FACTORS AFFECTING OSTRICH LEATHER TRAITS

by

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PHILOSOPHIAE DOCTOR

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Declaration

By submitting this thesis electronically, I declare that entirety of the work contained therein is my own, original work, that I am the owner of the copyright thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

.... 05/03/2008

SJ van Schalkwyk Date

In the loving memory of my parents, CHRISTENE VAN SCHALKWYK (12-11-1929 to 07-11-1993) and KOOT VAN SCHALKWYK (12-12-1930 to 15-11-2003), who always inspired me in searching and appreciating the wonders of science.

ABSTRACT

Although small, the South African ostrich industry contributes 60% to the total world production of slaughter ostriches. Ostrich leather contributes more than 50% of the R2.1 billion turnover of this industry. This study is the first structured investigation into the characteristics of ostrich leather focussing on factors such as age, nutrition, slaughter weight, and genetics, and the influence thereof on intrinsic leather traits.

Large variation in terms of skin quality was found between producers, month of the year and production years. The effect of age suggested that leather thickness and tensile strength increased with age while the number of nodules declined by 2.8 for every month increase in slaughter age. Slit tear strength and tensile strength increased with heavier slaughter weights. Older ostriches had higher values for slit tear strength and skin thickness. Nodule diameter increased at a rate of 0.08mm per month increase in age. Nodules with an average diameter of more than 4.0mm were only obtained in the combination of old heavy birds, while nodule diameter of the other age-weight combinations ranged between 3.3mm and 3.5mm.

Subjective assessment of nodule traits by participants with or without prior knowledge of age suggested that slaughter age accounted for 46% of the variation in estimated slaughter age. Nodule acceptability scores generally increased with an increase in slaughter age. Moderately acceptable scores were found in skins from birds 11 months and older.

The effect of energy and protein concentrations of ostrich diets suggested that raw skin areas were 19.4% and 21.8% larger at slaughter for birds receiving a diet containing 10.5 MJ/ME and 12.0 MJ ME/kg DM respectively, compared to that of birds receiving a 9.0 MJ ME/kg DM diet. Leather thickness taken parallel to the spine was increased by 13% when birds were fed the higher energy diet. Dietary protein concentrations failed to influence skin weight, skin area or any physical leather properties.

The genetic variation in nodule size measured at different sampling sites on the skin suggested that nodule size increased chronologically with age at the neck, back, upper leg, and flank and butt areas. Estimates of h^2 for nodule size ranged from 0.09 ± 0.07 on the flank region to 0.24 ± 0.10 on the upper leg region. Preliminary results seem to suggest that nodule size on different locations of the skin is not necessarily the same genetic trait. It was concluded that measurements at any specific site is unlikely to predict measurements at other sites with a high degree of accuracy due to the large variation that exists between measurement sites.

This dissertation provides an insight into the complexity of ostrich leather quality, and the interaction of leather traits, such as nodule size and shape, leather thickness and tensile strength, that determine ostrich leather quality.

OPSOMMING

Alhoewel klein, produseer die Suid-Afrikaanse volstruisbedryf 60% van die totale wêreldproduksie van slagvolstruise. Volstruisleer is verantwoordelik vir meer as 50% van die R 2.1 biljoen omset van die bedryf. Hierdie studie is die eerste gestruktureerde ondersoek na die intrinsieke eienskappe van volstruisleer en die invloed van ouderdom, voeding, slagmassa en genetika op hierdie eienskappe.

Groot variasie t.o.v. leerkwaliteit is waargeneem tussen produsente, maande van die jaar en produksiejare. Die effek van ouderdom toon dat leerdikte en treksterkte verhoog het met toename in ouderdom, terwyl die aantal knoppies afneem met 2.8 vir elke maand toename in slagouderdom. Skeur- en treksterkte het verhoog met 'n swaarder slagmassa (64kg vs. 99kg). Hoër waardes vir skeursterkte en veldikte is vir ouer voëls (384 dae vs. 234 dae ouderdom) verkry. Knoppie deursnit het teen 'n tempo van 0.08mm per maand toename in ouderdom verhoog. Knoppies met 'n gemiddelde deursit van groter as 4.0mm is slegs waargeneem in swaar-ou voëls, terwyl die knoppie deursnit van die ander massa-ouderdom kombinasies tussen 3.3mm en 3.5mm gewissel het.

Die subjektiewe waarneming van 28 respondente, ingelig of oningelig oor die betrokke slagouderdom, dui daarop dat die werklike slagouderdom verantwoordelik is vir 46% van die variasie in geskatte slagouderdom. Die puntetoekenning vir knoppie-aanvaarbaarheid het verhoog met 'n toename in slagouderdom. Aanvaarbare puntetoekenning vir knoppie-ontwikkeling is verkry vir voëls vanaf 11 maande en ouer.

Die effek van energie- en proteïenkonsentrasies in volstruisdiëte toon dat die rouveloppervlakte onderskeidelik 19.4% en 21.8 % groter was met slagting vir voëls wat onderskeidelik 'n 10.5 MJ/ME en 12.0 MJ ME/kg DM diëte gevoer is, in vergelyking met voëls wat 'n 9.0 MJ ME/kg DM dieet ontvang het. Leerdikte, geneem parallel met die ruggraat, het met 13% toegeneem wanneer die hoër energie dieet gevoer is. Dieetproteïen konsentrasies het geen invloed op velmassa, veloppervlakte of enige fisiese leerkwaliteitseienskappe gehad nie.

Die genetiese variasie in knoppiegrootte geneem op verskillende lokaliteite op die vel toon 'n chronologiese toename met ouderdom in die nek-, rug-, boud-, sy- en stuitjie gebiede. Beraamde h^2 vir knoppiegrootte wissel vanaf 0.09±0.07 op die sye tot 0.24±0.10 op die boudgedeelte. Voorlopige resultate dui aan dat knoppiegrootte op verskillende lokaliteite nie noodwendig dieselfde genetiese basis het nie. Die gebruik van een lokaliteit vir die voorspelling van die eienskappe van 'n ander, blyk nie sinvol te wees nie a.g.v. die groot variasie wat tussen verskillende lokaliteite bestaan.

Hierdie studie verskaf insig oor die kompleksiteit van volstruisleerkwaliteit en die interaksie van leereienskappe soos knoppiegrootte en –deursnit, veldikte en treksterkte, in die bepaling van leerkwaliteit.

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Chapter 1

General introduction

In South Africa, the ostrich industry is relatively small compared to other animal industries like poultry, red meat and dairy. Nevertheless, the industry has a gross turnover of approximately R 1.5 billion nationwide, with the Western Cape producing approximately 75% of the total income from ostrich products in South Africa. With South Africa currently providing approximately 65% of the ostrich leather produced globally (Future Sense Incorporated, 2004), it is clear that the industry is of major strategic importance to the local economy. The total investment in ostrich activities (i.e. production of slaughter birds, processing of skins, meat and feathers, and agri-tourism) exceeds R 2.1 billion. By value, the South African ostrich enterprise is one of the top twenty agro-based industries, and it ranks very high on the list of national exports. Ostrich production is mostly practiced in the Western Cape Province, Eastern Cape and pastoral areas of the Karoo. Ostrich farming complements crop production and horticulture, utilizing the by-products of cropping and adding stability to both the cropping and horticultural industries. Ostrich farming provides a livelihood for 20 thousand primary producers and farm labourers. The primary industry also benefits all participants in the associated secondary industries, namely the slaughter, tanning and feather industries. The ostrich industry thus has marked direct and carry-over effects on the local economy.

The main products of ostrich farming are skins, meat and feathers. Initially the booming feather trade was the major source of income for ostrich farmers in the late 18^{th} and early 19^{th} century (Smit, 1963). After the collapse of the feather market during the Second World War, the ostrich industry shrunk overnight. The end of the Second World War saw a resurgence of the industry, with feathers and biltong (i.e. dried meat) considered as the main products at the time (Smit, 1963). Later on leather became the most important product, contributing markedly to the revenue of commercial ostrich farmers. It was estimated that the contribution of ostrich leather to total income derived from slaughter ostriches amounted to approximately 70% in 1998 (Cloete *et al*., 1998). This contribution has, however, declined in recent years due to the increase in the popularity of ostrich meat in European countries (Hoffman, 2005). The increased emphasis on meat production was partly due to concerns regarding bovine spongiform encephalopathy (BSE). The status of ostrich meat as a healthy alternative red meat (Lambrechts & Swart, 1998) also contributed to an increase demand for ostrich meat. The relative importance of the respective products is depicted in Figure 1.

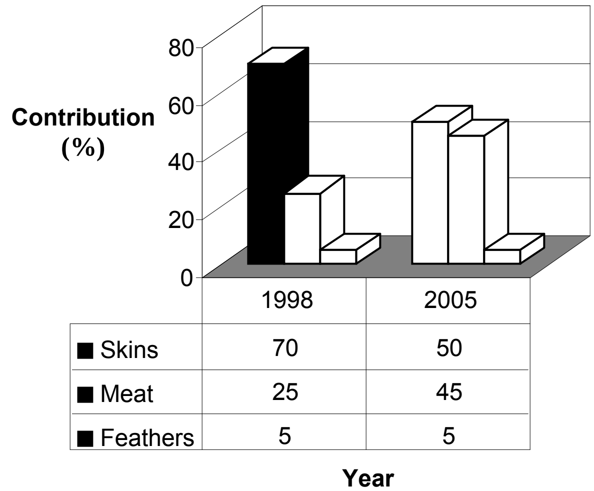

Figure 1. The relative importance of the various ostrich products, as adapted from Cloete *et al*. (1998) and Hoffman, (2005).

Ostrich leather is regarded as one of the most attractive, supple and durable of all exotic leathers (National Agricultural Marketing Council, 2003). Ostrich leather competes in the luxury market, and is marketed as a high value, exquisite product (Cooper, 2001; Adams & Revell, 2003). The occurrence of nodules on an ostrich skin, as determined by the feather follicles, adds to the unique appearance of ostrich leather. Despite its value, little is known about its physical properties, and the influence of different factors on ostrich leather quality (Sales, 1999). One of the only studies in this regard was undertaken by Angel *et al*. (1997). At present skin grading of ostriches strongly depends on physical damage (Meyer *et al*., 2003). Although the size and distribution of these nodules are alleged to contribute to the marketability of the product, no formal standards are available, while this contention is also the subject of some debate (Sales, 1999). The effects of age and slaughter weight on nodule number and size have not been substantiated in scientific work although Holtzhauzen & Kotze (1990) alleged that that nodule size is age-dependent.

From the percentages quoted in Figure 1, it is clear that leather is still considered as the primary product of an ostrich enterprise, contributing approximately 50% of the total income of ostrich producers, depending on the quality of the product. Given the importance of this product, the scarcity of scientific investigations regarding quality is difficult to understand. The flow of knowledge regarding ostrich leather is probably handicapped by aspects like intellectual property concerning the processing, tanning and treatment of ostrich skins.

Against this background, the present study focused on the intrinsic traits of ostrich leather, and the influence of factors such as age, slaughter weight, nutrition, and genetics, on these traits. The potential of different sampling sites for the objective assessment of ostrich leather traits were also investigated.

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Chapter 2

Evaluation of subjectively assessed nodule traits of ostrich skins as influenced by slaughter age[1]

Abstract

Ostrich skins (n = 214) were assessed by participants involved in the ostrich leather production and marketing chain. The participants were from various sectors in the ostrich industry, including producers, skin graders, leather marketers, agents and process managers. Skins were evaluated during two occasions, firstly without any knowledge of slaughter age, and thereafter with prior knowledge of slaughter age. Nodule acceptability and distribution for each skin were scored on a linear scale of 1 to 10. Slaughter age, as estimated by the participants during the first evaluation, was regressed on the actual age of the birds at slaughter. The derived regression indicated that actual slaughter age accounted for approximately 46% of the variation found in estimated slaughter age. Nodule acceptability scores generally increased with slaughter age. Average scores of at least moderately acceptable were only found in skins slaughtered at 11 months and older. A corresponding trend was found for nodule distribution scores with an increase in slaughter age. Between skin variance ratios were comparatively low for nodule acceptability (0.09-0.10), depending on prior knowledge of slaughter age or not) and nodule distribution (0.05-0.06). The between scorer variance ratio was generally higher, exceeding 0.35. Scores for nodule acceptability with or without prior knowledge of the age of individual skins at slaughter were essentially the same, as judged from a near unity covariance ratio between individual skins. A similar trend was observed for nodule distribution score. The need for practical methods for objective assessment of the acceptability of nodules and ostrich leather quality was expressed.

INTRODUCTION

Leather contributes markedly to the revenue of commercial ostrich farmers, as indicated by Van Zyl (2001). Ostrich leather competes in the luxury market, and is marketed as a unique, high-value product (Cooper, 2001; Adams & Revell, 2003). The occurrence of nodules on the ostrich skin, as a result of feather development, produces the unique appearance of ostrich leather. These nodules contribute markedly to leather quality (Sales, 1999). No formal standards are available to objectively determine either the acceptability or the distribution of these nodules, however, and skins are largely graded according to subjective evaluation. The effect of age at slaughter on average nodule diameter and the number of nodules per dm^2 of skin has recently been established on an objective basis (Cloete *et al.*, 2004; Meyer *et al.*, 2004). Both traits are clearly age-dependent, with nodule size increasing and nodule density decreasing with an increase in slaughter age. The latter studies were conducted against the background of allegations that tanneries adopted the assessment of nodule acceptability as part of their grading strategy

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to control an increasing supply of skins with unacceptably small nodules. This trend was linked to a propensity to slaughter ostriches earlier than the traditional 14 months of age, to minimize costs and risk (Meyer, 2003). The average nodule size allegedly gradually decreased in the broader industry, presumably due to a positive relationship of nodule size with slaughter age (Cloete *et al.*, 2004; Meyer *et al.*, 2004).

Against this background, this study focuses on the subjective evaluation of nodule acceptability and distribution on ostrich skins obtained from birds slaughtered at various ages, as assessed by various role-players throughout the ostrich leather production and marketing chain.

MATERIAL AND METHODS

A total of 214 ostrich skins obtained from birds slaughtered at the Oudtshoorn Experimental Farm was used in the study. The origin of the commercial ostrich flock at the Experimental Farm is well-documented (Van Schalkwyk *et al.*, 1996; Bunter, 2002). Ostriches that contributed data to the study were slaughtered at a range of ages, encompassing 4 to 14 months. After slaughter, the skins were processed and chrome crusted according to standard procedures (Meyer *et al.*, 2002). The skins were used to assess the acceptability of the nodules for market requirements, as determined through subjective scoring by 28 role-players in the ostrich leather production and marketing chain. These role-players consisted of primary producers (n = 7), skin graders (n = 3), leather marketers (n = 3), agents (n = 11) and people involved in the management of the production and marketing process (managers; n = 4). The scorers were chosen to represent a diverse range of sectors in the ostrich production and marketing chain, to ascertain whether the respective perceptions in the industry were compatible.

The skins were numbered individually and randomly placed on evaluation tables. The 28 scorers were asked to score individual skins for nodule distribution and for nodule acceptability for the marketplace. Skins were scored on a linear 10-point scale. In the case of acceptability 1-2 was regarded as highly undesirable, 3-4 as undesirable, 5-6 as moderately acceptable, 7-8 as highly acceptable and 9-10 as excellent. For distribution, 1-2 was regarded as a very poor distribution, 3-4 as poorly distributed, 5-6 as reasonably well distributed, 7-8 as well distributed and 9-10 as excellently distributed. Initially the scorers were asked to assess the skins without prior knowledge of the slaughter age of each bird. At this stage, they were also asked to estimate the age of the bird producing the specific skin. The skins were subsequently shuffled and the actual slaughter age was attached to the skin. The evaluation process was then repeated with the scorers knowing the age of the birds at slaughter.

After editing for incomplete records and scores outside the acceptable boundaries, the data set included complete information on 4018 observations, consisting of skin identity × scorer identity records. The data were normally distributed (Table 1), with the scorers using the entire allowed range of 1-10 in all instances. The data were thus subjected to standard mixed model analysis of variance procedures. The trade of the scorer (producer, grader, marketer, agent or manager) was treated as a fixed effect in the analysis. Effects of slaughter age were modelled, using a cubic spline (Verbyla *et al.*, 1999). Fixed linear and random nonlinear components of the spline were interacted with the trade of the scorer, using ASREML (Gilmour *et al.*, 1999). Random deviations from linearity conforming to a smooth trend were initially included in the model. Since these trends were not significant, they were excluded from the final analyses. The random effects of the identity of the skin and that of the scorer (nested within the trade of the scorer) were fitted simultaneously. Two-trait analyses were subsequently done, to obtain covariance components and ratios between scores for nodule acceptability and distribution. These covariance components were partitioned in skin identity, scorer identity and residual components. Scores for nodule acceptability and distribution (as obtained with or without prior knowledge of the age of the skin) were also correlated in two-trait analyses, as described above. These (co)variance components were used to obtain estimates of the repeatability of scores particular to specific skins or scorers, as well as the correlations mentioned previously.

Table 1. Descriptive statistics for the traits assessed during the study, as based on 4018 records for each trait. All traits encompassed the maximum allowable score of 1-10.

TRAIT	MEAN ± S.D.	COEFFICIENT OF VARIATION (%)	SKEWNESS	KURTOSIS
Nodule acceptability				
Slaughter age unknown	5.21 ± 1.72	33.0	0.074	-0.306
Slaughter age known	5.24 ± 1.61	30.7	0.040	-0.181
Nodule distribution				
Slaughter age unknown	6.21 ± 1.71	27.5	-0.283	-0.243
Slaughter age known	6.19 ± 1.72	26.2	-0.177	-0.415

RESULTS

When all 4018 observations were considered, the following regression was derived for the relationship between actual slaughter age (independent variable) and estimated slaughter age (dependent variable):

Estimated slaughter age = 3.72 ± 0.10 + 0.67 ± 0.01 actual slaughter age (r = 0.68)

Standard errors follow the intercept as well as the regression coefficient, which were both different from zero (P<0.01). The near linear relationship between actual age and age estimated by the scorers (according to the occupation of the scorer) is evident from Figure 1. Although the trade of the scorer interacted (P<0.05) with the linear and nonlinear components of the spline for age (as indicated by a fair degree of crossing over of lines), a clear increase was discernable for all trades.

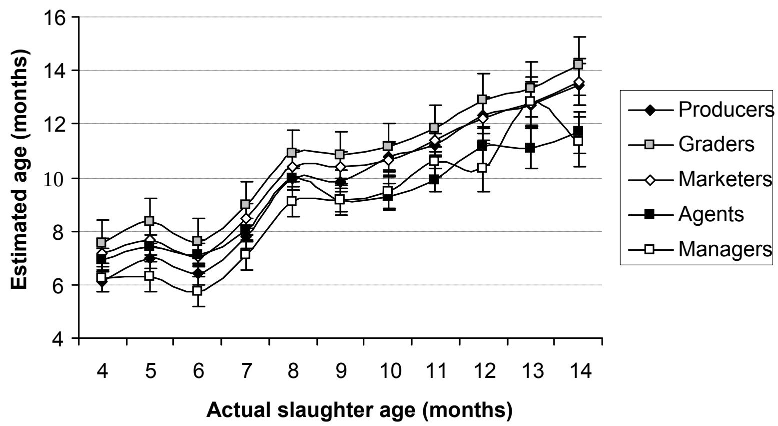

Figure 1. The relationship between actual slaughter age and slaughter age predicted by 28 scorers. The figure is presented as the interaction between the trade of the scorer and actual slaughter age. Vertical lines about the means reflect standard errors.

Derived coefficients of variation for the traits considered ranged from 26.2 to 33.0% (Table 1). Despite fairly high levels of variation, no evidence of non-normality was evident when derived coefficients for skewness and kurtosis were considered. Negative estimates of kurtosis indicate a relatively flat distribution for all traits. Acceptability scores of skin nodules judged in the absence of knowledge of age, increased with an increase in age at slaughter (Figure 2). Scores of moderate (acceptability 5-6 on the linear scale) was regarded as the minimum standard for acceptability. Based on average scores, it was evident that only skins of birds aged 11 months and older would qualify, when judged by producers, graders, agents and managers. Compared to other scorers, the marketers appeared to be generally stricter (P<0.05) as far as scoring for acceptability were concerned. Average scores of even the oldest birds barely reached the minimum requirement for acceptability according to their assessment.

From Figure 2 it was clear that the trade of the scorer once again interacted (P<0.05) with the linear and nonlinear components of the spline for slaughter age. The general tendency, however, reflected an increase in nodule acceptability with age for all trades.

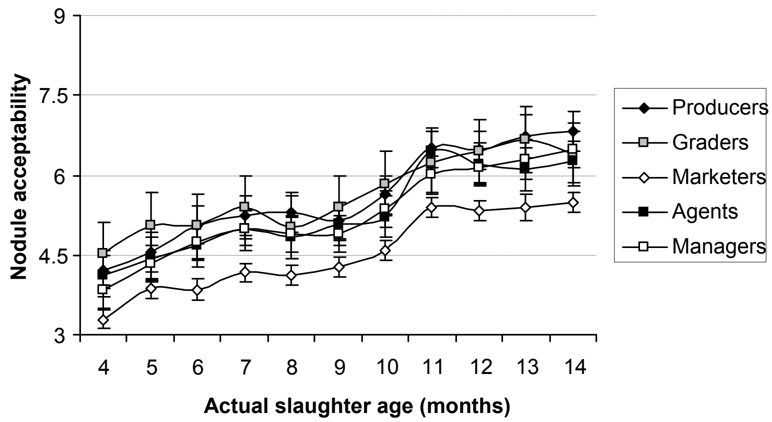

Figure 2. Nodule acceptability scores according to actual slaughter age and the trade of the scorers, when assessed without prior knowledge of the slaughter age of individual ostriches. Vertical lines about the means reflect standard errors.

From this perspective, overall trends for nodule acceptability were compared with or without information on age (Figure 3). The same basic trend was observed, although scorers tended (P<0.10) to award higher scores for nodule acceptability for skins of birds slaughtered at 11 months of age when the slaughter age were known.

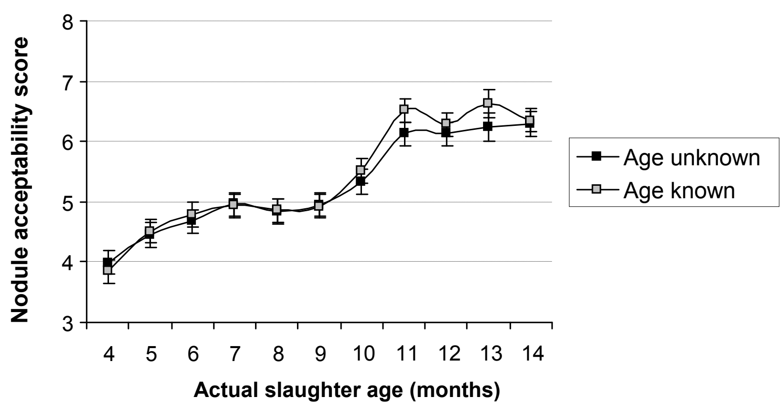

Figure 3. Mean nodule acceptability scores according to actual slaughter age for all scorers, with or without prior knowledge of the slaughter age. Vertical lines about the means reflect standard errors.

Scores for overall nodule distribution also showed a general increase (P<0.05) with an increase in slaughter age. The trade of the scorer interacted (P<0.05) with the linear and nonlinear components of the spline for slaughter age (Figure 4).

Figure 4. Nodule distribution scores according to actual slaughter age and the trade of the scorers, when assessed without prior knowledge of the slaughter age. Vertical lines about the means reflect standard errors.

At young ages, there was a suggestion for nodule distribution scores awarded when age was known to be below scores awarded when age was unknown (Figure 5). The converse was true at high ages, culminating in a tendency ($P<0.10$) towards a higher nodule distribution score when slaughter age was known at 13 months.

Figure 5. Mean nodule distribution scores according to actual slaughter age for all scorers, when assessed with or without prior knowledge of the slaughter age of individual skins. Vertical lines about the means reflect standard errors.

The between skin variance components were fairly low, leading to repeatability estimates (± s.e.) of 0.10 ± 0.02 and 0.09 ± 0.02 for nodule acceptability score, with and without prior knowledge of slaughter age. Corresponding estimates for nodule distribution score were 0.06 ± 0.01 and 0.05 ± 0.01, respectively. Between scorer variance ratios were higher; respectively 0.37 ± 0.07 and 0.43 ± 0.07 for nodule acceptability and 0.43 ± 0.07 and 0.45 ± 0.07 for nodule distribution. Repeatability results obtained from two-trait analyses were in all cases similar to, or within 0.01 of those derived from one-trait analyses. The between individual skin correlation between nodule acceptability and nodule distribution approached unity when age at slaughter was unknown (0.94 ± 0.03), and exceeded unity when age at slaughter were known (1.04 ± 0.03). Estimates of the between scorer correlation were somewhat lower at 0.54 ± 0.15, irrespective of whether slaughter age were known or not. The residual correlation amounted to 0.45 ± 0.01 when slaughter age was unknown and to 0.41 ± 0.01 when slaughter age was known. When correlations between nodule acceptability with or without prior knowledge of age were partitioned, the between individual skin component was estimated at 0.93 ± 0.03, the between scorer component at 0.77 ± 0.09 and the residual component at 0.25 ± 0.02. Corresponding correlations between nodule distribution with or without prior knowledge of slaughter age were 0.97 ± 0.04, 0.87 ± 0.05 and 0.26 ± 0.02 respectively.

DISCUSSION

The regression of estimated age of the bird at slaughter on actual slaughter age was significant (P<0.01). The scorers were thus able to estimate age at slaughter to a fair degree, based on the physical appearance of the tanned skin. However, variation in the dependent variable (actual slaughter age) only accounted for approximately 46% of the variation in estimated slaughter age. A very accurate linear regression equation in this instance would have had a slope of one and an intercept of zero. This clearly was not the case in the present study, the slope being below one and the intercept being above zero (P<0.01 in both cases). In very young birds, slaughter age was generally estimated higher than the actual age. The accurate prediction of age at slaughter, as based on the appearance of the nodules on the skin, was thus not possible. A general relationship between the two variables did, however, prevail. This result suggested that the scorers were able to respond to visual and/or tactile cues on the skin that assisted them in the estimation of slaughter age, although the relation was imperfect.

The acceptability of the nodules for the marketplace (as perceived by the scorers) improved with an increase in age at slaughter. It was demonstrated that objectively measured nodule size on ostrich skins also increased with slaughter age (Cloete *et al.*, 2004; Meyer *et al.*, 2004). The relative contribution of nodule size and nodule shape to nodule acceptability needs to be investigated further. The occurrence of nodules on ostrich skins produces the unique character of this specific type of leather, and it can therefore be expected that the size and shape of these nodules will play a role in the acceptability of ostrich leather in the marketplace.

Scorers from all trades recorded an increase in nodule acceptability with age at slaughter, but average scores given by marketers appeared to be more conservative than those given by the other leather trade representatives. This trend could be merely coincidental, since the means were obtained from the inputs of only three marketers. Alternatively, it could be speculated that marketers are intent on delivering a quality product to the next role-player in the marketing chain, resulting in them being stricter on a quality trait such as nodule acceptability than the scorers from other sectors of the marketing chain. This contention is, however, purely speculative and requires verification in further studies.

Scores for nodule distribution also improved with age, irrespective of the trade of the scorer. When nodule density was assessed objectively, it was found that the number of nodules per dm^2 decreased with an increase in slaughter age (Cloete *et al.*, 2004; Meyer *et al.*, 2004), implying that the average distance between nodules increased correspondingly. It seems therefore that assessment of nodule distribution was based on the proportional distribution of the nodules, and was not necessarily related to nodule density.

Knowledge with regard to the age at slaughter of individual skins did not result in marked changes in the derived age trends for nodule acceptability score or nodule distribution score. It thus seems as if the scorers assessed these two traits *per se*, without being unduly influenced by prior knowledge of the age of the individual birds at slaughter. The scorers did, however, tend to award higher scores for nodule acceptability to skins from birds slaughtered at 11 months and older when age was known; compared to when age was unknown. It is possible that preconceived notions in the ostrich industry could have influenced these scores, since a slaughter age of 11-12 months is widely being regarded as the minimum for achieving good skin grading results, while also saving on feed costs.

Both nodule acceptability and nodule distribution were essentially the same trait when assessed either in the presence or in the absence of knowledge on the age at slaughter of individual skins, as reflected by near unity between skin correlations. These results imply that, overall, average scores allocated to specific skins were markedly consistent. On the level of individual assessments made by scorers there appears to be higher levels of inconsistency, as reflected by markedly lower residual correlations amounting to only approximately 0.25. The distribution of the nodules, as assessed in the present study, seemed to closely reflect nodule acceptability. As a matter of fact, nodule acceptability score and nodule distribution score was essentially the same trait on an individual skin or animal level, as reflected by between individual correlations approaching or exceeding unity. In view of this evidence, it is debatable whether the industry representatives undertaking the scoring were able to differentiate clearly between the two traits.

Ideally, the between individual skin variance ratio would be expected to be high, indicating that specific skins were consistently allocated high or low scores by the bulk of the scorers (Roux, 1961). The between scorer variance ratio would be correspondingly low, indicating that the average scores allocated by all the scorers regressed back to a common mean, without some scorers being unduly conservative or liberal in their assessment of individual skins. This is clearly not the case, the between skin variance ratio being 10% or lower, while the between scorer variance ratio exceeded 35% in all cases. These results imply that the linear scale was not applied consistently by all the scorers. This is, however, not uncommon when traits are assessed subjectively in the animal sciences. In the study of Roux (1961), final year agricultural diploma students scored sheep according to Merino breed standards. The between sheep variance ratio in this study was 0.10, and the between scorer variance ratio 0.37. These results thus resembled those obtained in the present study closely. Roux (1961) emphasized the importance of a well-defined description of the subjective trait under assessment in studies of this nature. In the present study, the experience of the participants in the ostrich leather industry was assumed to be sufficient for consistence in their assessment, and no attempt was made to standardize their scores. Reflecting back, this was probably not the correct strategy. A number of studies on various livestock species indicated that well-defined subjective traits were scored very consistently when facilitated by aids like photographic standards. Individual scores for body plumage of layers were highly correlated between two experienced scorers, using a photographic standard as aid (0.87-0.94; Tauson *et al.*, 1984). Mean scores for the extent of udder oedema in dairy heifers of test scorers were closely related to that of an official scorer when using a graphic aid developed by the latter (0.94; Tucker *et al.*, 1992). Correlations pertaining to individual test scorers in relation to the official scorer were also high, ranging from 0.86 to 0.92. These examples serve to illustrate that the consistence of subjective scores can be improved upon by the provision of photographic or graphic aides. The development of a corresponding aid for the assessment of skin nodules should thus be considered.

CONCLUSIONS

The study indicated that nodule acceptability and nodule distribution scores on ostrich skins increased with slaughter age. It remains to be seen whether the increase in nodule acceptability score with an increase in slaughter age is mediated by the age-related change in nodule size of ostrich skins that is reported in the literature. Subjective assessment by the various role-players in the production and marketing chain of the ostrich industry was not very consistent, as indicated by fairly low between skin variance ratios. Alternative evaluation procedures need to be considered, to allow a greater measure of objectivity in the evaluation process. Such a development is likely to benefit all the participants throughout the ostrich leather production and marketing chain, by adding consistency to the evaluation of skin quality by various participants.

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Chapter 3

Effects of age on leather and skin traits of slaughter ostriches[2]

Abstract

Little is known about the factors affecting leather and skin traits in ostriches. The effect of age on physical skin traits of slaughter ostriches was consequently investigated. Forty skins representing slaughter ages ranging from 5 to 14 months were selected. Skins were selected to represent means of the respective age groups with regard to skin size and slaughter weight. It was evident that leather thickness increased with age. A similar tendency was observed for tensile strength. The number of nodules per dm² declined by 2.8 nodules for each month slaughter age increased. Average nodule diameter increased at a rate of 0.08 mm per month of age. The number of nodules per dm² decreased towards body positions situated nearer to the ventral aspect of the ostrich (upper leg and lower flank). Positions nearer to the centre back had more nodules per dm². The nodules on the neck and mid-crown area were smaller in diameter than those situated on the other body positions, with little difference between the upper leg, lower flank and butt positions. Repeatability estimates for the physical skin traits were in the medium to high range. Age thus affects physical leather traits to a lesser extent, apart from leather thickness. It does, however, exert an important influence on the nodule traits that were considered, and need to be considered in the marketing of ostrich leather.

INTRODUCTION

Leather contributes markedly to the revenue of commercial ostrich farmers. Cloete *et al*. (1998) estimated that the contribution of ostrich leather to total income amounted to approximately 70 %. This contribution has declined since then, with ostrich meat becoming more popular in European countries after the BSE scare. Leather is still estimated to contribute more than 50 % of the total income of ostrich producers, however, depending on the quality of the product.

Ostrich leather competes in the exotic leather market, and is marketed as a luxury product (Cooper, 2001; Adams & Revell, 2003). Despite its value, little is known about its physical properties, and the influence of various factors on it (Sales, 1999). At present skin grading of ostriches depends strongly on physical damage (Meyer *et al*., 2003b). Industry, however, requires information on aspects like the tensile strength of leather, to determine its suitability for usage in specific products. The occurrence of nodules on the ostrich skin, as determined by the feather follicles, adds to the unique appearance of ostrich leather and is

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therefore also an important aspect of leather quality. Although the size, shape and distribution of these nodules are alleged to contribute to the marketability of the product, no formal standards are available. This generalization is the subject of some debate (Sales, 1999).

Even though the effect of age on nodule traits has not been substantiated previously in scientific work, Holtzhauzen & Kotzé (1990) alleged that nodule size is age-dependent. This contention is supported by arguments that tanneries have recently added nodule size as a factor that determines grading in the assessment of skin quality, with a marked influence on the value of the skin. It was contended that this measure was adopted to control an increasing supply of skins with unacceptably small nodules, which resulted from the trend to slaughter ostriches earlier than the traditional 14 months of age, to minimize costs and risk (Meyer, 2003). Conventional wisdom has it that slaughter ages earlier than 14 months also result in unfavourable nodule shapes resulting from immature or 'green' feathers.

Against this background, this study focuses on the effect of age on physical characteristics important for the use of ostrich leather in various leather markets and related industries. The study also reports on the effect of age on nodule parameters measurable on the skin.

MATERIAL AND METHODS

A trial was conducted to investigate the effect of slaughter age on ostrich leather traits. For this purpose, approximately 524 ostrich skins from the Klein Karoo Agricultural Development Centre, slaughtered from 1997 to 2000, were available. The origin and history of the commercial ostrich flock at the Centre, as well as husbandry practices followed, are described adequately in the literature (Bunter, 2002). The skins that were available were screened to find four skins (two from males and two from females) to represent each slaughter age from five months to 14 months. Skins were selected to represent the mean slaughter weight and skin size of the respective age groups as closely as possible. The skin size refers to the size of the skin in the raw stage, as determined immediately after slaughter.

The selected skins were evaluated in the chrome-crusted stage at five different positions on the skin (see Figure 1) for the number of nodules in an area of one dm^2. The base diameter of 10 individual nodules within each site (chosen according to a predetermined grid) was measured with a Digimatic Caliper. The sizes of individual nodules were then averaged to obtain a single value for each position.

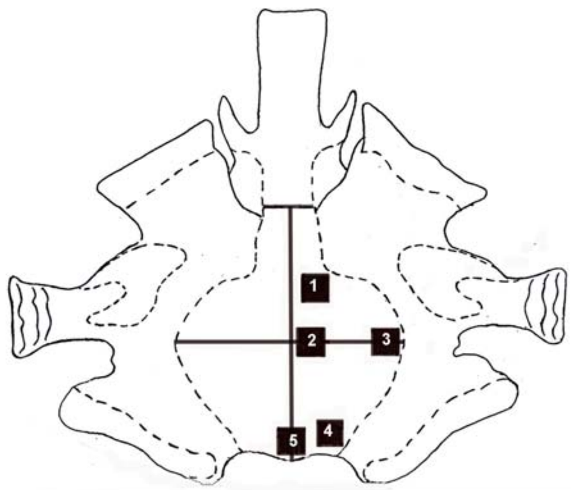

Figure 1. Image of an ostrich skin illustrating the five sample sites for the assessment of nodule traits.

An A4-sized leather sample from the butt locality (Site 5 in Figure 1) of each of these skins was obtained and tested at the SA Wool Testing Bureau. The butt region is considered an official sampling position for physical leather traits in lambs (Passman & Sumner, 1987; Snyman & Jackson-Moss, 2000). Samples were used to assess for tensile strength, elongation at grain break and slit tear strength on an Instron machine, as described by Snyman & Jackson-Moss (2000). Tensile strength was defined as the force required for the breaking of a dumbbell-shaped leather sample on the Instron. It was expressed in relation to the diameter at the narrowest part of the dumbbell-shaped piece of leather, and the thickness of the sample. Elongation at grain break was determined during the test for tensile strength. It was defined as the percentage stretch of the dumbbell shaped leather sample before it broke. The test for slit tear strength involved a rectangular leather sample with a small slit cut in it. The sample was then pulled apart by a clamp attached to its base and another clamp inserted through the slit. The point at which the slit starts to tear is defined as the slit tear strength. The slit tear strength was expressed in relation to average leather thickness. Leather thickness of each sample was measured in millimeters. Each sample was sub-sampled and assessed in duplicate on samples cut parallel to the spine and perpendicular to the spine, respectively (Cooper *et al*., 1997; Holst *et al*., 1997; Snyman & Jackson-Moss, 2000).

Monthly age group means could be described as longitudinal data. On the assumption that a specific trend would be discernable, a smoothing spline was fitted to the data (Verbyla *et al*., 1999). The spline consisted of three components, namely: a fixed linear component, random deviations from linearity following a smooth trend, and random deviations from linearity not conforming to a smooth trend. ASREML was used for this purpose (Gilmour *et al*., 1999). Other fixed effects contained in the model, included gender and orientation of the sample (parallel or perpendicular to the spine – Holst *et al*., 1997; Snyman & Jackson-Moss, 2000) for the physical leather traits. Sub-samples were taken parallel to or perpendicular to the spine for the assessment of physical leather traits, thus resulting in two measurements from the butt region of the same skin. Nodule number and nodule size were also recorded for five localities on each skin (Figure 1). The same skin was thus sampled repeatedly in both instances. To account for this, the identity of the skin was added as an additional random effect to the models of analysis (Gilmour *et al*., 1999). This procedure had the advantage that repeatability estimates could be calculated for the physical skin traits, as well as for the number and size of the nodules.

RESULTS

Group means for slaughter weight and raw skin area increased linearly with slaughter age (P<0.01; Figure 2). Random deviations from linearity not conforming to a smooth trend were also significant (P<0.05), but they were clearly of minor importance when the general pattern in Figure 2 was considered. The overall regressions (± s.e.) for an increase of one month in age amounted to 6.2 ± 0.4 kg for slaughter weight, and to 4.2 ± 0.7 for skin area (P<0.01).

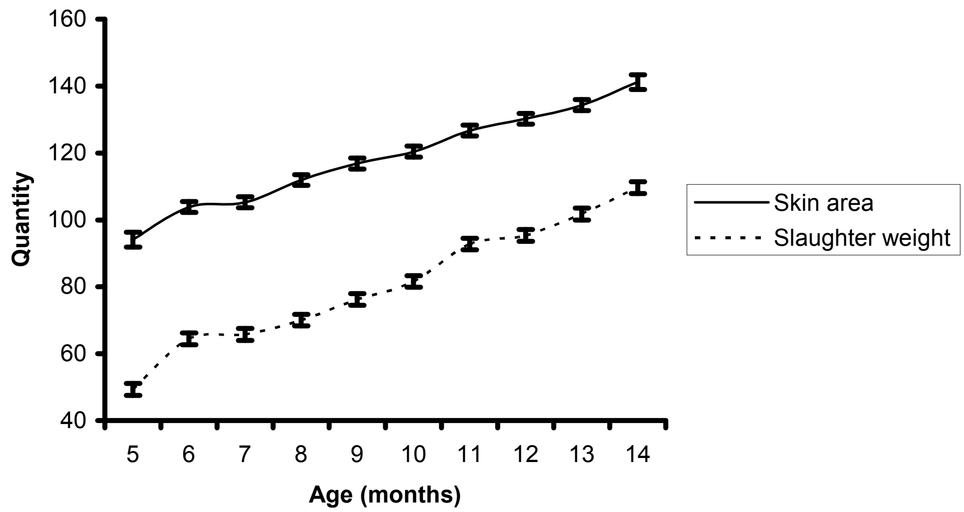

Figure 2. The relationship of slaughter weight (in kg) and raw skin area (in dm²) with slaughter age. Vertical bars about the means depict standard errors.

When physical leather traits were considered, there was a tendency (P<0.10) for tensile strength to increase by 0.43 N/mm² with an increase of one month in slaughter age (Table 1). An increase in skin thickness per month of age at slaughter amounted to 0.05 mm per month (P<0.01). No significant trends were obtained for elongation and slit tear strength. Overall, nodule number decreased at a rate of 2.8 nodules per dm² for each month increase in slaughter age (P<0.01). Nodule diameter increased by 0.08 mm per month as slaughter age increased (P<0.01).

Another significant fixed effect was that of gender, where males generally had thicker (P<0.05) skins than females (0.93 ± 0.03 vs. 0.82 ± 0.03 mm respectively). The average elongation at grain break of samples cut parallel to the spine was also somewhat lower (P<0.05) than that of samples cut perpendicular to the spine (26.9 ± 0.5 vs. 28.3 ± 0.5 % respectively). These fixed effects did not interact with age at slaughter (P>0.10).

Sample position had a marked influence upon the number of nodules per dm² and average nodule diameter (Table 2). The number of nodules per dm² generally decreased ($P<0.01$) towards the body positions situated nearer to the ventral aspect of the ostrich (upper leg and lower flank). The positions nearer to the back line had more nodules per dm². The nodules on the neck and mid-crown area were smaller ($P<0.01$) in diameter than those situated on the other body positions, with little difference between the latter three positions. The repeatability of leather traits was investigated as a by-product of the study (Table 3). These estimates were significant (i.e. more than twice the corresponding standard error), and at least medium in magnitude.

Table 1. Means (± s.e.) for physical leather properties and nodule parameters, as affected by slaughter age. Regressions of the respective dependent variables on age are also presented. Means are based on four observations, two males and two females per age category.

AGE AT SLAUGHTER	**PHYSICAL LEATHER PROPERTIES**				**NODULE TRAITS**	
	Strength (N/mm²)	**Elongation (%)**	**Slit tear strength (N/mm)**	**Thickness (mm)**	**Number (n/dm²)**	**Diameter (mm)**
Age (months)						
5	16.3 ± 1.3	26.7 ± 1.0	93.0 ± 5.4	0.66 ± 0.05	68.6 ± 1.7	3.05 ± 0.07
6	18.3 ± 1.2	27.1 ± 1.0	93.8 ± 5.0	0.71 ± 0.05	56.2 ± 1.5	3.32 ± 0.06
7	18.4 ± 1.1	28.0 ± 1.0	94.8 ± 4.7	0.77 ± 0.04	56.4 ± 1.5	3.29 ± 0.06
8	18.3 ± 1.0	27.7 ± 0.9	92.5 ± 4.5	0.80 ± 0.04	55.3 ± 1.5	3.20 ± 0.06
9	19.3 ± 1.0	28.7 ± 0.9	95.1 ± 4.4	0.87 ± 0.04	52.4 ± 1.5	3.32 ± 0.06
10	18.8 ± 1.0	27.5 ± 0.9	90.8 ± 4.4	0.86 ± 0.04	48.3 ± 1.5	3.50 ± 0.06
11	19.8 ± 1.0	27.9 ± 0.9	93.6 ± 4.5	0.95 ± 0.04	43.7 ± 1.5	3.55 ± 0.06
12	19.9 ± 1.1	28.2 ± 1.0	90.4 ± 4.7	0.97 ± 0.04	46.3 ± 1.5	3.56 ± 0.06
13	20.1 ± 1.2	26.4 ± 1.0	91.8 ± 5.0	1.02 ± 0.05	41.7 ± 1.5	3.70 ± 0.06
14	21.4 ± 1.3	27.7 ± 1.0	97.2 ± 5.4	1.13 ± 0.05	38.7 ± 1.7	3.89 ± 0.07
Regression (± SE)	0.43 ± 0.22	0.03 ± 0.19	0.01±0.97	0.05 ± 0.01	-2.79 ± 0.40	0.08±0.01
Significance	P<0.10	n.s.	n.s.	**	**	**

n.s. Not significant ($P>0.10$) ** Significant ($P<0.01$)

Table 2. Means (± s.e.) for the number of nodules per dm² (number) and the mean diameter of nodules (mm) measure at five body positions (as depicted in Figure 1) on ostrich skins.

BODY POSITION	**TRAIT**	
	Nodules per dm²	**Nodule diameter (mm)**
1 – Neck	59.2 ± 1.6^{c}	2.90 ± 0.07^{a}
2 – Mid crown area	61.2 ± 1.6^{c}	3.01 ± 0.07^{a}
3 – Upper leg	28.6 ± 1.6^{a}	3.64 ± 0.07^{b}
4 – Lower flank	42.1 ± 1.6^{b}	3.74 ± 0.07^{b}
5 – Butt	63.7 ± 1.6^{c}	3.76 ± 0.07^{b}

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

Table 3. Repeatability estimates for physical leather characteristics and nodule traits of ostrich skins.

TRAIT	REPEATABILITY ESTIMATE ± S.E.
Leather quality	
Tensile strength (N/mm²)	0.48 ± 0.13
Elongation (%)	0.35 ± 0.15
Slit tear strength (N/mm)	0.36 ± 0.15
Thickness (mm)	0.66 ± 0.10
Nodules	
Number (n)	0.30 ± 0.09
Diameter (mm)	0.40 ± 0.09

DISCUSSION

Few literature sources reporting physical parameters for ostrich leather are available and comparative values from other species were therefore considered. Averages generally accorded with values reported for calf (Cooper *et al*., 1997) and sheep leather (Snyman & Jackson-Moss, 2000). The thickness of ostrich leather also corresponded with values of approximately 1mm reported for leather derived from lambskin (Holst *et al*., 1997) and sheepskin (Snyman & Jackson-Moss, 2000). Angel *et al*. (1997) reported similar mean values for ostrich leather. They found that the average thickness (± s.d.) was 1.0 ± 0.3 mm, ranging between 0.7 and 1.4 mm, for ostriches slaughtered between 9.1 to 12.7 months of age on average. Angel *et al*. (1997) also stated that tensile strength of ostrich skins was very high, regardless of age. The tensile strength of 53 skins in the latter study was above 75 kg/cm² (or 7.4 N/mm²). Passman & Sumner (1987) found that the strength of lambskin increased with age, after correction for leather thickness. This is in partial agreement with results from the present study, where tensile strength tended to increase with age. Skins obtained from older birds were thicker. Angel *et al.* (1997) correspondingly found that ostrich leather thickness increased linearly with age, with a positive correlation of 0.59 existing between age and leather thickness. In lambskin, leather thickness was found to increase from 0.57 mm at 10 weeks of age to 0.67 at 30 weeks of age in the flank region (Passman & Sumner, 1987). Corresponding age differences in the butt region ranged from 0.71 mm to 0.82 mm over the same age interval.

The reduction in the number of nodules per dm² with an increased age could be explained by the fact that the number of nodules on any one ostrich skin is constant. Conversely, the size of the skin is growth dependent, and increases with age. It is therefore to be expected that the nodule density will decrease as the ostrich grows, since the same number of nodules is spread over an extended area. As far as nodule size were concerned, Mellett *et al*. (1996) suggested that the desired nodule size could be obtained as early as 10 months of age, while the ideal nodule shape can only be reached by 14 months. The present study did not attempt to measure the shape of the nodules, but their size continued to increase beyond 10 months of age. In the absence of specific guidelines for minimal requirements for nodule shape and size, it is impossible to arrive at conclusive recommendations as far as nodule diameter is concerned. Further research on this topic is indicated to gain a better understanding of the relative importance of nodule size and appearance for skin quality and price determination.

The marked variation in the number of nodules per dm^2 and nodule size is also of interest. In general, body sites with increased numbers of nodules per dm^2 also had smaller nodules. The butt area appears to be an exception to this generalization. This part of the skin combines a high nodule density with a large nodule size. At this stage, it cannot be taken for granted that trends in other ostrich populations will be similar to that of the present study, and further research appears to be warranted.

It is important to note that the repeatability estimates for physical leather traits were moderate. A degree of correspondence across localities on a skin cannot be regarded as indicative of selection response in such traits. However, breed differences in the physical leather characteristics of sheep suggest the possibility of genetic influences upon leather quality (Passman & Dalton, 1982; Passman & Sumner, 1987; Holst *et al*., 1997; Snyman & Jackson-Moss, 2000). Further research in this area is indicated, to explore the possibility of altering physical skin and nodule parameters by genetic selection.

The effect of gender on skin thickness was consistent with results reported by Van Schalkwyk *et al*. (2002). Meyer *et al*. (2003a) also reported that the average fat-free skin weight of male ostriches was heavier than that of female ostriches. It was found that male broiler chickens had slightly thinner skins, but that the thickness of the dermal layer was higher in males than in females (Christensen *et al*., 1994). Males also had stronger skins than females. No gender differences in tensile strength or slit tear strength were, however, found in the present study, when corrected for leather thickness.

Holst *et al*. (1997) reported that the tensile strength of lamb leather samples cut parallel to the spine was higher than that of samples cut perpendicular to the spine. The only significant influence of the orientation of the sample on skin characteristics in the present study was for elongation. In a previous study, Meyer *et al*. (2003b) found no difference in the relative size of scars left by cut wounds differing in orientation (parallel or perpendicular to the spine). It was argued that the structure of ostrich skin, which comprises of a collagen fiber matrix, contributed to this result.

CONCLUSIONS

Results from the present study clearly suggest that some physical leather traits as well as nodule distribution and nodule size were influenced by age. The importance of age on these parameters may differ according to the intended end use of a specific leather item (i.e. for clothing, footwear, belts etc. – see Sales, 1999 and Cooper, 2001). In view of the increasing importance of nodule size in the marketplace, it was evident that the largest nodule diameters could only be obtained in the oldest age group. Unless it is found to be possible to alter the physical appearance of nodules in another way (e.g. for instance by nutrition or breeding) producers may need to market ostriches at relatively high ages; namely between 12 and 14 months of age. Such a strategy is likely to result in poorer grading, unless skin damage can be prevented in some way. The likelihood of obtaining the highest grade for ostrich skins is clearly related to age (Meyer *et al*., 2002). Heavier groups of slaughter ostriches also sustained more skin damage than low live weight groups of the same age (Meyer *et al*., 2003a). The reduction in the proportion of first grade skins was attributed to the attainment of puberty in both instances, resulting in an associated increase in aggressive behaviour. Further studies on genetic, environmental and managerial aspects of skin size and skin quality thus seem a prerequisite for the proper understanding of the various interacting mechanisms involved in ostrich skin quality, including physical leather parameters. These aspects need to be understood for the further improvement of ostrich leather quality in the marketplace.

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Chapter 4

Effects of age and slaughter weight on ostrich skin and leather traits

Abstract

The separate and combined effects of age and slaughter weight on skin traits of slaughter ostriches were investigated in this trial. Twenty-five ostrich skins were selected from a total resource of 524 skins to represent four combinations in a 2 X 2 factorial design, with slaughter age and slaughter weight as factors. Values for tensile strength, slit tear strength and skin thickness were higher in ostriches with heavy slaughter weights than in those with lighter slaughter weights. The number of nodules per dm^2 decreased with an increase in slaughter weight. Ostriches in the old category had higher values for slit tear strength and skin thickness than those obtained for the young category. Slaughter age and slaughter weight interacted for average nodule diameter. Nodules with an average diameter of > 4.0 mm were only obtained in the combination of old-heavy birds at slaughter, while the average nodule diameter of the other age-weight combinations ranged between 3.3 mm and 3.5 mm. Repeatability estimates for the physical skin traits were in the medium to high range. Larger nodule sizes were only obtained in the ostriches conforming to the old slaughter age by heavy slaughter weight combination.

INTRODUCTION

Leather contributes markedly to the revenue of commercial ostrich producers. Cloete *et al.* (1998) estimated that the contribution of ostrich leather to the total income generated from a slaughter bird amounted to approximately 70%. This contribution has declined since then, with ostrich meat becoming more popular in European countries. Leather is, however, still estimated to contribute more than 50% of the total income of ostrich producers, depending on the quality of the product.

Ostrich leather competes in the luxury market, and is marketed as a high value, exotic leather (Cooper, 2001; Adams & Revell, 2003). The occurrence of nodules on the ostrich skin, as determined by the feather follicles, adds to the unique appearance of ostrich leather. Despite its value, little is known about its physical properties, and the influence of factors such as gender and age on these properties (Sales, 1999). Grading of skins, when graded by means of guidelines currently applied in the industry, is largely influenced by the extent of physical damage to a skin (Meyer *et al.*, 2003b). Although the size and distribution of these nodules are alleged to contribute to the marketability of the product, no formal standards for the qualification and quantification of ostrich skin quality traits are available (Sales, 1999).

Holtzhauzen & Kotze (1990) alleged that nodule size is age-dependent. However, the effects of age and slaughter weight on nodule number and size have not been substantiated in scientific work. The present study thus investigated the individual and combined effects of age and pre-slaughter live weight on qualitative leather traits in ostriches.

MATERIALS AND METHODS

Approximately 1100 skins from slaughter birds produced at the Oudtshoorn Experimental Farm, slaughtered from 1997 to 2000, were available for the study. A total of 524 skins were chosen from this supply and evaluated in this study. Table 1 gives the ranges that were used to select the skins from the latter group that were screened to investigate the effect of slaughter age and live weight at slaughter on leather traits.

Table 1. Ranges for the selection of skins to investigate the effect of age and live weight on ostrich leather traits.

AGE GROUP	**Age interval**	**WEIGHT GROUP**	
		Light	**Heavy**
Young	175-325 days	48-57 kg	80-118 kg
Old	326-475 days	56-97 kg	113-132 kg

The experimental design was a 2 X 2 factorial, with slaughter age (young vs. old) and slaughter weight (light vs. heavy) as main effects. A total of 25 skins were used, with 6-7 skins per treatment. Slaughter weight was defined as the weight of slaughter birds as weighed on the farm, prior to transport to the abattoir. Skin size was determined immediately after slaughter in the raw stage. Skins were evaluated at five different positions on the skin in the chrome-crusted stage (see Figure 1) for the number of nodules in an one dm^2 area. The base diameter in mm of ten representative individual nodules was also measured with a Digimatic calliper at each of these sites, and averaged to obtain a single value for each position.

A sample of the leather at the butt region of each of these skins was obtained and tested at the SA Wool Testing Bureau. Presently no standard region has been identified for representative sampling of ostrich leather physical quality traits. In lambs, the butt region is considered an official sampling position for physical leather traits (Passman & Sumner, 1987; Snyman & Jackson-Moss, 2000) and as this is a region on the ostrich skin with a lower financial value, it was decided to use this site for sampling. Samples were assessed for tensile strength, elongation at grain break and slit tear strength on an Instron machine, as described by Snyman & Jackson-Moss (2000) and Cloete *et al.* (2004). Tensile strength was defined as the force required to break a dumbbell-shaped leather sample on the Instron. It was expressed in relation to the diameter at the narrowest part of the dumbbell-shaped piece of leather, and the thickness of the sample. Elongation at grain break was determined during the test for tensile strength. It was defined as the percentage stretch of the dumbbell shaped leather sample before it broke. The test for slit tear strength involved a rectangular leather sample with a small slit cut in it. The sample was then pulled apart by a clamp attached to its base and another clamp inserted through the slit. The point at which the slit starts to tear is defined as the slit tear strength. The slit tear strength was expressed in relation to average leather thickness. Leather thickness of each sample was measured in millimetres. Each sample was assessed in duplicate on samples cut parallel to the spine and perpendicular to the spine, respectively (Cooper *et al.*, 1997; Holst *et al.*, 1997; Snyman & Jackson-Moss, 2000).

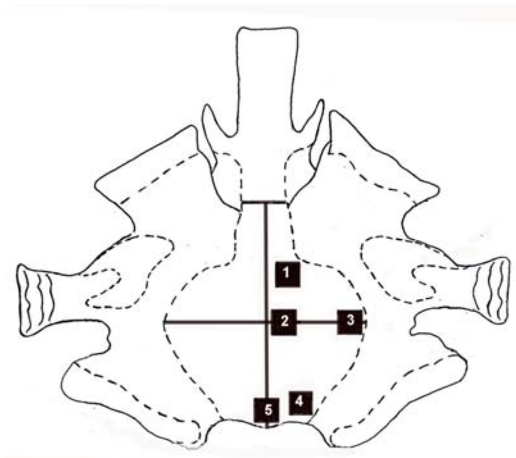

Figure 1. A diagram of an ostrich skin, depicting the five sample sites for the assessment of nodule size and the number of nodules on each skin.

The data were analysed according to standard procedures for a 2 (slaughter age) X 2 (slaughter weight) factorial experimental design. During the assessment of nodule number and diameter, means were obtained for the respective positions on the skin, as depicted in Figure 1. The same animal was sampled repeatedly in this experiment. Samples were taken parallel to or perpendicular to the spine for the physical leather traits, while nodule number and average nodule size were recorded for five localities on each skin (Figure 1). To account for the fact that the same skin was sampled repeatedly, identity of the animal was added as an additional random effect to the model of analysis (Gilmour *et al.*, 1999). This procedure had the added advantage that repeatability estimates could be calculated for the physical skin traits, as well as the number and size of nodules.

RESULTS

Although the interaction between slaughter age and slaughter weight was generally not significant, it is tabulated in Table 2 to depict the results at the interaction level. Overall, slaughter ostriches in the old category were 64% older than those termed as young ($P<0.01$; Table 2). The birds in the high weight group were, on average, younger ($P<0.05$) than their low weight contemporaries. The difference ($P<0.05$) in slaughter weight amounted to 53% in favour of the high weight group, expressed relative to the low weight group. Slaughter weight was also affected by the main effect of age, with old birds being 40% heavier ($P<0.01$) than the younger birds.

Table 2. Main effect means (±s.e.) for age (young vs. old) and slaughter weight (light vs. heavy) on slaughter traits and leather quality parameters in slaughter ostriches.

AGE CATEGORY	**YOUNG**		**OLD**		**SIGNIFICANCE**		
Slaughter weight category	**Light**	**Heavy**	**Light**	**Heavy**	**Age (A)**	**Slaughter weight (SW)**	**A X SW**
Number of observations:	7	6	6	6			
Slaughter traits							
Slaughter age (days)	253 ^{b} ± 15	216 ^{a} ± 16	396 ^{c} ± 16	372 ^{c} ± 16	**	*	n.s.
Weight (kg)	52.4 ^{a} ± 3.7	83.5 ^{b} ± 4.1	76.2 ^{b} ± 4.1	113.8 ^{c} ± 4.1	**	**	n.s.
Raw skin area (dm²)	97 ^{a} ± 3	115 ^{b} ± 4	111 ^{b} ± 4	141 ^{c} ± 4	**	**	n.s.
Leather quality							
Tensile strength (N/mm²)	16.9 ^{a} ± 1.0	20.7 ^{b} ± 1.1	18.9 ^{a,b} ± 1.1	20.4 ^{b} ± 1.1	n.s.	*	n.s.
Elongation (%)	28.7 ± 1.0	27.2 ± 1.1	28.0 ± 1.1	29.8 ± 1.1	n.s.	n.s.	n.s.
Slit tear strength (N/mm)	103 ^{b} ± 5	95 ^{a,b} ± 5	88 ^{a} ± 5	89 ^{a} ± 5	*	n.s.	n.s.
Thickness (mm)	0.68 ^{a} ± 0.04	0.85 ^{b} ± 0.05	0.89 ^{b} ± 0.05	1.14 ^{c} ± 0.05	**	**	n.s.
Nodules							
Number (n/dm²)	67.6 ^{c} ± 2.0	51.1 ^{b} ± 2.1	51.8 ^{b} ± 2.1	40.5 ^{a} ± 2.1	**	**	n.s.
Diameter (mm)	3.34 ^{a} ± 0.10	3.48 ^{a} ± 0.11	3.44 ^{a} ± 0.11	4.03 ^{b} ± 0.11	**	**	*

$^{a, b, c}$ Means with different superscripts differ (P<0.05) in rows

n.s. Not significant (P>0.05)

* Significant (P<0.05)

** Significant (P<0.01)

Overall, the tensile strength of leather from heavier birds was 16% higher than that of lighter contemporaries (Table 2). Elongation was independent (P>0.05) of both age and slaughter weight. Younger birds performed better (P<0.05) than the older birds for slit tear strength when the data were corrected for leather thickness. On average, older, heavier birds had thicker (P<0.05) skins compared to young, lighter contemporaries.

The number of nodules per dm² on the skins of older, heavier birds was fewer (P<0.05) than on the skins of young, lighter birds. An interaction (P<0.05) between age and slaughter weight was obtained for nodule diameter. No significant difference in nodule diameter was found between light and heavier birds in the young age group (P>0.05). However, the nodules of the heavier birds were larger (P<0.05) in diameter than that of lighter contemporaries in the old slaughter age group. The mean of the latter group also did not differ from that estimated for the younger birds (P>0.05).

Sample position had a marked influence upon the number of nodules per dm² and nodule diameter (Table 3). The number of nodules per dm² generally decreased ($P<0.01$) towards the body positions situated nearer to the ventral aspect of the ostrich (upper leg and lower flank). The positions nearer to the back line had more nodules per dm², with a suggestion of an increase from the anterior to the posterior aspect of the ostrich. The nodules on the neck and mid-crown area were smaller ($P<0.01$) in diameter than those situated on the other body positions, with little difference between the latter three positions.

Table 3. Means (±s.e.) for the number of nodules per dm² (number) and the mean diameter of nodules (mm) on five body positions (as depicted in Figure 1) of the slaughter ostriches.

BODY POSITION	TRAIT	
	Nodules per dm²	Nodule diameter (mm)
1 – Neck	$61.1^{c} \pm 1.4$	$3.13^{a} \pm 0.07$
2 – Mid crown area	$63.6^{c,d} \pm 1.4$	$3.14^{a} \pm 0.07$
3 – Upper leg	$29.9^{a} \pm 1.4$	$3.84^{b} \pm 0.07$
4 – Lower flank	$42.8^{b} \pm 1.4$	$3.91^{b} \pm 0.07$
5 – Butt	$66.6^{d} \pm 1.4$	$3.83^{d} \pm 0.07$

[a,b,c,d] Means in columns with different superscripts differ significantly ($P<0.05$)

Repeatability estimates, with a few exceptions, were significant (i.e. more than twice the corresponding standard error), and of medium to high magnitude (Table 4).

Table 4. Repeatability estimates for physical leather characteristics of ostrich skins.

TRAIT	REPEATABILITY ± S.E.
Leather quality	
Tensile strength (N/mm²)	0.24 ± 0.20
Elongation (%)	0.28 ± 0.20
Slit tear strength (N/mm)	0.27 ± 0.20
Thickness (mm)	0.51 ± 0.16
Nodules	
Number (n)	0.41 ± 0.11
Diameter (mm)	0.47 ± 0.10

DISCUSSION

As literature sources reporting physical parameters for ostrich leather are scarce, comparative values from other species were therefore also considered. Averages obtained during this study accorded with values reported for calf (Cooper *et al.*, 1997) and sheep leather (Snyman & Jackson-Moss, 2000). The thickness of ostrich leather also corresponded with values of approximately 1mm reported for lambskin (Holst *et al.*, 1997) and sheepskin (Snyman & Jackson-Moss, 2000) leather. Similar values were previously reported for ostrich leather by Angel *et al.* (1997). They found that the average thickness (± s.d.) was 1.0 ± 0.3 mm, ranging between 0.7 and 1.4 mm, for ostriches slaughtered on average ages between 9.1 to 12.7 months.

The separate and combined effects of ostrich slaughter age and slaughter weight on skin area were evident. The fact that the heavy weight birds were on average younger than the light weight birds could be attributed to the sampling of fast-growing birds, i.e. slaughter birds which could to an extent be regarded as outliers for the former group. Likewise, it was impossible to sample birds from the young slaughter age categories that had the same slaughter weight than those groups termed as old. Thus, although the experiment was designed to allow the partitioning of the effects of age and slaughter weight on skin traits, it was impossible to do so conclusively.

Although age did not have an influence on tensile strength and elongation in this investigation, earlier work by Cloete *et al.* (2004) indicated a tendency for tensile strength to increase by 0.43 N/mm^2 with an increase of one month in slaughter age. In the study of Cloete *et al.* (20040, age had no effect on elongation. Angel *et al.* (1997) stated that tensile strength of ostrich skins was very high, regardless of age. The tensile strength of 53 skins in their study was above 75 kg/cm^2 (or 7.4 N/mm^2). Passman & Sumner (1987) found that the strength of lambskin increased with age, after correction for leather thickness. Slit tear strength of skins obtained from young birds were superior to that of old birds after adjustment for leather thickness, whereas Cloete *et al.* (2004) found no fixed trend pertaining to slit tear strength. Skins obtained from older birds were also thicker, and consistant with the earlier work is the phenomenon that nodule density decreases with age. Angel *et al.* (1997) correspondingly found that ostrich leather thickness increased linearly with age, with a positive correlation of 0.59 ($P<0.01$) existing between age and leather thickness. Similarly, age also resulted in an increase in skin thickness of 0.05 mm per month (Cloete *et al.*, 2004). In lambskin, leather thickness was found to increase from 0.57 mm at 10 weeks of age to 0.67 at 30 weeks of age in the flank region (Passman & Sumner, 1987). Corresponding age differences in the butt region ranged from 0.71 mm to 0.82 mm over the same age interval.

In studies by Cloete *et al.* (2004) and Cloete *et al.* (2006), it was found that nodule size increased with age. However, the results from this investigation would also seem to indicate that it is not age alone, but also body weight (size) that has an influence on nodule size. When average nodule diameter was considered, it was clear that the largest nodule diameters could only be obtained in the ostriches conforming to the combination of old slaughter age and heavy slaughter weight. In this respect, Mellett (1995) suggested that the desired nodule size could be obtained as early as 10 months of age, while the ideal nodule shape can only be reached by 14 months.

Nodule density varied with positions on the skin. Nodule numbers per dm² were very low on the upper leg region (position 3 in Figure 1), intermediate on the lower flank region (position 4), and higher nearest to the centre back of the ostrich (positions 1, 2 and 5). Average nodule diameter was also variable between body positions. Smaller diameters were obtained on the neck and mid crown area (positions 1 and 2). Nodules with a larger diameter were found in the other three regions (positions 3, 4 and 5). While the results suggest that nodule density generally increase as nodule size decreases, the butt area appears to be an exception to this generalization. This part of the skin combines high nodule numbers with larger sizes. The five sampling positions for nodule density and diameters in the present investigation are the same as that used in the earlier investigation (Cloete *et al.*, 2004) and the same trends as discussed above were noted. No additional results to substantiate or refute these trends were found in the literature.

The largest nodule diameters could only be obtained in ostriches conforming to the combination of old slaughter age and heavy slaughter weight. Unless it is found to be possible to alter the physical appearance of nodules in another way, e.g. by nutrition or selection, producers may need to market ostriches at relatively older ages and heavier slaughter weights to ensure that they are not penalised for too small nodule sizes. Presently, a too small nodule size would result in a fall of one grading unit, resulting in substantial financial losses for the producer. Unless skin damage can be minimised or prevented, such a strategy is likely to result in poorer grading.

Grading of skins is clearly related to age (Meyer *et al.*, 2002), while heavier groups of slaughter ostriches sustained more skin damage than light weight groups of the same age (Meyer *et al.*, 2003a). This result was attributed to the earlier attainment of puberty in the former group. Further studies on genetic, environmental and managerial aspects of skin size and skin quality thus seems a prerequisite for the proper understanding of the various interacting mechanisms involved in ostrich skin size and quality. These aspects need to be understood for the further improvement of leather quality in the marketplace.

It is important to note that the repeatability estimates for physical leather traits were moderate, whereas the estimates calculated in our earlier work (Cloete *et al.*, 2004) were higher. At this stage it is unclear whether such traits would respond to selection for nodule size and shape, should it be desired. Further research in this area is required.

CONCLUSIONS

Results from the present study clearly support earlier suggestions that certain physical leather traits as well as nodule distribution and size are dependent on bird age and/or slaughter weight. The importance of these factors may differ according to the intended end use of a specific leather item, e.g. for clothing, footwear, and belts. In the absence of specific guidelines for minimal requirements for nodule form and size, it is impossible to arrive at conclusive recommendations as far as nodule diameter is concerned. Further research on this topic is indicated to gain a better understanding of the relative importance of nodule size and appearance for skin quality and price determination.

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Chapter 5

The effects of dietary energy and protein concentrations on ostrich skin quality[3]

Abstract

The effects of energy and protein concentrations (with associated amino acid concentrations) in ostrich diets on leather quality of the skins of 50 ostriches were investigated. Energy concentrations were 9.0, 10.5 and 12.0 MJ ME/kg diet and protein concentrations were 130, 150 and 170 g/kg diet. The physical leather parameters that were assessed included tensile strength, elongation, slit tear strength and skin thickness. All traits were assessed in samples taken parallel or perpendicular to the spine in the butt region of the slaughter bird. The raw skin weights of ostriches consuming the diets with energy concentrations of 10.5 MJ ME/kg and 12.0 MJ ME/kg diet were respectively 19.4% and 21.8% heavier at slaughter than those of their contemporaries on the 9.0 MJ ME/kg DM diet. A corresponding trend was found for trimmed skin weight, and the increase in skin weight with diets higher in energy exceeded 10%. Differences between skin area means only approached significance, with a tendency to increase with an increased energy concentration. Leather thickness taken parallel to the spine was increased by 13% in the diet containing 12 MJ ME/kg diet, compared to the diet containing 9.0 MJ ME/kg. Dietary protein concentrations failed to influence skin weight, skin area or any of the physical leather properties. The skins of male ostriches were thicker than those of females. The study suggested that the lowest levels of energy and protein supplied were sufficient to prevent a decline in physical leather quality.

INTRODUCTION

Leather contributes markedly to the revenue of commercial ostrich farmers. Cloete *et al.* (1998) estimated that ostrich leather contributed approximately 70% to the total income obtained by ostrich farmers during the mid 1990's. This contribution has declined since, with ostrich meat becoming more popular in Europe after the bovine spongiform encephalopathy (BSE) scare. However, leather is still estimated to contribute more than 50% of the total income of ostrich products, depending on product quality (Hoffman, 2005).

Ostrich leather competes in the exotic leather market, and is marketed as a luxury product (Cooper, 2001; Adams & Revell, 2003). Despite its value, little is known about its physical properties and the influence of various factors on skin traits (Sales, 1999). Skin grading of ostriches depends strongly on physical damage

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(Meyer *et al.*, 2003b). However, industry also requires information on the influence of nutrition on ostrich leather quality. Brand *et al.* (2000) reported that dietary energy concentrations between 9.0 and 12.0 MJ ME/kg feed resulted in an increase in growth rate of slaughter ostriches, while absolute skin area was not significantly improved. Both these traits were independent of protein concentrations between 130 and 170 g/kg diet. These studies have not yet been extended to cover factors associated with leather quality. It is known that the tensile strength of leather is of paramount importance to determine whether it is suitable for usage in specific products. The aim of the present study is therefore to extend the previous work of Brand *et al.* (2000) to determine the effects of dietary treatments on physical quality aspects of ostrich leather.

MATERIALS AND METHODS

Animals were obtained from the ostrich flock at the Oudtshoorn Experimental Farm. The background and origin of the population are well described (Bunter & Cloete, 2004). Ninety slaughter ostriches were randomly allocated to 18 groups at roughly four months of age, with five birds per group. These groups were randomly allocated to nine treatments in a 3 X 3 factorial design. The factors were energy concentrations of 9.0, 10.5 and 12.0 MJ ME/kg feed and protein concentrations of 130, 150 and 170 g/kg feed (with associated amino acid concentrations). The physical composition and estimated chemical analyses of the diets are provided in Table 1.

The birds received the respective diets *ad libitum*, and were finished to an age of 11 months and an average (± s.d.) live weight of 94 ± 10 kg. The birds were slaughtered according to standard South African procedures (Van Schalkwyk *et al.*, 2005). The skins were weighed immediately after skinning, with the subcutaneous fat still attached (raw skin weight). Trimmed skin weight was determined after the subcutaneous fat was removed. Skin area was also determined at this stage. All the skins were then processed to the chrome-crusted stage, using standard procedures (Meyer *et al.*, 2003a; b). A leather sample was obtained from the most caudal part of the skin, in the middle of the back. This site is commonly referred to as the butt region in research on leather characteristics (Cloete *et al.*, 2004). All samples were tested at the SA Wool Testing Bureau. Samples were assessed for tensile strength, elongation at grain break and slit tear strength on an Instron® machine, as described by Snyman & Jackson-Moss (2000). Tensile strength was defined as the force required breaking a dumbbell-shaped leather sample on the Instron®. It was expressed in relation to the diameter at the narrowest part of the dumbbell-shaped piece of leather and the thickness of the sample. Elongation at grain break was determined during the test for tensile strength. It was defined as the percentage stretch of the dumbbell shaped leather sample before it broke. The test for slit tear strength involved a rectangular leather sample with a small slit cut in it. The sample was then pulled apart by a clamp attached to its base and another clamp inserted through the slit. The point at which the slit starts to tear is defined as the slit tear strength. Slit tear strength was expressed in relation to average leather thickness, by including leather thickness as a covariate in the analysis of variance. Leather thickness of each sample was measured in millimetres. Each sample was assessed in duplicate on samples that were cut either parallel to the spine or perpendicular to the spine, respectively (Cloete *et al.*, 2004).

Table 1. Physical composition (expressed as g/kg feed) and calculated chemical analysis (based on table values and expressed as g/kg except energy) of the experimental diets used in the experiment.

ENERGY (MJ ME/kg)		9.0			10.5			12.0	
PROTEIN (g/kg)	130	150	170	130	150	170	130	150	170
Physical composition									
Lucerne	117.8	320.5	523.2	244.7	352.3	59.8	371.6	384.0	396.4
Oat bran	561.5	425.7	289.8	292.3	218.7	144.9	23.1	11.7	0.0
Maize	148.7	90.3	31.8	335.9	284.9	234.0	523.0	479.6	436.1
Soyabean meal	127.7	130.0	13.23	87.1	111.7	136.2	46.5	93.3	140.1
Dicalciumphosphate	12.9	11.7	10.5	11.5	10.3	9.0	10.1	8.8	7.5
Feed lime	20.6	11.7	2.7	18.3	12.5	6.8	15.9	13.4	10.8
Salt	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Premix*	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Lysine	1.2	0.6	0.0	1.0	0.5	0.0	0.8	0.4	0.0
Methionine	0.6	0.7	0.7	0.3	0.3	0.4	0.0	0.0	0.0
Chemical composition (estimated)									
Energy (MJ ME/kg)	9.05	9.03	9.00	10.63	10.65	10.5	12.20	12.10	12.00
Protein	122.0	141.1	160.1	121.0	140.5	160.1	120.0	140.0	160.0
Lysine	6.7	7.9	9.0	6.7	7.9	9.0	6.7	7.9	9.0
Methionine-cystine	3.7	4.3	4.9	3.7	4.3	4.9	3.7	4.3	4.9
Tryptophan	1.7	2.5	3.2	1.7	2.5	3.2	1.7	2.5	3.2
Threonine	4.0	5.4	6.7	4.0	5.4	6.7	4.0	5.4	6.7
Arginine	6.4	7.4	8.4	6.4	7.4	8.4	6.4	7.4	8.4
Crude fibre	196.5	220.8	245.1	165.2	178.8	192.5	133.8	136.9	139.9
Fat	13.7	13.7	13.7	19.4	18.8	18.2	25.1	23.9	22.7
Ca	14.0	13.0	12.0	14.0	13.0	12.0	14.0	13.0	12.0
P	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8

* Commercially available mineral-vitamin premix

Since individual data were recorded, animals were treated as experimental units. The data were analysed as a 3 (energy concentrations) X 3 (protein concentrations) X 2 (gender – male or female) factorial design

(Snedecor & Cochran, 1967). Least-squares procedures were used to account for unbalanced data (Harvey, 1990). The least significant difference method was used to discern significant differences between means. These tests were only conducted when it was protected by a significant ($P < 0.05$) F-value in the analysis of variance table (Snedecor & Cochran, 1967). Skin weight, raw skin area and physical leather characteristics were independent of the interaction between energy and protein concentrations and only main effects were tabulated. The effect of gender was mostly unimportant, and noted in the text where significant differences were found. Interactions of gender with protein or energy concentrations were also not significant. Male:female ratios on the respective dietary treatments ranged from 0.60:0.40 to 0.43:0.57.

RESULTS AND DISCUSSION

The raw skin weights of ostriches consuming the diets with energy concentrations of 10.5 MJ ME/kg and 12.0 MJ ME/kg DM were respectively 19.4% and 21.8% heavier ($P<0.05$) at slaughter than those of birds on the 9.0 MJ ME/kg diet (Table 2). Fat deposition increased as energy concentration increased, in agreement with results reported by Brand *et al.* (2004), using energy concentrations ranging between 7.5 MJ ME/kg and 11.5 MJ ME/kg feed. A corresponding trend was found for trimmed skin weight. The increase in skin weight ($P<0.05$) with diets higher in energy amounted to 13.8% for the diet containing an energy concentration of 10.5 MJ ME/kg, and to 10.2% for the diet containing 12 MJ ME/kg. These trends accorded with the general pattern followed by growth rate from four to 11 months by the experimental animals (Brand *et al.*, 2000). Differences between raw skin area means only approached significance ($P = 0.08$). The absolute difference in skin area between the lowest and the highest energy concentrations amounted to 4.3 dm^2 or 3.2% relative to the 9 MJ ME/kg diet. Given that the means were based on the same data, it is not surprising that the means for raw skin area reported in Table 2 were identical to those reported earlier (Brand *et al.*, 2000). Brand *et al.* (2004) subsequently reported that the skin size of 12-month-old slaughter ostriches was increased by 5 dm^2 (from 135 to 140 dm^2) by an increase in dietary energy concentration from 7.5 MJ ME/kg to 9.5 MJ ME/kg feed. However, a further increase in dietary energy concentration to 11.5 MJ ME/kg feed did not result in a further increase in skin size.

All skin attributes were unaffected by concentrations of crude protein of between 130 and 170 g/kg feed in the experimental diets ($P>0.20$; Table 3). Brand *et al.* (2000) correspondingly did not report any effect of these protein concentrations on skin area. In a later study, skin size of 12-month-old ostriches was once again independent of dietary protein concentration at levels as low as 80 g crude protein/kg feed (Brand *et al.*, 2004). Skin area was independent of gender. Male ostriches tended to have heavier skins than females after the fat was trimmed away (4.96 ± 0.11 *vs*. 4.73 ± 0.12 kg; $P<0.20$), a result consistent with that of Meyer *et al.* (2003a).

Table 2. Means (± s.e.) for skin weight and skin area for ostriches consuming diets with energy concentrations ranging between 9.0 and 12.0 MJ ME/kg feed (means based on 15 – 18 observations).

TRAIT	ENERGY CONCENTRATION (MJ ME/kg FEED)			SIGNIFICANCE
	9.0	10.5	12.0	
Crude skin weight (kg)	6.84 ± 0.38 [a]	8.17 ± 0.37 [b]	8.33 ± 0.39 [b]	*
Trimmed skin weight (kg)	4.48 ± 0.13 [a]	5.10 ± 0.13 [b]	4.97 ± 0.14 [b]	**
Skin area (dm²)	133.8 ± 1.3	136.3 ± 1.3	138.1 ± 1.4	0.08

* – Significant (P<0.05), ** – Significant (P<0.01), [a, b] – Means in rows with different superscripts differ (P<0.05)

Table 3. Means (± s.e.) for skin weight and skin area for ostriches consuming diets with crude protein concentrations ranging between 130 and 170 g/kg feed (means based on 14 – 21 observations).

TRAIT	CRUDE PROTEIN CONCENTRATION (g/kg FEED)			SIGNIFICANCE
	130	150	170	
Crude skin weight (kg)	7.97 ± 0.41	7.79 ± 0.34	7.85 ± 0.39	0.79
Trimmed skin weight (kg)	4.90 ± 0.14	4.79 ± 0.12	4.86 ± 0.14	0.84
Skin area (dm²)	135.1 ± 1.4	135.3 ± 1.2	137.8 ± 1.4	0.29

The means presented in Tables 4 and 5 for leather strength, elongation and slit tear strength were consistent with earlier results obtained for 11-month-old ostriches (Cloete et al., 2004). Corresponding means in the latter study were 19.8 N/mm² for leather strength, 27.9% for elongation and 93.6 N/mm for slit tear strength. An increase of 1 mm in leather thickness accounted for an increase of 7.64 ± 2.08 N in slit tear strength in samples taken parallel to the spine. The corresponding increase in slit tear strength in samples taken perpendicular to the spine was 3.81 ± 0.96 N. Leather thickness in this study (1.15 to 1.30 mm) was somewhat thicker compared to means for 11-month-old ostriches in the previous study of Cloete et al. (2004), where it averaged 0.95 mm.

Physical leather characteristics were largely independent (P>0.20) of dietary energy concentrations (Table 4). The exception was leather thickness taken parallel to the spine, which was 13.0 % higher (P<0.05) on the diet containing 12 MJ ME/kg diet, compared to the diet containing 9 MJ ME/kg diet. This trend was, however, not supported by results obtained when the sample was taken perpendicular to the spine. This result can be considered as coincidental, unless future studies yield the same result. Dietary protein concentrations in this study did not affect any of the physical leather characteristics (P>0.12; Table 5). No references with regard to the effect of dietary protein and energy concentrations upon leather quality parameters in ostrich skins could be sourced. Further research on this topic is thus indicated.

Table 4. Means (± s.e.) for physical leather attributes of ostriches consuming diets with energy concentrations ranging between 9.0 and 12.0 MJ ME/kg feed (means based on 15 – 18 observations).

TRAIT	**ENERGY CONCENTRATION (MJ ME/kg FEED)**			**SIGNIFICANCE**
	9.0	**10.5**	**12.0**	
Parallel to the spine				
Tensile strength (N/m²)	18.1 ± 0.7	18.6 ± 0.6	18.8 ± 0.7	0.44
Elongation (%)	31.8 ± 0.8	31.6 ± 0.8	33.4 ± 0.9	0.28
Slit tear strength (N/mm)	101.2 ± 5.5	106.6 ± 5.4	98.3 ± 5.8	0.48
Thickness (mm)	1.15^{a} ± 0.04	$1.17^{a b}$ ± 0.4	1.30^{b} ± 0.04	*
Perpendicular to the spine				
Tensile strength (N/m²)	20.7 ± 1.2	23.4 ± 1.2	20.7 ± 1.3	0.21
Elongation (%)	27.1 ± 0.7	26.3 ± 0.7	26.6 ± 0.7	0.77
Slit tear strength (N/mm)	90.0 ± 3.0	95.7 ± 2.9	94.8 ± 3.1	0.37
Thickness (mm)	1.18 ± 0.05	1.21 ± 0.05	1.18 ± 0.5	0.91

* – Significant (P < 0.05); $^{a\,b}$ – Means with different superscripts differ (P < 0.05) in rows

Table 5. Means (± s.e.) for physical leather attributes of ostriches consuming diets with different protein concentrations ranging between 130 and 170 g/kg feed (means based on 14 – 21 observations).

TRAIT	**PROTEIN CONCENTRATION (g/kg FEED)**			**SIGNIFICANCE**
	130	150	170	
Parallel to the spine				
Tensile strength (N/mm²)	18.3 ± 0.7	19.4 ± 0.6	17.8 ± 0.7	0.22
Elongation (%)	31.6 ± 0.9	32.7 ± 0.8	32.5 ± 0.9	0.60
Maximum force (N/mm)	105.5 ± 5.8	102.5 ± 4.9	99.4 ± 5.6	0.78
Thickness (mm)	1.24 ± 0.04	1.18 ± 0.4	1.20 ± 0.04	0.54
Perpendicular to the spine				
Tensile strength (N/mm²)	20.2 ± 1.3	21.4 ± 1.1	23.3 ± 1.3	0.26
Elongation (%)	25.9 ± 0.8	27.8 ± 0.7	26.2 ± 0.8	0.12
Maximum force (N/mm)	89.1 ± 3.2	96.6 ± 2.7	94.7 ± 3.1	0.21
Thickness (mm)	1.21 ± 0.05	1.16 ± 0.04	1.20 ± 0.5	0.79

Male ostriches produced skins with thicker (P<0.05) leather than females. Means for samples cut parallel to the spine were 1.30 ± 0.03 *vs.* 1.12 ± 0.04 mm for males and female, respectively. Corresponding values for samples cut perpendicular to the spine were 1.27 ± 0.04 *vs*. 1.11 ± 0.04 mm, respectively (P<0.05). The thicker skin thickness recorded for male ostriches in this study is consistent with results previously reported by Cloete *et al.* (2004) and Engelbrecht *et al.* (2005).

CONCLUSIONS

The higher energy diets caused higher levels of fat deposition, resulting in heavier raw skin weights. However, the resultant gain in saleable skin was much smaller, although it still approached significance. At the levels supplied in this study protein concentrations, with associated amino acid compositions, did not affect quantitative leather traits. The qualitative leather traits that were assessed were largely independent of the concentrations of dietary energy or protein tested. These results indicate that the lowest levels of energy and protein supplied in the present study, namely 9.0 MJ ME/kg feed and 130 g/kg feed respectively, did not compromise physical leather quality in slaughter ostriches.

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Chapter 6

The assessment of sampling sites for the objective evaluation of ostrich leather traits

Abstract

The effect of sampling site within and out of the crown area on objective ostrich leather characteristics was investigated in two studies. Samples were obtained in duplicate, both in directions parallel to the spine and perpendicular to the spine. In the first study, marked variation was observed in tensile strength, elongation, slit tear strength and leather thickness of samples taken at 11 locations on ten ostrich skins (four in the area of the skin with nodules and seven in the area without nodules). Contrast analyses indicated that samples in the areas with nodules have a higher tensile strength and a lower elongation than those taken from the areas without nodules. No differences were found in the case of samples taken perpendicular to the spine. When samples taken on the right side of slaughter birds were contrasted with those taken on the left side it was shown that skins were bilaterally symmetric. In view of the lack of differences between skin areas with and without nodules, a further investigation was conducted, using four sampling sites in the area with nodules from 21 skins. Marked variation between sites were observed. As the butt area was previously used as a sampling site for the sampling of objective skin attributes, this area was compared to the other three sites. Contrasts observed were significant for tensile strength and elongation for samples taken parallel to the spine, and for elongation and slit tear strength in samples taken perpendicular to the spine, respectively. Repeatability estimates derived from between skin variance components ranged from not estimable (i.e. between skin variance was below zero) to moderate for the respective traits. Regressions of the respective traits measured at other locations on the same trait measured in the butt region, were variable in sign and magnitude. It was concluded that measurements at any specific site is unlikely to predict measurements at the other sites with a high degree of accuracy.

INTRODUCTION

So far, research on the physical leather properties of ostriches is limited to a few studies. It has been shown that physical leather properties (i.e. tensile strength, elongation and slit tear strength) are not markedly affected by age at slaughter (Cloete *et al.*, 2004) or by dietary protein and energy concentrations (Cloete *et al.*, 2006). Leather thickness, on the other hand, was affected by gender, with males generally having thicker skins than females (Engelbrecht *et al.*, 2005; Cloete *et al.*, 2006).

In the previous studies, a leather sample for objective assessment was obtained from the most caudal part of the skin, in the middle of the back. This site is commonly referred to as the butt region in research on leather characteristics (Cloete *et al.*, 2004). Given that the crown area, i.e. the central diamond-shaped area that represents the area with the most nodules, is regarded as the most valuable part of the skin, it is conceivable that destructive sampling outside of this area would also have the lowest impact on the cutting value of the skin (Engelbrecht *et al.*, 2005). However, no objective assessment of differences between sampling sites on the ostrich skin has been carried out so far. Therefore it is not known whether specific sites on the skin, i.e. within or outside the crown area, best represent other skin areas.

Against this background, ostrich skins were sampled within and out of the crown area for the evaluation of physical leather properties. The correlations between the physical traits between the different sites on the same skin were calculated to investigate the possibility of using a specific site as predictor of the quality at alternative sampling sites.

MATERIAL AND METHODS

All the skins used in the investigation were processed to the chrome-crusted stage of the tanning process, using standard procedures (Meyer *et al.*, 2003a, b). The skins were obtained from an ostrich flock maintained at the Oudtshoorn Experimental Farm, outside Oudtshoorn, South Africa. The experimental site, the animal resource and the general management of birds at the site is adequately described in the literature (Bunter & Cloete, 2004). A total of ten skins were sampled at 11 sites within and outside of the crown area. The sampling sites are depicted in Figure 1. Twenty-one skins were then sampled at the four sites that are situated in the crown area, namely the butt, flank, upper leg and lower neck. These sites were selected to be on the edges of the area with nodules, to ensure that a maximum area would remain after the sampling of a specific skin (Figure 1). On ten of these skins, samples were also obtained from seven sites with no feather nodules, namely the left side of the belly, the left wing, the left upper leg, the upper neck, the right side of the belly, the right wing and the right upper leg (Figure 1).

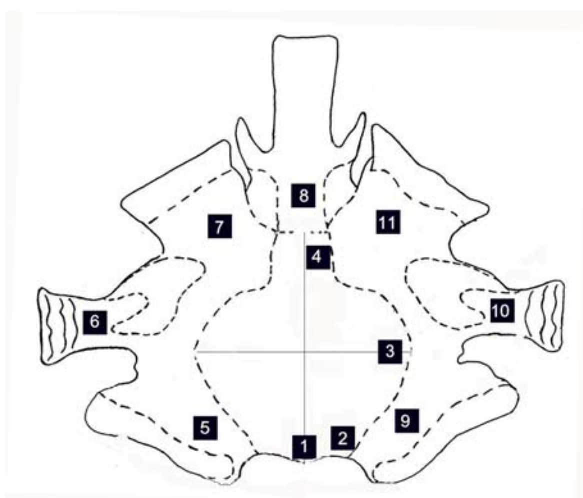

Figure 1. A Diagram of an ostrich skin indicating the eleven sample sites for the assessment of objective skin traits. Localities 1-4 are in the crown area, while localities 5-11 are outside the crown area (i.e. the surfaces without nodules).

An A4-sized leather sample was obtained from each of the sampling sites and assessed at the SA Wool Testing Bureau for tensile strength, elongation at grain break and slit tear strength on an Instron® machine, as described by Cloete *et al.* (2004; 2006). Tensile strength was defined as the force required for breaking a dumbbell-shaped leather sample on the Instron® machine. It was expressed in relation to the diameter at the narrowest part of the dumbbell-shaped piece of leather and the thickness of the sample. Elongation at grain break was determined during the test for tensile strength. It was defined as the percentage stretch of the dumbbell shaped leather sample before it broke. The test for slit tear strength involved a rectangular leather sample with a small slit cut in it. The sample was then pulled apart by a clamp attached to its base and another clamp inserted through the slit. The point at which the slit starts to tear is defined as the slit tear strength. Slit tear strength was expressed in relation to average leather thickness, by including leather thickness as a covariate in the analysis of variance. Leather thickness of each sample was measured in millimetres. Each sample was assessed in duplicate on samples that were cut either parallel to the spine or perpendicular to the spine, respectively (Cloete *et al.*, 2004).

Analyses of skin quality trait data were complicated by the fact that the same skin was sampled repeatedly, and that the assumption for analysis of variance were thus not met. This problem was addressed by using a repeatability model, and estimating the intra-class correlation representing the covariance arising from the repeated samples obtained from the same skin. The added advantage of this approach was that it was possible to obtain an indication of the measure whereby samples at certain localities on the skin may indicate measurements at other localities. Repeatability was estimated as follows (Turner & Young, 1969):

$$t = \sigma^2_b/(\sigma^2_b + \sigma^2_w)$$

with t the estimated intra-class correlation,

σ^2_b the between skin variance component,

σ^2_w the within skin or residual variance component

Standard errors for t was estimated by using the procedures described by Harvey (1990).

Initial analyses involved a factorial approach. Apart from a random skin effect, factors that were included in the model were the orientation of the sample (i.e. parallel or perpendicular to the spine), and the 11 sample localities. It became evident that sample orientation interacted with the location at which the sample was taken in all cases. Since the intention of the research were not to compare the orientation of the samples, it was decided to analyze the data using a completely randomized design, accounting only for random skin effects and fixed locality effects in the analysis. Separate analyses were conducted for samples obtained parallel and perpendicular to the spine. The same basic approach was followed when data from the 21 skins sampled only on the four areas of the skins with nodules, were assessed. The only difference in the analyses conducted was that the fixed effect of location only had four levels in this instance. Means were compared by using a LSD test that was protected by a significant F-value in the analysis of variance table

(Snedecor & Cochran, 1969). Standard linear regression techniques were employed to assess relationships of sample from others sites with those obtained from the butt area, in view that the later was used for the sampling of skins in previous studies (Cloete *et al.*, 2004; 2006).

RESULTS

Means for the respective leather quality traits, as measured on the 11 localities on the skin are presented in Table 1. Owing to the large number of comparisons that were required, it was attempted to simplify the conclusions. Clear differences among means were evident, as reflected from the levels of significance presented in Table 1.

Table 1. Means of leather quality traits measured at 11 localities on ostrich skins (n=10). Two samples were taken in duplicate at each locality, parallel to or perpendicular to the spine. The first four localities were situated in areas of the skin with nodules, and the other seven in areas of the skin without nodules.

LOCALITY (NUMBER) AND ORIENTATION RELATIVE TO THE BACKLINE	PHYSICAL LEATHER TRAIT			
	Tensile strength (N/mm^2)	Elongation (%)	Slit tear strength (N/mm)	Thickness (mm)
Parallel to the spine				
Significance level	0.07	**	**	**
Butt (1)	19.0	32.1	92.6	1.16
Flank (2)	20.5	28.7	84.9	0.96
Upper leg (3)	20.5	31.0	83.7	1.13
Bottom of neck (4)	18.9	23.3	63.5	1.06
Left of belly (5)	16.6	39.7	79.2	1.01
Left upper leg (6)	20.2	40.0	120.6	1.22
Left wing (7)	16.8	35.6	95.6	1.21
Upper neck (8)	14.9	27.4	48.0	0.89
Right of belly (9)	17.6	31.8	75.1	0.93
Right upper leg (10)	15.1	52.3	106.8	1.17
Right wing (11)	18.0	31.4	78.2	1.05
SE Mean	1.5	2.4	5.8	0.06
Perpendicular to the spine				
Significance level	**	**	**	**
Butt (1)	21.1	27.1	93.8	1.12
Flank (2)	21.6	35.2	76.0	0.97
Upper leg (3)	17.0	32.6	105.3	1.25
Bottom of neck (4)	9.1	58.9	89.0	1.03
Left of belly (5)	18.7	36.7	75.9	0.98
Left upper leg (6)	19.5	29.3	93.6	1.23
Left wing (7)	15.4	33.0	92.7	1.13
Upper neck (8)	5.3	61.0	54.1	0.96
Right of belly (9)	14.1	31.1	71.5	1.03
Right upper leg (10)	25.6	40.1	125.8	1.21
Right wing (11)	20.9	41.0	89.4	1.13
SE Mean	1.6	2.4	6.3	0.06

** Means within orientation were significant ($P<0.01$)

Linear contrasts were computed to compare samples taken from the nodulated area of the skin with those taken from the parts without nodules. In samples orientated parallel to the spine, tensile strength was higher (P<0.05) in those areas with nodules than in the parts without nodules. The opposite was true for elongation, where values in the areas without nodules were on average higher (P<0.05). No differences were found for slit tear strength and skin thickness in the contrast analyses. These trends were not as evident for samples taken perpendicular to the spine – this may have been attributed to the much larger variation found between sites.

Samples taken on the left side of the skins were similar to those taken on the right sides of the skins when the contrasts between the left and right sides of the skin were tested in those locations without nodules. From these results it is evident that skins are bilaterally symmetric as far as physical leather traits outside the crown area are concerned.

When sampling sites with nodules were considered, the average tensile strength of samples taken parallel to the spine were higher (P<0.05) on the flank than those from the bottom part of the neck or the butt (Table 2).

Table 2. Means of leather quality traits measured at four localities on the crown area with nodules from ostrich skins (n=21). Two samples were taken in duplicate at each locality, parallel or perpendicular to the spine.

LOCALITY (NUMBER) AND. ORIENTATION RELATIVE TO THE SPINE	**PHYSICAL LEATHER TRAIT**			
	Tensile strength (N/mm^2)	**Elongation (%)**	**Slit tear strength (N/mm)**	**Leather thickness (mm)**
Parallel to the spine				
Significance level	*	**	**	**
Butt (1)	19.2	32.8	100.5	1.19
Flank (2)	22.0	28.4	85.4	1.00
Upper leg (3)	21.1	32.0	91.9	1.19
Bottom of neck (4)	18.5	24.2	66.3	1.12
SE Mean	0.9	0.7	6.3	0.05
Perpendicular to the spine				
Significance level	**	**	**	**
Butt (1)	21.2	27.9	95.3	1.17
Flank (2)	21.5	35.0	75.6	0.96
Upper leg (3)	17.9	33.1	111.2	1.35
Bottom of neck (4)	10.1	58.5	92.2	1.11
SE Mean	0.9	2.4	4.0	0.05

** Means within orientation were significant (P<0.01)
* Means within orientation were significant (P<0.05)

In the samples taken perpendicular to the spine, the difference (P<0.05) between the lower neck and the other locations were much larger, contributing to the initial interaction found between orientation of the sample and the location on the skin found in the preliminary analyses. With regard to the elongation of samples taken parallel to the spine, the largest means were found for samples obtained from the butt and upper leg regions, which were higher (P<0.05) than corresponding means for the flank, and particularly the lower part of the neck. When the samples taken perpendicular to the spine were considered, it was evident that the mean for elongation in the lower neck sample was markedly higher (P<0.05) than for any other site. The mean for butt samples was correspondingly lower than those calculated for the flank and upper leg sites. When slit tear strength was considered for samples taken parallel to the spine, it was evident that it increased (P<0.05) from the lower neck to the flank and upper leg, with the highest mean estimated for samples obtained from the butt region. In the case of the samples taken perpendicular to the spine, the lowest mean was calculated for the flank region, and the highest for the upper leg region (P<0.05). Samples taken parallel to the spine, as obtained from the butt, upper leg and lower neck location were thicker (P<0.05) than those obtained from the flanks of the skins. A similar trend was evident in the samples taken perpendicular to the spine, but a further increase was evident in samples obtained from the upper leg.

Seeing that samples taken from the butt region were previously used to represent the entire skin, those samples were contrasted with the means from the other sites. In samples taken parallel to the spine, significance levels for linear contrasts were 0.22 for tensile strength, 0.000 for elongation, 0.000 for slit tear strength and 0.06 for leather thickness. Corresponding values for samples taken perpendicular to the spine were 0.000, 0.000, 0.58 and 0.59 respectively.

Between-skin repeatability estimates for tensile strength were below 10%, except for those samples taken perpendicular to the spine in those parts of the skin with nodules (Table 3).

Table 3. Repeatability estimates (± s.e.) for leather quality traits measured at 11 localities on ostrich skins (n=10), or at four localities in those areas with nodules on ostrich skins (n=21). Two samples were taken in duplicate on each locality, parallel to or perpendicular to the spine.

LOCALITY AND ORIENTATION RELATIVE TO THE GRAIN	PHYSICAL LEATHER TRAIT			
	Tensile strength (N/mm^2)	Elongation (%)	Slit tear strength (N/mm)	Leather thickness (mm)
Parallel to the spine				
All areas	0.00±0.05	0.01±0.05	0.17±0.11	0.19±0.11
Areas with nodules	0.00±0.00	0.27*±0.12	0.30*±0.12	0.38*±0.12
Perpendicular to the spine				
All areas	0.04±0.06	0.05±0.07	0.42*±0.11	0.11±0.09
Areas with nodules	0.21±0.12	0.00±0.00	0.21±0.12	0.14±0.11
Overall				
All areas	0.03±0.04	0.03±0.04	0.26*±0.11	0.18*±0.09
Areas with nodules	0.08±0.06	0.17*±0.08	0.25*±0.09	0.30*±0.09

* Means within locality and orientation were significant (P<0.05)

If the significance (P<0.05) of these estimates of t were defined as an estimate exceeding twice the corresponding standard error, none of these estimates reached this level. In the case of elongation, only the estimate derived from the samples taken parallel to the spine in the areas of the skins with nodule exceeded 20%. This t-value was also significant when the criterion given earlier was used. Estimates for slit tear strength were moderate in magnitude and generally significant ($P<0.05$) for samples obtained parallel and perpendicular to the spine. In the case of leather thickness, estimates were slightly lower, and generally significant ($P<0.05$) in the samples obtained parallel to the spine in the areas with skin nodules. It was also significant in the overall analyses when all sampling sites within and outside the crown were considered.

Individual relationships of skin quality traits on areas of the skin with nodules with the corresponding trait measured on the butt were depicted as scatter-plots. Regressions of the obtained measurements on the butt on corresponding values obtained from other samples were also computed. In the case of the regression of tensile strength of the other localities upon measurements at the butt sampling site, it is evident that the relationships were generally poor and variable in sign (Table 4). Conclusions with regard to elongation were largely similar to that for tensile strength. Regressions were mostly positive in the case of slit tear strength, and R^2 values exceeded 10% of the overall variation on two occasions. In the case of leather thickness, regressions were mostly positive, and the correlations ranged from very low to moderate. Only a few correlations derived from samples taken parallel to the spine reached statistical significance ($P < 0.05$), involving the traits elongation and leather thickness.

Table 4. Regression coefficients (b) and correlations (r) for relationships of leather quality traits measured in the butt region of ostrich skins (n=21) on the same trait measured in a section of the crown area. Two samples were taken in duplicate at each locality, parallel or perpendicular to the spine.

ORIENTATION AND DEPENDENT VARIABLE	TENSILE STRENGTH		ELONGATION		SLIT TEAR STRENGTH		THICKNESS	
	b	r	b	r	b	r	b	r
Parallel to the spine								
Flank	-0.11	-0.06	0.456	0.34	0.295	0.29	0.671	0.65**
Upper leg	0.57	0.35	0.612	0.48*	0.352	0.27	0.853	0.62**
Lower neck	-0.44	-0.29	0.496	0.56**	-0.064	-0.06	0.293	0.22
Perpendicular to the spine								
Flank	0.264	0.42	-0.714	-0.36	0.170	0.16	0.052	0.06
Upper leg	0.110	0.15	0.075	0.06	0.374	0.23	0.594	0.33
Lower neck	0.205	0.28	-0.727	-0.17	-0.246	0.20	-0.107	0.10

* Significant ($P<0.05$)
** Significant ($P<0.01$)

The relationship between tensile strength measurements derived from flank and butt samples taken perpendicular to the spine are illustrated in Figure 2.

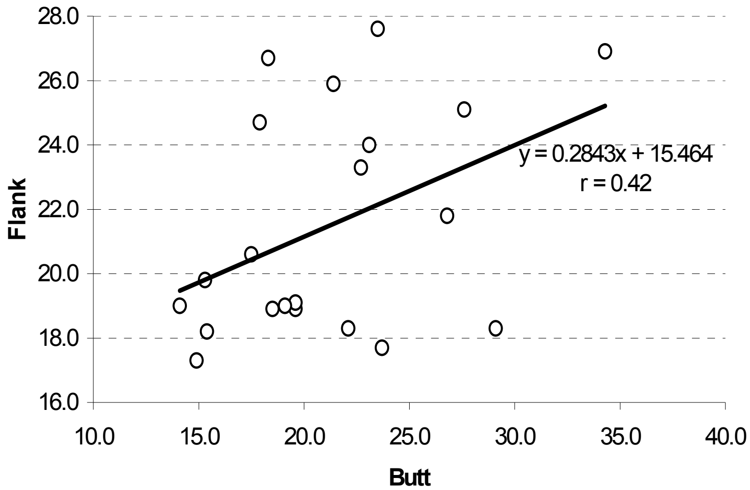

Figure 2. The relationship between tensile strength (N/m²) derived from samples from the butt or flank regions of ostrich skins, obtained perpendicular to the spine.

It is evident that the data points were scattered about the regression line, although the fit was the best of all the relationships obtained for tensile strength. The relationship between samples obtained parallel to the spine in the flank and butt regions for leather thickness is depicted in Figure 3. Although the goodness of fit is obviously better in this case, the variation in leather thickness in the butt region still only accounted for 42% of the variation in the flank region.

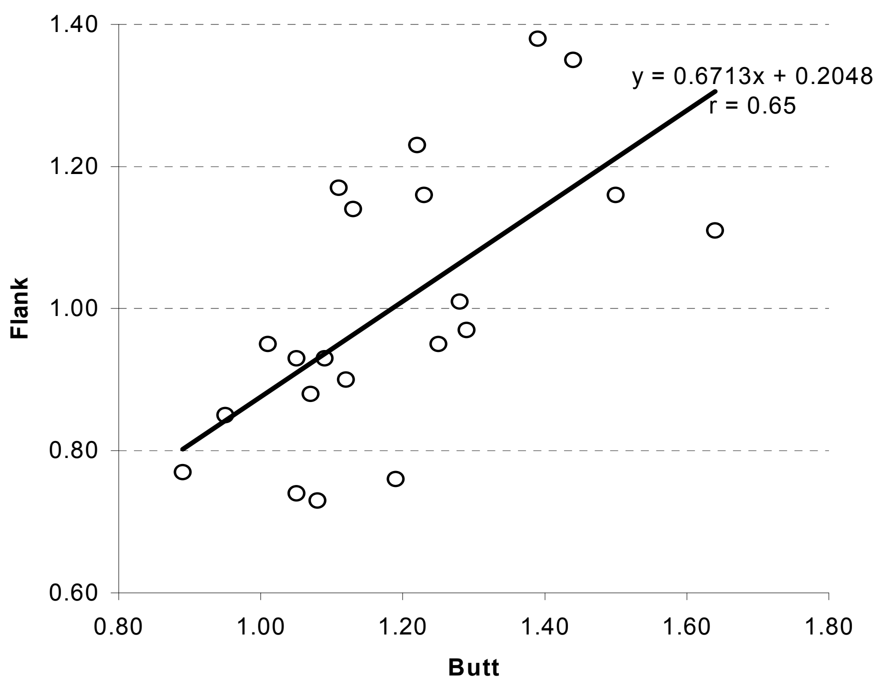

Figure 3. The relationship between leather thickness (mm) derived from samples from the butt or flank regions of ostrich skins, obtained parallel to the spine.

DISCUSSION

The average means for the physical skin characteristics from the butt samples in the present study were consistent with those reported previously (Cloete *et al.*, 2004; 2006). This is the first scientific report where samples other than that from the butt region have been subjected to objective analyses. Some of the results were surprising, for example, samples taken in the neck region having a relatively low tensile strength but a high elasticity (elongation). The latter could be due to the fact that the neck skin is very pliable in the ostrich and thus would require a high level of elasticity.

Another interesting phenomenon was the fact that the samples without nodules had the same physical quality characteristics as nodules located within the commercially more important crown area. One of the significant contrasts between the crown area and the area without nodules involved an improvement in the tensile strength of samples taken in the former area. This is reassuring, since it was assumed in the trade that the skin's tensile strength is compromised in the areas with nodules, since the feather shafts penetrate the skin in these areas and it seemed reasonable that this mechanical process could have resulted in an impaired strength of the leather produced in these areas.

Concentrating on those samples obtained from the areas of the skin with nodules, it was noted that repeatability estimates derived from the intra-class correlation involving the between skin variance component were significant for all traits except tensile strength when the samples were taken parallel to the spine. However, these correlations were only moderate. The only significant individual correlations between measurements made on the butt sampling site and other sites involved samples taken parallel to the spine. Elongation at grain break were previously reported to be slightly longer in butt samples taken parallel to the spine compared to those taken perpendicular to the spine (Cloete *et al.*, 2004). It is interesting to note that values for the elongation at grain break of the neck samples taken perpendicular to the spine was particularly long in the present study, while the same effect was not observed in samples taken parallel to the spine. Tensile strength was also severely compromised in neck samples taken perpendicular to the skin compared to other sampling sites. This effect was not as noticeable in samples taken parallel to the spine.

CONCLUSIONS

Based on the significant repeatability estimates for samples taken parallel to the spine it is proposed that samples for the analysis of physical leather properties should be orientated in this way. The butt sampling site did not have any apparent advantages over other sites. However, it appears to be a logical site to sample skins, since sampling in this region would have the smallest impact upon the commercial value of skins. Further research is needed to confirm or refute the findings of the present study. Another facet that warrants further research is an in depth study of the collagen fibers and their orientation in the different regions to try and explain the reasons for the unexpected results (e.g. the neck region).

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The willingness of the Klein Karoo Co-operation to place ostrich skins for the project at our disposal is acknowledged. We also wish to express our gratitude to the staff of the Klein Karoo Agricultural Development Centre for establishing the resource of ostrich skins.

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Chapter 7

Genetic variation in nodule size at different sites on the skins of slaughter ostriches[4]

Abstract

Nodule size is an important indicator of leather quality in the ostrich leather trade. The present study investigated genetic variation in nodule size at five sites on the skin, namely the neck, back, upper leg, flank and butt. Nodule size increased with an increased chronological age at all sites. Estimates of h^2 for nodule size ranged from 0.09 ± 0.07 on the flank region to 0.24 ± 0.10 on the upper leg region. Genetic correlations between nodule sizes measured at different sites were generally lower than expected, linked to high standard errors and mostly not significant. These preliminary results seem to suggest that nodule size on different locations of the skin is not necessarily the same genetic trait. Apart from the limitations evident from these results, the objective measurement of nodules on ostrich skins is tedious when done manually, with little prospect for automation. The number of nodules per dm^2 (nodule density) was considered within skin sites as an indirect criterion for the improvement of nodule size. However, genetic correlations between nodule density and nodule size were negative, variable in size and generally not significantly different from zero or unity. Based on these preliminary results, alternative strategies for the genetic improvement of ostrich skin nodule size should be considered.

INTRODUCTION

Leather contributes markedly to the revenue of commercial ostrich farmers. Cloete *et al.* (1998) estimated that ostrich leather contributed approximately 70% to the total income obtained by ostrich farmers during the mid 1990's. This contribution has since declined, with ostrich meat becoming more popular. Leather is, however, still estimated to contribute more than 50% to the total income of ostrich producers, depending on the quality of the product (Hoffman, 2005).

Ostrich leather competes in the exotic leather market, and is marketed as a luxury product (Cooper, 2001; Adams & Revell, 2003). Despite its value, little is known about its physical properties and the influence of various factors thereon (Sales, 1999; Meyer, 2003). There is consensus that the size and general appearance of the nodules on ostrich skins contribute markedly to its value in the marketplace (Meyer *et*

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al., 2004; Engelbrecht *et al.*, 2005; Van Schalkwyk *et al.*, 2005a). Previous studies have suggested genetic variation in qualitative nodule traits (Meyer *et al.*, 2004; Engelbrecht *et al.*, 2005), suggesting that it can be improved by selection. However, marked variation occurs in nodule parameters measured at different locations on the ostrich skin (Cloete *et al.*, 2004; Meyer *et al.*, 2004). The aim of the present study was therefore to extend the previous work of Meyer *et al.* (2004), by determining whether the heritability of nodule traits varies between locations on the ostrich skin.

MATERIAL AND METHODS

Approximately 500 South African Black slaughter ostriches from the commercial ostrich population at the Oudtshoorn experimental farm were used. The background and origin of the population are well described in the literature (Van Schalkwyk *et al.*, 1996; Bunter & Cloete, 2004). The birds were slaughtered according to standard South African procedures (Van Schalkwyk *et al.*, 2005b). All the skins were processed to the chrome-crusted stage, using standard procedures (Meyer *et al.*, 2003a; b). Complete pedigree records (i.e. both sire and dam identities) were available for 439 of these ostriches, while sire identity only was known for a further 41 birds. These data were used to estimate genetic and environmental parameters for two skin traits. For this purpose, average nodule size and density for each skin were determined at five localities of 1 dm^2 each, as described by Cloete *et al.* (2004). The localities were situated on the neck, mid-crown area, upper leg, lower flank and in the middle of the rear back area (subsequently referred to as the butt). The base diameter of 10 individual nodules within each site (chosen according to a predetermined grid) was measured with a Digimatic Caliper (Toolquip & Allied, P.O. Box 687, Goodwood 7459, South Africa) and the number of nodules was counted. An average value was subsequently derived from these measurements. This mean nodule diameter (subsequently referred to as nodule size) and density (nodules/dm^2) were obtained for the respective localities on the skin. In preliminary analyses all nodules were also measured on the mid-crown and upper leg regions of 10 skins. Correlations of means derived from all measurements with means derived from 10 measurements were $\geq$0.89. It was thus decided that means derived from 10 measurements were representative of the nodule size of specific skins.

In the previous study of Meyer *et al.* (2004), data were analysed across localities, using an unstructured repeatability model. However, this approach assumes equal means and variances for the traits (nodule size and nodule density) across localities. This was clearly not the case in the literature (Cloete *et al.*, 2004; Meyer *et al.*, 2004). The present study therefore estimated heritability for each location. Apart from random animal effects, year of slaughter was fitted as fixed and age at slaughter was fitted as a linear covariate. Initially single-trait animal models were fitted, using ASREML (Gilmour *et al.*, 1999). These analyses were followed with a multi-trait analysis involving nodule size at all five sites as different traits. This multi-trait analysis involving nodule size in the neck region failed to converge, and this location was excluded. Genetic and environmental correlations between nodule sizes at the respective sites were estimated from this analysis. Two-trait animal models involving nodule size and nodule density at each locality were fitted next, to obtain genetic correlations between these traits at the respective sites.

RESULTS AND DISCUSSION

Traits were normally distributed in the majority of cases (Table 1). A significant deviation from normality in the case of nodule density on the upper leg was attributed to kurtosis rather than skewness. Interpretation of results was thus continued as motivated by Glass *et al.* (1972). Coefficients of variation (CV's) ranged from 17.9% to 25.2% in the case of nodule density, and from 11.7% to 13.7% in the case of nodule size. Corresponding CV's in the study of Meyer *et al.* (2004) were 33.4 for nodule density and 15.2 for nodule size, when measurements made at different locations were treated as the same trait. Means pertinent to each location were consistent with those available in the literature (Cloete *et al.*, 2004; Meyer *et al.*, 2004).

Table 1. Descriptive statistics for nodule density and nodule size measured on different locations on ostrich skins.

TRAIT AND LOCATION	NUMBER OF SKINS	MEAN ± S.D.	COEFFICIENT OF VARIATION	SKEWNESS	KURTOSIS	RANGE
Nodule density						
Neck	480	54.2 ± 10.3	19.0	0.99	1.29	35 – 98
Mid crown	480	57.8 ± 10.4	17.9	0.91	1.23	36 – 106
Upper leg	480	28.0 ± 6.4	22.9	1.40	3.83	17 – 64
Lower flank	479	37.9 ± 9.5	25.2	0.79	0.98	4 – 76
Butt	479	58.0 ± 12.2	21.1	0.85	1.16	31 – 114
Nodule size						
Neck	480	3.24 ± 0.45	13.7	0.29	-0.35	2.17 – 4.58
Mid crown	480	3.22 ± 0.39	12.0	0.28	-0.11	2.32 – 4.51
Upper leg	480	3.71 ± 0.49	13.1	0.21	-0.20	2.42 – 5.01
Lower flank	479	3.89 ± 0.45	11.7	0.15	-0.41	2.73 – 5.03
Butt	479	3.93 ± 0.48	12.3	0.03	-0.46	2.75 – 5.40

Nodule density decreased with an increased chronological age as skin area and bodyweight increased at all sites (Cloete *et al.*, 2004). Respective regressions (± s.e.) of nodule density on age (expressed per day) were -0.056 ± 0.009 at the neck, -0.066 ± 0.009 at the back, -0.0039 ± 0.006 at the upper leg, -0.079 ±

0.008 at the flank and -0.090 ± 0.010 at the butt. Nodule size, on the other hand, increased with an increased chronological age at all sites. Corresponding regressions (± s.e.) of nodule size on age (expressed as mm/day) were respectively 0.0031 ± 0.0004, 0.0027 ± 0.0004, 0.0036 ± 0.0005, 0.0029 ± 0.0004 and 0.0041 ± 0.0004 at the five sites. It is generally accepted that nodule density decreases with slaughter age while nodule size increases (Cloete *et al.*, 2004; Meyer *et al.*, 2004). These results are therefore not surprising.

Estimates of heritability (h^2) ranged from zero to 0.22 for nodule density, with three estimates that were near 0.10 (Table 2). Only the h^2 estimate estimated for the mid crown locality was significant, i.e. more than twice the corresponding standard error. Four h^2 estimates for nodule size were approximately 0.10, while a higher estimate of 0.23 was found for the upper leg region. The latter estimate also reached significance ($P<0.05$). It is notable that most estimates coincided with previous estimates of 0.10 for both traits when slightly fewer records were analysed across localities, using an unstructured repeatability model (Meyer et al., 2004).

Table 2. Variance components and ratios for nodule size and nodule density, measured at five body locations on 480 slaughter ostriches (with: σ^2_a, the direct additive variance; σ^2_e, the residual variance; σ^2_p, the overall phenotypic variance).

TRAIT AND LOCALITY	σ^2_a	σ^2_e	σ^2_p	h^2 ± s.e.
Nodule density				
Neck	4.44	60.77	65.21	0.07 ± 0.07
Mid crown	15.08	52.12	67.20	0.22 ± 0.09
Upper leg	0.09	29.68	29.77	0.00 ± 0.06
Lower flank	3.74	37.36	41.10	0.09 ± 0.07
Butt	7.46	70.67	78.12	0.10 ± 0.08
Nodule size				
Neck	0.0092	0.1189	0.1282	0.07 ± 0.08
Mid crown	0.0091	0.0820	0.0911	0.10 ± 0.08
Upper leg	0.0359	0.1231	0.1589	0.23 ± 0.10
Lower flank	0.0125	0.1181	0.1306	0.10 ± 0.07
Butt	0.0116	0.1031	0.1148	0.10 ± 0.08

Heritability estimates derived from the multi-trait analysis on nodule size (Table 3) were within 0.01 of those derived from the initial single-trait analyses (Table 2). Genetic correlations between nodule sizes measured at different sites were positive but differed from zero only between the mid crown and the butt, as well as between the upper leg and the lower flank. No significant differences from unity were found (P>0.05), but several genetic correlations were below 0.50. The study therefore failed to prove conclusively if nodule size measured at the respective sites were the same trait, but some genetic correlations were lower than expected. It is conceded that studies of this nature would preferably involve more than 1000 observations, but the labour involved in processing a skin manually proved to be too much to assess more skins. Two recorders working together could process one location on a skin in ~6 minutes, implying that it took at least a man hour to process a single skin. It was attempted to automate the process using image analysis, a technology that was successfully applied to ostrich eggshell traits (Cloete Jr *et al.*, 2006). However, a lack of contrast on chrome-crusted skins as well as a lack of control over the shadows casted by the nodules complicated this endeavour. Correlations between nodule sizes derived from image analysis and those measured directly ranged from 0.12 to 0.59 for the respective localities.

When considering environmental correlations among nodule sizes for the respective sites, it was evident that these correlations were positive, moderate in size and significant (P < 0.05).

Table 3. (Co)variance rations for nodule size measured at different sites on the ostrich skin, as derived from the multi-trait analysis. Heritability estimates are presented in bold figures on the diagonal, genetic correlations are above the diagonal and environmental correlations in italics below the diagonal.

LOCATION	MID CROWN	UPPER LEG	LOWER FLANK	BUTT
Mid crown	**0.11 ± 0.08**	0.44 ± 0.33	0.48 ± 0.41	0.82 ± 0.26
Upper leg	*0.47 ± 0.04*	**0.24 ± 0.10**	0.81 ± 0.26	0.55 ± 0.30
Lower flank	*0.54 ± 0.03*	*0.55 ± 0.03*	**0.09 ± 0.07**	0.32 ± 0.48
Butt	*0.55 ± 0.03*	*0.41 ± 0.04*	*0.56 ± 0.03*	**0.11 ± 0.09**

Correlations between nodule density and nodule size are presented in Table 4. Genetic correlations of nodule density with nodule size were negative and moderate to high in magnitude. However, the estimates were associated with large standard errors, and were significant only at the butt location (P < 0.05). The genetic correlation was unity in that case. Meyer *et al.* (2004) found a genetic correlation of -0.72 between nodule density and nodule size in an unstructured repeatability model analysis across locations. This genetic correlation seemed to hold some promise with regard to indirect selection for nodule size on live birds. The outcome of the present study is less optimistic, suggesting that alternative approaches should be considered. Phenotypic and environmental correlations within locations were negative and significant ($P<0.05$), and generally similar in sign and magnitude.

Table 4. Genetic, phenotypic and environmental correlations between nodule density and nodule size at different locations on ostrich skins.

LOCATION	GENETIC CORRELATION	PHENOTYPIC CORRELATION	ENVIRONMENTAL CORRELATION
Neck	-0.68 ± 0.52	-0.37 ± 0.04	-0.35 ± 0.06
Mid crown	-0.51 ± 0.36	-0.25 ± 0.04	-0.21 ± 0.07
Upper leg	-0.46 ± 2.27	-0.24 ± 0.04	-0.25 ± 0.07
Lower flank	-0.72 ± 0.40	-0.28 ± 0.04	-0.23 ± 0.06
Butt	-1.00 ± 0.43	-0.23 ± 0.05	-0.15 ± 0.07

CONCLUSIONS

Some evidence of genetic variation in objectively measured nodule size of ostrich skins was obtained in this study. However, the derived h^2 estimates were generally lower than the estimated 0.31 obtained by Engelbrecht *et al.* (2005) for subjectively assessed nodule size. The latter study used a resource of sample skins on a structured 9-point scale to guide the assessor, with scores from 1-3 regarded as poor, 4-6 as average and 7-9 as good. The procedure of Engelbrecht *et al.* (2005) was much less time-consuming than the methods applied in the present study and it is therefore suggested that their procedure be used in future assessments of nodule size.

The issue of finding an indicator trait for nodule size on live birds remains unresolved. Genetic correlations with slaughter weight were favourable in the study of Engelbrecht *et al.* (2005). At 0.64, the genetic correlation was also of the same magnitude as those estimated for nodule density in the present study. Further work on this topic is therefore required.

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Chapter 8

Case study: The South African ostrich skin grading and evaluation system

Abstract

A perception exists amongst ostrich producers that the grading they receive for the ostrich skins is influenced by the supply – when the latter is high, lower grades are awarded and *vice versa*. The impact that month of slaughter may have on the grading awarded skins has also been raised by the producers. A data resource consisting of ~220 000 skins of birds slaughtered between July 2002 – June 2006 was used to provide insight into these issues. The slaughter birds were produced by 176 ostrich farmers, and were slaughtered at the Mosstrich Abattoir outside Mossel Bay, South Africa. Results indicated that downgrading because of lesions (either raw or healed) accounted for more than 50% of the skins downgraded due to both primary and secondary causes. There were no robust seasonal trends in the grades awarded to the skins across years. However, the producer (i.e. source of the skins) had a strong influence on the grades awarded. It would seem that producers with better management practices consistently received better grading for skins produced. It is speculated that this could also be linked to the type of production system, for skins originating from producers who raise their birds extensively and thus slaughter birds at an older age, had lower grades compared to slaughter birds raised in a feedlot system. The data analyses also clearly indicated that grading did not become stricter as slaughter numbers increased. This finding is of great value to the industry as it will help displace any mistrust that producers may have towards the industry as pertaining to the current subjective skin grading system, and thus the income generated from slaughter bird production.

INTRODUCTION

Ostrich leather is characterized by quill sockets or nodules, created by the feather follicles on the back and the belly of the ostrich (Sales, 1999). The presence of these nodules is what gives ostrich leather its uniqueness (Swart, 1981), and the size and shape of these nodules are important in determining the value or quality of the skin (Mellett *et al.*, 1996, Meyer *et al.*, 2004). Ostrich skins are classified according to size (A, B, C or D) and skin quality grading (i.e. 1^{st}, 2^{nd}, 3^{rd}, 4^{th} or 5^{th} grade). These two parameters ultimately determine the income generated per skin (Van Schalkwyk *et al.*, 1999). To increase the percentage of 1^{st} grade (i.e. the best quality) skins, factors that influence and that may compromise skin quality need to be addressed by the producer (Lunam & Weir, 2006).

The grading of ostrich skins has undergone drastic changes over the last few decades due to changes in the ostrich production industry. Before deregulation of the South African industry in 1993, the value of an ostrich skin was determined by the raw skin yield only (Swart, 1981). By 1998 the focus shifted, and leather quality was largely defined by the absence of skin defects (Anonymous, 1998). Today tanned ostrich leather should be free of damage, follicles or feather buds should be well-defined with a rounded shape, whereas the leather should also be of sufficient strength to use in the manufacturing of leather products (Mellett *et al.*, 1996).

The evaluation and grading of skins, however, is mainly a subjective procedure. The lack of objective methods of measuring quality characteristics such as follicle development makes it very difficult to accurately determine the value of an ostrich skin. The stage of evaluation of skins was recently changed from the wet to the crust phase of the tanning process, mainly because of the difficulty of accurately determining skin quality of raw skins.

Another factor contributing to uncertainty in the grading system is the lack of properly defined market requirements. Depending on the end use of the leather, different buyers require leather with different characteristics. While sufficient strength and thickness is an important attribute for boot manufacturers, softness and suppleness is more important traits for the clothing industry.

Ostriches were previously slaughtered at approximately 14 months of age (Swart, 1981). Since optimal nodule size and shape, and optimal skin size were generally achievable by 14 months of age (Mellett *et al.*, 1996), nodule development (i.e. in terms of size and shape) of most skins received at tanneries were of an acceptable standard. The overproduction of slaughter birds, which followed after the deregulation of the industry in 1993, resulted in an unexpected increase in ostrich skins of lower quality, which the market could not absorb. This oversupply resulted in declining prices being fetched, as well as stricter grading criteria (Van Zyl, 2001). Cloete *et al.* (1998) found that skin damage increased with an increase in age, and this results in severe downgrading of skins between 12 and 14 months of age.

From 2000 onwards producers gradually started slaughtering younger ostriches. This trend was driven by increasing production costs, mainly due to higher feed and pharmaceutical costs, and by poorer grading performance of skins from older slaughter birds (Meyer *et al.*, 2002a; Meyer, 2003). The development of the ostrich meat market and the higher contribution of meat to overall income of producers (Hoffman, 2005) also contributed to this trend. The slaughtering of these younger ostriches resulted in large volumes of skins with inferior follicle development. During 2003, grading criteria were adapted to also consider follicle development when determining the value of an ostrich skin, effectively penalising producers that would slaughter their ostriches at a too young age. Ostrich leather quality is therefore currently determined by both its quantitative (i.e. skin yield) and qualitative (i.e. lack of defects and acceptable nodule development) characteristics. Current grading criteria therefore include skin yield, the presence of visible defects and nodule development.

MATERIAL AND METHODS

A case study was undertaken of a resource of ~220 000 skins of birds slaughtered over a period of four years (July 2002 – June 2006) from 176 producers producing slaughter birds for the Mosstrich Group. Mosstrich is a commercial ostrich abattoir situated near Mossel Bay in the Southern Cape region of South Africa. Mosstrich was established in 1996 and is the second largest ostrich abattoir in the world, having a daily slaughter capacity of 450 birds. Skins were tanned at SCOT (South Cape Ostrich Tanning), which is an affiliate of the Mosstrich Group. The bulk (70%) of the slaughter birds were sourced from the districts of Caledon, Bredasdorp, Swellendam, Heidelberg, Riversdal, Albertinia and Mossel Bay, while the rest came from the Oudtshoorn and Calitzdorp districts in the Klein Karoo region. Approximately 70% of the farmers contributing data make use of chick raisers to grow out their chicks. At a weight of approximately 55 kg the chicks are moved to farms where they are finished until slaughtered at an age between 11 and 14 months. Birds in the southern Cape are typically kept to an age of 14 months before they are slaughtered, while birds obtained from the Klein Karoo region are slaughtered at 11 to 12 months. Birds in the Klein Karoo are mostly kept in feedlots at a very high feed cost, on dry meal diets, whereas birds in the Southern Cape mostly browse planted pastures. Farmers in the latter region therefore find it more cost-effective to market older and heavier birds.

Slaughter birds are transported to the abattoir after a 14-day quarantine period, to be slaughtered 12-14 hours later. Fresh skins are derind, salted and stored for 24 hours at a temperature of 4ºC before the tanning process is started. Skins are graded after three weeks, i.e. when the skins reach the chrome crust stage of tanning according to standard procedures (Meyer et al., 2002a). The grading at Mosstrich is done subjectively according to skin size and grading norms.

Skin sizes are grouped as follows:

- 7.1 A+ size = 156+ square decimetres.
- 7.2 A size = 130 to 155 square decimetres.
- 7.3 B size = 120 to 129 square decimetres.
- 7.4 C size = 100 to 119 square decimetres.
- 7.5 D size = 80 to 99 square decimetres.

Skins are graded into five categories according to the following norms:

Grade One

- At least three quarters of the skin must be free from any defects.
- One defect (excluding a hole), in any of the quarters, if it is not larger than 40 mm in diameter is allowed.
- One healed wound not larger than the distance between two quills is allowed on the crown.
- A small number of visible defects outside the crown area will be allowed.

Grade Two

- At least two continuous quarters must be free from any defects.
- One defect in any two adjacent quarters, if it is not larger than 80 mm in diameter is allowed.
- Two defects in any two adjacent quarters, if both are not larger than 40 mm in diameter are allowed.
- Two healed wounds not larger than the distance between three quills each are allowed on the crown area.
- A few visible defects outside the crown area will be allowed.

Grade Three

- At least one quarter must be free from defects.
- One defect in any one of three quarters, if it is not larger than 120 mm in diameter is allowed.
- No more than two defects in any of three quarters, if one is not larger than 80 mm in diameter and one is not larger than 40 mm in diameter.
- Three defects in any of three quarters, if all of them are not larger than 40 mm in diameter individually are allowed.
- Three healed wounds not larger than the distance between four quills each are allowed on the crown area.
- A number of visible defects outside the crown area are allowed.

Grade Four

- A skin of which the grading falls outside the norm for a third grade skin, but where the affected crown area is not larger than 25% of the total crown area.
- The affected skin area should not be larger than 25% of the total skin area.

Grade Five

- A skin of which the affected crown area is smaller than 50% of the total crown area.
- The affected skin area should not be larger than 50% of the total skin area.

Skins are micro-chipped during the wet tanning stage. The graders had no prior knowledge of the origin of skins, as skins in the crust stage are only bar-coded. Downgrading is done based on specific visible defects on the skin and classified into primary and secondary reasons. Primary and secondary reasons may include raw lesions, healed lesions, diseases, damage during tanning (manufacturing), tick bytes, pitting, hair follicles, small nodules, white spots and other reasons.

All data regarding skin size and reason for downgrading were captured and used to determine the commercial value of each skin. Data of 176 produces that supplied slaughter birds to Mosstrich during the period July 2002 to June 2006 were investigated. A total of 230 699 skins were accounted for during this period. After editing for completeness and very small contributions by individual producers (<10 skins), 220 168 of these skins were retained for further analyses. The number of birds supplied by producers ranged from 18 for the smallest to 14 217 for the largest producer.

Grading results were analysed by a mixed model, involving the fixed effects of year and month, the year by month interaction and the random effect of producer. ASREML software (Gilmour et al., 1999) was used for this purpose. Solutions for each producer were obtained from the analysis and presented graphically to illustrate differences between producers for average grading received for skins. Since low numbers were preferable (i.e. Grade 1 is best), the producers with the smallest solution would have the best results. The suggestion that skin grading becomes more stringent when more skins are available was investigated by regressing mean monthly grade on the number of skins harvested in that month. The monthly number of skins processed ranged from 7 410 for November 2004 to 841 for September 2005.

RESULTS

In total, 166 825 skins were downgraded for at least one reason. The primary and secondary (n = 162 965) reasons for downgrading were determined and expressed relative to the total number of skins downgraded. This information gave an indication of the relative importance of different classified causes for downgrading.

The results of the primary and secondary causes responsible for downgrading (pooled across years) are presented in Figure 1 and Figure 2, respectively. It was evident that downgrading because of lesions (either raw or healed) accounted for more than 50% of the skins that were downgraded for both primary and secondary causes. Tick marks, hair follicles, white spots and diseases accounted only for ~10% of the recorded cases of downgrading. As individual causes, these causes of downgrading failed to reach the 3% level. Other causes of downgrading were manufacturing (12.5% as a primary cause and 8.3% as a secondary cause), small nodules (8.8% as a primary cause and 7.4% as a secondary cause) and pitting (4.0% as a primary cause and 4.3% as a secondary cause).

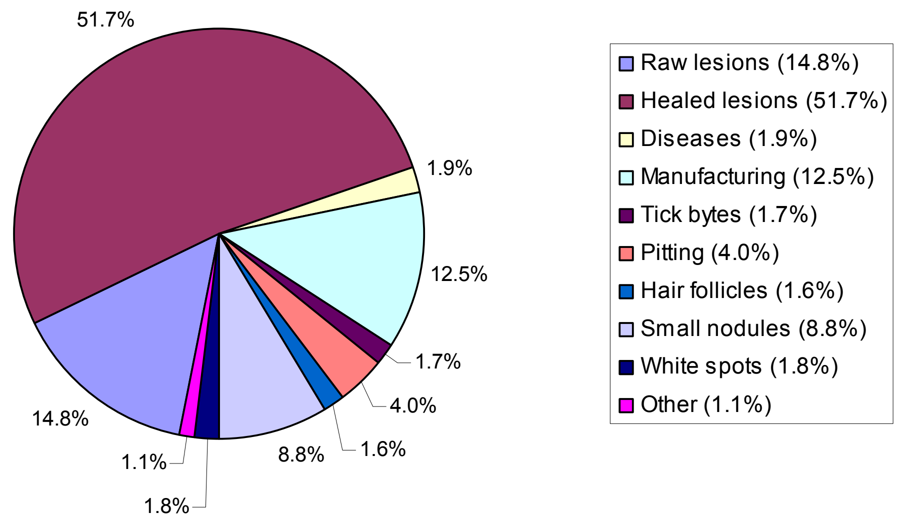

Figure 1. Primary causes for the downgrading of ostrich skins. Individual slices of the pie are annotated with the percentage of skins that were downgraded for that specific reason.

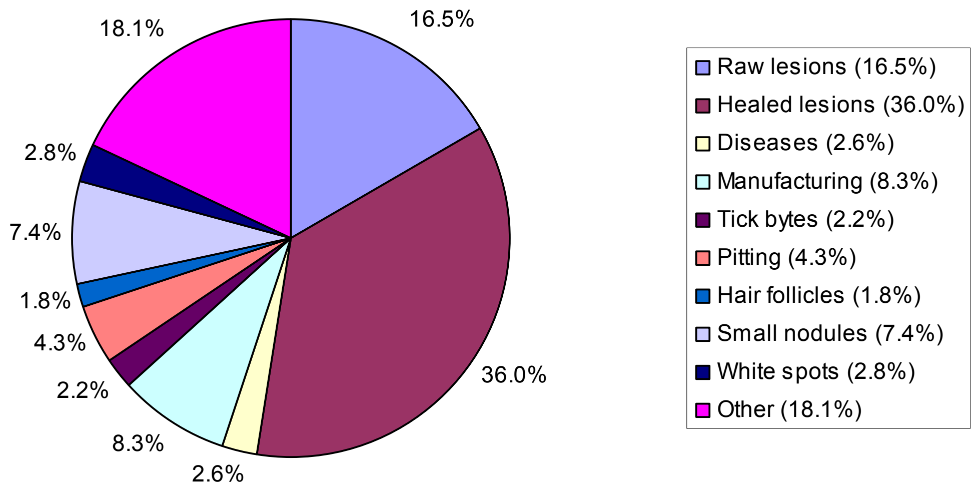

Figure 2. Secondary causes for the downgrading of ostrich skins. Individual slices of the pie are annotated with the percentage of skins that were downgraded for that specific reason.

The solutions for individual producers regarding skin grading ranged between -0.605 for the best producer to 0.998 for the producer faring the worst (Figure 3). Both estimates were fairly accurate, as depicted by relatively small standard errors. Solutions for producers that were represented by small numbers of skins were accompanied by fairly large standard errors, as depicted in Figure 3. It was thus evident that skins delivered by the best producer were > 0.6 grades better than the average grading, whereas the grading of the poorest producer was ~1 grade worse than the average grading.

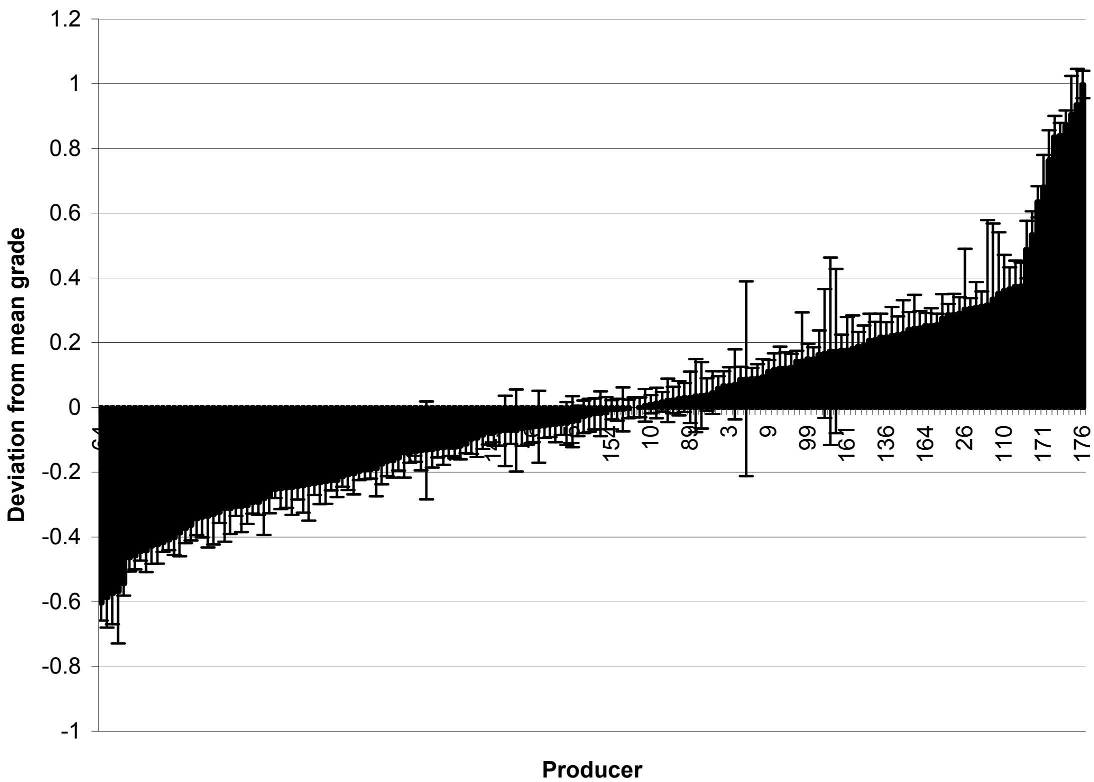

Figure 3. Solutions for 176 producers for average skin grading over a period of 4 years, ranked from the best to the worst. Standard errors are depicted by vertical lines on the solutions of individual producers.

It was evident that year interacted ($P<0.01$) with month for average skin grading. It thus follows that there were no robust seasonal trends across years. The seasonal patterns for 2002-03 to 2005-06 are depicted in Figure 4. Seasonal grading from July to June of the following year seemed to improve somewhat during 2003-04 and 2005-06 (i.e. lower values are found). No apparent trend was evident for 2002-03, while a slight seasonal improvement during the early months of the 2004-05 season was followed by a marked worsening in grading during May and June.

When the year-month trend was presented on a continuous scale, predicted values ranged between a mean grade of ¬2.2 to a mean grade of just above 3 (Figure 5). When trends over time were considered, average grading seemed to be quite stable up to June 2003. Subsequently, there was some evidence of an improvement from July 2003 to April 2005. Grading then worsened at the end of the 2004-05 marketing season (as stated above), before another slight improvement toward the end of the recording period.

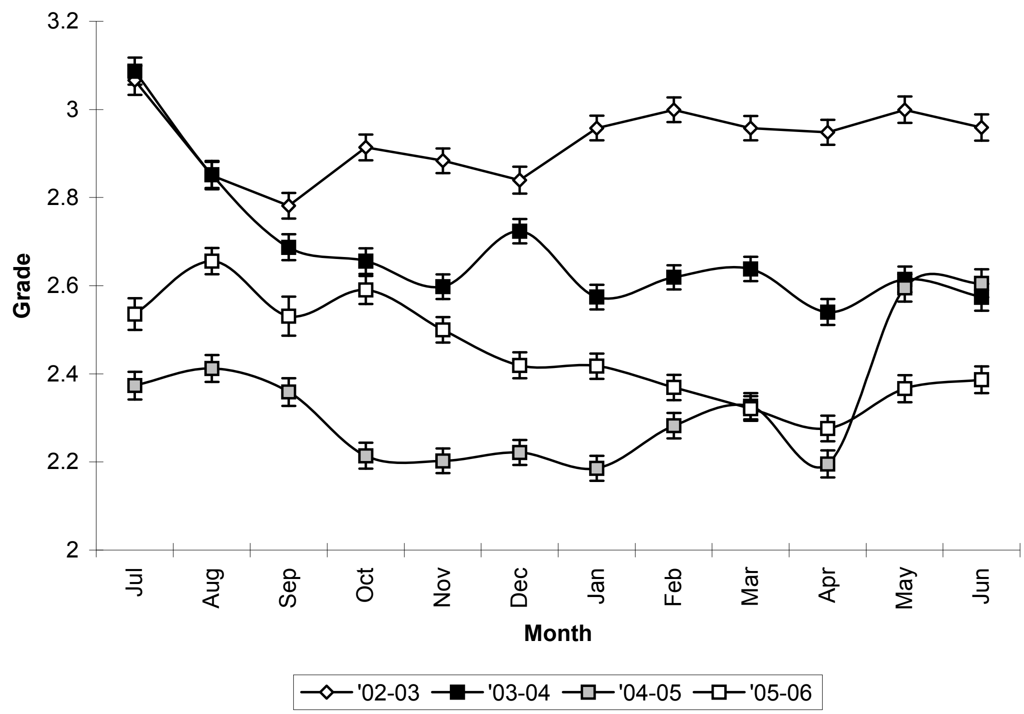

Figure 4. The interaction between month and production year for average skin grade during the production years of 2002-03 to 2005-06. Standard errors are depicted by vertical lines around the individual means.

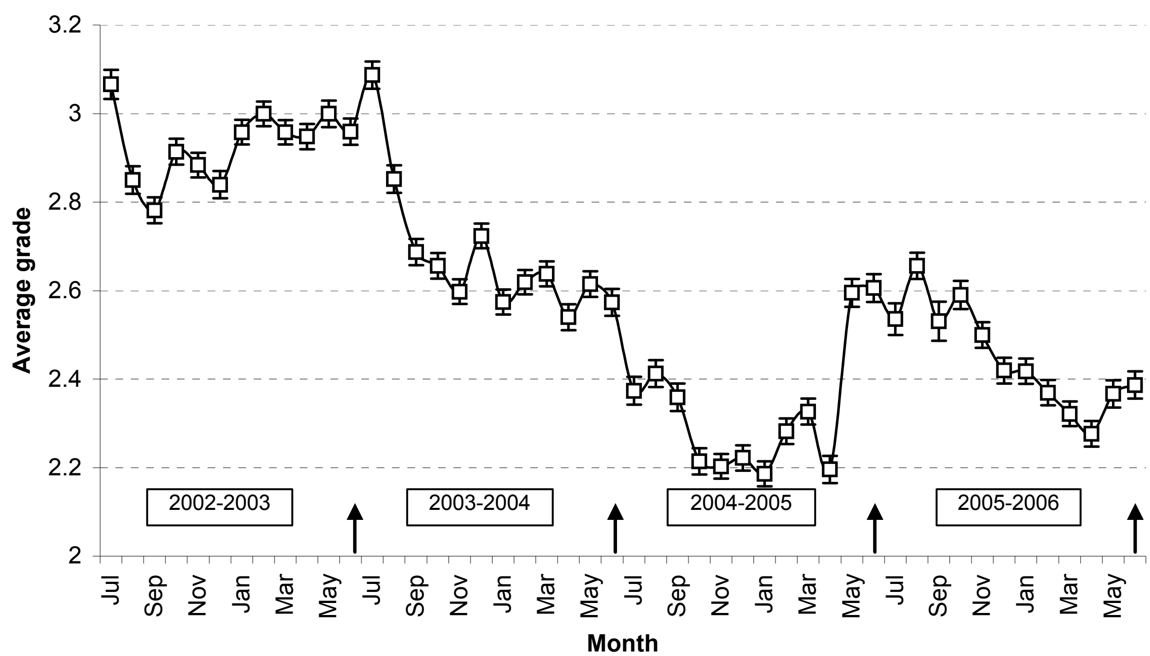

Figure 5. Predicted values for months for the entire experimental period. Standard errors are depicted by vertical lines around the individual means. Arrows indicate start/end of production seasons.

The average monthly grading was not related to the number of skins processed per month ($R^2 < 0.01$; Figure 6). The lack of a relationship between number of skins and average grading do not support the contention that grading becomes more strict when the number of skins on offer are high, or more relaxed when skins are in short supply.

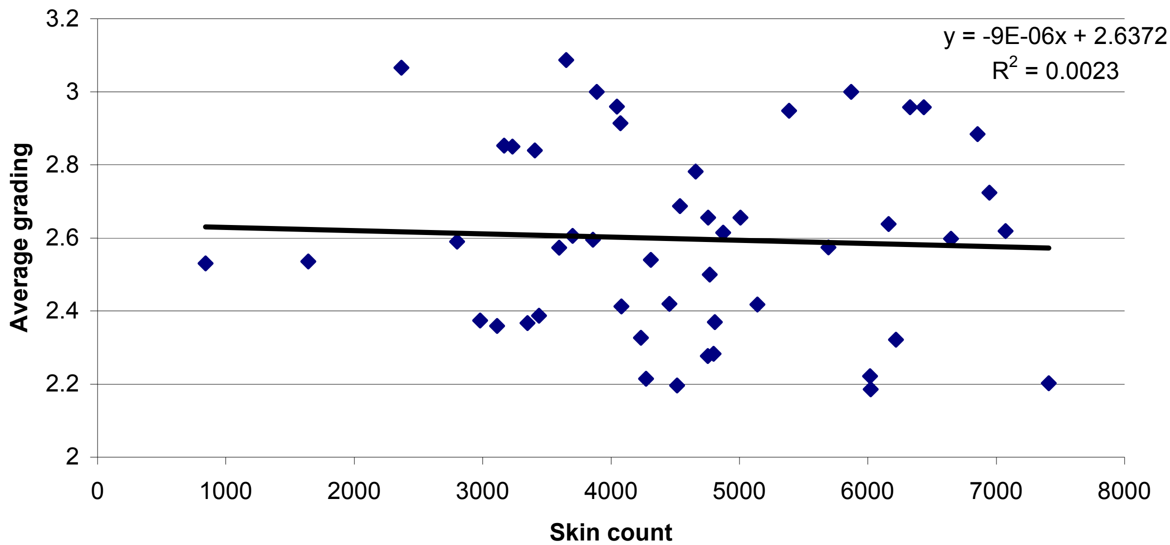

Figure 6. The relationship between average skin grading and the number of skins produced on a monthly basis.

DISCUSSION

From the results it is evident that skin damage accounted for the vast majority of cases where skins are downgraded. Either raw or healed lesions were the major primary and secondary causes of skins being downgraded. The high level of damage due to raw or healed wounds can be attributed to the fact that ostriches are maintained in free-range production systems in the southern Cape where they are kept on open pastures at a carrying capacity of approximately five birds per hectare. Birds are often rotated between camps, which can lead to additional skin damage due to injuries sustained when running into shrubs or fences. Under these extensive conditions, birds may be frightened by dogs, porcupines, small game and unexpected noises such as thunder, especially during night time. Juvenile birds may also be trampled because of the enclosed environment they are kept in (Meyer *et al.*, 2002a, Meyer, 2003). Previous results suggest that skin damage at an early stage was persistent to slaughter age (Meyer *et al.*, 2003b). Under these conditions, kick and scratch marks are assumed to be caused by toenails. Scratch marks are probably the result of toenail inflicted damage at a young age, while kick marks probably result from toenail damage later in life.

Meyer *et al.* (2002a) and Meyer (2003) showed that the removal of toenails effectively reduces both scratch and kick marks at slaughter age. The permanent removal of toenails at hatch resulted in an improvement of up to 50% in skin grading. The removal of toenails, however, became an animal welfare issue and was therefore not adopted as a standard industry practice in South Africa. Other solutions should be found to curb high financial losses due to large scale downgrading as a result of lesions of new and healed wounds. Apart from lesions inflicted by toenails, other environmental structures, such as fences, vegetation or buildings can also contribute towards skin damage. It is evident that the longer birds are kept on farms the higher the risk of skin damage become.

Concerns were raised by the graders of ostrich skins that the incidence of tick marks, white spots and pitting are on the increase. At present there is limited data to substantiate this allegation, but damage resulting from tick bites was also perceived by the local state veterinarians to be on the increase. This trend may be the cause of an increased resistance of external parasites against specific chemicals. The aetiology of pitting and white spots is poorly understood at present, and requires further study. Other defects that are discriminated against, such as hair follicles and small nodules were shown to have a genetic basis (Engelbrecht *et al.*, 2005). Selection may thus play a role in the alleviation of these sources of downgrading. Age also plays an important role pertaining to nodule shape and nodule size, as shown by Meyer *et al.* (2004). The manipulation of this trait by increasing the slaughter age of animals also seems feasible, within the constraints of the increased feed costs associated with a longer finishing period.

Marked variation in skin grading were reported between producers. Nel *et al.* (2000) suggested that, although substantial variation in skin grading is observed between farms, marked variation was also found between different slaughter batches from the same farm. Nel *et al.* (2000) also suggested that some farmers possess better farming skills than others. Inherent features on the farm, such as the topography, vegetation as well as structural obstacles such as fences, may all contribute to changes in skin grading in subtle or less subtle ways.

Overall grading did not show consistent seasonal trends when assessed across years. However, a highly significant interaction between year and month were evident from the data. There was a gradual improvement in skin grading from June 2003 to April 2005. Ostrich production in the southern Cape relies heavily on the availability of pastures as an affordable source of roughage. Access to pasture is thus expected to play a major role in decisions pertaining to the slaughter age of birds. During periods of limited pasture growth, more expensive supplementary diets are given (Cloete *et al.*, 1998). Another factor that could have contributed to the observed trends was the ban on the export of ostrich meat on 12 August 2004. The ban on the export of South African ostrich products was lifted on 12 October 2005. During this period ostrich meat prices declined by more than R12 per kg carcass weight. Producers experienced a period of financial difficulty, and were forced to keep birds for longer periods in an effort to increase income by slaughtering heavier birds. A longer finishing period is expected to result in a deterioration of skin grading (Meyer *et al.*, 2002b). It is thus possible that the deterioration in skin grading during the autumn and winter of 2005 was associated with farmers maintaining slaughter birds for a longer period in the hope of being able to increase the income from the skins by slaughtering heavier birds with larger skins.

Results also suggest that grading did not become stricter as slaughter numbers increased. For many years ostrich processing plants were accused of altering grading norms according to the availability of skins. From this viewpoint, the outcome of the present study is very reassuring.

CONCLUSIONS

It is evident that skin grading is complex, and many factors contributed to the realisation of good grades for ostrich skins. It is thus of utmost importance that farmers attempt to minimize risks as pertaining to downgrading of the skins as far as possible. Due to the extensive nature of ostrich farming, natural elements are thought to play a major role in the downgrading but these are not properly defined at present. Other factors, such as physical damage, processing damage, hair follicles and small nodules are easier to alleviate, using information from this study and that available in the literature. However, this case study also identified the need for further research into the aetiology of skin damage. Such studies will promote a better understanding of the various interacting factors associated with ostrich skin defects. It is anticipated that such research will contribute to an increased income and therefore result in an increase in the stability of the ostrich industry.

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Chapter 9

Literature review: ostrich leather quality

Although relatively small, the South African ostrich industry is the livelihood of about 20 000 people. The ostrich industry is one of the top 20 agro-based industries in the country, and ranks very high in terms of export value. Ostrich leather is considered the cornerstone of the local industry, being the main income-generating product. Ostrich leather currently contributes between 40% to 50% to the total income generated from a slaughter bird. During the last few decades, income generated from ostrich leather, i.e. relative to ostrich meat, has declined as the demand for and the value of ostrich meat has increased. Possibilities of avian influenza (AI) outbreaks, which in most instances up to now, result in a ban on the export of ostrich meat, have made producers wary of the economic viability of this industry. It is thus of the utmost importance that ostrich producers derive the maximum income from skins produced to be able to buffer a possible loss of income generated from the export of ostrich meat.

Despite the value and importance of leather to the ostrich industry, very little research has been done to improve ostrich leather quality. Before the deregulation of the industry, research was not published due to intellectual property rights that prevented the free dissemination of information. The first scientific study that was published on ostrich skin quality only appeared in 1996 (Mellett *et al.*, 1996). Most research reports published since then focussed on pre-slaughter factors that influence leather quality. Research regarding processing techniques is mostly done in-house by the various processing plants and is therefore not widely available. Ostrich leather quality is currently determined by both its quantitative and qualitative characteristics. Grading criteria include skin yield, the presence of visible defects and nodule development, all of which determine the value of the skin and thus the price paid to the producer.

As a result of the general lack of scientific research on ostrich skin quality, this study was initiated during the late 1990's to increase the knowledge regarding ostrich skin quality and to refute the many speculations and allegations that exist in the industry around leather quality. During the last decade, various factors that influence ostrich leather quality were investigated against the backdrop of continuous changes in the ostrich industry, since these had important consequences for skin quality requirements, which changed according to changing market preferences.

The dissertation set out to address factors affecting ostrich leather traits in an effort to present the industry with a tool to enhance leather quality to maximize the income derived from this product. Although there are certain factors that were not addressed, this dissertation provides a valuable insight into the complexity and interaction of factors such as age, slaughter weight, nutrition, and genetics, and the influence thereof on leather quality. Conclusions from this study are organized according to the traits measurable in a laboratory (i.e. leather tensile strength, elongation slit tear strength and leather thickness) and those assessed by direct measurement on experimental sites, or by subjective assessment (i.e. nodule size and nodule shape).

This review thus focus on the existing knowledge of the various aspects of ostrich leather quality based on the available reports, with specific reference to the contribution of the research contained in this thesis towards addressing the lack of knowledge in the specific fields. Where deemed necessary, shortcomings will be indicated and recommendations made regarding future research needs.

INTRINSIC FACTORS

Structure of ostrich skin

The first and only in-depth study of the composition and structure of ostrich skin was recently done by Lunam & Weir (2006). It was reported that the surface of ostrich skin consists of a thin epidermis, comprising of two to three layers of cells covered by keratin that provides protection from abrasion, assist in control of water loss and act as a physical barrier to invasion by bacteria and other microbial organisms. The epidermis is reportedly removed during liming and is therefore not a component of tanned skin.

Lunam & Weir (2006) also indicated that the dermis was the main component of ostrich skin and consisted of three-dimensional arrays of collagen fibres orientated perpendicular to one another and predominantly aligned parallel to the surface of the skin. Lunam & Weir (2006) alleged that the integrity of the collagen fibres is crucial to skin quality since their three-dimensional cross-weave arrangement provides strength and flexibility to ostrich skin. Strength and flexibility is important to ensure sufficient strength for making leather products (Mellett *et al.*, 1996).

Lunam & Weir (2006) further indicated that the grain layer is relatively thin, well vascularised and composed of compact collagen fibres. The grain and corium layers are separated by a thin layer of loose connective tissue also containing numerous blood vessels. This high vascularity near the surface of the skin probably accounts for the susceptibility of ostriches to lamination and bruising (Lunam & Weir, 2006), contributing to the high prevalence of skin damage on ostrich skins – an important factor for skin quality.

Regarding the mechanical behaviour of ostrich skin, one report was found where chemically treated ostrich pericardium was subjected to tensile testing. Both unsutured and sutured ostrich pericardium exhibited strong resistance to rupture (García Páez *et al.*, 2002). During an earlier study, tensile strength, elongation at break and slit tear strength were assessed from samples of the butt region of the skin from ostriches of different slaughter ages (Cloete *et al.*, 2004; Chapter 3). Means of 19.8 N/mm² for leather strength, 27.9% for elongation and 93.6 N/mm for slit tear strength were reported. Repeatability estimates (± s.e.) were significant and in the medium range at 0.48 ± 0.13 N/mm² for tensile strength, 0.35 ± 0.15% for elongation and 0.36 ± 0.15 N/mm for slit tear strength. Slit tear strength increased with an increase in leather thickness.

Lunam & Weir (2006) stated that tensile strength was dependent on the arrangement of collagen fibres within the dermis. They reported, however, that tear strength was significantly higher parallel compared to perpendicular to the spine. Tear strengths reported for the skins from adult (14 months of age) ostriches were 39.03 ± 7.89 N/mm parallel and 35.81 ± 6.88 N/mm perpendicular to the spine (Lunam & Weir, 2006). However, Cloete *et al.* (2004; Chapter 3) found an inverse tendency for elongation at grain break, with samples cut parallel to the spine having a lower elongation at grain break than those cut perpendicular to the spine (Chapter 3).

In an effort to predict physical traits on the skin as a whole, but especially in the crown area, which is commercially the most valuable area, tensile strength, slit tear strength and leather thickness were investigated on the crown and the area surrounding it (Chapter 6). Leather thickness of males compared, when compared to that of females, was consistently thicker for both the butt and crown sampling sites (Chapters 4 & 5). The crown area indicated higher tensile strength but a lower elongation at break than the area around the crown. Variation between sites was observed when three sample areas in the crown area were compared in a further study (Chapter 3). Due to the variation between sampling sites, birds and gender, it poses a challenge for the assessment of physical skin quality traits. An interesting, although expected, result noted was that when samples taken on the right side of slaughter birds were contrasted with those taken on the left side it was shown that skins were bilaterally symmetric (Chapter 6).

Previously Swart (1981) indicated that the thickness of processed leather (i.e. up to a thickness of approximately 1.45 mm) determined the substance of the leather, where after the substance remained unchanged. Angel *et al.* (1997) reported an average leather thickness of 1.0 ± 0.3 mm (ranging from 0.7 to 1.4 mm) for ostriches slaughtered between 9.1 and 12.7 months of age. Swart (1981) stated that leather thickness accounted for 68.48% of the variation in the substance of ostrich leather. Although skins are not graded specifically according to substance, it is important in determining the acceptability of the leather for the various end users. Substance also influences the processing of the leather.

More research is needed to determine the importance of the substance and thickness of ostrich leather and to determine what the minimum quality requirements for the physical leather characteristics are. It seems, however, that the structure of ostrich skin generally provides sufficient strength for the processing of the leather for leather products, which is probably why minimum requirements have not been established yet.

The effect of bird variation

Ostrich leather is characterized by its quill sockets or nodules which are created by the feather follicles (Sales, 1999). The nodules make ostrich leather unique (Swart, 1981), and nodule size and shape are important in determining the value or quality of the skin (Mellett *et al.*, 1996; Meyer *et al.*, 2004). Little research regarding the effect of bird variation on skin quality was previously available. The only skin quality variation previously reported was by Swart (1981), who reported that the number of nodules on ostrich skins varied between 1032 and 1762 (average 1461.57 ± 13.58, CV = 9.2%).

Another important characteristic of an ostrich skin is the lack of uniformity in nodule appearance and distribution. Besides the occurrence of nodules only on certain parts of the skin, the appearance and distribution of the nodules in the nodulated area are also visibly different on different locations on the skin. This indicates that sampling of certain parts of the skin might not yield results that are representative of the whole skin.

The size of the nodulated area (the diamond-shaped area on the back of the ostrich, referred to as the crown area) was investigated in the study. Results indicated that the crown area represents 20.2 ± 2.5 % of the total skin area (Cloete *et al.*, 1998a). Engelbrecht *et al.* (2005) subsequently showed that the size of this area may be determined by genetic factors and that selection for a higher percentage of nodulated skin may be feasible. Heritability estimates for crown width amounted to 0.42 ± 0.08. When skin size was included as a covariate in the analyses, it amounted to 0.28 ± 0.07, indicating that some genetic variation remains. This accorded with the between breeding pair repeatability estimates of 0.26 ± 0.10 for the size of the crown area, as reported by Cloete *et al.* (1998a).

Ostrich skins were also evaluated on different locations to determine whether there were within skin variation (Cloete *et al.*, 2004, Chapter 3 and 9), and to explore the possibility of altering physical skin and nodule parameters by genetic selection (Cloete *et al.*, 2006b; Chapter 7). It seemed that location had a marked influence on nodule size and density (Chapters 4, 5, 6, 8 & 9). Meyer *et al.* (2004) also confirmed that the locality on the skin significantly influenced nodule size and nodule density. Nodule density generally decreases towards the ventral aspect of the ostrich, with the highest density found on the back line. The nodules on the neck and mid-crown area are also generally smaller than those located on the sides and towards the back of the ostrich (Cloete *et al.*, 2004, 2006b; Chapters 4 & 8).

It was found that nodule density generally decreased as nodule size increased. The butt area was an exception in this regard, having a high density of large nodules (Cloete *et al.*, 2006b; Chapter 7). The repeatability estimates of the leather traits investigated were mostly significant and moderate in magnitude (Cloete *et al.*, 2006b; Chapter 7).

Estimates of heritability of nodule size ranged from 0.07 ± 0.08 to 0.24 ± 0.10 between the different locations on the skin (Cloete *et al.*, 2006b; Chapter 7). Genetic correlations between nodule sizes measured at different sites were generally lower than expected and mostly not significant, indicating that nodule size on different locations on the skin was not necessarily the same genetic trait. Nodule density was also determined within skin sites as an indirect criterion for the improvement of nodule size. Genetic correlations between nodule density and nodule size were negative, variable in size and generally not significantly different, however, phenotypic and environmental correlations were generally negative and significant.

Meyer *et al.* (2002b) also evaluated genetic parameters for certain ostrich slaughter traits. A heritability of 0.32 ± 0.08 for slaughter weight, 0.21 ± 0.06 for raw skin yield and 0.21 ± 0.08 for crust skin yield was estimated. Genetic correlations between slaughter weight and skin yield were very high (>0.83), while the corresponding phenotypic correlations were 0.77 for both raw and crust skin yield. Estimates of heritability for both nodule size and density were low at 0.10, but still differed significantly from zero, while nodule size and density were negatively correlated at all levels. A high negative genetic correlation was also found between nodule size and nodule density (-0.72).

Recently Engelbrecht *et al.* (2005) also reported significant genetic variation for pre-slaughter live weight, skin size, crown width, crown shape, nodule size, nodule shape, and the prevalence of hair follicles. Estimates of heritability (± s.e.), genetic and environmental correlations reported for the respective traits are shown in Table 1. Engelbrecht *et al.* (2005) indicated that genetic improvement of these traits may be feasible since significant variation was found. The high and favourable genetic correlations of live weight, which is easily measurable, with skin traits such as skin size, crown width, crown shape, nodule size and nodule shape, was stressed due to the implication that indirect selection for these traits may also be feasible (Engelbrecht *et al.*, 2005). Cloete *et al.* (2006b; Chapter 7) found less optimistic results, however, suggesting that alternative approaches should also be considered.

The effect of sampling at alternative sites on physical leather characteristics was also investigated during this study (Chapter 6) since no objective assessment of differences between sampling sites has been done previously. Samples were taken both perpendicular and parallel to the spine. These samples were taken at 11 sampling sites per skin and included samples that were either nodulated or had no nodules. Significant repeatability estimates for samples taken in the crown area, parallel to the spine, suggested that samples for analysis of physical leather characteristics should in future be orientated this way and taken within the nodulated area when possible. None of the sampling sites could, however, be identified as being representative of the entire skin.

Table 1. (Co) variance components and ratios (± s.e.) for slaughter and skin traits of ostriches. Heritabilities on the diagonal are depicted in bold italics. Environmental correlations are presented above the diagonal and genetic correlations below the diagonal (Engelbrecht *et al.*, 2005).

	TRAIT							
	LW	**SSZ**	**LT**	**CW**	**CS**	**NSZ**	**NS**	**HF**
σ² (a)								
	88.42	45.11	0.0018	670.2	133.3	0.56	0.29	0.78
σ² (e)								
	106.44	51.74	0.0240	909.8	554.5	0.77	1.08	1.87
				RATIOS				
LW	**0.46 ± 0.09**	0.74 ± 0.04	0.32 ± 0.06	0.48 ± 0.06	0.45 ± 0.03	0.41 ± 0.03	0.18 ± 0.04	0.07 ± 0.08
SSZ	0.91 ± 0.03	**0.47 ± 0.09**	0.29 ± 0.06	0.57 ± 0.05	0.64 ± 0.04	0.46 ± 0.03	0.27 ± 0.03	0.08 ± 0.08
LT	-0.12 ± 0.30	0.02 ± 0.29	**0.06 ± 0.04**	0.26 ± 0.06	0.10 ± 0.05	0.29 ± 0.06	0.11 ± 0.05	0.09 ± 0.05
CW	0.84 ± 0.06	0.78 ± 0.07	-0.15 ± 0.30	**0.42 ± 0.08**	0.28 ± 0.06	0.44 ± 0.14	0.54 ± 0.15	-0.02 ± 0.07
CS	0.85 ± 0.09	0.82 ± 0.09	-0.53 ± 0.31	0.67 ± 0.13	**0.19 ± 0.06**	0.44 ± 0.17	0.39 ± 0.22	0.04 ± 0.06
NSZ	0.64 ± 0.10	0.64 ± 0.10	0.17 ± 0.29	0.29 ± 0.07	0.11 ± 0.06	**0.43 ± 0.08**	0.31 ± 0.06	0.14 ± 0.07
NS	0.50 ± 0.16	0.58 ± 0.15	0.60 ± 0.27	0.05 ± 0.07	-0.08 ± 0.05	0.80 ± 0.11	**0.20 ± 0.06**	-0.04 ± 0.06
HF	-0.03 ± 0.18	-0.11 ± 0.18	0.39 ± 0.29	0.00 ± 0.18	-0.28 ± 0.20	0.10 ± 0.18	0.15 ± 0.20	**0.31 ± 0.07**

The butt area which was previously used as a sampling site was compared against three areas in the crown region. However, the correlation between the different sampling sites was very low and none of the samples were considered being suitable as a sampling site for prediction of the physical quality of the entire skin. Another aspect investigated was whether samples should be taken perpendicular or horizontal to the spine. The former seemed to be the better sampling procedure and a significant difference for tensile strength was noted for samples taken perpendicular to the spine.

Another characteristic that influences skin quality is the natural presence of bristle hairs or filoplumes on ostrich skin. The removal of the hairs results in tiny pinholes (hair follicles) in the tanned skin which could lead to downgrading of the skins should they occur extensively between feather follicles (Lunam & Weir, 2006). Engelbrecht *et al.* (2005) found that the prevalence of hair follicles was independent of slaughter age. The estimated heritability was relatively high, however, at 0.31 ± 0.07, indicating that there is a possibility of minimizing the occurrence of hair follicles through genetic selection.

The high degree of variation within and between ostrich skins poses a challenge for the attainment of optimal leather quality. Specific quality requirements need to be established by the various processing industries in order to ensure that ostrich skins that are produced comply with the needs of each specific industry. Once specific quality requirements are provided it will be possible to canalize specific skins, which comply to those standards, towards the end user with those specific requirements. This will ensure that optimal use is made of the natural variation that exists between ostrich skins. More research is, however, needed to identify methods of attaining objective, representative values for the skin quality of a specific skin in order to comply with specific market requirements to make the pricing and selection process more objective.

Genetic improvement of ostrich skin quality also requires more investigation. The development of a structured breeding plan can in future aid in attaining optimal skin quality at earlier stages to lower costs and maximize income.

The effect of gender

The lack of information on the potential effect of gender on skin quality prompted this part of the study. Various studies indicated that body weight and skin yield were influenced by gender (Cloete *et al.*, 1998b; Van Schalkwyk *et al.*, 1999; Cloete *et al.*, 2006a; Chapter 2). Skins (i.e. fat removed) of males were 10.1% heavier than that of females (Van Schalkwyk *et al.*, 1999). Meyer *et al.* (2002b) confirmed that skin yield was dependent of gender and also indicated that males had significantly heavier skins than females (Meyer *et al.*, 2003a). This was also later supported by Cloete *et al.* (2006a; Chapter 2).

Leather thickness as measured within the crown area and in the butt region, was consistently found to be thicker in males than females (Van Schalkwyk *et al.*, 2002; Cloete *et al.*, 2004, 2006a; Chapters 4 & 6). This result was also noted by Engelbrecht *et al.* (2005), who measured leather thickness on the non-nodulated flank area of the skin. Additionally, it was shown that nodule traits were also affected by gender, with male slaughter ostriches generally having larger nodules and more well-shaped nodules than females (Engelbrecht *et al.*, 2005).

Cloete *et al.* (2004) further reported that there were no gender differences in tensile strength and slit tear strength, when corrected for leather thickness (Chapter 3). When physical leather characteristics were later investigated in groups of ostriches of different ages and weights (Chapters 6 and 7), no gender differences were once again reported for any of the traits (i.e. tensile strength, elongation and slit tear strength) considered after correcting for leather thickness.

Meyer *et al.* (2003a) found that when males and females were reared separately, the male groups had more skin damage at slaughter than the female groups. This can be attributed to more active and aggressive behaviour shown by young male chicks resulting in them damaging each others skins. However, the gender of ostrich chicks are mostly not known up to slaughter stage when feather moulting or colouration starts occurring as ostriches apparently also do not exhibit the same degree of gender differentiation as other domesticated species. Sexing of day old chicks can be done by visual appraisal of the cloaca with a 95% accuracy but this is time consuming and also requires a high level of expertise (Deeming *et al.*, 1996). Meyer *et al.* (2003a) did not note a difference between the separate sex reared or mixed gender groups as pertaining to the damage in the crown area, and suggested that raising male and female chicks separately would not have a beneficial effect on skin grading.

The effect of genotype

Zimbabwe Blue ostriches (*Struthio camelus* var. *australis*) are larger than South African Black ostriches (*Struthio camelus* var. *domesticus*) and produce larger skins at a specific age than the South African Blacks. More recently it was confirmed that there are significant differences in live weight at slaughter between the two genotypes (Brand *et al.*, 2005a; Hoffman *et al.*, 2007). Due to the high correlation between live weight and skin yield (Engelbrecht *et al.*, 2005), it can be expected that skin yield will therefore also differ significantly between these two genotypes. Unfortunately the effect of genotype on leather quality has not been documented yet and remains largely unknown. This study field warrants urgent investigation since the available knowledge indicates that it is worth pursuing.

PRE-SLAUGHTER FACTORS

The effect of age and weight

Initially slaughter of birds at 14 months of age was widely promoted to obtain optimal leather quality (Swart, 1981). Mellett *et al.* (1996) stated that leather quality is primarily dependent on the degree of maturity, i.e. slaughter age and not slaughter weight. However, there is considerable debate as to the effect of age on ostrich leather quality (Angel *et al.*, 1997). It was previously alleged that the optimum nodule size could only be achieved at 14 to 16 months of age (Mellett *et al.*, 1996). Notwithstanding, Mellett (1991) indicated that an acceptable skin size of 120dm² was already achievable by 10 months of age. Due to the declining feed efficiency after nine months of age (Raines, 1995), the increasing cost of feed, as well as the fact that optimal slaughter weight can now be obtained at a younger age due to improved feeding regimes, ostriches are now mostly slaughtered at 11 to 12 months of age. Leather quality is however allegedly compromised when slaughtering ostriches at these younger ages. This ongoing debate warranted scientific research to determine the effect of both slaughter age and slaughter weight on the various aspects of leather quality, which ultimately led to this study.

The separate and combined effects of age and weight on leather traits are discussed in Chapter 4. An experiment was designed to partition the effects of age and slaughter weight on skin traits. However, this was not possible as the results indicated that the weight and age of a slaughter bird are confounded. Slaughter weight of the experimental birds was influenced by age, with old birds being 40% heavier than the younger birds in the trial.

Some of the first attempts to research factors that may influence skin quality focused on live weight as a predictor of skin yield, and yielded correlations of slaughter weight with skin yield. Early estimations exceeded 0.90 (Swart, 1981). However, Angel *et al.* (1997) later found a poor relationship between body weight and skin size (r^2 = 0.16, P > 0.05). A correlation of 0.69 was estimated when using data from various producers (Cloete *et al.*, 1998b). Regressions of skin yield on slaughter weight showed a tendency (P = 0.06) to differ between producers, demonstrating the difficulties in predicting the economic yield of the skin from the live weight of the bird. It was contended that slaughter age, nutritional and managerial background as well as line, strain or other genetic effects may have contributed to the observed results. Some of these factors were investigated as part of this study and will be discussed accordingly.

The above-mentioned reports did not refer to the effect of the age of the slaughter birds, probably because age was not always a known factor. The effect of age on ostrich skin quality was therefore an important factor investigated of this study (Cloete *et al.*, 2004; Van Schalkwyk *et al.*, 2005; Chapters 4 and 6). Results indicated that both slaughter weight and raw skin yield increased linearly with increasing slaughter age (Cloete *et al.*, 2004; Chapter 3). Slaughter weight was shown to increase by 6.2 ± 0.4 kg and skin yield increased by 4.2 ± 0.7 dm^2 for every month of increase in slaughter age, respectively.

Early reports alleged that nodule size and shape were also age dependent, increasing with an increase in age (Mellett *et al.*, 1996). Swart (1981) indicated that when ostriches are slaughtered too young, even ripe follicles could result in poorly shaped nodules on the skins. Swart (1981) found that slaughter age apparently accounted for 45.57% of the variation in nodule size, while skin thickness accounted for 47.9% of the variation. Mellett *et al.* (1996) stated that optimum nodule size could only be achieved at 14 to 16 months of age. After an age of 19 months, follicle size and shape apparently did not change much, provided the ostriches were slaughtered with ripe feathers (Mellett *et al.*, 1996).

Results from this study confirmed that nodule development improved with age, and that an acceptable nodule size and shape were attained at approximately 11 months of age (Van Schalkwyk *et al.*, 2001, 2005; Chapters 4 and 6). The appearance of nodules seemed to be age dependent at first, regardless of weight. A significant interaction between age and slaughter weight for nodule size was however later identified (Chapter 4). No significant differences in nodule size were found between lighter and heavier young ostriches, while the nodules of heavier old birds were larger than those of lighter old birds. The lighter old ostriches also had a similar mean nodule size compared to the young ostriches in this study.

Nodule size was shown to increase by 0.08 mm per month as slaughter age increased, while nodule density decreased at a rate of 2.8 nodules / dm^2 per month increase in slaughter age (Cloete *et al.*, 2004; Chapters 4 & 5). The age dependency of nodule size and shape was confirmed by Meyer *et al.* (2004), Cloete *et al.* (2006b) and Brand *et al.* (2006a). Nodule density was once again shown to decrease with increasing slaughter age as well as with increasing body weight within age groups (Chapter 4).

Subjective evaluation of nodule traits further indicated that the acceptability of nodule development, as perceived by role players from the production and marketing chain of the ostrich industry, increased with an increase in slaughter age (Chapter 4). Average scores of at least moderate acceptability were found only in skins from birds slaughtered at 11 months of age and older (Van Schalkwyk *et al.*, 2005; Chapter 4), confirming work done earlier in the study.

Swart (1981) indicated a close relationship between slaughter age and the substance of processed skins (r^2 = 71.29%). Van Schalkwyk *et al.* (2001), however, indicated that leather substance was a function of weight. Swart (1981) reported that leather thickness increased curvi-linearly with an increase in slaughter age, and linearly with an increase in slaughter weight. Slaughter weight apparently only accounted for 45.49% of the variation in leather thickness, while slaughter age accounted for 67.37% of the variation. The study of Swart (1981) also found variation in nodule size and suggested that the variation not explained by either age or skin thickness, were probably related to genetic causes. Later research suggested that both nodule size and nodule shape was heritable (Engelbrecht *et al.*, 2005), thus agreeing with these preliminary observations.

Mellett *et al.* (1996) showed that skin thickness was also related to animal age, which in return influenced strength and resulted in a more acceptable or improved nodule shape. Angel *et al.* (1997) showed a linear increase in leather thickness with age (0.0021 mm per day between 7.3 and 16 months of age, r^2 = 0.59). This study accorded with above-mentioned results, also showing that leather thickness increased with age (Cloete *et al.*, 2004; Chapter 3) and weight (Chapter 4). The increase in skin thickness per month of age at slaughter amounted to 0.05 mm, which is in line with the results of Angel *et al.* (1997).

Regarding tensile strength, Angel *et al.* (1997) demonstrated that tensile strength and resistance to grain tract (lastometer evaluation) was high for the 53 skins used in their study, regardless of age (between 7.3 and 16 months). Resistance to grain tract were higher than the minimum standard of the shoe and boot industry for all the skins (all older than 7.3 months), while tensile strength were above the maximum point in the Scott Tester system.

During this study it was shown that tensile strength had a tendency to increase by 0.43 N/mm² for every increase of one month in slaughter age (Cloete *et al.*, 2004, Chapter 3). However, further investigations (Chapter 4) showed that tensile strength was unaffected by age when evaluated in specific age categories. The reason for this inconsistency is not clear and warrants further investigation.

No significant trends for elongation or slit tear strength were originally found (Chapter 3). Further investigations showed that elongation was independent of slaughter weight as well (Chapter 4), while the slit tear strength of skins from young ostriches were higher than those from older birds, when corrected for leather thickness. Tensile strength was also shown to increase with increasing weight (Chapter 4). However, the effect of age and weight was not considerable. This contradiction in the results on the effect of age on some of the quality traits emphasise the need for additional research on bigger groups with larger age variation to try and quantify this phenomenon.

Age was also shown to influence another important skin quality aspect, namely skin damage. Skin grading showed a sharp decline from nine to 14 months slaughter age (Van Schalkwyk *et al.*, 2001). Meyer *et al.* (2002b) confirmed these results by also indicating that slaughter age exerted an important influence on the proportion of first grade skins, which declined by 0.00196±0.00020% for each day increase in slaughter age. In addition, Meyer (2003) demonstrated a positive correlation between aggression and weight, which resulted in more skin damage in heavier birds.

Lastly, it is important to note that research results from the 1980's and early 1990's may not compare well with more current results, since those results were typically drawn from slaughter birds with weights of approximately 75-80 kg at 14 months of age (Swart, 1981; Jarvis, 1998), while slaughter weights of above 100 kg at 14 months, or younger, is achievable at present. In fact, it was previously recommended that ostriches should not be slaughtered lighter than 73 kg or younger than 14 months for optimal leather quality (Swart, 1981). However, presently birds are slaughtered at a combination of >90 kg live weight and an age of 11 to 12 months with acceptable nodule development (Van Schalkwyk *et al.*, 2001).

The effect of nutrition

No references regarding the effect of nutrition on leather quality existed previously. This was therefore one of the aspects that was investigated in this study, thus providing the industry with the first scientific indications of the effect of nutrition on leather quality.

It was shown that dietary protein had no effect on skin characteristics measured but weight and therefore skin size decreased with a lowering of dietary energy levels (Chapter 2). From the case study it was evident that the variation in skin grading (a combination of skin and nodule size and degree of skin damage) was not only large between producers but also between months and years (seasonal effect) of production (Chapter 3). This was shown to be the result of present farming practices (especially on skin damage) as well as specific crises that hampered the industry such as the ban on meat exports due to AI. The later would cause farmers to slaughter their birds at a younger age as they would fear a ban on the slaughtering of birds due to the AI outbreak. From the study (Chapter 3) it was evident that improved on-farm management practices to prevent skin damage results in better skin grading and therefore an increased income. Due to the extensive nature of raising slaughter birds, this poses a challenge in understanding behavior patterns of ostriches and the adaptation of on-farm structures accordingly. During this study it became evident that slaughter at a combination of 90 kg and an age of 11 to 12 months obtained acceptable nodule development and skin size and slaughter weight as well as a good feather income. Lately there is a surge towards a larger carcass with a slaughter mass of between 95 and 100 kg due to the increased meat income. This poses new challenges to both the producers as well as the leather industry due to increased feed costs and decreased skin quality because of the time constraint.

Van Schalkwyk *et al.* (2001) indicated that neither protein levels, nor sulphur containing amino acids, had any effect on nodule development. However, research on grazing ostriches showed that inadequate nutrition negatively impacted on nodule development, specifically where no supplemental feed were given on oat pastures (Van Schalkwyk *et al.*, 2001). These ostriches grew slower and were ultimately lighter.

Van Schalkwyk *et al.* (2002; Chapter 5) further investigated the effect of dietary energy and protein levels on leather quality by comparing physical leather parameters of ostriches that received rations with different energy and protein levels. Skin area increased linearly with an increase in dietary energy level. Leather thickness taken along the fibre grain also increased linearly by 0.71 ± 0.30 mm per 1.5 MJ ME/kg DM increases. It was also shown by Cloete *et al.* (2006a; Chapter 5) that raw skin weights of ostriches consuming diets with higher energy concentrations (i.e. 10.5 and 12.0 MJ ME/kg DM) were heavier than those on lower energy diets (9.0 MJ ME/kg DM). Dietary protein levels between 130 and 170 g/kg feed failed to influence any skin characteristics measured. The lowest levels of energy and protein supplied (9.0 MJ ME/kg and 130 g/kg diet) did therefore not compromise physical leather quality.

Brand *et al.* (2000; 2004; 2005b; 2006a, b, c) also conducted several studies regarding the influence of nutrition on skin quality. Brand *et al.* (2000) showed that skin yield was significantly influenced by the energy content of the diet. Birds fed a diet with a low energy level (9.0 MJ ME) had a smaller skin size than those on higher energy diets. Protein content of the diet did not affect skin yield, whereas it had a significant effect on skin grading due to increased damage to skins of ostriches on a high protein diet. The energy content of the diet, on the other hand, had no effect on the amount of skin damage.

Further studies confirmed these results. Dietary energy levels of 7.5 MJ ME/kg feed (Brand *et al.*, 2004) and 8.5 MJ ME/kg feed (Brand *et al.*, 2005b) significantly lowered skin yield compared to higher dietary energy levels of 9.5 to 12.5 MJ ME/kg feed. Skin size was once again unaffected at the lowest dietary protein (80 g/kg feed) and lysine (3.3 g/kg) levels (Brand *et al.*, 2004), while skin grading, as determined by skin damage, was not affected by dietary energy level (Brand *et al.*, 2004; 2005b).

Brand *et al.* (2006b) indicated that tanned skin size was approximately 4% smaller in groups consuming low energy diets compared to groups consuming high energy diets (135.1 vs. 140.5 dm^2). Nodule density (number of nodules per square decimetre) was correspondingly higher in the groups consuming low energy diets (44.7 vs. 42.8 nodules per dm^2). Other leather characteristics like nodule size, grain damage, skin damage, pinholes and skin thickness was not affected by dietary energy content, while dietary protein and amino acid levels failed to influence any of the above-mentioned characteristics (Brand *et al.*, 2006b).

It seemed that nutrition has a limited effect on ostrich skin quality when ostriches receive balanced rations complying with minimum standards for protein and energy levels. However, the effect of dietary protein on skin damage might warrant further research.

The effect of feather harvesting

The old practice of partially plucking young ostriches between seven and eight months of age leads to a delay in the time ostriches are slaughtered so as to avoid slaughtering birds with growing blood feathers (Jarvis, 1998). Skin quality is consequently influenced as explained earlier due to the increase in slaughter age.

Previously, feather harvesting practices resulted in skin damage when too many feathers were removed during plucking of live ostriches. The skin was exposed to sunburn which resulted in permanent scars that lowered the value of the skin at slaughter (Swart, 1979), since the feathers on the sides of the ostriches were also harvested. It was assumed that this led to the observed larger size of the follicles on the sides when compared to the follicles on the middle of the back, which were not harvested. Swart (1981) and Mellett *et al.* (1996) both concluded that an increase in the number of feather harvests per bird was concomitant with an increase in nodule size. However, according to Jarvis (1998), scientific proof of this appeared to be lacking. Research trials later showed that the harvesting of body feathers did in fact influence nodule development (Swart *et al.*, 1984; Van Schalkwyk *et al.*, 2001). The nodules of harvested sides were visibly larger than those of the sides that were not harvested (Van Schalkwyk *et al.*, 2001).

Brand *et al.* (2006c) later showed that a group of birds of which the feathers were harvested at six months of age tended to have a larger skin size than birds of which the feathers were not harvested. Pinholes (hair follicles) were also significantly more in the group where feathers were not harvested, while their nodules were also significantly smaller than those from the birds that were harvested (3.28mm vs. 3.38mm), confirming above-mentioned results.

Nodule shape is another trait that is also influenced by feather harvesting. The shapes of the nodules are determined by the stage of feather growth when the feathers are harvested (Swart, 1981). Plucking of green feathers (i.e. feathers that are not ripe, also known as blood feathers) results in the follicle being stretched out (Mellett *et al.*, 1996) or being without form (Sales, 1999). At slaughter, all the feathers are removed from the skin and the stage of feather growth at slaughter will therefore determine the nodule shape. Swart (1981) indicated that green body feathers at slaughter led to feather follicles or nodules that are inferior in appearance and therefore suggested that birds be slaughtered with ripe body feathers. Cooper (2001) furthermore advised that feathers should be removed with caution so as not to damage the follicles, which could also result in an inferior nodule shape.

Traditional feather harvesting, on the live bird as discussed above has been abandoned as a husbandry practice due to welfare concerns. Research in this regard was consequently also abandoned.

The effect of external parasites

Cooper (2001) argued that certain types of skin damage may be attributed to arthropod infestations. It was also alleged that the ostrich quill mite (*Pterolichus bicaudatus*) and ostrich feather louse (*Struthioliperus struthionis*) may lower skin and leather quality via pruritis and/or excessive preening and feather loss (Cooper, 2005). However, no scientific research on this topic could be found. It is, however, commonly accepted that ticks cause visible scars on ostrich skins where they bite or suck on the skin (Meyer, 2003). More research is needed to determine the influence of the known ostrich external parasites on ostrich skin quality, especially due to the increasing occurrence of fine damage on ostrich skins which is presumably linked with parasitic infestations.

The effect of other management practices

Angel (1996) pointed out that leather quality is affected at the farm level where the ostriches are being raised and that improved on-farm management can improve leather quality. MacNamara *et al.* (2003) also indicated that downgrading of ostrich skins in Australia often results from skin damage that occurs prior to or during slaughter of the bird. Inadequate handling and holding facilities, as well as inadequate transportation conditions also results in the infliction of damage to ostrich skins (Cooper, 2001). In recent years most leather quality research has been directed to decreasing skin damage through altered husbandry practices (Lunam & Weir, 2006).

Nel *et al.* (2000) conducted a survey to investigate the influence of management practices in the Klein Karoo region of South Africa on the quality grading of ostrich skins. Slaughter producers reported scratch marks, kick marks, chafe marks and other scars to be the main reasons for downgrading of their skins. The survey pointed out that production area, experience as a slaughter producer, regularity of handling birds during their lifetime, transport conditions when taken to the abattoir, and the size of grazing camps significantly influenced or tended to influence skin grading. Technical research on this topic was indicated to better understand the underlying causes of skin damage, since it was obviously a multi-factorial issue.

Meyer (2003) subsequently performed a number of research trials to investigate the factors related to on-farm skin damage. It was reported that cut wounds and scratch marks inflicted experimentally on birds from one to 13 months of age persisted through to slaughter, which indicated that on-farm damage during the lifetime of an ostrich was important in determining leather quality at slaughter (Meyer *et al.*, 2003b). Meyer *et al.* (2002b) also showed that no genetic variation existed for skin grade, as determined by damage, indicating that the grading of the skin was predominantly affected by the environment.

Meyer *et al.* (2003a) subsequently investigated separate-sex rearing and weight classification as possible management strategies to improve skin quality. It had no definite benefits for leather quality, however, due to increased skin damage in the all-male groups and contradictory results for low and high weight groups, with the control groups in both instances being intermediate with regard to skin grading.

In a case study (Chapter 3) undertaken on skin grades evaluated in the crust stage of tanning of birds slaughtered during 2003-2006 at the Mosstrich Abattoir (South Cape, South Africa) it was found that large variation occurred in the skin grades. The main effects that influenced this variation included producer, and season (month and year). Interpretation of the data was confounded by the fact that producers frequently slaughtered birds that were still not ready (too young) for slaughter due to factors such as droughts (insufficient pasture feed) or avian influenza. Similarly, when there is abundant grazing (approximately 80% of the birds reared in the South Cape, South African are free-ranged on planted pastures) producers tend to keep their birds to an older age to increase the body weight of the birds and thus the income generated from the skins and meat.. The case study also showed that the perception amongst producers that during periods of oversupply, skin grading was more strict and less so during periods of undersupply, was false.

Meyer *et al.* (2002a) further indicated that claw injuries were an important factor affecting skin grading, and that permanent declawing of day-old ostrich chicks improved skin quality significantly by reducing both scratch and kick marks. Glatz (2005) also indicated that the skin grades of declawed birds were significantly better than those of birds that were not declawed. Declawing is widely practised in Australia to reduce the incidence of scars from claw injuries (Glatz, 2005) resulting in an increase in skin quality (Lunam & Weir, 2006). The practice has welfare implications, however, which ultimately signifies that more research is still needed in order to find alternative practical solutions for the problem of on-farm skin damage, which is still a major factor influencing ostrich skin quality. Indications are that improved husbandry practices can improve skin quality by minimizing skin damage (Nel *et al.*, 2000; Meyer, 2003). More research into this study field is needed to identify practical solutions to on-farm skin damage.

POST-SLAUGHTER FACTORS

The effect of storage and preservation

Certain defects on processed skins are possibly caused by storage or curing procedures. Stone *et al.* (1998) investigated a wet-salted ostrich skin sample displaying the occurrence of grain defects thought to be associated with cure problems. No evidence of bacterial build-up was however found, and the cure quality of the skin sample was satisfactory. The authors recommended that the cure consistency and salt uptake be investigated on a larger number of samples.

Russel & Kohl (1999) subsequently did a more comprehensive investigation of the salt curing procedures and resulting leather quality. No significant differences were observed in salt uptake between the nodulated and non-nodulated areas of the skin. Some incidence of surface pitting was present in the nodulated areas of some of the skins. The evidence suggested however that the lesions were linked to conditions prevailing on the live bird rather than being introduced later during the curing stage.

Recently Lunam & Weir (2006) looked at the effects of different storage conditions on ostrich skin quality. They found that a bactericide / fungicide pre-treatment of salted skins prior to storage does not improve skin quality. Salting is however essential for long-term storage to prevent downgrading of the skins as a result of bacterial damage. The data suggested that salted skins may be stored for up to 19 weeks either at room temperature or at 4-6 ºC without compromising skin quality. Although minor deterioration of the salted skins occurred with storage at room temperature without bactericide pre-treatment, this had no observable effect on skin quality after tanning. Only skins that were stored unsalted were downgraded as a result of bacterial damage. Skins stored without salting also had flattened follicles due to degradation of the collagen fibres within the dermis. It was suggested that the bacteria responsible for collagen degradation in ostrich skin are Gram-negative and that their growth is inhibited by salting (Lunam & Weir, 2006). Gram-positive bacteria were found to be salt-tolerant as they colonised both the non-salted and salted skins. Yeast and two types of fungi were also found on the ostrich skins, but the significance of their presence for skin quality is unknown. Although short-term storage without salt for two weeks had no visible detrimental effect on the quality of tanned skins, it was indicated that salting should be performed as soon as possible following flaying of the skins in order to reduce the growth of potentially collagenolytic micro-organisms (Lunam & Weir, 2006).

Storing had no noticeable effect on the architecture of the dermis, while orientation, salting and storage temperature also had no effect on slit tear strength following storage for 19 weeks (Lunam & Weir, 2006). Research will have to continue to establish optimal storage conditions and preservation of ostrich skins.

The effect of processing

Slaughter birds should be properly bled at slaughter as it prevents blood from being left in the skin where it decomposes and leaves conspicuous marks, resulting in the skins being downgraded (Cooper, 2001). The importance of skilled workman for flaying of the skin at slaughter was also emphasized to prevent nick marks and tears (Sales, 1999).

No further research reports on the effect of processing on ostrich leather quality were found. Research regarding processing techniques is probably not published due to its importance in giving processing units a competitive edge through innovative techniques that gives the leather an even more unique look. However, research will have to be ongoing in order to maintain the innovative edge that makes ostrich leather exotic and unique.

A study field that will in future become more important is finding environmentally friendly preservation and processing methods that are not detrimental to skin quality.

ASSESSMENT OF LEATHER QUALITY

Swart (1981) indicated that most of the quality characteristics that determine the value of a slaughter bird are not measurable on a live ostrich. He subsequently identified live weight, age and growth phase of body feathers as indicators of skin quality at slaughter. More research was indicated to determine if leather quality could be accurately predicted at the point of slaughter (Mellett *et al.*, 1996).

During this study subjective assessment of leather quality was used to determine the effect of slaughter age on the acceptability of ostrich leather quality, specifically nodule acceptability (Van Schalkwyk *et al.*, 2005; Chapter 2). Fairly low between skin variance ratios indicated that subjective assessment was not very consistent. Similarly, the between scorer variance ratio was relatively high, exceeding 0.35, indicating that the linear scale was not applied consistently by all the scorers. This indicated that there is a need for alternative evaluation methods to allow a greater measure of objectivity and consistency in the assessment of ostrich leather quality.

Subjective evaluation methods employed by Engelbrecht *et al.* (2005) yielded better results, but still had certain limitations. Current objective methods of determining leather quality, for instance by physical measurement of nodule size and density, on the other hand are tedious and time-consuming (Cloete *et al.*, 2006b; Chapter 6). Nodule density was considered as an indirect selection criterion for the improvement of nodule size, but was shown to be less than optimal. The assessment of physical leather characteristics was also investigated in this study to determine the optimal sample site for such measurements (Chapter 6). It was found that the skins were bilaterally symmetric, but no specific site could be identified that accurately predicted the measurements at the other sites.

Today skin quality is seen as consisting of nodule size, shape and subjective evaluation of any visible skin damage present in the crust stage of tanning. In practice, shape and more so size is subjectively evaluated in the tanneries. When objectively measured it was evident from the study that nodule size increases with age and that an acceptable size is reach at 11-12 months of age. The location of sampling had a marked influence on nodule size and density. The highest and lowest density is usually found in the neck and the flank regions, respectively. Nodule size is usually smaller on the neck and the mid-crown area. It was shown that nodule size was mostly age dependent (Chapter 3). However, this seemed to be more pronounced in older birds, where larger older birds had larger nodules than smaller old birds. This was not observed for the younger birds (Chapter 5).

Ostrich leather is regarded as a fashion commodity, and changes in specific market preferences for skins with larger or smaller nodules, may dictate the age at which birds needs to be slaughtered in order to provide in the consumer's demands. It was also evident from the study that nodule size differs between sampling sites. The possibility of genetic selection for nodule size presents the industry with an opportunity to address such a phenomenon.

CONCLUSIONS

Alternative strategies for the objective assessment of leather quality consequently need to be investigated and considered. A facet that has not yet received any research attention is the measurement of skin characteristics on the live birds as a determinant of the potential leather quality. Presently, further research is being conducted to determine the heritability of the various ostrich skin quality characteristics. A limitation, however, is that the measurement of the various leather quality attributes can only be made on the skin once the birds has been slaughtered. Presently, research on a process of progeny testing to identify sires and dams with superior leather quality attributes are underway. This, however, is time consuming and expensive due to the long generation interval of ostriches, which hampers progress in terms of selection for superior skin quality.

A report by the National Agricultural Marketing Council (2003) identified a focus on the quality of South African ostrich leather and the development of new applications / products for ostrich leather as one of the key issues that need to be addressed in future for the ostrich industry to stay competitive in the global market. This study aimed to facilitate this process by providing a better insight in factors involved with the quantitative and qualitative aspects of ostrich leather. It signifies the beginning of a more scientific approach to skin quality and management of ostrich flocks for commercial production purposes.

Until quite recently, the available literature on ostrich leather quality was scarce. This dissertation thus makes a significant contribution towards increasing the knowledge of factors such as age, nutrition, and genetic selection that influence ostrich leather traits, as well as refute many speculations about ostrich leather quality and the determination thereof in the ostrich industry.

Note: Papers emanating from results of this study have been published in the following scientific journals and presented at symposia and congresses:

Peer reviewed papers:

Cloete, S.W.P., Van Schalkwyk, S.J., Brand, T.S., Hoffman, L.C. and Nel, C.J., 2006. The effects of dietary energy and protein concentrations on ostrich skin quality. *S. Afr. J. Anim. Sci.* 36, 40-44.

Cloete, S.W.P., Van Schalkwyk, S.J., Engelbrecht, A. & Hoffman, L.C., 2006. Genetic variation in nodule size at different sites on the skins of slaughter ostriches. *S. Afr. J. Anim. Sci.* 36, 160-164.

Cloete, S.W.P., Van Schalkwyk, S.J., Hoffman, L.C. & Meyer, A., 2004. Effect of age on leather and skin traits of slaughter ostriches. *S. Afr. J. Anim. Sci.* 34, 80-86.

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Contributions at local and overseas scientific meetings:

Meyer, A., Cloete, S.W.P., Van Schalkwyk, S.J. & Bunter, K.L., 2002b. Genetic parameters for live weight and skin traits in ostriches. *Proc. 2nd World Ostrich Cong.*, Ed. J.O. Horbañczuk, 26-29 September, Warsaw, Poland, pp. 236-237.

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