates.

Table 1 Definitions of the attributes used in the sensory analysis of the *M*. *gastrocnemius* and *M*. *iliofibularis* of ostrich meat (AMSA, 1978)

Attributes	Description	Score
Ostrich meat aroma	Take a few short sniffs as soon as you remove the foil	100 - Extremely intense 0 - Extremely bland
Flavour	This is a combination of taste and flavour experienced prior to swallowing	100 - Extremely intense 0 - Extremely bland
Initial impression of juiciness	The amount of fluid exuded on the cut surface when pressed between your thumb and forefinger	100 - Extremely juicy 0 - Extremely dry
Sustained juiciness	The impression that you form after the first two to three chews using the molar teeth	100 - Extremely juicy 0 - Extremely dry
First bite	The impression of tenderness after the first two to three chews using the molar teeth	100 - Extremely tender 0 - Extremely tough
Residue	The amount of residue left in the mouth after the first twenty chews, using the molar teeth	100 - Abundant 0 - None

Statistical analysis

For the pH_{24} and instrumental colour of the ostrich meat, a two-factor factorial experiment was performed in a randomised block design with 21 block replications (carcasses). The factors were three genotypes (Black x Black, Blue x Black and Blue x Blue) and 10 muscles (*M*. *femorotibialis accessorius*, *M*. *flexor cruris lateralis*, *M*. *iliofemoralis*, *M*. *iliofemoralis externus*, *M*. *gastrocnemius*, *M*. *iliofibularis*, *M iliotibialis lateralis*, *M*. *obturatorius medialis*, *M*. *iliotibialis cranialis* and the *M*. *fibularis longus*). Regarding the percentage drip loss, percentage cooking loss and instrumental tenderness of the ostrich meat, a two-factor factorial experiment was performed in a randomised block design with 21 block replications (carcasses). The factors were three genotypes (Black x Black, Blue x Black and Blue x Blue) and 6 muscles (*M*. *gastrocnemius*, *M*. *iliofibularis*, *M iliotibialis lateralis*, *M*. *obturatorius medialis*, *M*. *iliotibialis cranialis* and the *M*. *fibularis longus*).

For the sensory analysis of ostrich meat a two-factor factorial experiment was performed in a randomised block design with 10 block replications (carcasses) tasted by 8 trained panel members. The factors were three genotypes (Black x Black, Blue x Black and Blue x Blue) and 2 muscles (*M*. *gastrocnemius* and the *M*. *iliofibularis*). The means of the 8 panel members were calculated before subjected to analysis of variance (ANOVA). An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an ANOVA using SAS version 9 (SAS, 1999) statistical software. Regarding all the statistical analyses, the ANOVA was performed on the full model with factors and interactions included. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 5% significance level to compare treatment means (Ott, 1998). Results were defined as being not significant at a level of $P>0.05$ and

significant at a level of $P \leq 0.05$. In few cases deviations from normality were the cause of outliers, which were removed before the final analysis. Where there was still significant evidence of non-normality, this could be ascribed to kurtosis rather than skewness. Interpretation of results was thus continued as motivated by Glass *et al*. (1972). Correlations were made using the Pearson product moment correlation coefficient.

RESULTS AND DISCUSSION

Physical characteristics

Results from the literature as pertaining to the physical meat quality characteristics of ostrich are summarised in Table 2. Although the ostrich genotypes were not noted, according to Mellett (University of Stellenbosch, Stellenbosch, South Africa, personal communication) it can be accepted that the ostrich genotype used by Sales (1994), Sales (1996), Sales and Mellett (1996), Mellett and Sales (1997) and Hoffman and Fisher (2001) was *Struthio* (*S*.) *camelus* var. *domesticus* (Black x Black).

Table 2 Summary of literature regarding physical characteristics for ostrich meat in general, as well as for different ostrich muscles irrespective of genotype

	pH_{24}	L* value	a* value	b* value	Cooking loss (%)	Shear force (N/1.27cmΦ)	References
General							
	6.06				35.55		Heinze *et al*., 1986
	5.88-6.87	27.35-37.05	13.65 - 21.60	0.06 - 5.98	16.55 - 39.84		Dunster & Scudamore-Smith, 1992
						33.5	Sales, 1994
	5.86	36.74	22.84	6.57		27.0	Paleari *et al*., 1998
Muscles							
M. gastrocnemius	6.11						Morris *et al*., 1995a
M. gastrocnemius pars externa		37.80	14.60	1.90			Pollok *et al*., 1997
M. gastrocnemius pars interna	5.92				35.80	29.7	Sales, 1996
	6.05						Sales & Mellett, 1996
M. iliofemoralis	5.79				31.90	26.4	Sales, 1996
	5.84						Sales & Mellett, 1996
M. iliofemoralis externus	5.95						Morris *et al*., 1995a
M. iliofibularis	6.04				36.00	44.4	Sales, 1996
	6.04						Morris *et al*., 1995a
	6.13						Sales & Mellett, 1996
		38.00	15.10	2.20		57.4	Mellett & Sales, 1997
		29.42	5.48	3.51			Pollok *et al*., 1997
					31.91	44.4	Hoffman & Fisher, 2001
M. iliotibialis lateralis	5.97						Morris *et al*., 1995a
	5.84				36.40	34.6	Sales, 1996
	5.94						Sales & Mellett, 1996
						40.0	Mellett & Sales, 1997
M. obturatorius medialis	5.84						Morris *et al*., 1995a

The means and standard deviations (± SD) for pH_{24} for the different genotypes of ostrich from this investigation are presented in Table 3. The pH_{24} values observed in this study correspond well with those noted in the literature (Table 2). However, it must be noted that the majority of previous research (Table 2) was done on ostriches from the genotype *S. camelus* var. *domesticus* (Black x Black). According to Table 3, the pure Blue genotype had a significantly higher pH_{24} ($P \leq 0.05$) compared to the pure Black genotype for 70% of the muscles (*M. femorotibialis accessorius*, *M. fibularis longus*, *M. gastrocnemius*, *M. iliofemoralis externus*, *M. iliofibularis*, *M. iliotibialis cranialis* and the *M. iliotibialis lateralis*). Taking into account that the pure Blue ostriches are significantly larger ($P \leq 0.05$) than the pure Black ostriches (Refer to Chapter 4, Table 1) and that some of the phenotypic characteristics of this genotype include their very long legs and neck, these characteristics as well as an observed "skittishness", make this genotype more difficult to manage and handle, especially during the ante-mortem stages. According to Lawrie (1998), difficulty in pre-slaughter handling causes animals to stress and with pre-slaughtering stress glycogen is depleted in the muscles and meat will ultimately have a high post-mortem pH_{24} (Lawrie, 1998). Lawrie (1998) also noted that the animals in a group that had shown the greatest resistance to handling produced muscles with a high pH_{24}.

In all three genotypes the most acidic muscle ($P \leq 0.05$) was the *M. flexor cruris lateralis*, whilst the muscle with the highest ($P \leq 0.05$) pH_{24} was the *M. iliofibularis* (Table 3). Because of its pH_{24} ranging between normal (pH > 5.8) and extremely dark, firm and dry (pH < 6.2), also known as DFD, ostrich meat is often classified as an intermediate meat type (Sales & Mellett, 1996). According to Lawrie (1998), DFD is a condition found in meat with deficient glycogen levels. Undesirable aspects of DFD meat include less acceptable flavour, dark colour, sticky texture, high WHC (low moisture loss) and greater susceptibility to microbial growth during storage (Bailey, 1986).

Table 3 Means (± SD) for pH_{24} of muscles for different genotypes of ostrich

Muscles	pH_{24}		
	Black x Black	Blue x Black	Blue x Blue
M. femorotibialis accessorius	$5.81 \pm 0.068^{b}{}_{ab}$	$5.80 \pm 0.117^{b}{}_{bcd}$	$6.01 \pm 0.438^{a}{}_{cd}$
M. fibularis longus	$5.80 \pm 0.065^{b}{}_{ab}$	$5.86 \pm 0.163^{b}{}_{b}$	$6.20 \pm 0.332^{a}{}_{b}$
M. flexor cruris lateralis	$5.75 \pm 0.054_{b}$	$5.71 \pm 0.032_{d}$	$5.74 \pm 0.028_{g}$
M. gastrocnemius	$5.79 \pm 0.075^{b}{}_{ab}$	$5.83 \pm 0.157^{b}{}_{bc}$	$6.03 \pm 0.382^{a}{}_{c}$
M. iliofemoralis	$5.75 \pm 0.062_{b}$	$5.76 \pm 0.079_{bcd}$	$5.85 \pm 0.106_{efg}$
M. iliofemoralis externus	$5.80 \pm 0.047^{b}{}_{ab}$	$5.80 \pm 0.039^{b}{}_{bcd}$	$5.92 \pm 0.177^{a}{}_{de}$
M. iliofibularis	$5.87 \pm 0.059^{c}{}_{a}$	$6.02 \pm 0.234^{b}{}_{a}$	$6.52 \pm 0.170^{a}{}_{a}$
M. iliotibialis cranialis	$5.81 \pm 0.100^{b}{}_{ab}$	$5.79 \pm 0.049^{b}{}_{bcd}$	$5.95 \pm 0.240^{a}{}_{cde}$
M. iliotibialis lateralis	$5.76 \pm 0.073^{b}{}_{b}$	$5.74 \pm 0.039^{b}{}_{cd}$	$5.87 \pm 0.163^{a}{}_{ef}$
M. obturatorius medialis	$5.75 \pm 0.045_{b}$	$5.74 \pm 0.029_{cd}$	$5.79 \pm 0.000_{fg}$

LSD (Least Significant Difference, $P=0.05$) = 0.110

$^{a-c}$ Means in rows, with different superscripts are significantly different, $P \leq 0.05$

$_{a-g}$ Means in columns, with different subscripts are significantly different, $P \leq 0.05$

The means and standard deviations (± SD) for the colour characteristics (L*, a* and b* values, hue angle (°) and chroma value) for the different genotypes of ostrich are presented in Tables 4 and 5. As noted in Table 2, the present results for the L* value correspond well with previous investigations. The L* value (lightness) did not differ significantly (*P>0*.05) between genotypes for the majority of the muscles (Table 4). However, the exception includes the *M*. *fibularis longus*, *M*. *iliofemoralis externus* and the *M*. *iliofibularis*. The *M*. *fibularis longus* and the *M*. *iliofibularis* were lighter (higher L* value) (*P*≤0.05) in the pure Black genotype (Table 4) compared to the pure Blue genotype. Therefore, the latter two muscles had a higher L* value (*P*≤0.05) in the pure Black genotype. The general dark colour of meat is a result of the high pH_f (Lawrie, 1998). Therefore, the latter result is expected, because the dark purplish-red colour of ostrich meat may be a result of its high final pH. The colour of the pure Blue genotype will therefore be darker (lower L* value) because of the high pH_{24}, as noted in Table 3. In contrast to the above, the *M*. *iliofemoralis externus* was significantly lighter (*P*≤0.05) in the pure Blue genotype compared to the pure Black genotype (Table 4).

As noted in Table 4, for the pure Black genotype the lightest (*P*≤0.05) muscle was the *M*. *femorotibialis accessorius* (L* = 33.2 ± 1.70) and the most gray (lowest L* value) muscle was the *M*. *flexor cruris lateralis* (L* = 29.3 ± 1.64, *P*≤0.05). In the Blue x Black and the pure Blue genotype the lightest (*P*≤0.05) muscle was the *M*. *iliofemoralis externus* (L* = 32.4 ± 2.31 and 34.4 ± 2.34), whereas the most gray (*P*≤0.05) muscle was the *M*. *fibularis* longus (L* = 28.5 ± 2.46 and 27.6 ± 1.20) (Table 4). It is interesting to note that for the pure Black and the Blue x Black genotypes the difference between the highest and lowest L* value is 3.9 units. However, for the pure Blue genotype the same range equals 6.8 units, which indicates a much wider range in lightness and darkness of colour between muscles from this genotype.

The results found for the a* value were within the range reported in the literature (Table 2). A high a* value indicates a muscle that is more red, whereas a high b* value indicates a muscle that is more yellow. According to Table 4, half of the muscle groups of the pure Black genotype (*M*. *femorotibialis accessorius*, *M*. *fibularis longus*, *M*. *gastrocnemius*, *M*. *iliofemoralis* and the *M*. *iliofibularis*) had a significantly higher (*P*≤0.05) a* (red) value compared to the pure Blue genotype.

Present results measured for the b* value were somewhat higher than those reported in the literature (Table 2). Paleari *et al*. (1998) reported a b* value of 6.57, whereas the highest b* value in the present study was 9.27 (Tables 2 and 4). A high b* value indicates a product with less yellow but more blue undertones. With the exception of the *M*. *gastrocnemius* and the *M*. *iliotibialis lateralis*, there were no significant differences (*P*>0.05) between genotypes for the b* values (Table 4). For both the above muscles, the pure Black genotype had a significantly higher b* (yellow) value (*P*≤0.05). These two muscles are therefore more yellow (*P*≤0.05) in the pure Black genotype compared to the pure Blue genotype (Table 4).

Joubert (2003) calculated a hue angle of 30.83º to 32.42º for the *M*. *iliofibularis* derived from ostriches on various feeding regimes. Results for the same muscle in the present study were somewhat lower (28 ± 4.2º to 29 ± 4.0º), as can be noted in Table 5. Regarding colour intensity (hue angle) no significant genotype differences (*P*>0.05) were observed (Table 5). The only exception is for the *M*. *iliotibialis lateralis,* where the hue angle was higher (*P*≤0.05) in the Blue x Black genotype compared to the

pure Blue genotype (Table 5). Therefore, the *M*. *iliotibialis lateralis* displayed a browner meat colour ($P \leq 0.05$) in the Blue x Black genotype.

Joubert (2003) notes chroma values that ranged from 15.69 to 17.19 for the *M*. *iliofibularis* derived from ostriches on various feeding regimes. According to Table 5, results for the same muscle in the present study were somewhat lower (13.5 ± 0.68 to 16.1 ± 1.67). As noted in Table 5, chroma (colour saturation) differed significantly between genotypes for 50% of the muscle groups (*M*. *femorotibialis accessorius*, *M*. *fibularis longus*, *M*. *gastrocnemius*, *M*. *iliofemoralis* and the *M*. *iliofibularis*). Similar results were found for the a* (red) value. Chroma/saturation is calculated by an equation consisting of the a* (red) value and the b* (yellow) value. Therefore, results found for the a* (red) value will also affect the chroma, as can be seen in Tables 4 and 5. In these five muscles the chroma values were higher ($P \leq 0.05$) for the pure Black genotype compared to the pure Blue genotype (Table 5). These five muscles from the pure Black genotype were more saturated in colour and therefore appeared brighter ($P \leq 0.05$). Highly significant negative correlations were found between post-mortem pH_{24} and the lightness ($P < 0.01$, r = -0.200), the redness ($P < 0.01$, r = -0.309), the yellowness ($P < 0.01$, r = -0.186) and consequently the chroma ($P < 0.01$, r = -0.312) of the meat. The latter correlation was expected, because the a* value and the b* value form part of the equation used for determining colour saturation. As the pH_{24} increased, the meat was darker, less red, less yellow and less saturated in color and therefore appeared duller. According to Lawrie (1998), the dark colour of meat in general is a result of the high final pH (pH_{24}) of the meat, whereas the dark colour of ostrich meat partially is a result of the high pigment content of the meat (Sales, 1996).

The means and standard deviations (± SD) for percentage drip loss (%), percentage cooking loss (%) and shear force (N/1.27cmΦ) for the different genotypes of ostrich are presented in Table 6.

Joubert (2003) noted percentage drip loss values ranging from 2.07% to 2.56% for the *M*. *iliofibularis* derived from ostriches on various feeding regimes. However, results for the same muscle in the present study were somewhat lower (0.7 ± 0.85% to 2.1 ± 0.40%), as noted in Table 6. In two thirds (*M*. *fibularis longus*, *M*. *iliofibularis*, *M*. *iliotibialis cranialis* and the *M*. *obturatorius medialis*) of the muscle groups used for drip loss determination, the pure Black genotype had a higher ($P \leq 0.05$) percentage drip loss compared to the pure Blue genotype (Table 6). The lower percentage drip loss of the pure Blue genotype is a result of the higher pH_{24} of this genotype (Table 3). One of the large muscles available on the ostrich meat market is the *M*. *gastrocnemius* (Mellett, 1992). Note that for this muscle no significant differences ($P > 0.05$) were found between genotypes (Table 6).

The *M*. *iliofibularis* had the lowest ($P \leq 0.05$) percentage drip loss in all three genotypes. This is of great significance, seeing that this muscle has a high economic value in the ostrich meat industry (Mellett, 1992). As pH_{24} increased, there was a slight decrease in the percentage drip loss ($P < 0.01$, r = -0.236). The lower percentage of drip loss for the pure Blue genotype is therefore as result of the higher pH_{24} of this genotype (Table 3).

Table 4 Means (± SD) for colour characteristics (L*, a* and b* value) of muscles for different genotypes of ostrich

Muscles	L* value			a* value			b* value		
	Black x Black	Blue x Black	Blue x Blue	Black x Black	Blue x Black	Blue x Blue	Black x Black	Blue x Black	Blue x Blue
M. femorotibialis accessorius	$33.2 \pm 1.70_{a}$	$32.3 \pm 2.14_{a}$	$32.1 \pm 1.60_{bc}$	$14.4 \pm 1.33^{a}{}_{b}$	$14.5 \pm 1.57^{a}{}_{bc}$	$11.5 \pm 1.23^{b}{}_{ef}$	$7.4 \pm 2.20_{bcd}$	$7.1 \pm 2.20_{cd}$	$6.1 \pm 0.85_{b}$
M. fibularis longus	$29.8 \pm 1.80^{a}{}_{cde}$	$28.5 \pm 2.46^{ab}{}_{c}$	$27.6 \pm 1.20^{b}{}_{f}$	$13.3 \pm 2.04^{a}{}_{b}$	$13.6 \pm 2.97^{a}{}_{bc}$	$10.7 \pm 1.15^{b}{}_{f}$	$6.4 \pm 1.83_{d}$	$6.7 \pm 2.61_{d}$	$6.0 \pm 1.93_{b}$
M. flexor cruris lateralis	$29.3 \pm 1.64_{e}$	$28.7 \pm 1.25_{c}$	$29.5 \pm 0.64_{de}$	$14.4 \pm 1.31_{b}$	$14.3 \pm 1.05_{bc}$	$13.6 \pm 1.72_{bc}$	$8.1 \pm 1.57_{abc}$	$7.8 \pm 1.29_{abcd}$	$6.4 \pm 1.89_{b}$
M. gastrocnemius	$30.6 \pm 2.12_{bcde}$	$29.2 \pm 2.25_{c}$	$29.2 \pm 0.96_{def}$	$14.2 \pm 2.12^{a}{}_{b}$	$13.4 \pm 2.01^{ab}{}_{bc}$	$12.1 \pm 2.81^{b}{}_{cdef}$	$7.3 \pm 1.66^{a}{}_{bcd}$	$6.8 \pm 2.13^{ab}{}_{cd}$	$5.5 \pm 1.97^{b}{}_{b}$
M. iliofemoralis	$29.5 \pm 1.16_{de}$	$29.8 \pm 1.30_{bc}$	$31.0 \pm 0.85_{bcd}$	$14.5 \pm 1.51^{a}{}_{b}$	$13.9 \pm 1.53^{ab}{}_{bc}$	$12.4 \pm 0.75^{b}{}_{bcde}$	$7.2 \pm 1.56_{bcd}$	$7.8 \pm 2.34_{abcd}$	$6.7 \pm 1.28_{ab}$
M. iliofemoralis externus	$32.1 \pm 1.76^{b}{}_{ab}$	$32.4 \pm 2.31^{b}{}_{a}$	$34.4 \pm 2.34^{a}{}_{a}$	$14.6 \pm 1.58_{b}$	$15.0 \pm 1.33_{b}$	$14.1 \pm 0.82_{b}$	$8.4 \pm 1.28_{ab}$	$8.4 \pm 1.47_{abc}$	$8.3 \pm 1.53_{a}$
M. iliofibularis	$31.3 \pm 2.59^{a}{}_{abcd}$	$30.3 \pm 3.55^{ab}{}_{bc}$	$29.2 \pm 1.13^{b}{}_{ef}$	$14.0 \pm 1.39^{a}{}_{b}$	$13.2 \pm 1.51^{ab}{}_{c}$	$11.8 \pm 0.64^{b}{}_{def}$	$7.8 \pm 1.46_{abcd}$	$7.1 \pm 1.53_{bcd}$	$6.5 \pm 0.79_{b}$
M. iliotibialis cranialis	$32.5 \pm 2.17_{a}$	$31.3 \pm 2.59_{ab}$	$32.4 \pm 1.67_{b}$	$16.7 \pm 1.40_{a}$	$17.1 \pm 1.50_{a}$	$16.1 \pm 1.38_{a}$	$9.3 \pm 1.09_{a}$	$8.9 \pm 2.23_{a}$	$8.3 \pm 0.99_{a}$
M. iliotibialis lateralis	$31.6 \pm 1.57_{abc}$	$31.4 \pm 2.04_{ab}$	$30.3 \pm 0.30_{cde}$	$13.5 \pm 1.52_{b}$	$13.9 \pm 1.30_{bc}$	$13.2 \pm 0.44_{bcd}$	$8.1 \pm 1.70^{a}{}_{abcd}$	$8.8 \pm 1.82^{a}{}_{ab}$	$6.3 \pm 1.31^{b}{}_{b}$
M. obturatorius medialis	$31.4 \pm 1.73_{abcd}$	$31.6 \pm 2.21_{ab}$	$31.6 \pm 1.55_{bc}$	$13.9 \pm 1.64_{b}$	$13.9 \pm 2.10_{bc}$	$12.8 \pm 1.61_{bcde}$	$6.6 \pm 1.71_{cd}$	$6.9 \pm 2.01_{cd}$	$7.1 \pm 2.15_{ab}$
LSD (*P=0.*05)		1.87			1.72			1.71	

LSD, Least Significant Difference, *P*=0.05

$^{a-b}$ Means in rows, within physical characteristics, with different superscripts are significantly different, *P*≤0.05

$_{a-f}$ Means in columns, with different subscripts are significantly different, *P*≤0.05

Table 5 Means (± SD) for colour characteristics (hue angle and chroma) of muscles for different genotypes of ostrich

Muscles	Hue angle (°)			Chroma		
	Black x Black	Blue x Black	Blue x Blue	Black x Black	Blue x Black	Blue x Blue
M. femorotibialis accessorius	$27 \pm 7.2_{ab}$	$26 \pm 7.8_{b}$	28 ± 4.4	$16.3 \pm 1.52^{a}{}_{bc}$	$16.3 \pm 1.59^{a}{}_{bc}$	$13.0 \pm 1.11^{b}{}_{de}$
M. fibularis longus	$26 \pm 8.0_{ab}$	$26 \pm 8.1_{ab}$	29 ± 9.2	$14.9 \pm 1.82^{a}{}_{c}$	$15.3 \pm 3.35^{a}{}_{c}$	$12.4 \pm 0.97^{b}{}_{e}$
M. flexor cruris lateralis	$29 \pm 5.3_{ab}$	$29 \pm 4.6_{ab}$	25 ± 8.2	$16.6 \pm 1.39_{bc}$	$16.3 \pm 1.05_{bc}$	$15.2 \pm 1.33_{bc}$
M. gastrocnemius	$27 \pm 8.3_{ab}$	$27 \pm 8.4_{ab}$	25 ± 9.9	$16.0 \pm 1.74^{a}{}_{bc}$	$15.2 \pm 1.96^{ab}{}_{c}$	$13.5 \pm 2.49^{b}{}_{cde}$
M. iliofemoralis	$26 \pm 5.5_{ab}$	$29 \pm 8.2_{ab}$	28 ± 5.1	$16.3 \pm 1.42^{a}{}_{bc}$	$16.1 \pm 1.67^{a}{}_{bc}$	$14.2 \pm 0.76^{b}{}_{cde}$
M. iliofemoralis externus	$30 \pm 5.6_{ab}$	$29 \pm 5.7_{ab}$	30 ± 3.8	$16.9 \pm 1.20_{b}$	$17.2 \pm 1.35_{b}$	$16.4 \pm 1.33_{ab}$
M. iliofibularis	$29 \pm 4.0_{ab}$	$28 \pm 4.2_{ab}$	29 ± 3.2	$16.1 \pm 1.67^{a}{}_{bc}$	$15.0 \pm 1.86^{ab}{}_{c}$	$13.5 \pm 0.68^{b}{}_{cde}$
M. iliotibialis cranialis	$29 \pm 3.5_{ab}$	$27 \pm 5.1_{ab}$	27 ± 2.3	$19.1 \pm 1.34_{a}$	$19.3 \pm 2.12_{a}$	$18.1 \pm 1.54_{a}$
M. iliotibialis lateralis	$31 \pm 7.3^{ab}{}_{a}$	$32 \pm 6.2^{a}{}_{a}$	25 ± 4.8^{b}	$15.9 \pm 1.06_{bc}$	$16.2 \pm 1.63_{bc}$	$14.7 \pm 0.64_{bcd}$
M. obturatorius medialis	$25 \pm 5.7_{b}$	$27 \pm 7.9_{ab}$	29 ± 9.9	$15.5 \pm 1.84_{bc}$	$15.7 \pm 1.99_{bc}$	$14.8 \pm 0.93_{bcd}$
LSD (*P=0*.05)		5.9			1.81	

LSD, Least Significant Difference, *P*=0.05

$^{a-b}$ Means in rows, within physical characteristics, with different superscripts are significantly different, *P*≤0.05

$_{a-e}$ Means in columns, with different subscripts are significantly different, *P*≤0.05

Table 6 Means (± SD) for percentage drip loss, percentage cooking loss and shear force of muscles for different genotypes of ostrich

Muscles	Drip loss (%)			Cooking loss (%)			Shear force (N/1.27cmΦ)		
	Black x Black	Blue x Black	Blue x Blue	Black x Black	Blue x Black	Blue x Blue	Black x Black	Blue x Black	Blue x Blue
M. fibularis longus	$2.9 \pm 1.04^{a}{}_{ab}$	$2.0 \pm 0.52^{b}{}_{ab}$	$2.2 \pm 0.04^{b}{}_{ab}$	$37.6 \pm 1.88^{a}{}_{ab}$	$36.3 \pm 1.15^{a}{}_{a}$	$33.9 \pm 2.10^{b}{}_{c}$	$66 \pm 15.4_{ab}$	$67 \pm 13.7_{a}$	$63 \pm 47.8_{ab}$
M. gastrocnemius	$2.1 \pm 0.79_{c}$	$1.9 \pm 0.54_{ab}$	$2.2 \pm 0.11_{ab}$	$38.0 \pm 1.29_{a}$	$37.6 \pm 1.67_{a}$	$36.6 \pm 2.52_{b}$	$63 \pm 10.6_{ab}$	$74 \pm 16.4_{a}$	$64 \pm 10.3_{ab}$
M. iliofibularis	$2.1 \pm 0.40^{a}{}_{c}$	$1.8 \pm 0.22^{a}{}_{b}$	$0.7 \pm 0.85^{b}{}_{c}$	$38.0 \pm 2.25^{a}{}_{a}$	$36.6 \pm 2.42^{a}{}_{a}$	$34.6 \pm 1.41^{b}{}_{c}$	$59 \pm 9.9_{ab}$	$57 \pm 11.1_{ab}$	$50 \pm 0.0_{bc}$
M. iliotibialis cranialis	$2.8 \pm 0.65^{a}{}_{ab}$	$2.0 \pm 0.60^{b}{}_{ab}$	$2.0 \pm 0.01^{b}{}_{b}$	$36.1 \pm 1.77_{b}$	$34.4 \pm 1.83_{b}$	$35.4 \pm 0.99_{bc}$	$48 \pm 6.8_{b}$	$47 \pm 4.8_{b}$	$45 \pm 9.2_{bc}$
M. iliotibialis lateralis	$2.5 \pm 0.66^{a}{}_{bc}$	$1.7 \pm 0.44^{b}{}_{b}$	$2.6 \pm 0.29^{a}{}_{a}$	$37.6 \pm 1.70^{ab}{}_{ab}$	$36.3 \pm 0.96^{b}{}_{a}$	$38.7 \pm 0.95^{a}{}_{a}$	$69 \pm 16.1_{a}$	$75 \pm 23.4_{a}$	$77 \pm 36.1_{a}$
M. obturatorius medialis	$3.3 \pm 0.93^{a}{}_{a}$	$2.5 \pm 0.91^{b}{}_{a}$	$2.1 \pm 0.00^{b}{}_{ab}$	$33.2 \pm 0.93^{a}{}_{c}$	$31.4 \pm 2.19^{a}{}_{c}$	$28.6 \pm 0.00^{b}{}_{d}$	$52 \pm 5.9_{ab}$	$47 \pm 12.9_{b}$	$37 \pm 0.0_{c}$
LSD (*P=0*.05)		0.54			1.79			19.2	

LSD, Least Significant Difference, *P*=0.05

^{ab} Means in rows, within physical characteristics, with different superscripts are significantly different, *P*≤0.05

$_{a-d}$ Means in columns, with different subscripts are significantly different, *P*≤0.05

Results for percentage cooking loss were similar to those noted in the literature (Table 2). The pure Black genotype had a significantly higher ($P \leq 0.05$) percentage cooking loss for 50% of the muscle groups (*M. fibularis longus*, *M. iliofibularis* and the *M. obturatorius medialis*) compared to the pure Blue genotype (Table 6). The pH and tempo of pH decline both influence the WHC of meat (Swatland, 1995). A higher final pH results in a higher WHC and a lower moisture loss. Therefore pH will also influence the percentage cooking loss of the meat. The lower percentage cooking loss of the pure Blue genotype is therefore due to the higher pH_{24} of this genotype (Table 3). No significant differences ($P > 0.05$) were observed regarding percentage cooking loss between genotypes for the remainder of the muscles (Table 6).

Results for instrumental tenderness (shear force) in the present investigation were higher than those indicated in the literature (Table 2). According to Table 6, no significant differences ($P > 0.05$) were found between genotypes for any of the muscles. Girolami *et al*. (2003) studied the shear force of the *M. gastrocnemius* (40.1 N/1.27cmΦ ± 5.4), *M. iliofibularis* (11.7 N/1.27cmΦ ± 0.6) and the *M. iliotibialis* (14.9 N/1.27cmΦ ± 2.8) derived from pure Blue ostriches (*S. camelus australis*). As noted in Table 6, the present results for the pure Blue genotype were relatively higher than the results indicated by Girolami *et al*. (2003). Although Girolami *et al*. (2003) used the same method for shear force determination, the diameter of the muscle core differed (1 cm). In the present study the muscle with the highest ($P \leq 0.05$) shear force in all three genotypes was the *M. iliotibialis lateralis*. Therefore the *M. iliotibialis lateralis* was found to be the toughest muscle as determined by instrumental analysis. It is interesting to note that shear force is highly correlated ($P < 0.01$, $r = 0.466$) with percentage cooking loss. Collagen is the principal fibrous protein in connective tissue (Tarrant, 1998). When collagen is exposed to heat of about 65°C, it contracts to one quarter of its original length (Bailey & Sims, 1977). This contraction causes an increase in tension and fluid is exuded from the muscle, resulting in an increase of meat toughness (Bailey & Sims, 1977). Therefore, the more collagen that is present in the meat, which contracts at high temperatures, the more fluid is exuded (cooking loss) and the tougher the meat is. It can also be argued that when more water is present in the piece of meat used for shear force determination, the higher the dilution is of the connective tissue per area present in the meat.

Sensory characteristics

The means and standard deviations (± SD) for the sensory attributes of the meat derived from the different genotypes of ostrich are presented in Table 7. No significant differences ($P > 0.05$) were found between the different genotypes for any of the sensory attributes (Table 7). When comparing the two muscles, no significant differences ($P > 0.05$) were observed for aroma and flavour (Table 7). Pollok *et al*. (1997) and Girolami *et al*. (2003) also found that muscle type had no effect on intensity of meat flavour. The *M. iliofibularis* was significantly higher ($P \leq 0.05$) regarding sustained juiciness (Table 7). However, for initial juiciness, there was only a tendency for the *M. iliofibularis* to be juicier than the *M. gastrocnemius* (Table 7). It therefore seems that the *M. iliofibularis* is juicier than the *M. gastrocnemius*. Studies done by Harris *et al*. (1993) also indicated that the *M. iliofibularis* was identified as juicier more frequently than the *M. gastrocnemius*.

Tenderness refers to the ease of shearing or cutting during mastication, as well as the amount of residue remaining in the mouth after chewing (Gillespie, 1960; Forrest *et al*., 1975). Lawrie (1998) and Sales (1999) stated that the presence of connective tissue in the meat will have an effect on its tenderness. The more connective tissue present in the meat, the more residue will remain in the mouth after chewing. The *M*. *iliofibularis* had a significantly higher ($P \leq 0.05$) value for the attribute first bite and a significantly lower ($P \leq 0.05$) value for the attribute residue. These results indicate that a descriptive sensory panel perceived the latter muscle to be more tender ($P \leq 0.05$) than the *M*. *gastrocnemius*. Girolami *et al*. (2003) studied the sensory tenderness of the *M*. *gastrocnemius* and the *M*. *iliofibularis* derived from pure Blue ostriches (*S*. *camelus australis*). The *M*. *iliofibularis* was found to be more tender ($P < 0.001$) than the *M*. *gastrocnemius* (Girolami *et al*., 2003). Studies done by Harris *et al*. (1993) also indicated that the *M*. *iliofibularis* was identified as tender more frequently than the *M*. *gastrocnemius*.

Table 7 Mean panel scores (± SD) for the sensory attributes of the *M*. *gastrocnemius* and *M*. *iliofibularis* for different genotypes of ostrich

Attributes	*M. gastrocnemius*			*M. iliofibularis*			LSD
	Black x Black	Blue x Black	Blue x Blue	Black x Black	Blue x Black	Blue x Blue	
Ostrich meat aroma[c]	70.0 ± 4.63	70.1 ± 4.50	69.5 ± 1.21	68.4 ± 2.74	69.1 ± 2.22	66.7 ± 0.85	7.65
Flavour[d]	68.2 ± 1.72	65.8 ± 1.96	66.3 ± 2.75	67.1 ± 1.65	67.1 ± 0.95	67.4 ± 0.70	2.73
Initial juiciness[e]	65.4 ± 3.68[b]	68.5 ± 4.71[ab]	66.5 ± 1.03[b]	72.9 ± 3.57[ab]	74.3 ± 3.16[ab]	77.4 ± 0.24[a]	8.93
Sustained juiciness[f]	62.7 ± 3.84[b]	64.6 ± 5.03[b]	62.2 ± 1.41[b]	71.8 ± 4.18[a]	74.1 ± 4.58[a]	75.5 ± 2.85[a]	4.65
First bite[g]	65.6 ± 2.87[b]	59.4 ± 8.23[b]	63.4 ± 1.25[b]	83.2 ± 3.98[a]	81.6 ± 6.57[a]	84.1 ± 6.80[a]	6.89
Residue[h]	31.4 ± 4.89[a]	38.0 ± 7.47[a]	33.2 ± 5.65[a]	12.0 ± 4.07[b]	11.4 ± 8.91[b]	8.8 ± 8.26[b]	11.57

LSD, Least Significant Difference, $P=0.05$

[ab] Means in rows with different superscripts are significantly different, $P \leq 0.05$

[c] 0 = extremely bland; 100 = extremely intense

[d] 0 = extremely bland; 100 = extremely intense

[e] 0 = extremely dry; 100 = extremely juicy

[f] 0 = extremely dry; 100 = extremely juicy

[g] 0 = extremely tough; 100 = extremely tender

[h] 0 = none; 100 = abundant

Significant correlations were found for juiciness and some of the physical and other sensory characteristics. In this investigation sustained juiciness was negatively correlated with shear force ($P \leq 0.05$, r = -0.443) and initial juiciness was positively correlated with sensory tenderness (first bite) ($P < 0.01$, r = 0.621), as well as negatively correlated with the amount of residue present in the meat ($P < 0.01$, r = -0.568). These results illustrate the fact that the drier the meat, the tougher it seems (Davis *et al*., 1979; Hawkins *et*

al., 1987). When collagen, the principal fibrous protein in connective tissue (Tarrant, 1998), contracts during heating (internal temperature of approximately 65^{o}C), there is an increase in tension and fluid is exuded from the muscle, resulting in an increase in meat toughness (Bailey & Sims, 1977).

As expected, initial juiciness was also highly correlated (P<0.01, r = 0.726) with the sustained juiciness. Furthermore, sustained juiciness was also correlated with percentage cooking loss (P<0.01, r = -0.614). The WHC of meat affects the juiciness during chewing (Offer & Trinick, 1983; Trout, 1988; Barge *et al*., 1991).

Significant correlations were also found for sensory tenderness and some of the physical and other sensory characteristics. As the pH_{24} of the meat increased, the first bite value increased (P≤0.05, r = 0.516) and the amount of residue decreased (P≤0.05, r = -0.521). Therefore, the tenderness of the meat increased as the pH_{24} increased. This is due to the post-mortem activation of enzymes. During the post-mortem period the pH drop causes the concentration of Ca^{++} ions in the muscle fibres to increase (Dransfield, 1992; Dransfield *et al*., 1992; Dransfield, 1993). This increase in Ca^{++} ions activates calpain I, which causes initial tenderisation in meat (Dransfield, 1992; Dransfield *et al*., 1992; Dransfield, 1993). As the pH drops even further, more Ca^{++} ions are release and calpain II is activated at this higher concentration of Ca^{++} ions (Dransfield, 1992; Dransfield *et al*., 1992; Dransfield, 1993). Therefore, calpain II is responsible in further stages of tenderisation as used in aging of meat (Dransfield, 1992; Dransfield *et al*., 1992; Dransfield, 1993). However, it is known that ostrich muscles attain their lowest pH rapidly (Botha *et al*., 2004), after which the pH starts to increase (Tables 2 and 3). It is postulated that this rapid decrease in pH was sufficient to activate the calpain I system, but the meat was frozen within 24 h and it is therefore doubtful that the calpains II system would have caused any tenderisation.

First bite showed a highly negative correlation (P<0.01, r = -0.701) and residue a positive correlation (P<0.01, r = 0.650) with shear force. Both the latter correlations illustrated the fact that first bite decrease (low value for sensory tenderness) and residue increase (high value for residue) with an increase in shear force (high value for shear force). First bite was also negatively correlated to percentage cooking loss (P≤0.05, r = -0.474). As the percentage cooking loss decreased, the sensory tenderness increased. A similar result was also found for sensory tenderness and juiciness: the more tender the meat (high first bite value), the higher the sustained juiciness of the meat (P<0.01, r = 0.848). Again this illustrates the link between tenderness and juiciness of the meat (Davis *et al*., 1979; Hawkins *et al*., 1987). It can be argued that the more water present in the piece of meat that the panel member analysed, the higher the dilution of the connective tissue per volume of the meat. Therefore, the dryer (less juicy) the meat, the higher the content of connective tissue per bite and the tougher the meat is perceived to be.

CONCLUSION

This study investigated the influence of crossbreeding SAB and ZB ostriches on the physical and sensory attributes of ostrich meat. In general, the results corresponded well with those in the literature. Significant genotype differences were observed for the pH_{24}, colour characteristics (excluding the hue angle), percentage drip loss and percentage cooking loss. When viewing the results of this study, it can be

concluded that meat derived from the pure Blue genotype was of better physical quality than the meat derived from the pure Black genotype. However, no significant genotype differences were found regarding the eating quality (sensory attributes) of the meat. This is of great significance for the ostrich industry. Ostriches from the pure Blue genotype and the Blue x Black genotype were larger and produced more meat per ostrich slaughtered (refer to Chapter 4, Table 1). Meat from the different genotypes was perceived to be the same regarding the sensory attributes. Therefore, crossbreeding between SAB and ZB ostriches can be a viable option to produce larger birds with more meat, without negatively affecting the eating quality of the meat. The different muscles also differed significantly regarding the physical and sensory quality characteristics. These muscle differences can be used in the marketing of the respective ostrich muscles.

Further research with more ostriches present in the Black x Blue genotype and the Blue x Blue genotype is recommended to ensure improved reliability. Studies on other populations of SAB and ZB ostriches will also add robustness to the present findings.

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CHAPTER 6

Chemical composition of South African Black (SAB), Zimbabwean Blue (ZB) and SAB x ZB ostrich muscles

Chemical composition of South African Black (SAB), Zimbabwean Blue (ZB) and SAB x ZB ostrich muscles

ABSTRACT

Crossbreeding with SAB ostriches (*Struthio camelus* var. *domesticus*) and ZB ostriches (S*truthio camelus australis*) is a viable option for producing ostriches with a higher quantity of meat and a larger skin area. However, it is important that the breeding should not affect the meat quality negatively. Three genotypes of ostrich, resulting from crossbreeding with SAB ostriches and ZB ostriches, were used to investigate the influence of crossbreeding on the chemical quality of various muscles. The characteristics were the total percentages moisture, protein, lipid and ash; content of myoglobin, cholesterol and the different types of collagen; and the mineral composition. Muscles used for proximate analysis include the *M*. *femorotibialis accessorius*, *M*. *flexor cruris lateralis*, *M*. *iliofemoralis*, *M*. *iliofemoralis externus*, *M*. *gastrocnemius*, *M*. *iliofibularis*, *M iliotibialis lateralis*, *M*. *obturatorius medialis*, *M*. *iliotibialis cranialis* and the *M*. *fibularis longus*. The *M*. *gastrocnemius* and *M*. *iliofibularis* were analysed to determine the remainder of the chemical quality characteristics. Ostriches at the commercial standard slaughter age of 14 months were used in this study. The percentage of moisture of eight of the ten muscle groups from the pure Blue genotype was the highest compared to both the other genotypes. The latter genotype had a higher percentage of moisture ($P \leq 0.05$) than the Blue x Black genotype for the *M*. *femorotibialis accessorius*, *M*. *flexor cruris lateralis* and the *M*. *iliofemoralis externus*. Furthermore, the *M*. *fibularis longus* had the highest percentage of moisture ($P \leq 0.05$) in all three genotypes. No significant differences ($P > 0.05$) were found between genotypes or between muscles regarding the percentage of protein present in the meat. However, the percentage of lipid of eight of the ten muscle groups from the pure Blue genotype was the lowest compared to the other two genotypes, though it was higher ($P \leq 0.05$) in the *M*. *gastrocnemius* and the *M*. *iliotibialis cranialis* compared to that of the pure Black genotype. The *M*. *gastrocnemius* had the lowest ($P \leq 0.05$) percentage of lipid for all three genotypes. No significant differences ($P > 0.05$) were found between genotypes or muscles for the pure Black and Blue x Black genotype regarding percentage ash. However, in the pure Blue genotype the *M*. *iliofemoralis* had the highest ($P \leq 0.05$) percentage of ash, whereas the *M*. *iliofibularis* had the lowest ($P \leq 0.05$) percentage of ash. The highest ($P > 0.05$) content of soluble collagen, myoglobin and cholesterol was found in the Blue x Black genotype, whereas the lowest percentage of the latter constituents was found in the pure Blue genotype. The myoglobin content of the *M*. *gastrocnemius* was significantly higher ($P \leq 0.05$) in the Blue x Black genotype and significantly lower in the pure Blue genotype ($P \leq 0.05$). The insoluble collagen content of the *M*. *gastrocnemius* from the pure Blue genotype was higher ($P \leq 0.05$) compared to the Blue x Black genotype. Although not significant ($P > 0.05$), the total and insoluble collagen content of the *M*. *gastrocnemius* was higher than that of the *M*. *iliofibularis* in the pure Blue genotype. The iron content of the *M*. *gastrocnemius* was the highest ($P \leq 0.05$) in the Blue x Black genotype and the lowest ($P \leq 0.05$) in the pure Blue genotype. As the percentage of moisture in the meat increased, both the percentage of protein ($P < 0.01$, $r = -0.521$) and lipids ($P < 0.01$, $r = -0.637$) present in the meat decreased. An increase in the percentage of lipid also resulted in a decrease in the percentage of protein ($P < 0.01$, $r = -0.270$) and an

increase in the cholesterol content ($P \leq 0.05$, r = 0.405). As the iron content in the meat increased, the myoglobin content increased ($P < 0.01$, r = 0.622), as well as the darkness of the meat (L* value: $P \leq 0.05$, r = -0.436). Although, genotype did influence the chemical characteristics of the meat, this did not occur to such an extent that consumers would notice it or that it would affect the health of consumers.

Keywords: Proximate chemical analysis, collagen, myoglobin, cholesterol, minerals, ostrich muscles

INTRODUCTION

It is estimated that over 90% of the ostrich meat produced in South Africa is exported and in total South Africa contributes up to 70% (950 000 tons per annum) of the total ostrich meat produced worldwide (Hoffman, 2005). Recent statistics regarding the income generated from the various ostrich products indicate that the feathers contribute only 5% to the income, whereas the leather and the meat each contribute 50% and 45% respectively (Hoffman, 2005). The proportional economic value of the meat relative to that of the whole bird has increased over the last few years, while the value of the skin and feathers has decreased (Petitte & Davis, 1999; Van Zyl, 2001; Cloete *et al*., 2002; Hoffman, 2005). This shift to meat as a primary source of income has emphasised the need for more information regarding the quality characteristics of ostrich meat.

Various subspecies of ostrich are characterised by phenotypic differences (Duerden, 1919; Sauer, 1968; Brown *et al*., 1982; Freitag, 1992), including the size of the bird and the growth rate (Madeiros, 1995). Considerable variation in mature live weight is found between Zimbabwean Blue (ZB) ostriches (125 kg) and South African Black (SAB) ostriches (115 kg), as studies by Jarvis (1998) indicate. The chicks of ZB ostriches have a faster growth rate and normally reach a body weight of 95 kg earlier than chicks from the other subspecies (Jarvis, 1998). The more common genotype found and used for ostrich production in South Africa is the SAB ostrich (Madeiros, 1995). Therefore, the ostrich producers will benefit from crossbreeding ZB ostriches and SAB ostriches, if the offspring can grow faster and be larger, without affecting the meat quality negatively. Larger birds will probably produce more meat and a larger skin area that will result in a higher income for the producer per unit slaughtered.

Various studies have been conducted on the chemical characteristics of ostrich meat. However, according to Mellett (University of Stellenbosch, Stellenbosch, South Africa, personal communication), most of these studies investigated the chemical meat quality of the SAB ostrich (*Struthio* (*S*.) *camelus* var. *domesticus*). Only two investigations of the chemical meat quality of other subspecies of ostrich (*S*. *camelus australis* and *S*. *camelus massaicus*) could be sourced (Horbańczuk *et al*., 1998; Girolami *et al*., 2003). A limiting factor in research on ostrich genotypes is that the specific genotype of ostrich is usually not stated by analysts. Another problem in this field of research is that the results are often contradictory. Therefore, it is impossible to develop clear-cut guidelines pertaining to the effect of crossbreeding and genotypes on the chemical composition of ostrich meat. However, it is important to note that genotype does affect the chemical quality of meat. Although several authors have suggested that the crossbreeding of different genotypes of ostriches could improve overall performance, there is currently a tendency to crossbreed

Kenyan Rednecks (*S. camelus massaicus*), ZB and SAB without scientific evidence to guide crossbreeding decisions (Petitte & Davis, 1999).

Perceived healthiness of food is of great importance to the consumer (Fisher *et al*., 2000a) and consumers want to be informed of the nutrient composition of food (Sales & Hayes, 1996; Horbańczuk *et al*., 1998). A lack of public knowledge about the nutritive value of ostrich meat hampers its utilisation (Sales, 1995). Increasing consumer awareness towards the use of alternative exotic types of meat for improved nutritional value and flavour creates an important potential market interest in ostrich meat (Paleari *et al*., 1995). Ostrich meat is considered a healthier product, because of its low intramuscular fat and cholesterol content (Mellett, 1992; Shanawany, 1995; Sales, 1998). The high content of iron makes ostrich meat suitable for use in the diets of teenage and adult women (Stipanuk, 2000), whereas the low content of sodium (Sales & Hayes, 1996) adds value to this type of meat for use in salt-restricted diets of individuals suffering from hypertension (Stipanuk, 2000).

The value of an animal carcass relative to market conditions is influenced by, amongst other factors, the quality of lean meat (Swatland, 1995). The type of muscle influences the content of intramuscular fat (Sales, 1994; Sales & Hayes, 1996; Girolami *et al*., 2003), the presence of different types of collagen (Sales *et al*., 1996b; Girolami *et al*., 2003), the quantity of myoglobin (Lawrie, 1998), cholesterol content (Sales, 1998) and the mineral composition (Sales & Hayes, 1996). According to Mellett (1996a), the majority of ostrich meat cuts found in the ostrich meat market consist of whole, individual muscles, for example, the fan fillet (*M. iliofibularis*) and the big drum (*M. gastrocnemius*). The *M. iliofibularis*, *M. iliofemoralis* and the *M. iliotibialis lateralis* have high economic value, whilst the *M. iliotibialis cranialis*, *M. flexor cruris lateralis*, *M. obturatorius medialis*, *M. femorotibialis accessorius*, *M. fibularis longus* and the *M. gastrocnemius* are some of the larger muscles available in the ostrich meat market (Mellett, 1992).

The present study was therefore undertaken to determine the effect of crossbreeding ZB ostriches and SAB ostriches on the chemical quality of the meat of various individual muscles, thereby providing the ostrich meat industry with scientific information on the effect of crossbreeding the latter two genotypes on the chemical quality characteristics of ostrich meat. The latter characteristics include the moisture, protein, lipid, ash, collagen, myoglobin, cholesterol contents and the mineral composition of the meat.

MATERIALS AND METHODS

Experimental birds and location

A total of 16 ostriches (*S. camelus*), comprised of different genotypes of ostriches, were included in this study to determine the chemical properties of the meat (Fig. 1). The proximate chemical analysis was done on the following ten muscles: *M. femorotibialis accessorius*, *M. flexor cruris lateralis*, *M. iliofemoralis*, *M. iliofemoralis externus*, *M. gastrocnemius*, *M. iliofibularis*, *M iliotibialis lateralis*, *M. obturatorius medialis*, *M. iliotibialis cranialis* and the *M. fibularis longus*. The *M. gastrocnemius* (big drum) and *M. iliofibularis* (fan fillet) are commonly available on the market for consumers to purchase (Mellett, 1992). The *M. iliofibularis* is also described as a muscle with high economic value (Mellett, 1992). Therefore, the latter two muscles were

used to determine their total collagen (mg/g), soluble collagen (mg/g), insoluble collagen (mg/g), myoglobin (mg/100 g) and cholesterol (mg/100 g) contents.

The ostriches were slaughtered during February 2005 at the Klein Karoo Co-operative in Oudtshoorn, South Africa. Experimental birds used in the study comprised of genotypes resulting from crossbreeding between SAB and ZB ostriches (Fig. 1).

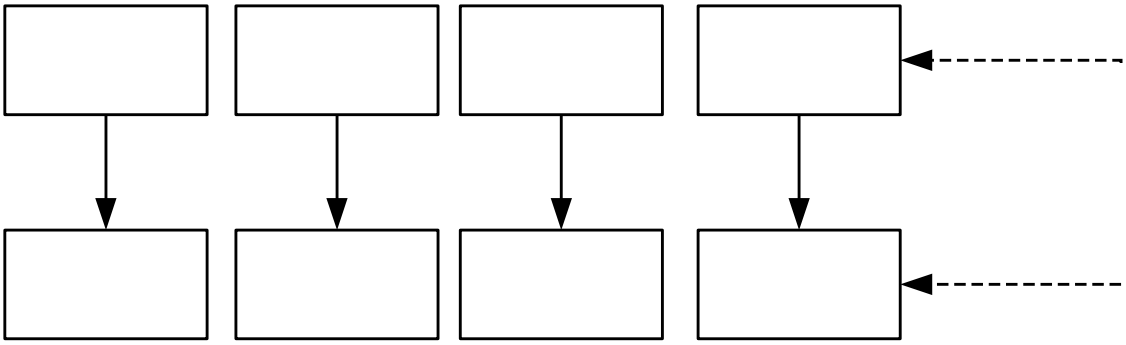

Figure 1 The distribution of slaughtered ostriches used for the chemical studies according to genotypes

The same standard procedures were followed for all the birds. Ostriches were reared on the Oudtshoorn Experimental Farm near Oudtshoorn, South Africa and kept under the same conditions. The topography is rolling with isolated shrubs and a rocky surface. Birds were kept in one flock and housed in a paddock of one hectare. Foraging material in the paddocks was limited and was consumed shortly after the ostriches were introduced to the paddock. No artificial shelter was present. All birds received the same *ad libitum* diet (10.5 MJ energy, 160 g protein/kg dry matter) and had free access to drinking water. Routine management included the harvesting of the white plumage (clipping and plucking). A standard drenching, vaccination and ectoparasitic treatment was applied to all birds. Ostriches were more or less the same age (14 months) at slaughtering. This is the age at which ostriches are slaughtered commercially (Sales, 1999).

Slaughtering

Ostriches were slaughtered at a commercial abattoir at Oudtshoorn following commercial procedures, which involved lairage in roofed pens for a period of 24 h with free access to drinking water. The ostriches were electrically stunned (105–110 V, 400-800 mA, 10 s). After stunning, ostriches were suspended by both legs and bled. A high neck cut and a cut to the aortic vein (thoracic stick) were used to exsanguinate the birds. Bleeding was allowed for 10-15 min, after which plucking, skinning, evisceration and health inspection took place. Following health inspection, legs (drumsticks) were removed within 45 min after stunning. Legs were allowed to chill for 24 h at 0-4°C, after which the left leg was deboned by hand into 10 specific individual muscles (Table 2). These muscles were identified as described by Mellett (1996b). The large membranes and visible fat were trimmed from the individual muscles before subjecting muscles to further analysis. Muscles were places in polyethylene bags, vacuum-sealed and placed in a freezer at -20°C. Pre-preparation for all the chemical analysis included homogenising the lean meat using a Dampa Cutter (Italy, Model no. CT35N). Homogenised meat samples were placed in new polyethylene bags,

vacuum-sealed and placed in a freezer at –20°C until further chemical analysis could be carried out. The vacuum-packed, homogenised meat samples were thawed 12 h prior to chemical analysis.

Chemical analysis

The chemical analysis consisted of proximate chemical analysis (total percentage moisture, protein, lipid and ash) of ten ostrich muscles, as well as the total collagen (mg/g), soluble collagen (mg/g), insoluble collagen (mg/g), myoglobin (mg/100 g), cholesterol (mg/100 g) contents and the mineral composition of the *M. gastrocnemius* and *M. iliofibularis*.

Total percentage moisture, protein and ash of the thawed, homogenised ostrich muscles were determined according to the Association of Official Analytical Chemist's Standard Techniques (AOAC, 2002). The moisture content was analysed by drying a 2.5 g sample at 100°C for a period of 24 h (Method 934.01, AOAC, 2002), after which ashing was done on the dry moisture samples at 500°C for a period of 6 h. To determine protein content the dried, defatted samples were ground with a pestle in a mortar to a fine powder. The protein powder was used to weigh off samples of 0.100 mg into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. A calibration sample (LECO Corporation, USA, Part number 502-092) was analysed with each batch of samples to ensure accuracy and recovery rate. The total lipid content was determined by extracting the fat with a 2:1 mixture of chloroform:methanol (Lee *et al*., 1996).

The amino-acid hydroxyproline is present in collagen and its presence is therefore a reliable indicator of the collagen content present in meat (Sims & Bailey, 1981). Hydroxyproline was determined according to the method of Kolar (1990). A 4 g thawed, homogenised meat sample was hydrolysed in 6 M HCl at 110°C for 12 to 16 h, filtered and diluted to determine total collagen content. To determine soluble and insoluble collagen content, a thawed, homogenised meat sample of 8 g was first separated into soluble and insoluble constituents using NaCl (1%), after which the soluble and insoluble collagen was hydrolysed in 6 M HCl at 110°C for 12 to 16 h, filtered and diluted. Hydroxyproline was oxidised with choloramine-T, excess choloramine-T was deactivated with perchloric acid and the hydroxyproline chromogen was then activated using the colour reagent, 4-dimethylaminobenzaldehyde to develop a pink colour. After calibration, the absorbencies were measured spectrometrically at 560 nm.

Thawed, homogenised meat samples were used to extract myoglobin according to the method described by Krzywicki (1982). Five grams of the homogenised meat sample were weighed out in duplicate per sample, and placed into 50 ml polypropylene centrifuge tubes. Samples were then further homogenised in a 25 ml ice-cold sodium phosphate buffer (pH 6.8, 0.04 M) for 40-45 s at low speed, ensuring that the meat was mixed thoroughly in the solution. Homogenised samples were stored at 4ºC for 1 h, after which the samples were centrifuged at 9000 rpm for 45 min at 4ºC. The supernatant was filtered through Whatman no. 1 filter paper. Individual absorbencies were read at 700 and 525 nm, using phosphate buffer as the blank. The following equation was used to calculate the percentage myoglobin present in the samples:

Myoglobin (mg/ml) = $(A_{525} - A_{700})$ x 2.303 x dilution factor

The cholesterol content was determined using a modified, combined method of Kovacs *et al*. (1979) and Van Jaarsveld *et al*. (2000). The lipids in a 2 g sample of thawed homogenised meat were extracted with choroform/methanol (CM 2:1 v/v) according to a modified method of Folch *et al*. (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (Kinematica, type PT 10-35, Switzerland) was used to homogenise the samples within the extraction solvent, ensuring that the meat was mixed thoroughly in the solution. Sub-samples of the homogenised sample were transferred to a Klimax tube, after which Stigmasterol (3-B-hydroxy-24-ethyl-5.22-cholestadiene; Sigma Chemical Co., USA) was added as internal standard. The contents of the tubes were dried under nitrogen in a 45°C water bath. Ethanol and KOH (50% v/v) were used to saponifise the extractions for 1 h at 70°C in a water bath. After cooling, distilled water and hexane were added. The top phase was transferred to a blood tube and again dried under nitrogen in a 45°C water bath. CS_2 (Sigma Aldrich, HPLC Grade min 99.9%, Catalogue no. 27, 066-0) was added and the resultant extraction was analysed by GLC (Thermo Finnigan Focus GC equipped with flame ionisation detection). A 15 m BPX50 glass column of 0.53 mm internal diameter, 0.50 µm film was used (SGE, Australia). Gas flow rates were: hydrogen (carrier), 30 ml/min; air, 200 ml/min; and nitrogen, 25 ml/min. Temperatures were: injector temperature 220°C; column temperature 250°C; and detector temperature 260°C.

The defatted meat samples were cremated to ash to determine the mineral composition of the meat. The samples (1-3 g) were air-dried and ground to pass through a 0.5 to 1.0 mm sieve. The samples were then ashed overnight in a muffle furnace at 550°C. A 6 M HCl solution was prepared by diluting 500 cm^3 of a 36% (m/m) HCl solution to 1 dm^3. After ashing, 5 cm^3 of a 6 M HCl was added to dissolve the cooled sample. The samples were then dried on a water bath. After cooling, a 5 cm^3 6 M HNO_3 solution was added to the samples. The 6 M HNO_3 solution was prepared by diluting 429 cm^3 of a 65% (m/m) solution to 1 dm^3. After adding the latter solution, the samples were heated on a water bath and removed after boiling point was reached. The solution was subsequently filtered through filter paper into a 100 cm^3 volumetric flask and diluted to volume with deionised water (Giron, 1973). Mineral concentrations (phosphorus, potassium, calcium, magnesium, sodium, iron, copper, zinc, manganese) were then determined by using the Inductively Coupled Plasma Spectrometry (ICP) detection method (Method No: AgriLASA 6.1.1, Handbook of Feed & Plant Analysis, Volume 2).

Statistical analysis

For the proximate chemical analysis (total percentage of moisture, protein, lipid and ash) of the ostrich meat, a two-factor factorial experiment was performed in a randomised block design with 16 block replications (carcasses). The factors were three genotypes (Black x Black, Blue x Black and Blue x Blue) and 10 muscles (*M. femorotibialis accessorius*, *M. flexor cruris lateralis*, *M. iliofemoralis*, *M. iliofemoralis externus*, *M. gastrocnemius*, *M. iliofibularis*, *M iliotibialis lateralis*, *M. obturatorius medialis*, *M. iliotibialis cranialis* and the *M. fibularis longus*). Regarding the total collagen, soluble collagen, insoluble collagen, myoglobin, cholesterol content and the mineral composition of the ostrich meat, a two-factor factorial experiment was performed in a randomised block design with 16 block replications (carcasses). The factors were three genotypes (Black x Black, Blue x Black and Blue x Blue) and 2 muscles (*M. gastrocnemius* and *M. iliofibularis*). An experimental unit was a single carcass. The variables were recorded as interval data and

subjected to an analysis of variance (ANOVA) using SAS version 9 (SAS, 1999) statistical software. Regarding all the statistical analyses, the ANOVA was performed on the full model with factors and interactions included. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 5% significance level to compare treatment means (Ott, 1998). Results were defined as being not significant at a level of $P>0.05$ and significant at a level of $P\leq0.05$. In few cases deviations from normality were the cause of outliers, which were removed before the final analysis. Where there was still significant evidence of non-normality, this could be ascribed to kurtosis rather than skewness. Interpretation of results was thus continued as motivated by Glass *et al*. (1972). Correlations were made using the Pearson product moment correlation coefficient.

RESULTS AND DISCUSSION

Results from the literature pertaining to the chemical quality characteristics of ostrich meat and other species of meat-producing animals are summarised in Tables 1, 4 and 6. Although the specific ostrich genotypes were not noted, Mellett (University of Stellenbosch, Stellenbosch, South Africa, personal communication) stated that it can be accepted that the ostrich genotype used by Sales (1994), Sales (1996), Sales and Hayes (1996), Sales *et al*. (1996a), Sales (1998), Sales *et al*. (1999) and Fisher *et al*. (2000b) was *S. camelus* var. *domesticus* (Black x Black).

The means and standard deviations (± SD) for proximate chemical analysis of the different genotypes of ostrich from this investigation are presented in Tables 2 and 3. As noted in Tables 1 and 2 it can be concluded that moisture percentage of the muscles from this present investigation compared well with those quoted in the literature. In some cases moisture percentages were found to be somewhat lower than the results indicated in Table 1. However, in general this deviation was not more than a percentage unit. Although not significant in all the muscles, it was noted that the percentage of moisture of 80% of the muscles from the pure Blue genotype was the highest compared to the other two genotypes (Table 2). The pure Blue genotype also had a significantly ($P\leq0.05$) higher percentage of moisture than the Blue x Black genotype for the *M. femorotibialis accessorius*, *M. flexor cruris lateralis* and the *M. iliofemoralis externus* (Table 2). As noted in Table 2, quite the opposite was found for the *M. obturatorius medialis*, where the percentage of moisture was higher ($P\leq0.05$) in the Blue x Black genotype compared to the pure Blue genotype.

Regarding differences between the muscles, the *M. fibularis longus* had the highest percentage of moisture ($P\leq0.05$) in all three genotypes (Table 2). In both the pure Black genotype and the Blue x Black genotype, the *M. flexor cruris lateralis* had the lowest ($P\leq0.05$) percentage of moisture (Table 2). The moisture content values were higher than for beef and turkey, but similar to that of chicken (Tables 1 and 2). However, Sales and Hayes (1996) and Paleari *et al*. (1998) state that the moisture content of ostrich meat is higher than that of beef and turkey, as well as chicken.

Table 1 Summary of literature regarding proximate chemical analysis for ostrich, beef, chicken and turkey in general, as well as for different ostrich muscles irrespective of genotype

	Moisture (%)	Protein (%)	Lipid (%)	Ash (%)	References
General					
Ostrich	75.1-76.6	17.5-22.2	0.5-3.6	0.3-1.1	Dunster & Scudamore-Smith, 1992; Sales, 1996 ; Sales *et al*., 1996a; Paleari *et al*., 1998; Fisher *et al*., 2000b; Girolami *et al*., 2003
Beef	71.6-75.0	18.0-22.0	2.0-14.7	1.0-1.2	Paul & Southgate, 1978; Holland *et al*., 1993; Kreibich & Sommer, 1995; Paleari *et al*., 1998
Chicken	73.0-75.5	21.4 -24.0	1.0-4.3	1.0	Paul & Southgate, 1978; USDA, 1979; Kreibich & Sommer, 1995
Turkey	74.8	20.4	3.8	1.0	Paleari *et al*., 1998
Muscles					
M. fibularis longus	77.2	21.0	0.2	1.1	Sales, 1996
M. flexor cruris lateralis	74.6-75.3	21.0-22.4	0.8-3.4	1.1	Sales, 1996; Pollok *et al*., 1997
M. gastrocnemius			2.3		Girolami *et al*., 2003
M. gastrocnemius pars externa	75.6	22.9	2.0		Pollok *et al*., 1997
M. gastrocnemius pars interna	76.0-77.7	19.9-22.4	0.3-1.7	1.0-1.2	Sales, 1996; Sales & Hayes, 1996; Pollok *et al*., 1997; Sales *et al*., 1999
M. iliofemoralis	74.8-75.4	21.9-22.0	0.7-3.1	1.2	Sales, 1996; Pollok *et al*., 1997; Sales *et al*., 1999
M. iliofemoralis externus	75.6	21.6	3.7		Pollok *et al*., 1997
M. iliofibularis	75.9-78.0	20.9-21.8	0.3-2.7	1.0-1.1	Sales, 1996; Sales & Hayes, 1996; Pollok *et al*., 1997; Sales *et al*., 1999; Girolami *et al*., 2003
M. iliotibialis cranialis	75.4-77.3	20.0-21.7	0.5-3.0	1.2	Sales, 1996; Pollok *et al*., 1997
M. iliotibialis lateralis	75.7-77.4	20.5-22.0	0.4-2.4	1.2	Sales, 1996; Pollok *et al*., 1997; Sales *et al*., 1999
M. obturatorius medialis	74.5	22.1	3.2		Pollok *et al*., 1997

Table 2 Means (± SD)[#] for proximate analysis (moisture and protein) of muscles from different genotypes of ostrich

Muscles	Moisture (%)			Protein (%)		
	Black x Black	Blue x Black	Blue x Blue	Black x Black	Blue x Black	Blue x Blue
M. femorotibialis accessorius	75.6 ± 1.47$^{b}{}_{ab}$	75.6 ± 1.66$^{b}{}_{ab}$	77.1 ± 0.22$^{a}{}_{a}$	21.6 ± 1.59$_{ab}$	21.5 ± 1.56$_{ab}$	20.3 ± 0.48$_{c}$
M. fibularis longus	76.1 ± 1.10$_{a}$	75.9 ± 0.48$_{a}$	76.8 ± 0.43$_{a}$	21.3 ± 0.64$_{ab}$	20.8 ± 1.05$_{b}$	20.8 ± 0.06$_{bc}$
M. flexor cruris lateralis	73.0 ± 1.33$^{b}{}_{d}$	73.4 ± 1.67$^{b}{}_{d}$	75.1 ± 1.37$^{a}{}_{bc}$	21.8 ± 1.04$_{ab}$	21.2 ± 0.99$_{ab}$	20.7 ± 1.95$_{bc}$
M. gastrocnemius	75.8 ± 1.24$_{a}$	75.8 ± 0.79$_{ab}$	76.2 ± 0.07$_{ab}$	21.9 ± 0.91$_{a}$	22.4 ± 0.88$_{a}$	22.1 ± 0.29$_{ab}$
M. iliofemoralis	73.6 ± 1.23$_{cd}$	73.7 ± 1.27$_{dc}$	74.8 ± 1.67$_{c}$	22.0 ± 0.96$_{a}$	21.8 ± 0.90$_{ab}$	21.1 ± 1.96$_{bc}$
M. iliofemoralis externus	75.3 ± 1.62$^{ab}{}_{ab}$	74.5 ± 1.05$^{b}{}_{bcd}$	76.1 ± 0.04$^{a}{}_{ab}$	21.6 ± 1.40$_{ab}$	21.7 ± 1.25$_{ab}$	20.9 ± 0.69$_{bc}$
M. iliofibularis	75.6 ± 1.87$_{ab}$	75.9 ± 1.09$_{a}$	75.8 ± 0.59$_{abc}$	21.4 ± 1.73$_{ab}$	21.4 ± 0.93$_{ab}$	22.0 ± 0.48$_{ab}$
M. iliotibialis cranialis	74.9 ± 1.57$_{ab}$	75.1 ± 0.95$_{ab}$	75.4 ± 0.30$_{bc}$	20.5 ± 1.45$_{b}$	20.7 ± 0.63$_{b}$	21.2 ± 0.00$_{bc}$
M. iliotibialis lateralis	75.0 ± 1.19$_{ab}$	74.6 ± 0.74$_{bcd}$	75.4 ± 0.52$_{bc}$	21.4 ± 1.07$_{ab}$	21.6 ± 1.01$_{ab}$	21.5 ± 0.42$_{abc}$
M. obturatorius medialis	74.4 ± 1.28$^{ab}{}_{bc}$	74.8 ± 1.13$^{a}{}_{abc}$	73.4 ± 0.00$^{b}{}_{d}$	21.9 ± 1.41$_{a}$	21.5 ± 1.06$_{ab}$	22.8 ± 0.00$_{a}$
		1.26			1.41	

[#] SD: Standard deviation; LSD: Least significant difference (P=0.05)

[a,b] Means in the same row, within chemical characteristics, with different superscripts are significantly different (P≤0.05)

[a-d] Means in the same column with different subscripts are significantly different (P≤0.05)

Table 3 Means (± SD)[#] for proximate analysis (lipid and ash) of muscles from different genotypes of ostrich

Muscles	Lipid (%)			Ash (%)		
	Black x Black	Blue x Black	Blue x Blue	Black x Black	Blue x Black	Blue x Blue
M. femorotibialis accessorius	2.6 ± 0.48$_{bcd}$	2.6 ± 0.49$_{de}$	2.5 ± 0.67$_{cde}$	1.17 ± 0.205	1.18 ± 0.070	1.19 ± 0.042$_{abcd}$
M. fibularis longus	2.5 ± 0.63^{ab}$_{cd}$	2.9 ± 0.79^{a}$_{cde}$	1.9 ± 0.44^{b}$_{ef}$	1.15 ± 0.057	1.19 ± 0.047	1.10 ± 0.064$_{bcd}$
M. flexor cruris lateralis	3.8 ± 0.61$_{a}$	4.2 ± 0.79$_{a}$	3.6 ± 0.67$_{ab}$	1.20 ± 0.059	1.17 ± 0.092	1.18 ± 0.044$_{abcd}$
M. gastrocnemius	2.4 ± 0.42^{a}$_{d}$	1.9 ± 0.36^{ab}$_{f}$	1.6 ± 0.15^{b}$_{f}$	1.18 ± 0.043	1.23 ± 0.070	1.22 ± 0.030$_{abcd}$
M. iliofemoralis	3.6 ± 0.71$_{a}$	3.8 ± 0.81$_{ab}$	3.7 ± 0.06$_{a}$	1.22 ± 0.016	1.14 ± 0.181	1.27 ± 0.022$_{a}$
M. iliofemoralis externus	2.7 ± 0.37$_{bcd}$	3.4 ± 0.93$_{bc}$	2.8 ± 1.01$_{cd}$	1.21 ± 0.041	1.12 ± 0.197	1.24 ± 0.061$_{abc}$
M. iliofibularis	2.7 ± 0.39$_{bcd}$	2.4 ± 0.55$_{ef}$	2.2 ± 0.08$_{def}$	1.15 ± 0.083	1.15 ± 0.037	1.06 ± 0.110$_{d}$
M. iliotibialis cranialis	3.7 ± 0.56^{a}$_{a}$	3.4 ± 0.53^{ab}$_{bc}$	3.0 ± 0.30^{b}$_{bc}$	1.14 ± 0.102	1.12 ± 0.097	1.09 ± 0.109$_{cd}$
M. iliotibialis lateralis	3.1 ± 0.73$_{abc}$	3.3 ± 0.98$_{bcd}$	3.0 ± 0.86$_{bc}$	1.21 ± 0.033	1.23 ± 0.055	1.26 ± 0.072$_{ab}$
M. obturatorius medialis	3.2 ± 0.58$_{ab}$	3.1 ± 0.64$_{bcd}$	2.9 ± 0.00$_{bc}$	1.26 ± 0.171	1.11 ± 0.199	1.15 ± 0.000$_{abcd}$
		0.69			0.165	

[#] SD: Standard deviation; LSD: Least significant difference (P=0.05)

[a,b] Means in the same row, within chemical characteristics, with different superscripts are significantly different (P≤0.05)

[a-f] Means in the same column with different subscripts are significantly different (P≤0.05)

Results of the present investigation for the percentage of protein correspond well with results found in the literature (Table 1). As noted in Table 2, no significant differences (P>0.05) or patterns whatsoever were found between genotypes regarding the percentage of protein present in the ostrich meat. Results comparing protein content of ostrich meat to protein content of meat derived from other species of meat-producing animals are contradictory. Results for the protein content of this investigation indicated that the protein content of ostrich meat is higher than that of turkey, more or less the same as that of beef, but lower than that of chicken (Tables 1 and 2). According to Joubert (2003), ostrich meat has been traditionally marketed as lean meat with a high protein content compared to beef, chicken and pork. Paleari *et al*. (1998) found that ostrich meat is slightly higher in protein content compared to beef and turkey, whereas Sales and Hayes (1996) found that beef is higher in protein content. Schweigert (1987) found that the protein content, as well as the amino acid composition of meat protein, irrespective of species, remains constant independent of cut. Ostrich meat is similar in protein content and amino acid composition compared to other conventional meat types (Sales & Hayes, 1996).

Most of the studies listed in Table 1 only mention the percentage of ether-extractable fat. This investigation made use of a different method (chloroform-methanol extraction) to determine the percentage of lipid present in the ostrich meat. According to Jensen (2004), ether-extraction is used to determine total fat content consisting of triglycerides (neutral lipids). However, other lipid components (charged lipids) such as phospholipids and free fatty acids are not included using this type of extraction (Jensen, 2004). Although these latter lipid components have a relatively low concentration in meat products (1% or less), in some cases it is important to include them for a true total fat measurement (Jensen, 2004). Results from the literature using the ether-extraction method are summarised in Table 1 and indicate a lipid percentage range of 0.2 – 3.7%. The chloroform-methanol extraction method used in the present investigation would have included the phospholipids and other minor lipids (Jensen, 2004). The lipid range from the present investigation was 1.6 – 4.2%, indicating somewhat higher values for lipids (Table 3) because of the method used. Research done by Girolami *et al*. (2003) on *S*. *camelus australis* (Blue x Blue) indicated percentages of lipids of 1.99 ± 0.10%, 1.24 ± 0.10% and 2.26 ± 0.10% for the *M*. *iliofibularis*, *M*. *gastrocnemius* and the *M*. *iliotibialis*, respectively. The same subspecies (*S*. *camelus australis*) was investigated by Horbaňczuk *et al*. (1998), indicating percentages of lipids of 1.50 ± 0.06% for the *M*. *iliofibularis* and 1.54 ± 0.07% for the *M*. *gastrocnemius*. The results of the present investigation for lipid content (Table 3) in pure Blue ostriches deviate less than a percentage unit from results by Horbaňczuk *et al*. (1998) and Girolami *et al*. (2003). Similar to moisture percentage, eight of the ten muscle groups from the pure Blue genotype also had the lowest percentage of lipids (Table 3). This difference was not significant (P>0.05) in all the muscles. Regarding the *M*. *gastrocnemius* and the *M*. *iliotibialis cranialis*, a higher (P≤0.05) percentage of lipids were found in the pure Blue genotype compared to the pure Black genotype (Table 3). According to Table 3, the *M*. *flexor cruris lateralis* had the highest percentage of lipids in both the pure Black and the Blue x Black genotype, whereas the *M*. *gastrocnemius* had the lowest (P≤0.05) percentage of lipids for all three genotypes.

Ostrich meat is considered a healthier product and is even described as an alternative for red meat (Sales, 1994; Sales, 1998), because of its low intramuscular fat content (Mellett, 1992; Shanawany, 1995; Sales, 1998). The lipid content of ostrich meat in the present investigation (Table 3) was lower than that of

beef and was more or less the same as that of chicken and turkey, the so-called white meat types (Table 1). According to Sales (1994), ostrich meat is lower in lipid content than beef, mutton and pork.

As the content of moisture in the ostrich meat increased, the content of the lipids ($P<0.01$, r = -0.637) and protein ($P<0.01$, r = -0.521) both decreased. This is a result of a natural correlation between the percentage of water, protein and lipids in a part-whole relationship in the meat (Lawrie, 1998). Furthermore, as the content of lipids present in the ostrich meat increased, a descriptive sensory panel (refer to Chapter 5) perceived the meat to have a higher degree of sustained juiciness ($P\leq0.05$, r = 0.458). As a result of the naturally low percentage of intramuscular fat in ostrich meat (Mellett, 1992; Shanawany, 1995; Sales, 1998), a loss of sustained juiciness occurs during mastication and the consumer is left with the perception of a dry product (Sales, 1999). However, as the lipid content increases, the sustained juiciness of the meat also increases, as can be seen in the latter significant correlation.

Results for the percentage of ash of the present study correlate well with those noted in the literature (Table 1). No significant differences ($P>0.05$) or patterns were found between genotypes or between muscles for the pure Black and Blue x Black genotype regarding percentage ash (Table 3). The only exception was found between muscles in the pure Blue genotype. In this genotype the *M. iliofibularis* had the lowest ($P\leq0.05$) percentage of ash, whereas the *M. iliofemoralis* had the highest ($P\leq0.05$) percentage of ash (Table 3). The ash content of ostrich meat from this investigation (Table 3) is similar to the ash content mentioned for beef (Table 1), but slightly higher than that of chicken and turkey (Table 1). According to Sales and Hayes (1996), the ash content of ostrich meat is higher than that of beef and chicken, whereas Paleari *et al*. (1998) found beef to have a higher ash content.

The means and standard deviations (± SD) for the different types of collagen content, myoglobin content and cholesterol content of the *M. gastrocnemius* and *M. iliofibularis* for the different genotypes of ostrich from this investigation are presented in Table 5. The total content of collagen found in the present investigation was more or less similar to that noted in Table 4 for ostrich meat in general. However, the total collagen content, as well as the insoluble collagen content of the *M. gastrocnemius* and the *M. iliofibularis* (Table 5), was much lower than that found by other researchers specifically for these latter two muscles (Table 4). It must be noted that limited research is available on the different types of collagen content and the myoglobin content in ostrich meat.

Research by Girolami *et al*. (2003) on *S. camelus australis* (Blue x Blue) indicated a cholesterol content of 60.70 ± 1.40 mg/100 g and 59.96 ± 1.40 mg/100 g for the *M. iliofibularis* and the *M. gastrocnemius*, respectively. Horbaňczuk *et al*. (1998) mentioned a cholesterol content of 65.63 ± 2.69 mg/100 g for the *M. iliofibularis* and 68.38 ± 2.19 mg/100 g for the *M. gastrocnemius* of the same subspecies (*S. camelus australis)*. Results of the present investigation for the cholesterol content of the *M. iliofibularis* (61 ± 1.1 mg/100 g) for the pure Blue genotype (Table 5) correspond well with results reported by Girolami *et al*. (2003), however, they are somewhat lower than those of Horbaňczuk *et al*. (1998). Conversely, the cholesterol content of the *M. gastrocnemius* (76 ± 15.6 mg/100 g) from the pure Blue genotype was much higher than that indicated by both Horbaňczuk *et al*. (1998) and Girolami *et al*. (2003).

Table 4 Summary of literature regarding percentage of total collagen, insoluble collagen and content of cholesterol for ostrich, beef, chicken and turkey in general, as well as for different ostrich muscles irrespective of genotype

	Total collagen (%)	Insoluble collagen (%)	Cholesterol (mg/100 g)	References
General				
Ostrich	0.16 - 0.44		33.8 - 62.0	Heinze *et al*., 1986; Sales, 1994; Sales, 1996 ; Sales *et al*., 1996a; Paleari *et al*., 1998; Girolami *et al*., 2003
Beef	0.18 - 0.34		50.1 - 60.0	Paul & Southgate, 1978; Boccard *et al*., 1979; Holland *et al*., 1993; Paleari *et al*., 1998
Chicken			70.0	Paul & Southgate, 1978; USDA, 1979
Turkey	0.14		36.6	Paleari *et al*., 1998
Muscles				
M. gastrocnemius		0.575		Sales, 1994
			60.0	Girolami *et al*., 2003
M. gastrocnemius pars externa			65.0	Pollok *et al*., 1997
M. gastrocnemius pars interna	0.61		58.7- 66.0	Sales, 1996; Pollok *et al*., 1997; Sales, 1998
M. iliofibularis	0.30	0.287	60.7 - 73.0	Sales, 1994 ; Sales, 1996; Pollok *et al*., 1997; Sales, 1998; Girolami *et al*., 2003

Table 5 Means (± SD)[#] for content of collagen, myoglobin and cholesterol of the *M. gastrocnemius* and *M. iliofibularis* from different genotypes of ostrich

Chemical parameters	Muscles	Black x Black	Blue x Black	Blue x Blue	LSD
Total collagen (mg/g)	*M. gastrocnemius*	1.12 ± 0.157	1.04 ± 0.078	1.16 ± 0.270$_a$	0.166
	M. iliofibularis	0.96 ± 0.006	1.03 ± 0.094	0.96 ± 0.005$_b$	
Soluble collagen (mg/g)	*M. gastrocnemius*	0.2387 ± 0.00196	0.2397 ± 0.00425	0.2386 ± 0.00188	0.0044
	M. iliofibularis	0.2373 ± 0.00139	0.2377 ± 0.00181	0.2362 ± 0.00031	
Insoluble collagen (mg/g)	*M. gastrocnemius*	0.71 ± 0.061^a	0.61 ± 0.096^b	0.74 ± 0.016^a $_a$	0.090
	M. iliofibularis	0.63 ± 0.014	0.63 ± 0.049	0.60 ± 0.125$_b$	
Myoglobin (mg/100 g)	*M. gastrocnemius*	9.0 ± 0.89^b	10.4 ± 2.14^a	7.6 ± 1.29^c	1.30
	M. iliofibularis	9.3 ± 1.82	9.3 ± 2.01	8.9 ± 1.72	
Cholesterol (mg/100 g)	*M. gastrocnemius*	91 ± 31.9	91 ± 26.2	76 ± 15.6	53.4
	M. iliofibularis	92 ± 29.4	99 ± 32.5	61 ± 1.1	

[#] SD: Standard deviation

[a-c] Means in the same row with different superscripts are significantly different ($P \leq 0.05$)

[a,b] Means in the same column, within chemical characteristics, with different subscripts are significantly different ($P \leq 0.05$)

LSD: Least significant difference ($P=0.05$)

As far as the content of soluble collagen, myoglobin and cholesterol (Table 5) is concerned, the highest and lowest values for both muscles were found in the same genotype. The highest contents for all three chemical constituents were found in the Blue x Black genotype, whereas the lowest contents were found in the pure Blue genotype (Table 5). For the latter three constituents only the myoglobin content of the *M. gastrocnemius* was significantly higher ($P \leq 0.05$) in the Blue x Black genotype and significantly lower ($P \leq 0.05$) in the pure Blue genotype ($P \leq 0.05$). As seen in Table 5, the only other significant genotype difference ($P \leq 0.05$) was found for insoluble collagen content of the *M. gastrocnemius*, where the insoluble collagen content of the latter muscle from the pure Blue genotype was higher ($P \leq 0.05$) than that of the Blue x Black genotype. The range for cholesterol content in the present investigation (Table 5) was much higher than indicated by previous researchers (Table 4). However, it should also be noted that the lipid content of the meat was also higher than indicated by previous researchers (Tables 1 and 3), as a result of more lipids being extracted using the chloroform-methanol extraction method (Jensen, 2004). As the lipid content of the ostrich meat increased, the cholesterol content of the meat also increased ($P \leq 0.05$, r = 0.405). According to Lawrie (1998), the main components of fat are fatty acids and unsaponifiable constituents, such as cholesterol. Therefore, the higher the content of lipids extracted, the more cholesterol would also have been extracted as a constituent of the lipids. However, Sales (1994) mentioned that the cholesterol content does not increase as intramuscular fat increases. According to Sales (1999), cholesterol is a structural component of cell membranes and the sub-cellular distribution of cholesterol differs in muscle tissue. Therefore, he states that an intramuscular fat content is poorly correlated to cholesterol content (Sales, 1994). However, according to the Jensen (2004), muscle fibres have approximately 75% of their cholesterol associated with membranes and the other 25% associated with their neutral lipids. Therefore, if the content of neutral lipids in the muscle increases, the content of cholesterol will also increase. Although there are contradictory opinions (Sales, 1999), it seems as though the cholesterol content may increase as the intramuscular fat content increases. Ostrich meat is usually considered a healthier product, partially because of its low cholesterol content (Mellett, 1992; Shanawany, 1995; Sales, 1998). As a result of the extraction method used, the cholesterol content (Table 5) of the present investigation was higher than results reported for beef, chicken and turkey (Table 4), whereas Pollok *et al*. (1997) noted that the cholesterol content of ostrich meat was similar to levels found in meat from other species.

When comparing muscles, it was found that the total and insoluble collagen content of the *M. gastrocnemius* was higher than that of the *M. iliofibularis* of the pure Blue genotype (Table 5). The latter result confirms the significant result found in Chapter 5 (Table 7) indicating that the *M. gastrocnemius* was tougher than the *M. iliofibularis*. A significant correlation was found between the total collagen content and instrumental tenderness ($P \leq 0.05$, r = 0.396). Young and Braggings (1993) found a similar correlation. This correlation can be explained by the fact that tenderness is related to the connective tissue present in the meat (Lawrie, 1998; Sales, 1999). Collagen is the principal fibrous protein in connective tissue (Tarrant, 1998) and this leads to the distinct correlation between total collagen content and the toughness of meat as illustrated.

An increase in insoluble collagen content of the meat, resulted in a decrease of the sustained juiciness of the meat ($P \leq 0.05$, r = -0.453). When collagen is exposed to heat of about 65^{o}C, it contracts to one quarter of its original length (Bailey & Sims, 1977). This contraction causes an increase in tension and

fluid is exuded from the muscle, resulting in an increase in meat toughness (Bailey & Sims, 1977), as well as a decrease in juiciness. However, at the same temperature (60-65^{o}C) a percentage of the collagen is solubilised and converted into gelatine (Lawrie, 1998). This soluble part of collagen does not influence meat toughness or juiciness. Therefore, it is postulated that it was only the insoluble collagen that affected the sustained juiciness of the meat.

The total collagen content of the present investigation (Table 5) was lower than corresponding results for beef and turkey (Table 4). According to Sales (1996), ostrich meat has a relatively low content of connective tissue. Sales (1994) stated that the total collagen content of ostrich meat is lower than that found in beef, mutton and pork. However, it must be noted that most of the superficial collagen is removed in the de-membraning of the muscles in the breaking plant prior to the muscle/meat being sold to the consumer (Saint, 1999), whilst this is not always the scenario with the more traditionally farmed species such as beef.

Pigment content contributes to the colour of meat (Sales, 1996). The red colour of meat is mainly the result of myoglobin, which accounts for 75% of the pigment in red meat (Lawrie, 1998). Lawrie (1998) indicated the myoglobin content of beef and mutton at 5 mg/100 g and 2.5 mg/100 g, respectively. In comparison to beef and mutton, ostrich meat is very dark in appearance (Otremba *et al*., 1999). According to Lawrie (1998) the dark colour of meat in general is a result of the high pH_f (Lawrie, 1998). Therefore, the dark colour of ostrich meat may be a result of the high pH mentioned in Chapter 5, Table 3 (Lawrie, 1998), as well as the myoglobin content (Table 5; Sales, 1996).

The means and standard deviations (± SD) for the mineral composition of the *M*. *gastrocnemius* and *M*. *iliofibularis* of the different ostrich genotypes from this investigation are presented in Table 7. The content of phosphorus, potassium, sodium and copper of this study (Table 7), was much lower than indicated in the literature (Table 6). However, the concentrations of the other minerals generally corresponded well with those reported in Table 6. Regarding the phosphorus, iron and manganese content of the ostrich meat, the highest and lowest contents for both the *M*. *gastrocnemius* and the *M*. *iliofibularis* were found in the same genotype (Table 7). The phosphorus and manganese contents were the highest in the pure Black genotype and the lowest in the pure Blue genotype for both muscles (Table 7). The genotype differences for the phosphorus content were not significant (P>0.05) in any of the muscles, but the manganese content differed significantly (P≤0.05) with respect to genotype in both muscles (Table 7). The manganese content in the pure Black genotype was significantly (P≤0.05) higher compared to the pure Blue genotype in both the *M*. *gastrocnemius* and the *M*. *iliofibularis* (Table 7), however, it must be noted that the latter is not necessarily a biologically significant difference. The iron content was the highest in the Blue x Black genotype and the lowest in the pure Blue genotype (Table 7). The only significant genotype difference (P≤0.05) for iron content was found in the *M*. *gastrocnemius* (Table 7).

Table 6 Summary of literature regarding mineral composition for ostrich, beef and chicken in general, as well as for different ostrich muscles irrespective of genotype

	Phosphorus (mg/100 g)	Potassium (mg/100 g)	Calcium (mg/100 g)	Magnesium (mg/100 g)	Sodium (mg/100 g)	Iron (mg/100 g)	Copper (mg/100 g)	Zinc (mg/100 g)	Manganese (mg/100 g)	References
General										
Ostrich	213	269 - 340	8	22	43 - 63	2.3	0.10	2.0	0.06	Paleari *et al*., 1995; Sales & Hayes, 1996
Beef	201	358	6	23	63	2.2	0.08	4.4	0.01	Paul & Southgate, 1978; Holland *et al*., 1993
Chicken	173	229	12	25	77	0.9	0.05	1.5	0.02	Paul & Southgate, 1978; USDA, 1979
Muscles										
	206	268	9	21	47	2.0	0.09	2.2	0.05	Sales & Hayes, 1996
M. gastrocnemius pars interna			5		72	2.3				Pollok *et al*., 1997
	214	272	9	22	41	2.5	0.10	1.1	0.05	Sales & Hayes, 1996
M. iliofibularis			6		75	4.4				Pollok *et al*., 1997

Table 7 Means (± SD)[#] for mineral composition of the *M. gastrocnemius* and *M. iliofibularis* from different genotypes of ostrich

Minerals	Muscles	Black x Black	Blue x Black	Blue x Blue	LSD
Phosphorus (mg/100 g)	*M. gastrocnemius*	135 ± 13.7	134 ± 8.9	134 ± 6.5	22.8
	M. iliofibularis	144 ± 32.4	140 ± 23.5	139 ± 8.3	
Potassium (mg/100 g)	*M. gastrocnemius*	132 ± 4.2	146 ± 22.3	141 ± 9.8$_b$	17.9
	M. iliofibularis	138 ± 2.4^b	141 ± 11.6^b	162 ± 2.7^a $_a$	
Calcium (mg/100 g)	*M. gastrocnemius*	6.5 ± 0.35	7.2 ± 1.60$_a$	6.7 ± 0.09	1.37
	M. iliofibularis	6.4 ± 0.52	5.6 ± 1.26$_b$	6.7 ± 0.02	
Magnesium (mg/100 g)	*M. gastrocnemius*	24.4 ± 2.25	25.0 ± 2.21	24.4 ± 3.47	2.58
	M. iliofibularis	25.0 ± 3.88	24.6 ± 2.27	26.7 ± 0.08	
Sodium (mg/100 g)	*M. gastrocnemius*	11.4 ± 1.20	12.5 ± 1.73	13.0 ± 1.41	11.60
	M. iliofibularis	19.2 ± 19.09	11.3 ± 1.10	14.1 ± 0.61	
Iron (mg/100 g)	*M. gastrocnemius*	1.9 ± 0.26^{ab}	2.1 ± 0.51^a	1.7 ± 0.09^b	0.40
	M. iliofibularis	1.8 ± 0.35	1.8 ± 0.45	1.7 ± 0.20	
Copper (mg/100 g)	*M. gastrocnemius*	0.022 ± 0.0045	0.031 ± 0.0145	0.025 ± 0.0071	0.0192
	M. iliofibularis	0.036 ± 0.0195	0.027 ± 0.0100	0.030 ± 0.0141	
Zinc (mg/100 g)	*M. gastrocnemius*	3.4 ± 0.85$_a$	3.2 ± 0.43$_a$	4.0 ± 0.71$_a$	0.87
	M. iliofibularis	1.2 ± 0.11$_b$	1.5 ± 0.47$_b$	1.6 ± 0.22$_b$	
Manganese (mg/100 g)	*M. gastrocnemius*	0.038 ± 0.0045^a	0.038 ± 0.0067^a	0.030 ± 0.0000^b	0.0067
	M. iliofibularis	0.042 ± 0.0084^a	0.037 ± 0.0050^{ab}	0.035 ± 0.0071^b	

[#] SD: Standard deviation

^{a,b} Means in the same row with different superscripts are significantly different ($P \leq 0.05$)

$_{a,b}$ Means in the same column, within chemical characteristics, with different subscripts are significantly different ($P \leq 0.05$)

LSD: Least significant difference ($P=0.05$)

Regarding differences between muscles, the zinc content of the *M. gastrocnemius* was higher ($P \leq 0.05$) than the zinc content of the *M. iliofibularis* in all three genotypes (Table 7). According to Lawrie (1998), potassium is quantitatively the most important mineral in traditional types of meat, followed by phosphorus. As can be seen in Table 7, ostrich meat is similar to traditional types of meat pertaining to the potassium and phosphorus content described by Lawrie (1998). Sales and Hayes (1996) and Pollok *et al*. (1997) also found that ostrich meat contains a greater content of iron than meat derived from beef, chicken and pork. The iron content of the present investigation corresponds well with that mentioned in the literature (Table 6). The sodium content of the ostrich muscles of this investigation was much lower to that derived from beef and chicken (Table 6). Sales and Hayes (1996) also found ostrich meat to have a low sodium content.

As the iron content in the ostrich meat increased, the meat became darker and had a lower L* value ($P \leq 0.05$, r = -0.436) and a higher content of myoglobin ($P<0.01$, r = 0.622). An increase in the content of myoglobin also resulted in the meat becoming darker and therefore having a lower L* value ($P<0.01$, r =

-0.577). The dark colour of ostrich meat is partially the result of the pigment content (Sales, 1996). According to Lawrie (1998), myoglobin accounts for 75% of the pigment in red meat and there is a central iron atom in every myoglobin molecule. Therefore, as the myoblobin content of the meat increases, the iron content increases and the meat becomes darker (low L* value), as can be deducted from the latter correlations. Pollok *et al*. (1997) found that the high iron content of ostrich meat contributes to the deep red colour of ostrich meat. Although the high iron content of this meat adds a health advantage to its consumption, the associated darker colour renders the meat less acceptable, especially in the case of female consumers (Kubberød *et al*., 2002).

CONCLUSION

The effect of ostrich genotype – including SAB, ZB and the genotype resulting from crossbreeding between the former two genotypes – on the chemical meat quality characteristics was investigated in this study. Genotype influenced the chemical quality of the muscles, including the percentage moisture, percentage lipid and mineral composition. It seems that meat derived from the pure Blue genotype had higher moisture, lower lipid and lower cholesterol content, resulting in meat with a healthier nutritional profile. However, these genotype differences were not of such a magnitude that they will influence the health of consumers considerably. Thus, crossbreeding of SAB and ZB ostriches can be a viable option to produce larger birds with more meat without negatively affecting the quality of the meat.

The muscles also differed regarding their chemical characteristics. These muscle differences can be used in the marketing of the various ostrich muscles, for example, the *M*. *gastrocnemius* had the lowest fat content.

There are three problems hindering the development of clear-cut guidelines pertaining to the effect of crossbreeding on the chemical composition of ostrich meat. Firstly, most studies available use the SAB genotype; secondly, limited research is available on specific chemical characteristics such as myoglobin and collagen; and thirdly, results in the literature are often contradictory.

Due to the possibilities of exploiting the health properties of ostrich meat as a market strategy and using the meat as a health product, it is recommended that further investigations should be done on the lipid and cholesterol content of ostrich and other types of meat. It is advised that the comparison of ostrich meat to beef, mutton, pork, chicken and fish should be done in a single study to ensure consistency of analytical methods used, although it can be argued, and correctly so, that the environmental factors (nutritional and genetic) have a stronger influence on the chemical composition of animals than does laboratory analysis of muscle/meat samples.

There is also a need for further investigation into the effect of genotype on the chemical quality of the meat with more ostriches present in the Black x Blue genotype and the Blue x Blue genotype to ensure more representative results. Studies on other populations of SAB and ZB ostriches will also add robustness to the present findings.

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CHAPTER 7

The fatty acid composition of muscles and fat depots of South African Black (SAB), Zimbabwean Blue (ZB) and SAB x ZB ostriches

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The fatty acid composition of muscles and fat depots of South African Black (SAB), Zimbabwean Blue (ZB) and SAB x ZB ostriches

ABSTRACT

Currently, crossbreeding in ostriches is being done without scientific evidence guiding the crossbreeding decisions. Crossbreeding with SAB ostriches (*Struthio camelus* var. *domesticus*) and ZB ostriches (*Struthio camelus australis*) seems to be a viable option for producing ostriches with a higher quantity of meat and a larger skin area. However, it is important that the breeding should not affect the meat quality negatively. Three genotypes of ostrich, resulting from crossbreeding with SAB ostriches and ZB ostriches, were used to investigate the influence of genotype on the fatty acid composition of the *M. gastrocnemius*, the *M. iliofibularis*, the abdominal fat depot and the breast fat depot. The fatty acid compositions were analysed quantitatively (mg/g) and qualitatively (percentage of total fatty acids present). Ostriches reared in the same pens and fed the same commercial diet were slaughtered at the standard commercial age of 14 months. The fatty acids C16:0 (16.5 ± 1.89% to 19.9 ± 2.11%), C18:0 (10.0 ± 1.31% to 11.8 ± 2.75%), C18:1*n*-9c (25.1 ± 0.04% to 29.3 ± 3.74%), C18:2*n*-6c (12.3 ± 2.20% to 13.7 ± 1.48%), C16:1*n*-7 (4.5 ± 1.17% to 5.6 ± 1.30%) and C20:3*n*-3 (6.1 ± 1.17% to 8.9 ± 0.73%) were present at the highest concentrations in the two muscles. Saturated fatty acids (SFA) contributed 30.4 ± 1.46% to 38.6 ± 6.16%, monounsaturated fatty acids (MUFA) contributed 33.2 ± 0.31% to 41.9 ± 3.07% and polyunsaturated fatty acids (PUFA) contributed 26.5 ± 5.34% to 33.2 ± 0.93% to the total fatty acids present in the ostrich meat. The concentration of SFA in the meat was higher ($P \leq 0.05$) in the Blue x Black and also in the *M. illiofibularis* of the pure Blue genotype compared to the pure Black genotype, whereas the concentrations of total unsaturated fatty acids (TUFA) in the meat were the highest ($P \leq 0.05$) in the *M. illiofibularis* of the pure Black genotype compared to the other two genotypes. Regarding the muscles, the pure Black genotype (only in the *M. illiofibularis*) had significantly higher ($P \leq 0.05$) desirable fatty acid (DFA) values (80.6 $\pm$ 1.6%) compared to the other two genotypes, while the concentration of MUFA was also higher ($P \leq 0.05$) in the pure Black genotype than in the other two genotypes. PUFA concentration in the muscles was higher ($P \leq 0.05$) in the *M. gastrocnemius* of the pure Blue genotype compared to the pure Black genotype. No significant genotype differences ($P > 0.05$) were observed for the total fatty acid content, the P:S ratio and the *n*-6:*n*-3 ratio of the muscles. In the fat depots C16:0 (29.6 ± 0.57% to 30.8 ± 1.28%), C18:1*n*-9c (30.1 ± 0.00% to 33.7 ± 0.60%), C18:0 (4.8 ± 0.00% to 5.7 ± 1.18%), C16:1*n*-7 (9.2 ± 1.17% to 10.5 ± 0.00%) and C18:2*n*-6c (12.4 ± 0.00% to 14.3 ± 1.28%) were the dominant fatty acids present. The concentration of SFA of both fat depots was significantly higher ($P \leq 0.05$) in the pure Blue genotype compared to the pure Black genotype, while the concentration of MUFA and TUFA in both fat depots was higher ($P \leq 0.05$) in the pure Black genotype compared to the pure Blue genotype. Regarding the fat depots, the PUFA concentration was the highest ($P \leq 0.05$) in the abdominal fat depot of the Blue x Black genotype compared to the pure Blue genotype. The percentage of DFA in the abdominal fat depot was significantly higher ($P \leq 0.05$) for the pure Black and the Blue x Black genotype. The SFA concentration was the highest ($P \leq 0.05$) in the abdominal fat depot of the pure Blue genotype, while the concentrations of PUFA and TUFA were the highest ($P \leq 0.05$) in the breast fat depot of

the pure Blue genotype. Results regarding the fat depots indicated concentrations of SFA ranging from 37.0 ± 0.68% to 40.7 ± 0.00%, MUFA ranging from 42.4 ± 0.00% to 44.3 ± 1.00% and PUFA ranging from 16.9 ± 0.00% to 19.2 ± 1.99%. No significant differences were observed for total fatty acid content (mg/g fat), with quantities ranging from 233 ± 18.9 mg/g to 242 ± 35.0 mg/g for the breast fat and 230 ± 7.3 mg/g to 264 ± 0.0 mg/g for the abdominal fat. The P:S ratio of the fat depots was the highest ($P \leq 0.05$) in the pure Black and Blue x Black genotype. Regarding differences between types of fat depot, the P:S ratio was the highest ($P \leq 0.05$) in the breast fat of the pure Blue genotype. The P:S ratio for the breast fat depot ranged from 0.50 ± 0.029 to 0.51 ± 0.066, while the P:S ratio for the abdominal fat ranged from 0.42 ± 0.000 to 0.49 ± 0.040. No significant differences ($P > 0.05$) or patterns were observed regarding the *n*-6:*n*-3 ratio of the fat depots. The *n*-6:*n*-3 ratio ranged from 3.3 ± 0.82 to 3.9 ± 1.56 in the breast fat depot and ranged from 3.0 ± 0.00 to 4.5 ± 1.73 in the abdominal fat depot. Results seem to indicate that the pure Black genotype has a more positive unsaturated fatty acid profile in both the muscles and both the fat depots. Therefore, the muscles derived from crossbred ostriches have a very positive fatty acid profile for human consumption. However, the fat depots of the Blue x Black genotype also seem to have a more positive unsaturated fatty acid profile.

Keywords: Fatty acid composition, ostrich muscles, ostrich fat depots, ostrich adipose tissue

INTRODUCTION

Healthy food is of great importance to consumers (Fisher *et al*., 2000) and hence consumers wish to be informed about the nutrient composition of food (Sales & Hayes, 1996; Horbaňczuk *et al*., 1998). According to the Vitamin Information Centre (2005), diet has an effect on the rising incidence of lifestyle and dietary-induced diseases such as depression, cardiovascular disease, obesity, Type 2 diabetes and osteoporosis. A balanced intake of fatty acids (low intake of saturated fatty acids and a high intake of polyunsaturated and monounsaturated fatty acids) is essential for healthy cell membranes, normal human development, healthy infant nutrition, mental health in adults, bone health, healthy skin, strong immunity, as well as for the prevention of cancer (Vitamin Information Centre, 2005). The so-called metabolic syndrome is a growing phenomenon worldwide and its spectrum includes cardiovascular disease, obesity, insulin resistance and Type 2 diabetes. The healthy consumption of fatty acids is important in preventing this syndrome and its associated illnesses (Vitamin Information Centre, 2005). Meat is seen as a major source of fat, especially saturated fatty acids (SFA) and it can contribute to various diseases, such as cardiovascular diseases and cancer (Stipanuk, 2000). A high intake of SFA, a high *n*-6:*n*-3 ratio, as well as a high intake of cholesterol, are risk factors for humans with coronary heart disease and atherosclerosis (Sales, 1998; Santos-Silva *et al*., 2002; Girolami *et al*., 2003; Vitamin Information Centre, 2005)

Wood *et al*. (2004) mention that the interest in the fatty acid composition of meat originated mainly from the need to find ways to produce healthier meat. Ostrich meat has a favourable fatty acid profile and contains a relatively high content of polyunsaturated fatty acids (PUFA) and a lower content of SFA (Mellett, 1992; Sales, 1998). According to Girolami *et al*. (2003), ostrich meat has a high concentration of the essential polyunsaturated linoleic (C18:2) and arachidonic (C20:4) acids and an excellent *n*-6:*n*-3 ratio. However, a lack of public knowledge about the nutritive value of ostrich meat hampers its utilisation (Sales, 1995).

Fatty acids play a major role in the metabolism of cholesterol. According to Stipanuk (2000), cholesterol is one of the first food components that medical doctors advise should be reduced in diets of hypercholesterolemic patients. However, cholesterol also has important life functions; for example, it forms part of cell membranes (Sales, 1999; Stipanuk, 2000). Lipoproteins mediate the exchange of cholesterol in the human body (Lawrie, 1998; Sales, 1999; Stipanuk, 2000). The low-density lipoproteins (LDL) transport more than two thirds of the blood cholesterol to the cells (Lawrie, 1998; Sales, 1999; Stipanuk, 2000). Factors that affect the LDL level in blood also affect the total blood cholesterol levels (Lawrie, 1998; Sales, 1999; Stipanuk, 2000). The high-density lipoproteins (HDL) transport cholesterol from the cells to the liver so that it can be eliminated from the body (Sales, 1999; Stipanuk, 2000). A low level of HDL increases the risk of arteriosclerosis and cardiovascular disease (Lawrie, 1998; Sales, 1999; Stipanuk, 2000). An increased intake of SFA increases the plasma level of LDL, whilst it is decreased by the intake of PUFA (Lawrie, 1998; Sales, 1999; Stipanuk, 2000). An intake of PUFA, however, also decreases the plasma level of HDL, whereas the intake of monounsaturated fatty acids (MUFA) decreases the level of LDL with no effect on the HDL (Mattson & Grundy, 1985; Lawrie, 1998; Sales, 1999; Stipanuk, 2000). Therefore, reducing SFA and increasing PUFA and MUFA results in reducing human blood cholesterol (Sinclair *et al*., 1982; Mattson & Grundy, 1985).

Phenotypic differences characterise the various subspecies of ostrich (Duerden, 1919; Sauer, 1968; Brown *et al*., 1982; Freitag, 1992). Jarvis (1998) indicates considerable variation in mature live weight between Zimbabwean Blue (ZB) ostriches (125 kg) and South African Black (SAB) ostriches (115 kg), whereas the chicks of ZB ostriches have a faster growth rate and normally reach a body weight of 95 kg earlier than chicks from the other subspecies. The SAB ostrich is more commonly used for ostrich production in South Africa (Madeiros, 1995). Therefore, the ostrich producers will theoretically benefit from crossbreeding ZB ostriches and SAB ostriches, if the offspring can grow faster and be larger without adversely affecting the meat quality. Larger birds will probably produce more meat and a larger skin area that will result in a higher income for the producer per unit slaughtered.

According to Mellett (University of Stellenbosch, Stellenbosch, South Africa, personal communication), ostriches used in the majority of meat quality studies done in South Africa are of the SAB genotype (*Struthio* (*S*.) *camelus* var. *domesticus*). Only two investigations of the fatty acid composition of meat from other subspecies of ostrich (*S. camelus australis* and *S. camelus massaicus*) could be sourced (Horbaňczuk *et al*., 1998; Girolami *et al*., 2003). Subspecies in other meat-producing animals are known to affect the concentration of fatty acids (Lawrie, 1998), whereas genotype affects adipose tissue and muscle fatty acid composition (Boylan *et al*., 1976; Kemp *et al*., 1981, Sañudo *et al*., 1998). Several authors have suggested crossbreeding of different genotypes of ostriches to improve overall performance. However, crossbreeding is currently done between Kenyan Rednecks (*S. camelus massaicus*), ZB and SAB ostriches without scientific evidence to guide these decisions (Petitte & Davis, 1999).

Nutrient composition differs between muscles in the same ostrich carcass (Sales, 1996; Sales & Hayes, 1996). Therefore type of muscle affects the concentration of fatty acids (Sales, 1994; Lawrie, 1998; Sales, 1998; Girolami *et al*., 2003). Sales (1998) found that the percentage of individual fatty acids, as well as the percentage of total SFA, MUFA and PUFA, differed between muscles in SAB ostriches. According to

Mellett (1996a), the majority of ostrich meat is sold as whole, individual muscles. The *M. gastrocnemius* is one of the larger muscles available in the ostrich meat market, while the *M. iliofibularis* has a high economic value (Mellett, 1992).

As opposed to what happens in broilers, extra-muscular fat forms a layer in the abdominal cavity of ostriches. Most of the flavour of ostrich meat is stored within this fat depot (Sales, 1994). This deposition of fat mainly in the abdominal cavity results in an exceptionally low intramuscular fat content of the meat (Sales, 1999). The breast fat, which is a layer of fat overlaying the sternum (Sales, 1999), supplies a smaller quantity of extra-muscular fat. Research on the detailed fatty acid analysis of bird fats is limited.

This investigation was undertaken to determine the effect of crossbreeding ZB ostriches and SAB ostriches on the fatty acid composition of the *M. gastrocnemius* and the *M. iliofibularis*, thereby providing the ostrich industry with scientific information regarding the effect of crossbreeding on the fatty acid profile of ostrich meat. However, considering the limited research done on ostrich adipose tissue in fat depots, this study was extended to determine the effect of crossbreeding ZB ostriches and SAB ostriches on the fatty acid composition of two different fat depots.

MATERIALS AND METHODS

Experimental birds and location

A total of 16 ostriches (*S. camelus*), comprised of different genotypes of ostriches, were included in this study to determine the fatty acid composition of the meat (Fig. 1). The fatty acid analysis was done on the *M. gastrocnemius* and the *M. iliofibularis*. According to Mellett (1992), the *M. gastrocnemius* (big drum) and *M. iliofibularis* (fan fillet) are commonly available on the market for consumers to purchase and the latter muscle has high economic value. However, for determining the abdominal fat only 14 ostriches were used (Fig. 2).

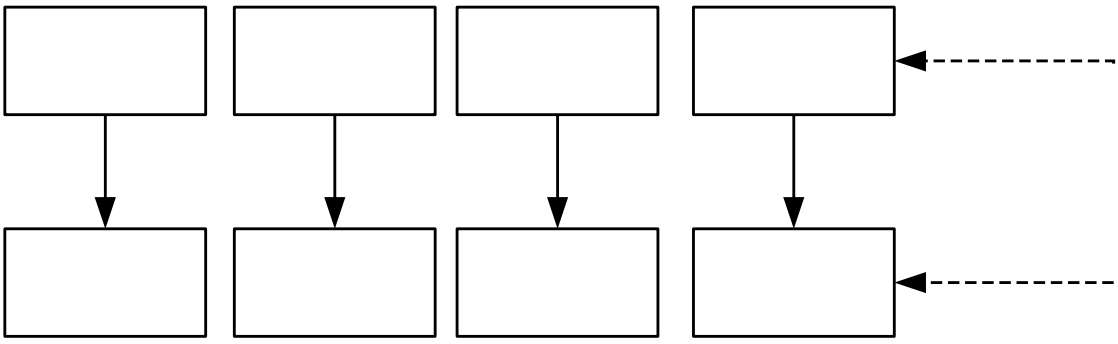

Figure 1 The distribution of slaughtered ostriches used for fatty acid analysis of the meat and breast fat according to genotypes

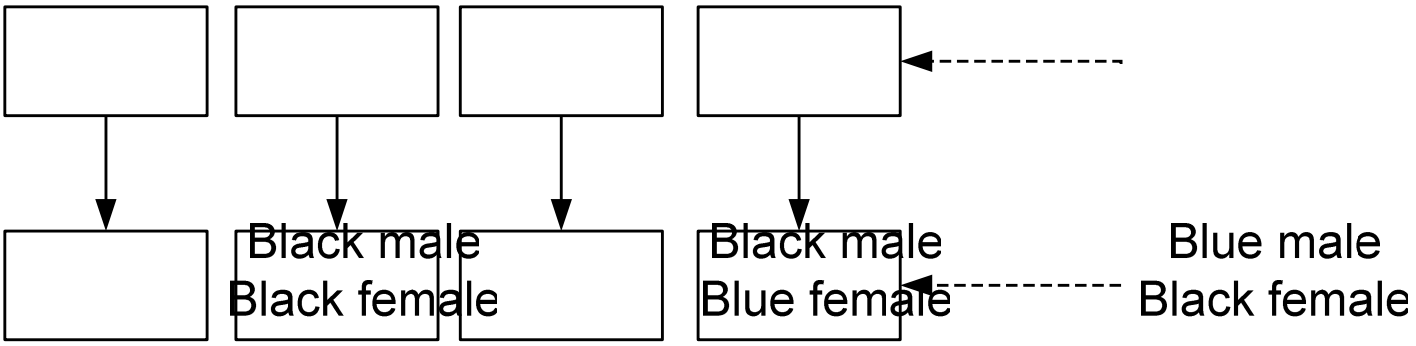

Figure 2 The distribution of slaughtered ostriches used for fatty acid analysis of the abdominal fat according to genotypes

The same standard procedures were followed for all the birds. Ostriches were reared on the Oudtshoorn Experimental Farm near Oudtshoorn, South Africa and kept under the same conditions. The topography is rolling with isolated shrubs and a rocky surface. Birds were kept in one flock and housed in a paddock of one hectare. Foraging material in the paddocks was limited and was consumed shortly after the ostriches were introduced to the paddock. No artificial shelter was present. All birds received the same *ad libitum* diet (10.5 MJ energy, 160 g protein/kg dry matter) and had free access to drinking water. Routine management included the harvesting of the white plumage (clipping and plucking). A standard drenching, vaccination and ectoparasitic treatment was applied to all birds. Ostriches were of the same age (14 months) at slaughtering. This is the age at which ostriches are slaughtered commercially (Sales, 1999).

Black x Black Black x Blue Blue x Black

53 0 8

Slaughtering

Ostriches were slaughtered during February 2005 at Klein Karoo Co-operative, a commercial abattoir in Oudtshoorn, South Africa, following commercial procedures, which involved lairage in roofed pens for a period of 24 h with free access to drinking water. The ostriches were electrically stunned (105–110 V, 400-800 mA, 10 s). After stunning, ostriches were suspended by both legs and bled. A high neck cut and a cut to the aortic vein (thoracic stick) were used to exsanguinate the birds. Bleeding was allowed for 10-15 min, after which plucking, skinning, evisceration and health inspection took place. Following health inspection, legs (drumsticks) were removed within 45 min after stunning. Legs were allowed to chill for 24 h at 0-4°C, after which the left leg was deboned by hand to remove the *M. gastrocnemius* and the *M. iliofibularis*. These muscles were identified as described by Mellett (1996b). The large membranes and visible fat were trimmed from the individual muscles before subjecting muscles to further analysis. Muscles were placed in polyethylene bags, vacuum-sealed and frozen at –20°C. Pre-preparation for all the chemical analysis included homogenising the lean meat using a Dampa Cutter (Italy, Model no. CT35N). Homogenised meat samples were placed in new polyethylene bags, vacuum-sealed and placed in a freezer at –20°C until further chemical analysis could be carried out. The vacuum-packed, homogenised meat samples were thawed 12 hours prior to chemical analysis. The main deposition of fat in the ostrich is in the abdominal cavity, while the breast fat is a layer of fat overlaying the sternum (Sales, 1999). After health inspection, fat samples were removed from the ostrich carcasses, placed in polyethylene bags and frozen at –20°C until further chemical analysis. Fat samples were not homogenised or thawed in order to prevent oxidation of the fatty acids.

Fatty acid analysis

The fatty acid content of the two muscles and fat depots was determined using the same method described by Tichelaar *et al*. (1998). Using thawed meat samples and frozen fat samples, the lipid in a 2 g sample of meat and a 1 g sample of fat was extracted with choroform/methanol (CM 2:1; v/v) according to a modified method of Folch *et al*. (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (Kinematica, type PT 10-35, Switzerland) was used to homogenise the sample within the extraction solvent. Heptadecanoic acid (C17:0) was used as an internal standard (Catalogue no. H3500, Sigma Aldrich Inc. 595 North Harrison Road, Bellefonte, PA 16823-0048, USA) to quantify the individual fatty acids. A sub-sample of the extracted lipids was transmethylated for 2 h at 70°C using methanol/sulphuric acid (19:1; v/v) as transmethylating agent. After cooling, the resulting fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane phase was transferred to a Klimax tube and dried under nitrogen. The FAME were purified by using TLC Silica gel 60 plates (Merck, Cat no. 1.05721.0001) and analysed by GLC (Thermo Finnigan Focus GC equipped with flame ionisation detection) using 60 m BPX70 capillary columns of 0.25 mm internal diameter, 0.25 µm film (SGE, Australia). Gas flow rates were: hydrogen, 25 ml/min; and hydrogen carrier gas 2-4 ml/min. Temperature programming was linear at 4°C/min, with an initial temperature of 140°C, a final temperature of 240°C, an injector temperature of 220°C and a detector temperature of 260°C. The FAME in the total lipids was identified by comparison of the retention times to those of a standard FAME mixture (SuplecoTM 37 Component FAME Mix, Catalogue no. 18919-1AMP, Lot no. LB-16064. Sigma Aldrich Inc. North Harrison Road, Bellefonte, PA 16823-0048, USA).

Statistical analysis

Regarding the fatty acid analysis of the meat and the breast fat, a two-factor factorial experiment was performed in a randomised block design with 16 block replications (carcasses). The factors were three genotypes (Black x Black, Blue x Black and Blue x Blue) and 2 muscles (*M*. *gastrocnemius* and *M*. *iliofibularis*) for the meat samples, whereas two types of fat (breast fat and abdominal fat) were used to analyse the data of the fat samples. However, only 14 block replications (carcasses) were used in order to analyse the data of the abdominal fat samples. An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an analysis of variance (ANOVA) using SAS version 9 (SAS, 1999) statistical software. Regarding all the statistical analyses, the ANOVA was performed on the full model with factors and interactions included. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at the 5% significance level to compare treatment means (Ott, 1998). Results were defined as being not significant at a level of $P>0.05$ and significant at a level of $P\leq0.05$. In few cases deviations from normality were the cause of outliers, which were removed before the final analysis. Where there was still significant evidence of non-normality, this could be ascribed to kurtosis rather than skewness. Interpretation of results was thus continued as motivated by Glass *et al*. (1972). Correlations were estimated using the Pearson product moment correlation coefficient.

RESULTS AND DISCUSSION

Due to the biological interaction between fat, cholesterol and fatty acids, the lipid and cholesterol contents of this present investigation as noted in Chapter 6 are summarised in Table 1.

Table 1 Means (± SD)[#] for lipid and cholesterol contents of the *M*. *gastrocnemius* and *M*. *iliofibularis* from different genotypes of ostrich (as summarised in Chapter 6)

Chemical parameters	Muscles	Black x Black	Blue x Black	Blue x Blue	LSD
Lipid (%)	*M*. *gastrocnemius*	2.4 ± 0.42[a]	1.9 ± 0.36[ab]	1.6 ± 0.15[b]	0.69
	M. *iliofibularis*	2.7 ± 0.39	2.4 ± 0.55	2.2 ± 0.08	
Cholesterol (mg/100 g)	*M*. *gastrocnemius*	91 ± 31.9	91 ± 26.2	76 ± 15.6	53.4
	M. *iliofibularis*	92 ± 29.4	99 ± 32.5	61 ± 1.1	

[#] SD: Standard deviation

[a-b] Means in the same row with different superscripts are significantly different ($P \leq 0.05$)

LSD: Least significant difference ($P = 0.05$)

The lipid and cholesterol contents in the present investigation (Table 1) were higher than indicated by previous researchers, as a result of more lipids being extracted using the chloroform-methanol extraction method (Jensen, 2004). Research by Girolami *et al*. (2003) on *S*. *camelus australis* (Blue x Blue) indicated a cholesterol content of 60.70 ± 1.40 mg/100 g and 59.96 ± 1.40 mg/100 g for the *M*. *iliofibularis* and the *M*. *gastrocnemius*, respectively. Horbańczuk *et al*. (1998) mentioned a cholesterol content of 65.63 ± 2.69 mg/100 g for the *M*. *iliofibularis* and 68.38 ± 2.19 mg/100 g for the *M*. *gastrocnemius* of the same subspecies (*S*. *camelus australis)*. Results of the present investigation for the cholesterol content of the *M*. *iliofibularis* (61 ± 1.1 mg/100 g) for the pure Blue genotype (Table 1) correspond well with results reported by Girolami *et al*. (2003), however, they are somewhat lower than those of Horbańczuk *et al*. (1998). Conversely, the cholesterol content of the *M*. *gastrocnemius* (76 ± 15.6 mg/100 g) from the pure Blue genotype was much higher than that indicated by both Horbańczuk *et al*. (1998) and Girolami *et al*. (2003).

No significant differences between muscles or genotypes were observed regarding the cholesterol content of the ostrich meat. As noted in Table 1, the highest and lowest values for cholesterol content of both muscles were found in the same genotype. Although not significant, the highest cholesterol content was found in the Blue x Black genotype, whereas the lowest cholesterol content was found in the pure Blue genotype (Table 1).

As the lipid content of the ostrich meat increased, the cholesterol content of the meat also increased ($P \leq 0.05$, r = 0.405). The main components of fat are fatty acids and unsaponifiable constituents, such as cholesterol (Lawrie, 1998). Therefore, the higher the quantity of lipids extracted, the more cholesterol would also have been extracted as a constituent of the lipids. However, Sales (1994) mentioned that the cholesterol content does not increase as intramuscular fat increases, noting also that cholesterol is a structural component of cell membranes and the sub-cellular distribution of cholesterol differs in muscle tissue (Sales, 1999; Cooper & Horbańczuk, 2002). Therefore, he states that intramuscular fat content is poorly correlated to cholesterol content (Sales, 1994). However, according to the Jensen (2004), muscle fibres have approximately 75% of their cholesterol associated with membranes and the other 25%

associated with their neutral lipids. Therefore, if the content of neutral lipids in the muscle increases, the cholesterol content will also increase. It therefore seems that, as opposed to statements by Sales (1999), the content of cholesterol may increase as the content of intramuscular fat increases.

According to Enser *et al*. (1998), it is useful to present the fatty acid composition in mg per g muscle, especially when calculating its nutritional value. Alternatively, the fatty acid composition can be expressed as a percentage of the total identified fatty acids present. The fatty acid composition (% of total fatty acids present) and fatty acid content (mg/g meat sample) of the *M*. *gastrocnemius* and *M*. *iliofibularis* from different genotypes of ostrich are presented in Table 2 and Table 3, respectively. All the fatty acids present in the muscles were analysed and presented, however, only specific fatty acids are discussed.

According to Table 2, the fatty acids palmitic (C16:0), stearic (C18:0), oleic (C18:1*n*-9c) and linoleic acid (C18:2*n*-6c) were present in the highest concentrations, followed by palmitelaidic (C16:1*n*-7) and eicosatrienoic acid (C20:3*n*-3) at somewhat lower concentrations. According to Lawrie (1998), intramuscular fat composition of all animal species consists mainly of palmitic (C16:0), stearic (C18:0), oleic (C18:1*n*-9c) and linoleic (C18:2*n*-6c) acid. As noted in the above results and also stated by Mellett (1996b), ostrich meat is no different. As with ostrich meat, a high percentage of oleic acid (C18:1*n*-9c) is also found in beef, pork, mutton and poultry (Cambero *et al*., 1991; Sales, 1998). SFA contributed 32.9 ± 2.74% to 36.4 ± 1.67% of the total fatty acids present in the *M*. *gastrocnemius* and 30.4 ± 1.46% to 38.6 ± 6.16% of the total fatty acids present in the *M*. *iliofibularis* (Table 2). The concentration of SFA was the highest ($P \leq 0.05$) in the *M*. *iliofibularis* of the pure Blue genotype (38.6 ± 6.16%). Palmitic acid (C16:0) was the SFA with the highest concentration ($P \leq 0.05$) in the *M*. *iliofibularis* of the pure Blue genotype (19.9 $\pm$ 2.11%) and the Blue x Black (19.2 $\pm$ 3.19%) genotype (Table 2). As noted in Table 2, concentrations of MUFA ranged from 33.2 ± 0.31% to 40.6 ± 4.22% in the *M*. *gastrocnemius* and 34.2 ± 0.02% to 41.9 ± 3.07% in the *M*. *iliofibularis*, while concentrations of PUFA ranged from 26.5 ± 5.34% to 33.2 ± 0.93% in the *M*. *gastrocnemius* and 27.7 ± 2.82% to 29.9 ± 4.51% in the *M*. *iliofibularis*. Approximately one third of the total fatty acids in the intramuscular fat of ostrich meat are monounsaturated (Table 2, Mellett, 1996b). Oleic acid (C18:1*n*-9c) contributed most to the MUFA, followed by a lower concentration of palmitelaidic acid (C16:1*n*-7), whereas linoleic acid (C18:2*n*-6c) was the PUFA present in the highest concentration and eicosatrienoic acid (C20:3*n*-3) was present at a lower concentration (Table 2). In ostrich meat oleic acid (C18:1*n*-9c) is the dominant fatty acid, followed by palmitic acid (C16:0) and then linoleic acid (C18:2*n*-6c) (Sales, 1994; Horbańczuk *et al*., 1998; Paleari *et al*., 1998; Sales, 1998; Hoffman & Fisher, 2001). Similar results were found in this investigation (Table 2). Oleic acid (C18:1*n*-9c) has health advantages in lowering the levels of blood cholesterol (Harris *et al*., 1993). Linoleic acid (C18:2*n*-6c) is an essential fatty acid (Lawrie, 1998; Stipanuk, 2000). According to Mellett (1996b), intramuscular ostrich fat contains 16.5% of the essential polyunsaturated *n*-6 fatty acid, linoleic acid (C18:2*n*-6c). Results of the present study (Table 2) are similar to these findings.

Table 2 Means (± SD)[#] of fatty acid composition (% of total fatty acids present) of the *M. gastrocnemius* and *M. iliofibularis* from different ostrich genotypes

Fatty acids	Muscles	Genotype			LSD
		Black x Black	Blue x Black	Blue x Blue	(*P*=0.05)
SFA					
C10:0	*M. gastrocnemius*	0.00 ± 0.000^{b}	0.21 ± 0.122^{a}	0.16 ± 0.120^{a}	0.116
	M. iliofibularis	0.02 ± 0.035^{b}	0.14 ± 0.067^{b}	0.13 ± 0.069^{ab}	
C12:0	*M. gastrocnemius*	0.09 ± 0.110^{b}	0.14 ± 0.048^{ab}	0.25 ± 0.065^{a}	0.145
	M. iliofibularis	0.07 ± 0.101	0.15 ± 0.075	0.20 ± 0.044	
C14:0	*M. gastrocnemius*	0.51 ± 0.181$_{a}$	0.38 ± 0.093	0.36 ± 0.253	0.242
	M. iliofibularis	0.23 ± 0.188$_{b}$	0.35 ± 0.104	0.38 ± 0.288	
C16:0	*M. gastrocnemius*	18.3 ± 1.60	17.3 ± 2.45	17.8 ± 0.06	2.40
	M. iliofibularis	16.5 ± 1.89^{b}	19.2 ± 3.19^{a}	19.9 ± 2.11^{a}	
C18:0	*M. gastrocnemius*	11.2 ± 2.28	11.8 ± 2.75	10.3 ± 1.38	3.05
	M. iliofibularis	11.0 ± 1.04	10.0 ± 1.31	10.6 ± 2.03	
C20:0	*M. gastrocnemius*	0.18 ± 0.070	0.21 ± 0.105	0.14 ± 0.052	0.654
	M. iliofibularis	0.14 ± 0.040	0.56 ± 0.746	0.14 ± 0.065	
C22:0	*M. gastrocnemius*	0.17 ± 0.096^{ab}	0.27 ± 0.173^{a}	0.11 ± 0.000^{b}	0.156
	M. iliofibularis	0.16 ± 0.076	0.13 ± 0.070	0.20 ± 0.117	
C24:0	*M. gastrocnemius*	1.10 ± 0.476	1.10 ± 0.632	1.13 ± 0.118	0.707
	M. iliofibularis	0.98 ± 0.223	0.84 ± 0.219	1.01 ± 1.144	
MUFA					
C14:1	*M. gastrocnemius*	0.09 ± 0.058	0.15 ± 0.092	0.11 ± 0.069	0.219
	M. iliofibularis	0.10 ± 0.065	0.18 ± 0.229	0.05 ± 0.072	
C16:1*n*-7	*M. gastrocnemius*	5.6 ± 1.30	4.5 ± 1.17	5.0 ± 0.80	1.11
	M. iliofibularis	4.6 ± 0.93	5.2 ± 1.15	5.1 ± 2.02	
C18:1*n*-9t	*M. gastrocnemius*	0.24 ± 0.085	0.55 ± 0.688	0.19 ± 0.034	0.843
	M. iliofibularis	0.24 ± 0.097	0.57 ± 0.452	0.27 ± 0.003	
C18:1*n*-9c	*M. gastrocnemius*	27.4 ± 1.35	26.5 ± 2.97	25.1 ± 0.04	2.76
	M. iliofibularis	29.3 ± 3.74^{a}	26.7 ± 2.85^{ab}	26.4 ± 2.02^{b}	
C20:1*n*-9	*M. gastrocnemius*	0.26 ± 0.046	0.30 ± 0.095	0.25 ± 0.010	0.086
	M. iliofibularis	0.29 ± 0.032	0.25 ± 0.047	0.28 ± 0.039	
C22:1*n*-9	*M. gastrocnemius*	0.08 ± 0.089	0.13 ± 0.070	0.14 ± 0.087$_{b}$	0.132
	M. iliofibularis	0.10 ± 0.078^{b}	0.08 ± 0.045^{b}	0.37 ± 0.245^{a}$_{a}$	
C24:1*n*-9	*M. gastrocnemius*	0.3 ± 0.15^{b}	0.6 ± 0.37^{b}	2.3 ± 0.53^{a}	1.13
	M. iliofibularis	1.0 ± 1.37	0.6 ± 0.60	1.5 ± 0.33	
PUFA					
C18:2*n*-6t	*M. gastrocnemius*	1.7 ± 1.48	1.1 ± 1.41	1.2 ± 1.48	1.98
	M. iliofibularis	2.4 ± 1.36	1.2 ± 1.09	1.2 ± 1.62	
C18:2*n*-6c	*M. gastrocnemius*	12.6 ± 0.92	13.1 ± 1.17	12.8 ± 0.10	1.79
	M. iliofibularis	13.7 ± 1.48	13.5 ± 0.99	12.3 ± 2.20	
C18:3*n* -6	*M. gastrocnemius*	0.05 ± 0.053	0.52 ± 0.491	0.19 ± 0.120	0.921
	M. iliofibularis	0.09 ± 0.065	0.65 ± 0.911	0.31 ± 0.050	

Table 2 (Continued) Means (± SD)[#] of fatty acid composition (% of total fatty acids present) of the *M. gastrocnemius* and *M. iliofibularis* from different ostrich genotypes

Fatty acids	Muscles	Genotype			LSD (*P*=0.05)
		Black x Black	Blue x Black	Blue x Blue	
C18:3*n* -3	*M. gastrocnemius*	1.7 ± 0.50	1.5 ± 0.40	1.7 ± 0.35	0.93
	M. iliofibularis	1.3 ± 0.66	1.6 ± 0.83	1.6 ± 0.25	
C20:2	*M. gastrocnemius*	0.2 ± 0.04^{b}	0.4 ± 0.34^{b}	1.1 ± 1.17$^{a}{}_{a}$	0.63
	M. iliofibularis	0.3 ± 0.10	0.3 ± 0.37	0.2 ± 0.05$_{b}$	
C20:3*n*-6	*M. gastrocnemius*	0.6 ± 0.08^{b}	1.9 ± 0.51^{a}	2.1 ± 0.09^{a}	0.64
	M. iliofibularis	0.7 ± 0.33^{b}	1.5 ± 0.31^{a}	2.0 ± 0.20^{a}	
C20:3*n*-3	*M. gastrocnemius*	7.2 ± 2.68	6.8 ± 1.84	8.9 ± 0.73	3.46
	M. iliofibularis	6.5 ± 2.38	6.1 ± 1.17	6.9 ± 3.35	
C20:4*n*-6	*M. gastrocnemius*	0.2 ± 0.08^{b}	0.4 ± 0.37^{b}	1.1 ± 0.00$^{a}{}_{a}$	0.59
	M. iliofibularis	0.2 ± 0.08	0.5 ± 0.41	0.5 ± 0.42$_{b}$	
C20:5*n*-3	*M. gastrocnemius*	0.55 ± 0.172	0.55 ± 0.285	0.70 ± 0.071	0.272
	M. iliofibularis	0.45 ± 0.181	0.52 ± 0.256	0.46 ± 0.090	
C22:2	*M. gastrocnemius*	0.3 ± 0.32	2.6 ± 4.16	0.6 ± 0.81	4.10
	M. iliofibularis	0.4 ± 0.29	2.3 ± 2.83	0.3 ± 0.19	
C22:5*n*-3	*M. gastrocnemius*	0.8 ± 0.50^{b}	0.6 ± 0.57^{b}	1.8 ± 0.01$^{a}{}_{a}$	0.75
	M. iliofibularis	0.9 ± 0.52	0.9 ± 0.38	0.3 ± 0.08$_{b}$	
C22:6*n*-3	*M. gastrocnemius*	0.6 ± 0.22	0.8 ± 0.49	1.1 ± 0.11	0.60
	M. iliofibularis	0.7 ± 0.38	0.7 ± 0.38	1.1 ± 0.91	
SFA	*M. gastrocnemius*	32.9 ± 2.74^{b}	36.4 ± 1.67^{a}	33.7 ± 1.24$^{ab}{}_{b}$	3.18
	M. iliofibularis	30.4 ± 1.46^{b}	35.9 ± 2.75^{a}	38.6 ± 6.16$^{a}{}_{a}$	
MUFA	*M. gastrocnemius*	40.6 ± 4.22^{a}	33.2 ± 3.96^{b}	33.2 ± 0.31^{b}	5.12
	M. iliofibularis	41.9 ± 3.07^{a}	34.2 ± 3.76^{b}	34.2 ± 0.02^{b}	
PUFA	*M. gastrocnemius*	26.5 ± 5.34^{b}	30.4 ± 4.67^{ab}	33.2 ± 0.93^{a}	6.42
	M. iliofibularis	27.7 ± 2.82	29.9 ± 4.51	27.2 ± 6.18	
TUFA	*M. gastrocnemius*	67.1 ± 2.74^{a}	63.6 ± 1.67^{b}	66.3 ± 1.24$^{ab}{}_{a}$	3.18
	M. iliofibularis	69.6 ± 1.46^{a}	64.1 ± 2.75^{b}	61.4 ± 6.16$^{b}{}_{b}$	
DFA	*M. gastrocnemius*	78.3 ± 1.25	75.4 ± 2.43	76.6 ± 2.62$_{a}$	4.60
	M. iliofibularis	80.6 ± 1.60^{a}	74.1 ± 2.97^{b}	72.0 ± 8.19$^{b}{}_{b}$	
n-6	*M. gastrocnemius*	15.2 ± 1.86	17.0 ± 3.21	17.3 ± 1.41	3.71
	M. iliofibularis	17.1 ± 1.44	17.4 ± 2.05	16.3 ± 1.25	
n-3	*M. gastrocnemius*	10.8 ± 3.64	10.3 ± 2.39	14.1 ± 0.36	4.36
	M. iliofibularis	9.9 ± 1.98	9.8 ± 2.33	10.4 ± 4.68	

[#] SD: Standard deviation

[a,b] Means in the same row with different superscripts are significantly different ($P \leq 0.05$)

[a,b] Means in the same column, within each fatty acid, with different subscripts are significantly different ($P \leq 0.05$)

LSD: Least significant difference (P=0.05)

Abbreviations: SFA: Saturated Fatty Acids
MUFA: Monounsaturated Fatty Acids
PUFA: Polyunsaturated Fatty Acids
TUFA: Total Unsaturated Fatty Acids
DFA: Desirable Fatty Acids (C18:0 + TUFA)
n-6 = C18:2*n*-6t + C18:2*n*-6c + C18:3*n* -6 + C20:3*n*-6 + C20:4*n*-6
n-3 = C18:3*n* -3 + C20:3*n*-3 + C20:5*n*-3 + C22:5*n*-3 + C22:6*n*-3

The concentration of SFA was significantly higher ($P \leq 0.05$) in the Blue x Black genotype compared to the pure Black genotype for both muscles (Table 2). However, it is also noted that the SFA in the pure Blue genotype was significantly higher ($P \leq 0.05$) compared to the pure Black genotype for the *M*. *illiofibularis* (Table 2). According to Table 2, the concentration of MUFA was higher ($P \leq 0.05$) in the pure Black genotype than in the two other genotypes. The PUFA concentration was the highest ($P \leq 0.05$) in the *M*. *gastrocnemius* of the pure Blue genotype when compared to the pure Black genotype (Table 2). As opposed to this, Sales (1994) found that the *M*. *gastrocnemius* and the *M*. *iliofibularis* from SAB ostriches contained higher percentages of total PUFA. According to Table 2, the concentration of total unsaturated fatty acids (TUFA) was the highest ($P \leq 0.05$) in the pure Black genotype compared to the Blue x Black genotype, as well as one of the muscles in the pure Blue genotype (*M*. *illiofibularis*). The latter muscle in the pure Black genotype also illustrated significantly higher ($P \leq 0.05$) desirable fatty acid (DFA) values (80.6 $\pm$ 1.6%) compared to the other two genotypes (Table 2). According to Rhee (1992), the DFA is the sum of the TUFA and stearic acid (C18:0). Stearic acid (C18:0), one of the dominant SFA in the present study, has health-promoting advantages, i.e. it lowers blood cholesterol. From these results it seems as though the pure Black genotype has a more positive unsaturated fatty acid profile in both muscles.

Present results for percentage fatty acid composition of meat derived from pure Black ostriches were generally the same as the results by Sales *et al*. (1996) and Sales (1998), except for the polyunsaturated arachidonic acid (C20:4*n*-6) of the current investigation, which was present in much lower concentrations (Table 2). According to Horbańczuk *et al*. (1998), the percentage of some individual fatty acids differed between the subspecies *S. camelus massaicus* (Red Neck) and *S. camelus australis* (pure Blue) ($P \leq 0.05$). With respect to the pure Blue genotype, results from this investigation (Table 2) were generally the same as results by Horbańczuk *et al*. (1998), except for the percentage of palmitic acid (C16:0) and oleic acid (C18:1*n*-9c), which were somewhat lower in the present study, while the total percentage of PUFA was somewhat higher in the present study. Girolami *et al*. (2003) conducted research on pure Blue ostriches. Results for pure Blue ostriches of the present study (Table 2) were generally the same as those reported by Girolami *et al*. (2003). Sales *et al*. (1996) and Paleari *et al*. (1998) reported that ostrich meat has a higher concentration of PUFA than beef, broilers and turkey. When comparing the results of this study (Table 2) to available results by Sales *et al*. (1996) and Paleari *et al*. (1998), ostrich meat also had a higher concentration of PUFA. However, present results for TUFA were much higher than those reported by Paleari *et al*. (1998).

Table 3 Means (± SD)[#] of fatty acid content (mg/g meat sample) of the *M. gastrocnemius* and *M. iliofibularis* from different ostrich genotypes

Fatty acids	Muscles	Genotype			LSD (*P*=0.05)
		Black x Black	Blue x Black	Blue x Blue	
Total FA	*M. gastrocnemius*	12 ± 3.2	14 ± 6.3	13 ± 3.2	4.6
	M. iliofibularis	15 ± 3.8	18 ± 4.7	15 ± 3.2	
SFA					
C10:0	*M. gastrocnemius*	0.000 ± 0.0000^{b}	0.025 ± 0.0093^{a}	0.019 ± 0.0105^{a}	0.0106
	M. iliofibularis	0.003 ± 0.0068^{b}	0.025 ± 0.0139^{a}	0.021 ± 0.0146^{a}	
C12:0	*M. gastrocnemius*	0.008 ± 0.0079^{b}	0.017 ± 0.0034^{ab}	0.031 ± 0.0005^{a}	0.0184
	M. iliofibularis	0.011 ± 0.0156^{b}	0.025 ± 0.0140^{a}	0.029 ± 0.0005^{a}	
C14:0	*M. gastrocnemius*	0.06 ± 0.030	0.05 ± 0.025	0.05 ± 0.044	0.041
	M. iliofibularis	0.03 ± 0.023	0.07 ± 0.032	0.06 ± 0.056	
C16:0	*M. gastrocnemius*	2.1 ± 0.71	2.5 ± 1.32$_{b}$	2.3 ± 0.57	1.01
	M. iliofibularis	2.5 ± 0.82^{b}	3.5 ± 1.42^{a} $_{a}$	3.1 ± 0.96^{ab}	
C18:0	*M. gastrocnemius*	1.2 ± 0.16$_{b}$	1.5 ± 0.38	1.3 ± 0.15	0.36
	M. iliofibularis	1.6 ± 0.42$_{a}$	1.8 ± 0.34	1.6 ± 0.02	
C20:0	*M. gastrocnemius*	0.019 ± 0.0015	0.026 ± 0.0094	0.018 ± 0.0023	0.1506
	M. iliofibularis	0.020 ± 0.0042	0.112 ± 0.1713	0.023 ± 0.0146	
C22:0	*M. gastrocnemius*	0.018 ± 0.0061^{ab}	0.031 ± 0.0109^{a}	0.015 ± 0.0035^{b} $_{b}$	0.0145
	M. iliofibularis	0.022 ± 0.0071	0.021 ± 0.0066	0.032 ± 0.0242$_{a}$	
C24:0	*M. gastrocnemius*	0.12 ± 0.047	0.14 ± 0.063	0.14 ± 0.021	0.085
	M. iliofibularis	0.14 ± 0.031	0.14 ± 0.028	0.14 ± 0.144	
MUFA					
C14:1	*M. gastrocnemius*	0.012 ± 0.0073	0.018 ± 0.0048	0.014 ± 0.0053	0.0394
	M. iliofibularis	0.014 ± 0.0086	0.033 ± 0.0437	0.007 ± 0.0094	
C16:1*n*-7	*M. gastrocnemius*	0.7 ± 0.31	0.7 ± 0.43	0.6 ± 0.05	0.32
	M. iliofibularis	0.7 ± 0.23	1.0 ± 0.44	0.8 ± 0.47	
C18:1*n*-9t	*M. gastrocnemius*	0.026 ± 0.0052	0.067 ± 0.0702	0.026 ± 0.0105	0.1170
	M. iliofibularis	0.037 ± 0.0176	0.098 ± 0.0855	0.041 ± 0.0090	
C18:1*n*-9c	*M. gastrocnemius*	3.2 ± 1.03	3.7 ± 1.80	3.3 ± 0.79	1.35
	M. iliofibularis	4.5 ± 1.60	4.9 ± 1.72	4.0 ± 0.52	
C20:1*n*-9	*M. gastrocnemius*	0.029 ± 0.0050$_{b}$	0.039 ± 0.0145	0.032 ± 0.0064	0.0115
	M. iliofibularis	0.042 ± 0.0090$_{a}$	0.044 ± 0.0088	0.042 ± 0.0028	
C22:1*n*-9	*M. gastrocnemius*	0.011 ± 0.0121	0.015 ± 0.0078	0.019 ± 0.0158$_{b}$	0.0175
	M. iliofibularis	0.013 ± 0.0092^{b}	0.013 ± 0.0065^{b}	0.053 ± 0.0259^{a} $_{a}$	
C24:1*n*-9	*M. gastrocnemius*	0.03 ± 0.008^{b}	0.08 ± 0.044^{b}	0.31 ± 0.144^{a}	0.186
	M. iliofibularis	0.14 ± 0.186	0.10 ± 0.130	0.24 ± 0.099	
PUFA					
C18:2*n*-6t	*M. gastrocnemius*	0.20 ± 0.169	0.11 ± 0.125	0.17 ± 0.229	0.271
	M. iliofibularis	0.37 ± 0.231	0.20 ± 0.182	0.21 ± 0.288	
C18:2*n*-6c	*M. gastrocnemius*	1.5 ± 0.47$_{b}$	1.8 ± 0.64$_{b}$	1.7 ± 0.39	0.50
	M. iliofibularis	2.0 ± 0.39^{ab} $_{a}$	2.4 ± 0.56^{a} $_{a}$	1.9 ± 0.05^{b}	
C18:3*n* -6	*M. gastrocnemius*	0.21 ± 0.104	0.23 ± 0.161	0.23 ± 0.099	0.168
	M. iliofibularis	0.19 ± 0.104	0.27 ± 0.182	0.24 ± 0.011	
C18:3*n* -3	*M. gastrocnemius*	0.006 ± 0.0061	0.055 ± 0.0364	0.027 ± 0.0217	0.1032
	M. iliofibularis	0.014 ± 0.0092	0.098 ± 0.1093	0.047 ± 0.0021	

Table 3 (Continued) Means (± SD)[#] of fatty acid content (mg/g meat sample) of the *M. gastrocnemius* and *M. iliofibularis* from different ostrich genotypes

Fatty acids	Muscles	Genotype			LSD (*P*=0.05)
		Black x Black	Blue x Black	Blue x Blue	
C20:2	*M. gastrocnemius*	0.03 ± 0.011	0.07 ± 0.105	0.12 ± 0.118	0.136
	M. iliofibularis	0.04 ± 0.021	0.07 ± 0.094	0.04 ± 0.000	
C20:3*n*-6	*M. gastrocnemius*	0.07 ± 0.021^{b}	0.24 ± 0.059^{a}	0.27 ± 0.054^{a}	0.090
	M. iliofibularis	0.11 ± 0.062^{b}	0.27 ± 0.087^{a}	0.30 ± 0.031^{a}	
C20:3*n*-3	*M. gastrocnemius*	0.84 ± 0.332	0.90 ± 0.273	1.14 ± 0.187	0.417
	M. iliofibularis	0.94 ± 0.340	1.05 ± 0.205	1.01 ± 0.297	
C20:4*n*-6	*M. gastrocnemius*	0.02 ± 0.004^{b}	0.05 ± 0.073^{ab}	0.14 ± 0.034^{a}	0.109
	M. iliofibularis	0.03 ± 0.008	0.09 ± 0.080	0.06 ± 0.050	
C20:5*n*-3	*M. gastrocnemius*	0.065 ± 0.0280^{b}	0.075 ± 0.0400^{b}	0.090 ± 0.0132^{a}	0.0319
	M. iliofibularis	0.064 ± 0.0206^{ab}	0.088 ± 0.0388^{a}	0.070 ± 0.0008^{b}	
C22:2	*M. gastrocnemius*	0.03 ± 0.039	0.44 ± 0.708	0.07 ± 0.085	0.813
	M. iliofibularis	0.07 ± 0.057	0.40 ± 0.483	0.04 ± 0.020	
C22:5*n*-3	*M. gastrocnemius*	0.10 ± 0.054	0.08 ± 0.086	0.23 ± 0.055$_{a}$	0.118
	M. iliofibularis	0.15 ± 0.115	0.17 ± 0.076	0.05 ± 0.002$_{b}$	
C22:6*n*-3	*M. gastrocnemius*	0.08 ± 0.039	0.10 ± 0.054	0.14 ± 0.047	0.080
	M. iliofibularis	0.11 ± 0.086	0.12 ± 0.057	0.16 ± 0.104	
SFA	*M. gastrocnemius*	3.8 ± 0.87	5.1 ± 2.29	4.4 ± 1.23	1.81
	M. iliofibularis	4.5 ± 1.17^{b}	6.4 ± 1.76^{a}	6.0 ± 2.17^{ab}	
MUFA	*M. gastrocnemius*	4.7 ± 1.54	4.7 ± 2.49	4.3 ± 1.01	1.80
	M. iliofibularis	6.3 ± 1.84	6.2 ± 2.15	5.3 ± 1.08	
PUFA	*M. gastrocnemius*	3.1 ± 1.02	4.1 ± 1.66	4.3 ± 0.93	1.52
	M. iliofibularis	4.1 ± 0.89	5.2 ± 1.13	4.1 ± 0.09	
TUFA	*M. gastrocnemius*	7.8 ± 2.38	8.9 ± 4.05	8.6 ± 1.95	2.91
	M. iliofibularis	10.4 ± 2.64	11.4 ± 2.98	9.3 ± 0.99	
DFA	*M. gastrocnemius*	9 ± 2.5	10 ± 4.4	10 ± 2.1	3.2
	M. iliofibularis	12 ± 3.0	13 ± 3.3	11 ± 1.0	
P:S	*M. gastrocnemius*	0.81 ± 0.200	0.84 ± 0.159	0.99 ± 0.064$_{a}$	0.236
	M. iliofibularis	0.91 ± 0.105	0.84 ± 0.170	0.73 ± 0.276$_{b}$	
n-6	*M. gastrocnemius*	2.0 ± 0.63	2.5 ± 0.91$_{b}$	2.6 ± 0.69	0.75
	M. iliofibularis	2.7 ± 0.55	3.3 ± 0.78$_{a}$	2.7 ± 0.33	
n-3	*M. gastrocnemius*	1.1 ± 0.44^{b}	1.2 ± 0.35^{ab}	1.6 ± 0.32^{a}	0.49
	M. iliofibularis	1.3 ± 0.37	1.5 ± 0.34	1.3 ± 0.40	
n-6:*n*-3	*M. gastrocnemius*	2.0 ± 0.44	2.1 ± 0.48	1.6 ± 0.11	1.01
	M. iliofibularis	2.2 ± 0.61	2.2 ± 0.63	2.2 ± 0.91	

[#] SD: Standard deviation; LSD: Least significant difference (*P*=0.05)

[a,b] Means in the same row with different superscripts are significantly different (*P*≤0.05)

$_{a,b}$ Means in the same column, within each fatty acid, with different subscripts are significantly different (*P*≤0.05)

Abbreviations:
SFA: Saturated Fatty Acids
MUFA: Monounsaturated Fatty Acids
PUFA: Polyunsaturated Fatty Acids
TUFA: Total Unsaturated Fatty Acids
DFA: Desirable Fatty Acids (C18:0 + TUFA)
P:S: Polyunsaturated:Saturated fatty acid ratio
n-6 = C18:2*n*-6t + C18:2*n*-6c + C18:3*n* -6 + C20:3*n*-6 + C20:4*n*-6
n-3 = C18:3*n* -3 + C20:3*n*-3 + C20:5*n*-3 + C22:5*n*-3 + C22:6*n*-3

No studies of the fatty acid content (mg/g meat) of ostrich meat could be sourced. The majority of studies available only discuss the fatty acid composition (%) of ostrich meat. As noted in Table 3, the total fatty acid content (mg/g meat) ranged from 12 ± 3.2 mg/g to 18 ± 4.7 mg/g. Although not significant (P>0.05), the total fatty acid content was the highest in the Blue x Black genotype for the *M*. *iliofibularis* (Table 3). This can possibly be influenced by the significantly higher (P≤0.05) content of SFA in the latter genotype, and more specifically the significantly higher (P≤0.05) content of C16:0 (3.5 ± 1.42 mg/g) in the Blue x Black genotype (Table 3).

Fatty acid composition is described by two important ratios: the PUFA to SFA (P:S) ratio; and the *n*-6:*n*-3 ratio (Enser *et al*., 1998; Paleari *et al*., 1998). Consumer awareness of the nutritional properties of meat has led to the Department of Health recommending a minimal P:S ratio of 0.45 and a maximum *n*-6:*n*-3 PUFA ratio of 4.0 for British diets as a whole (Department of Health, 1994; Enser *et al*., 1998). Higher values for the P:S ratio (above 0.45) and lower values for the *n*-6:*n*-3 ratio (below 4.0) indicate healthier food in relation to cardiovascular diseases (Enser *et al*., 1998).

There were no significant differences (P>0.05) between the respective genotypes for P:S ratio (Table 3), whilst the ratio ranged between 0.73 ± 0.276 and 0.99 ± 0.064. The P:S ratios of the present study are higher than the recommended minimal P:S ratio of 0.45 (Department of Health, 1994),. Paleari *et al*. (1998) reported a P:S ratio of 1.06, however, in the latter study the genotype of ostrich was not mentioned. When muscles within specific genotypes were compared, the P:S ratio was the highest (P≤0.05) in the *M*. *gastrocnemius* of the pure Blue genotype (Table 3). The P:S ratio in pure Blue ostriches was 1.16 ± 0.05 for the *M*. *gastrocnemius* and 0.83 ± 0.05 for the *M*. *iliofibularis* (Girolami *et al*., 2003). Present results in Table 3 for pure Blue ostriches (0.99 ± 0.064 for the *M*. *gastrocnemius* and 0.73 ± 0.276 for the *M*. *iliofibularis*) were similar to those reported by Girolami *et al*. (2003). The P:S ratio for beef is around 0.1, which is much lower than the recommended minimum value of 0.45. (Enser *et al*., 1998). Therefore, ostrich meat is considered a healthy alternative to the traditional types of red meat. Furthermore, ostrich meat can be considered outstanding in terms of health characteristics, because its ratio of saturated:monounsaturated:polyunsaturated fatty acids is 1:1:1 (Sales, 1994). Generally, results in Table 3 were consistent with this ratio.

The *n*-6:*n*-3 ratios for the three genotypes were also very similar (P>0.05) and ranged between 1.6 ± 0.11 to 2.2 ± 0.61 (Table 3). As noted in Table 3, the present values for the *n*-6:*n*-3 ratio were well below the recommended maximum value of 4 (Department of Health, 1994; Enser *et al*., 1998; Girolami *et al*., 2003). The *n*-6:*n*-3 ratios (Table 3) in the present investigation for the pure Black genotype (2.0 ± 0.44 for the *M*. *gastrocnemius* and 2.2 ± 0.61 for the *M*. *iliofibularis*), as well as the pure Blue genotype (1.6 ± 0.11 for the *M*. *gastrocnemius* and 2.2 ± 0.91 for the *M*. *iliofibularis*) were much lower than those reported by Girolami *et al*. (2003). Girolami *et al*. (2003) conducted research on pure Blue ostriches (*S. camelus australis*) and found that the ratios of *n*-6:*n*-3 for the *M*. *iliofibularis* and *M*. *gastrocnemius* were 7.57 ± 0.31 and 8.31 ± 0.31, respectively. Furthermore, according to Girolami *et al*. (2003), there were no significant differences (P>0.05) for this ratio between muscles in the pure Blue genotype. Similar results were found in the present investigation between muscles (Table 3). However, *n*-6:*n*-3 ratios of 3.72 and 0.4 have been reported for pure Black ostriches (Sales, 1994; Sales *et al*., 1996). Therefore, results for the pure Black genotype in this

investigation are in a similar range (Table 3). It must be noted that diet may have caused the differences between the studies available in the literature. Hoffman *et al*. (2005) found that the fatty acid profile of the muscles and the abdominal fat depot could be manipulated by feeding ostriches various levels of dietary fish oil. However, in the present study diet was eliminated as a variable by providing all the ostriches with the same commercial diet. According to Enser *et al*. (1996), the *n*-6:*n*-3 ratio in beef is beneficially low and is normally less than 3. However, the *n*-6:*n*-3 ratio noted for ostrich meat in this study had a maximum value of 1.6 and, therefore, ostrich meat can be considered a healthy alternative.

Only three significant correlations were observed: as the intensity of the sensory aroma increased, the percentage of PUFA ($P \leq 0.05$, r = 0.542) and the percentage of *n*-6 fatty acids increased ($P \leq 0.05$, r = 0.539), whilst an increase in the intensity of the sensory flavour was marked by a decrease in the percentage of *n*-6 fatty acids ($P \leq 0.05$, r = -0.465). Similar results were obtained by Sañudo *et al*. (2000) in lamb. According to these authors, the *n*-6 PUFA are important contributors to the odour and flavour of lamb. It seems, therefore, that this is also the case in ostrich meat. However, with respect to the latter correlation, it is postulated that oxidation occurred during processing, handling and transportation of meat, thereby resulting in a negative correlation.

The fatty acid composition (% of total fatty acids present) and fatty acid content (mg/g fat sample) of the breast fat and abdominal fat from different genotypes of ostrich are presented in Table 4 and Table 5 respectively. Once again all the fatty acids present in the fat depots were analysed and presented, however, only specific fatty acids are discussed.

According to Gunstone and Russell (1954), ostrich fat does not differ that much from other bird fats. It should be noted that Gunstone and Russell (1954) did not mention the genotype of ostrich used, nor the type of fat analysed, and used only one ostrich to determine its fatty acid composition. According to Gunstone and Russell (1954), the major fatty acids present are oleic (C18:1*n*-9c), palmitic (C16:0) and linoleic (C18:2*n*-6c) acid and each of these fatty acids contributes 39.8%, 24.8% and 17.1% respectively. The results of the present investigation are similar (Table 4): palmitic (C16:0) and oleic acid (C18:1*n*-9c) were present in the highest concentrations, followed by much lower concentrations of stearic (C18:0), palmitelaidic (C16:1*n*-7) and linoleic (C18:2*n*-6c) acid. However, results by Joubert (2003) for the concentrations of the following three fatty acids were lower: oleic (C18:1*n*-9c) at 22.77%; palmitic (C16:0) at 32.50%; and linoleic acid (C18:2*n*-6c) at 10.80%. According to Horbańczuk *et al*. (2004), the fatty acid concentration (%) does not differ between the two fat depots of ostriches reared on the same diet and in the same environment. Results of Hoffman *et al*. (2005) indicated that the fat depot of ostriches of commercial slaughter age can be changed by manipulating the dietary fatty acids; the more unsaturated the dietary fatty acids, the more unsaturated the fatty acids of the breast fat depot becomes.

Table 4 Means (± SD)[#] of fatty acid composition (% of total fatty acids present) of the breast fat and abdominal fat from different ostrich genotypes

Fatty acids	Fat type	Genotype			LSD (*P*=0.05)
		Black x Black	Blue x Black	Blue x Blue	
SFA					
C10:0	Breast fat	0.015 ± 0.0155	0.013 ± 0.0169	0.010 ± 0.0001	0.0296
	Abdominal fat	0.016 ± 0.0141	0.008 ± 0.0065	0.036 ± 0.0000	
C12:0	Breast fat	0.08 ± 0.038	0.08 ± 0.022	0.09 ± 0.057	0.062
	Abdominal fat	0.06 ± 0.042^{b}	0.09 ± 0.028^{ab}	0.13 ± 0.000^{a}	
C14:0	Breast fat	1.12 ± 0.141	1.06 ± 0.131	1.24 ± 0.036	0.230
	Abdominal fat	1.09 ± 0.075^{b}	1.11 ± 0.111^{b}	1.37 ± 0.000^{a}	
C16:0	Breast fat	29.6 ± 0.57^{b}	30.2 ± 1.31^{ab}	30.8 ± 1.28^{a}	1.17
	Abdominal fat	30.3 ± 0.57	30.4 ± 0.79	30.6 ± 0.00	
C18:0	Breast fat	5.0 ± 0.42$^{b}{}_{b}$	4.9 ± 0.50$^{b}{}_{b}$	5.7 ± 1.18$^{a}{}_{a}$	0.53
	Abdominal fat	5.6 ± 0.27$^{a}{}_{a}$	5.5 ± 0.47$^{a}{}_{a}$	4.8 ± 0.00$^{b}{}_{b}$	
C20:0	Breast fat	0.047 ± 0.0174	0.038 ± 0.0110	0.050 ± 0.0095	0.0150
	Abdominal fat	0.050 ± 0.0067^{ab}	0.045 ± 0.0096^{b}	0.062 ± 0.0000^{a}	
C22:0	Breast fat	0.018 ± 0.0053	0.106 ± 0.2613	0.011 ± 0.0019	0.2915
	Abdominal fat	0.018 ± 0.0065	0.014 ± 0.0103	0.009 ± 0.0000	
C24:0	Breast fat	0.40 ± 0.295	0.42 ± 0.196	0.08 ± 0.088$_{b}$	0.536
	Abdominal fat	0.33 ± 0.288^{b}	0.28 ± 0.197^{b}	2.84 ± 0.000$^{a}{}_{a}$	
MUFA					
C14:1	Breast fat	0.156 ± 0.0335	0.133 ± 0.0444	0.164 ± 0.0290	0.0599
	Abdominal fat	0.139 ± 0.0218^{b}	0.147 ± 0.0292^{b}	0.214 ± 0.0000^{a}	
C16:1*n*-7	Breast fat	9.7 ± 1.02	9.6 ± 0.89	9.5 ± 2.38	1.22
	Abdominal fat	9.2 ± 1.17^{b}	9.7 ± 0.88^{ab}	10.5 ± 0.00^{a}	
C18:1*n*-9t	Breast fat	0.102 ± 0.1025$^{b}{}_{b}$	0.189 ± 0.0663^{ab}	0.211 ± 0.0274$^{a}{}_{a}$	0.1029
	Abdominal fat	0.221 ± 0.0132$^{a}{}_{a}$	0.215 ± 0.0214^{a}	0.012 ± 0.0000$^{b}{}_{b}$	
C18:1*n*-9c	Breast fat	33.3 ± 1.34	33.2 ± 1.29	32.1 ± 0.59$_{a}$	1.37
	Abdominal fat	33.7 ± 0.60^{a}	32.5 ± 0.98^{a}	30.1 ± 0.00$^{b}{}_{b}$	
C20:1*n*-9	Breast fat	0.230 ± 0.0400	0.209 ± 0.0283	0.212 ± 0.0614	0.0219
	Abdominal fat	0.238 ± 0.0260^{a}	0.223 ± 0.0282^{ab}	0.211 ± 0.0000^{b}	
C22:1*n*-9	Breast fat	0.013 ± 0.0049	0.020 ± 0.0141	0.013 ± 0.0021	0.0179
	Abdominal fat	0.018 ± 0.0102	0.015 ± 0.0042	0.012 ± 0.0000	
C24:1*n*-9	Breast fat	0.7 ± 0.73	0.5 ± 0.44	0.3 ± 0.33$_{b}$	0.86
	Abdominal fat	0.3 ± 0.13^{b}	0.3 ± 0.24^{b}	1.3 ± 0.00$^{a}{}_{a}$	
PUFA					
C18:2*n*-6t	Breast fat	0.022 ± 0.0095	0.016 ± 0.0030	0.025 ± 0.0114	0.0268
	Abdominal fat	0.041 ± 0.0256^{a}	0.016 ± 0.0074^{ab}	0.013 ± 0.0000^{b}	
C18:2*n*-6c	Breast fat	14.0 ± 0.84	14.1 ± 1.30	14.3 ± 2.43$_{a}$	1.49
	Abdominal fat	14.3 ± 1.28^{a}	14.2 ± 0.85^{a}	12.4 ± 0.00$^{b}{}_{b}$	
C18:3*n* -6	Breast fat	0.097 ± 0.0533	0.099 ± 0.0387	0.098 ± 0.0107	0.0729
	Abdominal fat	0.119 ± 0.0251	0.093 ± 0.0232	0.103 ± 0.0000	

Table 4 (Continued) Means (± SD)[#] of fatty acid composition (% of total fatty acids present) of the breast fat and abdominal fat from different ostrich genotypes

Fatty acids	Fat type	Genotype			LSD (*P*=0.05)
		Black x Black	Blue x Black	Blue x Blue	
C18:3*n* -3	Breast fat	3.6 ± 0.40	3.4 ± 0.93	3.6 ± 0.28	1.56
	Abdominal fat	2.8 ± 1.54	3.5 ± 0.51	3.2 ± 0.00	
C20:2	Breast fat	0.11 ± 0.075	0.20 ± 0.250	0.10 ± 0.007	0.235
	Abdominal fat	0.12 ± 0.030	0.13 ± 0.069	0.07 ± 0.000	
C20:3*n*-6	Breast fat	0.07 ± 0.062	0.18 ± 0.216	0.13 ± 0.013	0.238
	Abdominal fat	0.09 ± 0.044	0.08 ± 0.030	0.08 ± 0.000	
C20:3*n*-3	Breast fat	0.12 ± 0.112^{b}	0.20 ± 0.116^{ab}	0.26 ± 0.119$^{a}{}_{a}$	0.136
	Abdominal fat	0.18 ± 0.081	0.16 ± 0.078	0.05 ± 0.000$_{b}$	
C20:4*n*-6	Breast fat	0.17 ± 0.145^{a}	0.05 ± 0.025^{b}	0.02 ± 0.017^{b}	0.095
	Abdominal fat	0.09 ± 0.120	0.05 ± 0.032	0.01 ± 0.000	
C20:5*n*-3	Breast fat	0.033 ± 0.0059	0.037 ± 0.0182	0.046 ± 0.0153$_{a}$	0.0242
	Abdominal fat	0.027 ± 0.0135	0.029 ± 0.0110	0.013 ± 0.0000$_{b}$	
C22:2	Breast fat	0.2 ± 0.43	0.1 ± 0.33	0.0 ± 0.00	0.78
	Abdominal fat	0.2 ± 0.36	0.2 ± 0.36	0.1 ± 0.00	
C22:5*n*-3	Breast fat	0.3 ± 0.34	0.2 ± 0.22	0.5 ± 0.72	0.51
	Abdominal fat	0.1 ± 0.08^{b}	0.2 ± 0.40^{b}	0.8 ± 0.00^{a}	
C22:6*n*-3	Breast fat	0.1 ± 0.03	0.2 ± 0.36	0.1 ± 0.10	0.76
	Abdominal fat	0.2 ± 0.34	0.2 ± 0.49	0.2 ± 0.00	
SFA	Breast fat	37.0 ± 0.68^{b}	37.3 ± 1.70^{ab}	38.3 ± 0.06$^{a}{}_{b}$	1.09
	Abdominal fat	37.9 ± 0.68^{b}	38.1 ± 1.17^{b}	40.7 ± 0.00$^{a}{}_{a}$	
MUFA	Breast fat	44.3 ± 1.00^{a}	43.9 ± 1.55^{a}	42.4 ± 2.06^{b}	1.27
	Abdominal fat	43.9 ± 0.70^{a}	43.1 ± 1.16^{ab}	42.4 ± 0.00^{b}	
PUFA	Breast fat	18.7 ± 0.94	18.8 ± 1.87	19.2 ± 1.99$_{a}$	1.48
	Abdominal fat	18.2 ± 1.00^{ab}	18.8 ± 1.18^{a}	16.9 ± 0.00$^{b}{}_{b}$	
TUFA	Breast fat	63.0 ± 0.68^{a}	62.7 ± 1.70^{ab}	61.7 ± 0.06$^{b}{}_{a}$	1.09
	Abdominal fat	62.1 ± 0.68^{a}	61.9 ± 1.17^{a}	59.3 ± 0.00$^{b}{}_{b}$	
DFA	Breast fat	68.0 ± 0.53	67.6 ± 1.38	67.3 ± 1.12$_{a}$	0.86
	Abdominal fat	67.7 ± 0.53^{a}	67.4 ± 1.05^{a}	64.1 ± 0.00$^{b}{}_{b}$	
n-6	Breast fat	14.3 ± 0.93	14.4 ± 1.40	14.6 ± 2.40$_{a}$	1.57
	Abdominal fat	14.6 ± 1.35^{a}	14.4 ± 0.85^{a}	12.6 ± 0.00$^{b}{}_{b}$	
n-3	Breast fat	4.0 ± 0.37	4.1 ± 0.91	4.5 ± 0.40	1.77
	Abdominal fat	3.3 ± 1.66	4.0 ± 0.74	4.2 ± 0.00	

[#] SD: Standard deviation
[a,b] Means in the same row with different superscripts are significantly different (*P*≤0.05)
[a,b] Means in the same column, within each fatty acid, with different subscripts are significantly different (*P*≤0.05)
LSD: Least significant difference (*P*=0.05)
Abbreviations: SFA: Saturated Fatty Acids
MUFA: Monounsaturated Fatty Acids
PUFA: Polyunsaturated Fatty Acids
TUFA: Total Unsaturated Fatty Acids
DFA: Desirable Fatty Acids (C18:0 + TUFA)
n-6 = C18:2*n*-6t + C18:2*n*-6c + C18:3*n* -6 + C20:3*n*-6 + C20:4*n*-6
n-3 = C18:3*n* -3 + C20:3*n*-3 + C20:5*n*-3 + C22:5*n*-3 + C22:6*n*-3

As noted in Table 4, the SFA concentrations ranged from 37.0 ± 0.68% to 38.3 ± 0.06% in the breast fat and from 37.9 ± 0.68% to 40.7 ± 0.00% in the abdominal fat. MUFA concentrations ranged from 42.4 ± 2.06% to 44.3 ± 1.00% in the breast fat and from 42.4 ± 0.00% to 43.9 ± 0.70% in the abdominal fat (Table 4). The concentration of MUFA consisted mainly of oleic acid (C18:1*n*-9c) (Table 4). However, as noted in Table 4, palmitelaidic acid (C16:1*n*-7) was also present at low concentrations. PUFA concentrations ranged from 18.7 ± 0.94% to 19.2 ± 1.99% in the breast fat and from 16.9 ± 0.00% to 18.8 ± 1.18% in the abdominal fat (Table 4). Linoleic acid (C18:2*n*-6c) was the PUFA present at the highest concentration, while alpha-linolenic acid (C18:3*n*-3) was present at the lowest concentration (Table 4). Horbaňczuk *et al*. (2003) noted that that the breast fat depot of five year-old culled birds contained 39% PUFA, much higher than indicated in the present investigation (Table 4). Girolami *et al*. (2003) conducted research on Blue Neck ostriches (*S. camelus australis*) and found that the fatty acid profile was significantly affected by age (10-11 vs. 14-15 months) at slaughter ($P<0.001$). However, as opposed to results by Horbaňczuk *et al*. (2003), older birds (14-15 months) showed an increase of total SFA ($P\leq0.05$) and MUFA ($P<0.001$) and a decrease of total PUFA ($P<0.001$) (Girolami *et al*., 2003). In general, the meat of younger animals contains a higher percentage of PUFA and less SFA than that of older animals (Lawrie, 1998). Gunstone and Russell (1954) mentioned myristic acid (C14:0) at concentrations of 0.9%, stearic acid (C18:0) at 5.9%, arachidonic acid (C20:4*n*-6) at 0.4%, palmitelaidic acid (C16:1*n*-7) at 6.1% and linolenic acid (C18:3) at 3.8% in the ostrich fat. As noted in Table 4, results of the present study were similar, except for arachidonic acid (C20:4*n*-6), which was present at lower concentrations (0.01 ± 0.000% to 0.17 ± 0.145%) and palmitelaidic acid (C16:1*n*-7) present at higher concentrations (9.2 ± 1.17% to 10.5 ± 0.00%).

Note that results for the fatty acid concentration of the abdominal fat derived from the pure Blue genotype was based on one ostrich only (Fig. 2) and further studies are strongly recommended to support or refute the present results. The concentration of SFA of both types of fat was significantly higher ($P\leq0.05$) in the pure Blue genotype compared to the pure Black genotype (Table 4). The concentration of MUFA in both types of fat was higher ($P\leq0.05$) in the pure Black genotype compared to the pure Blue genotype (Table 4), possibly as a result of the higher percentage of oleic acid (C18:1*n*-9c) in both the breast and abdominal fat. The PUFA concentration was the highest ($P\leq0.05$) in the abdominal fat of the Blue x Black genotype compared to the pure Blue genotype (Table 4). As noted in Table 4, the concentrations of TUFA were the highest ($P\leq0.05$) in the pure Black genotype compared to that of the pure Blue genotype for both fat depots. The concentration of TUFA also seems to be higher ($P>0.05$) in the Blue x Black genotype compared to the pure Blue genotype (Table 4). The percentage DFA in the abdominal fat is significantly higher ($P\leq0.05$) for the pure Black, as well as the Blue x Black genotype (Table 4).

Regarding fatty acid concentration differences between types of fat, the SFA were the highest ($P\leq0.05$) in the abdominal fat of the pure Blue genotype (Table 4). According to Table 4, the concentration of PUFA and TUFA were the highest ($P\leq0.05$) in the breast fat of the pure Blue genotype. According to Gunstone and Russell (1954), SFA accounted for 29-32% of the total fatty acids, while Joubert (2003) reported SFA concentrations of 46.71%. Joubert (2003) noted MUFA concentrations of 29.77% and PUFA concentrations of 23.52%. The MUFA concentrations of the present study ranged from 42.4 ± 0.00% to 44.3 ± 1.00%, while the PUFA concentrations ranged from 16.9 ± 0.00% to 19.2 ± 1.99% (Table 4). From the

above mentioned results it seems as though the fat depots of the pure Black genotype, and to a certain extent the Blue x Black genotype, both have a relatively positive unsaturated fatty acid profile.

Limited research is available on the fatty acid content (mg/g fat sample), the P:S ratio and the *n*-6:*n*-3 ratio of the breast fat and abdominal fat from ostriches. The total fatty acid content (mg/g fat) ranged from 233 ± 18.9 mg/g to 242 ± 35.0 mg/g for the breast fat and from 230 ± 7.3 mg/g to 264 ± 0.0 mg/g for the abdominal fat (Table 5). As indicated in Table 5, the total fatty acid content was the highest in the pure Blue genotype, because of a significantly higher ($P \leq 0.05$) content of SFA in the latter genotype. The P:S ratio for the breast fat ranged from 0.50 ± 0.029 to 0.51 ± 0.066, while the P:S ratio for the abdominal fat ranged from 0.42 ± 0.000 to 0.49 ± 0.040 (Table 5). Horbańczuk *et al*. (2003) noted that the breast fat depot of five year-old culled birds had a P:S ratio of 1.65. This is much higher than the P:S ratio indicated in the present results. According to Girolami *et al*. (2003), age affects the P:S ratio and a higher P:S ratio ($P<0.001$) is observed in older pure Blue ostriches, similarly to the findings of Horbańczuk *et al*. (2003). According to Table 5, the P:S ratio was the highest ($P \leq 0.05$) in the pure Black, as well as the Blue x Black genotype. Regarding differences between types of fat, the P:S ratio was the highest ($P \leq 0.05$) in the breast fat of the pure Blue genotype (Table 5). According to Table 5, the *n*-6:*n*-3 ratio ranged from 3.3 ± 0.82 to 3.9 ± 1.56 in the breast fat and from 3.0 ± 0.00 to 4.5 ± 1.73 in the abdominal fat. No significant differences ($P>0.05$) or patterns were observed regarding the *n*-6:*n*-3 ratio (Table 5).

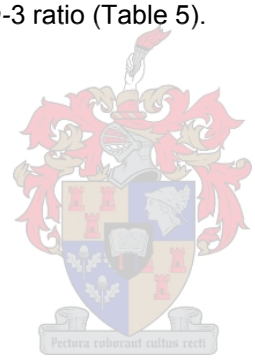

Table 5 Means (± SD)[#] of fatty acid content (mg/g fat sample) of the breast fat and abdominal fat from different ostrich genotypes

Fatty acids	Fat type	Genotype			LSD (P=0.05)
		Black x Black	Blue x Black	Blue x Blue	
Total FA	Breast fat	233 ± 18.9	238 ± 12.3	242 ± 35.0	35.9
	Abdominal fat	230 ± 7.3	231 ± 20.1	264 ± 0.0	
SFA					
C10:0	Breast fat	0.04 ± 0.036	0.03 ± 0.042	0.03 ± 0.004$_{b}$	0.072
	Abdominal fat	0.04 ± 0.034^{ab}	0.02 ± 0.015^{b}	0.09 ± 0.000$^{a}{}_{a}$	
C12:0	Breast fat	0.18 ± 0.087	0.20 ± 0.047	0.20 ± 0.108$_{b}$	0.134
	Abdominal fat	0.14 ± 0.097^{b}	0.21 ± 0.065^{ab}	0.34 ± 0.000$^{a}{}_{a}$	
C14:0	Breast fat	2.60 ± 0.360	2.54 ± 0.370	3.01 ± 0.523	0.633
	Abdominal fat	2.52 ± 0.216^{b}	2.55 ± 0.252^{b}	3.61 ± 0.000^{a}	
C16:0	Breast fat	69 ± 6.3	72 ± 2.7	75 ± 13.9	8.9
	Abdominal fat	70 ± 2.5^{b}	70 ± 7.1^{b}	81 ± 0.0^{a}	
C18:0	Breast fat	11.6 ± 1.06	11.6 ± 1.04	13.5 ± 0.88	1.98
	Abdominal fat	13.0 ± 0.98	12.6 ± 1.80	12.8 ± 0.00	
C20:0	Breast fat	0.106 ± 0.0337	0.090 ± 0.0270	0.120 ± 0.0055$_{b}$	0.0339
	Abdominal fat	0.115 ± 0.0165^{b}	0.104 ± 0.0238^{b}	0.163 ± 0.0000$^{a}{}_{a}$	
C22:0	Breast fat	0.041 ± 0.0122	0.233 ± 0.5596	0.027 ± 0.0008	0.6236
	Abdominal fat	0.041 ± 0.0148	0.033 ± 0.0235	0.025 ± 0.0000	
C24:0	Breast fat	0.9 ± 0.77	1.0 ± 0.50	0.2 ± 0.18$_{b}$	1.31
	Abdominal fat	0.8 ± 0.64^{b}	0.7 ± 0.50^{b}	7.5 ± 0.00$^{a}{}_{a}$	
MUFA					
C14:1	Breast fat	0.36 ± 0.083	0.32 ± 0.111	0.40 ± 0.127$_{b}$	0.144
	Abdominal fat	0.32 ± 0.056^{b}	0.34 ± 0.067^{b}	0.57 ± 0.000$^{a}{}_{a}$	
C16:1*n*-7	Breast fat	22.7 ± 3.18	22.8 ± 2.45	23.3 ± 9.08$_{b}$	4.35
	Abdominal fat	21.2 ± 2.12^{b}	22.3 ± 2.52^{b}	27.7 ± 0.00$^{a}{}_{a}$	
C18:1*n*-9t	Breast fat	0.24 ± 0.235$^{b}{}_{b}$	0.45 ± 0.152^{ab}	0.51 ± 0.008$^{a}{}_{a}$	0.230
	Abdominal fat	0.51 ± 0.036$^{a}{}_{a}$	0.50 ± 0.078^{a}	0.03 ± 0.000$^{b}{}_{b}$	
C18:1*n*-9c	Breast fat	78 ± 7.4	79 ± 5.3	77 ± 9.8	12.0
	Abdominal fat	78 ± 3.5	75 ± 5.6	79 ± 0.0	
C20:1*n*-9	Breast fat	0.53 ± 0.047	0.50 ± 0.080	0.50 ± 0.074	0.071
	Abdominal fat	0.55 ± 0.063	0.51 ± 0.065	0.56 ± 0.000	
C22:1*n*-9	Breast fat	0.030 ± 0.0132	0.047 ± 0.0323	0.032 ± 0.0093	0.0416
	Abdominal fat	0.042 ± 0.0226	0.034 ± 0.0106	0.031 ± 0.0000	
C24:1*n*-9	Breast fat	1.7 ± 1.88	1.3 ± 1.09	0.7 ± 0.89$_{b}$	2.18
	Abdominal fat	0.7 ± 0.31^{b}	0.8 ± 0.57^{b}	3.5 ± 0.00$^{a}{}_{a}$	
PUFA					
C18:2*n*-6t	Breast fat	0.050 ± 0.0236	0.038 ± 0.0070	0.058 ± 0.0187	0.0641
	Abdominal fat	0.095 ± 0.0585	0.038 ± 0.0174	0.033 ± 0.0000	
C18:2*n*-6c	Breast fat	32.4 ± 1.36	33.6 ± 4.27	34.2 ± 0.86	5.98
	Abdominal fat	32.9 ± 3.03	32.6 ± 1.95	32.7 ± 0.00	
C18:3*n* -6	Breast fat	0.22 ± 0.115	0.23 ± 0.087	0.24 ± 0.060	0.170
	Abdominal fat	0.28 ± 0.064	0.22 ± 0.063	0.27 ± 0.000	
C18:3*n* -3	Breast fat	8.3 ± 0.96	8.2 ± 2.36	8.5 ± 0.57	4.11
	Abdominal fat	6.5 ± 3.58	8.0 ± 1.58	8.4 ± 0.00	

Table 5 (Continued) Means (± SD)[#] of fatty acid content (mg/g fat sample) of the breast fat and abdominal fat from different ostrich genotypes

Fatty acids	Fat type	Genotype			LSD (P=0.05)
		Black x Black	Blue x Black	Blue x Blue	
C20:2	Breast fat	0.26 ± 0.173	0.47 ± 0.528	0.25 ± 0.053	0.480
	Abdominal fat	0.29 ± 0.078	0.31 ± 0.177	0.19 ± 0.000	
C20:3*n*-6	Breast fat	0.17 ± 0.140	0.42 ± 0.509	0.32 ± 0.077	0.566
	Abdominal fat	0.21 ± 0.107	0.19 ± 0.078	0.22 ± 0.000	
C20:3*n*-3	Breast fat	0.28 ± 0.257^{b}	0.48 ± 0.270^{ab}	0.61 ± 0.197$^{a}{}_{a}$	0.305
	Abdominal fat	0.40 ± 0.188	0.36 ± 0.193	0.12 ± 0.000$_{b}$	
C20:4*n*-6	Breast fat	0.38 ± 0.316^{a}	0.13 ± 0.058^{b}	0.05 ± 0.048^{b}	0.243
	Abdominal fat	0.21 ± 0.282	0.12 ± 0.082	0.04 ± 0.000	
C20:5*n*-3	Breast fat	0.076 ± 0.0149	0.087 ± 0.0442	0.107 ± 0.0212$_{a}$	0.0545
	Abdominal fat	0.061 ± 0.0320	0.066 ± 0.0261	0.033 ± 0.0000$_{b}$	
C22:2	Breast fat	0.5 ± 0.99	0.3 ± 0.79	0.0 ± 0.01	1.79
	Abdominal fat	0.5 ± 0.80	0.5 ± 0.83	0.2 ± 0.00	
C22:5*n*-3	Breast fat	0.6 ± 0.85	0.5 ± 0.53	1.4 ± 1.92	1.21
	Abdominal fat	0.2 ± 0.18^{b}	0.4 ± 0.90^{b}	2.0 ± 0.00^{a}	
C22:6*n*-3	Breast fat	0.1 ± 0.07	0.5 ± 0.86	0.3 ± 0.28	1.86
	Abdominal fat	0.4 ± 0.83	0.5 ± 1.20	0.5 ± 0.00	
SFA	Breast fat	86 ± 7.7	89 ± 3.1	93 ± 13.3$_{b}$	12.3
	Abdominal fat	87 ± 3.5^{b}	88 ± 9.7^{b}	108 ± 0.0$^{a}{}_{a}$	
MUFA	Breast fat	103 ± 10.1	105 ± 6.8	103 ± 19.8	16.7
	Abdominal fat	101 ± 1.8	100 ± 7.6	112 ± 0.0	
PUFA	Breast fat	43 ± 1.8	45 ± 6.1	46 ± 1.9	8.1
	Abdominal fat	42 ± 3.2	43 ± 4.2	45 ± 0.0	
TUFA	Breast fat	147 ± 11.5	149 ± 11.0	149 ± 21.7	24.0
	Abdominal fat	143 ± 4.5	143 ± 10.7	157 ± 0.0	
DFA	Breast fat	158 ± 11.9	161 ± 10.9	163 ± 20.9	25.5
	Abdominal fat	156 ± 5.3	156 ± 12.2	169 ± 0.0	
P:S	Breast fat	0.50 ± 0.029	0.51 ± 0.066	0.50 ± 0.051$_{a}$	0.047
	Abdominal fat	0.48 ± 0.033^{a}	0.49 ± 0.040^{a}	0.42 ± 0.000$^{b}{}_{b}$	
n-6	Breast fat	33.5 ± 1.16	34.8 ± 4.25	35.1 ± 0.64	6.02
	Abdominal fat	33.9 ± 3.28	33.5 ± 2.12	33.4 ± 0.00	
n-3	Breast fat	9.4 ± 1.20	9.8 ± 2.44	11.0 ± 2.55	4.73
	Abdominal fat	7.5 ± 3.89	9.4 ± 2.15	11.1 ± 0.00	
n-6:*n*-3	Breast fat	3.6 ± 0.46	3.9 ± 1.56	3.3 ± 0.82	13.93
	Abdominal fat	4.5 ± 1.73	3.7 ± 0.95	3.0 ± 0.00	

[#] SD: Standard deviation; LSD: Least significant difference (*P*=0.05)

[a,b] Means in the same row with different superscripts are significantly different (*P*≤0.05)

$_{a,b}$ Means in the same column, within each fatty acid, with different subscripts are significantly different (*P*≤0.05)

Abbreviations:
SFA: Saturated Fatty Acids
MUFA: Monounsaturated Fatty Acids
PUFA: Polyunsaturated Fatty Acids
TUFA: Total Unsaturated Fatty Acids
DFA: Desirable Fatty Acids (C18:0 + TUFA)
P:S: Polyunsaturated:Saturated fatty acid ratio
n-6 = C18:2*n*-6t + C18:2*n*-6c + C18:3*n* -6 + C20:3*n*-6 + C20:4*n*-6
n-3 = C18:3*n* -3 + C20:3*n*-3 + C20:5*n*-3 + C22:5*n*-3 + C22:6*n*-3

CONCLUSION

The ostrich production industry is in need of scientific guidelines regarding the crossbreeding of ostriches. The effect of ostrich genotype, including South African Black (*S. camelus* var. *domesticus*), Zimbabwean Blue (S. *camelus australis*) and the genotype resulting from crossbreeding between the former two genotypes on the fatty acid composition of their meat and fat depots were investigated. Genotype influenced the fatty acid composition of the muscles, as well as the fat depots. Results as a whole indicate that the pure Black genotype has a more positive unsaturated fatty acid profile in the *M*. *illiofibularis*, *M*. *gastrocnemius* and both the fat depots, while the fat depots of the Blue x Black genotype also seems to have a more positive unsaturated fatty acid profile. However, as the meat from the different ostrich genotypes investigated in this study can all contribute towards a healthy lifestyle, it can be postulated that the specific genotype differences in chemical composition encountered in this investigation will not affect human health negatively. The muscles also differed regarding their fatty acid composition. Therefore, crossbreeding of SAB and ZB ostriches can be a viable option to produce larger birds with more meat, without negatively affecting the fatty acid composition of the meat.

Further investigation into the effect of genotype on the fatty acid composition of the meat should be conducted, including more ostriches in the Black x Blue genotype and the Blue x Blue genotype to ensure more reliable results. To further support and complete the current results, studies on other populations of SAB and ZB ostriches are also recommended.

Studies on the effect of oxidation of fatty acids on the sensory aroma and flavour of ostrich meat should be conducted to understand the complexity of this relationship. More studies on ostrich fat depots should also be undertaken, considering that limited research is available on the fatty acid composition of the ostrich fat. Horbańczuk *et al*. (2003) noted that ostrich adipose tissue could possibly be used for supplementing human diets. According to Fezler (1995) and Sales (1999), oil from the emu and rhea is used in cosmetics and first-aid products, but the reason for the effectiveness and uniqueness of the oils is still unknown. Considering that the ostrich forms part of the same order of birds, namely Ratites (Sclater, 1906), ostrich oil should definitely be investigated further to exploit possible uses in the cosmetics and health industry, as well as to determine the efficacy of such products.

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CHAPTER 8

General discussion and conclusion

The international and national ostrich production industry is in need of scientific guidelines regarding the crossbreeding of ostriches. This study provides a preliminary framework with regard to the establishment of scientific crossbreeding principles for the ostrich industry. Seeing that this study is the first to determine the effect of crossbreeding South African Black (SAB) ostriches with Zimbabwe Blue (ZB) ostriches on reproduction criteria and meat quality, it is strongly advised that further studies should be undertaken to support or refute these findings.

Regarding the reproduction performance of the two genotypes, it seems viable to combine the relatively high live weight of ZB males with the relatively high reproduction performance of SAB females in a commercial crossbreeding operation. Heterosis for chick growth and survival may furthermore enhance productivity in the crossbred progeny. Although percentage carcass yields generally did not show significant genotype differences, weight characteristics did differ between the three genotypes. The pure Blue genotype was significantly larger, whereas the Blue x Black genotype seemed to be larger compared to the pure Black genotype.

Ostriches from the pure Blue genotype seemed to be more difficult to handle, because of their larger size. Consequently these ostriches were subjected to higher levels of pre-slaughter stress, resulting in a higher final pH and darker meat with a higher water-holding capacity. Meat with a higher final pH is normally more susceptible to microbial growth during storage. Therefore, microbial shelf life studies are recommended to determine the shelf life of ostrich meat derived from crossbred birds. Further studies are also required to determine whether the higher final pH of the pure Blue genotype is not due to the ostriches being inherently more agitated. A trained sensory profiling panel could not differentiate between meat from the three genotypes; therefore crossbreeding did not affect the eating quality of the meat negatively.

Genotype did influence the chemical quality of the meat. However, these differences are of such a low magnitude that they would have no effect on human health. It seems that meat derived from the pure Blue genotype had a healthier nutritional profile pertaining to moisture, lipid and cholesterol content. However, the pure Black genotype had a more positive unsaturated fatty acid profile. Within ostriches, the muscles differed regarding morphological, physical, sensory and chemical quality characteristics. These muscle differences can be exploited in the marketing of the various ostrich muscles. Chemical results indicate that ostrich meat is suitable as a healthier alternative for the traditional red meat derived from domestic livestock species such as beef and lamb.

The option of using ostrich meat as an alternative, healthier red meat product could be further exploited as a marketing strategy. It is recommended that marketing and economic studies should be done to determine if the above is possible and whether it will be successful. Comparative studies of ostrich meat

to beef, mutton, pork, chicken and fish are recommended to ensure consistency of analytical methods used. However, it can be argued, and correctly so, that the environmental (nutritional and genetic) effects have a stronger influence on chemical composition of meat than does laboratory analysis of muscle/meat samples. More research should be focused on the possible application of oil derived from ostrich fat in cosmetic and health products. To further complement the existing literature available on ostrich fat, the portion of extra-muscular fat found in the fan fillet (*M. iliofibularis*) should also be analysed to determine its fatty acid composition.

Studies should also be conducted to determine the effect of crossbreeding between these two genotypes on the skin size and quality, as leather still contributes 50% to the income derived from an ostrich. Since ZB ostriches reach slaughter weight earlier than do chicks from other genotypes, future studies on the growth rate of the crossbred offspring are recommended to determine whether the crossbred ostriches grow faster, thereby providing the ostrich producer with a faster turnover from bird to meat. However, slaughter at an earlier age could compromise important skin quality traits, such as nodule size. Therefore, together with the indicated growth rate studies, the researcher should investigate the effect of earlier slaughter on skin quality traits. Future studies on other populations of ZB and SAB ostriches will add robustness to recommendations for the implementation of scientifically-based crossbreeding systems in commercial ostrich production. A similar study incorporating all the aspects of the present study is recommended on the effect of crossbreeding Massai ostriches (*Struthio camelus massaicus*) with SAB ostriches, since the former subspecies is even larger than the ZB ostriches (refer to Chapter 2).

In conclusion, crossbreeding between SAB and ZB ostriches seems to be a viable option to produce larger birds with more meat without negatively affecting the overall quality of the meat.