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# Gamebirds: A sustainable food source in Southern Africa?

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**Abstract** In order to alleviate the current food security situation the world is faced with, it is essential to investigate meat sources which have the potential to be used in a sustainable manner. This review provides substantial arguments to prove the viability of sport hunted wildfowl as a food source in Southern Africa. However, before the use of wildfowl meat can be realised, there are certain challenges to overcome in order to ensure meat of the best possible quality reaches the consumer. Important aspects to consider regarding the eating quality of wildfowl meat are identified and include the physical activity of the different portions and muscle fibre types, diet, breeding, age and gender as well as the post mortem handling/ageing of the meat. The safety issues involved in producing gamebird meat i.e. shot contamination (microbial or lead), are also discussed. Other areas that warrant scientific research include investigating the intrinsic and extrinsic factors that may have an influence on the ultimate meat quality and exploring possible techniques of improving the eating quality of wildfowl meat. The insights these investigations will provide have the potential to increase the commercial viability, directly or indirectly, of African wildfowl meat and thus contribute to food security.

**Keywords** Wildfowl · Use of gamebird meat · Egyptian geese · Guineafowl · Meat quality · Food security

## Introduction

The current situation that the world is faced with, regarding food security, not only calls for critical evaluation of ways to approach this problem, but effective action in order to improve food security. In 2009, it was estimated that 1.02 billion people in the world did not have a diet which provides the minimum nutritional requirements (FAO 2009). As emphasized by Von Braun (2007), in Sub-Saharan Africa specifically, there has been a 26 % increase in the number of food-insecure individuals since 1992. In emerging countries such as those in Africa, meat can be used to decrease undernourishment and improve the food security situation (McNeill and van Elswyk 2012). Therefore, as the consumption of animal-protein in Africa between 1995 and 2005 was only 17 % of the recommended protein intake (FAO 2011), increasing meat as a food source would be beneficial. One of the strategies suggested by Godfray et al. (2010), with the aim of overcoming this food security challenge, is to reduce the wastage of food. This, however, is mainly aimed at the loss of food products due to a lack of infrastructure and appropriate food related knowledge within developing countries. Nonetheless, reducing food wastage is not only related to products that are already part of the production chain but also to food (meat) that is not yet used as a food source. Therefore, it is vital to explore meat sources which have the potential to be used in a sustainable manner. In southern Africa, specifically South Africa, meat of sport hunted wildfowl, especially Egyptian geese (*Alopochen aegyptiacus*) and guineafowl (*Numida maleagris*) as well as various wild pigeon breeds, have this potential.

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Gamebird hunting originated with the ancient Egyptians who used falcons, dogs and other weapons and techniques in order to outsmart these birds (Viljoen 2005). In Europe, with the invention of the shotgun, gamebird hunting developed into a major sport involving vast amounts of tradition, prestige and ethics (Viljoen 2005). The sport became popular, as well as a tradition, in numerous countries around the world and gamebird meat certainly forms part of the culinary customs of these countries. Gamebird dishes seem to be especially popular in countries such as Britain and France. However, in southern Africa the gamebird industry and gamebird hunting or wingshooting have not yet developed their full potential. More specifically, the sustainable utilisation of gamebirds, which could be beneficial for South Africa, has not been accomplished (Berruti 2005).

Exploitation of gamebirds for meat presents challenges. For example, certain species, such as the Egyptian goose, are regarded as agricultural pests due to the damage they cause to crops and the consequent financial losses for farmers (Mangnall and Crowe 2001, 2002). Also there is such limited information regarding the quality (physical and nutritional) of gamebird meat. In addition, ensuring the safety of the meat is an area of concern that needs to be addressed as its contamination due to shooting or improper slaughtering and cooling procedures can be hazardous. Investigation and overcoming these challenges are essential if the use of gamebird meat is to be a success.

## Gamebirds and their classification

Gamebirds are a group of birds which are hunted mainly for recreational reasons (Viljoen 2005; Little and Crowe 2011) but have also been used as a food source. This is mainly due to their ability to endure continuous harvesting (Little and Crowe 2011). The expression "gamebird" describes a very broad collection of birds and these have been classified by Little and Crowe (2011) as land fowl and waterfowl. Species of the following orders (Table 1) are regarded as gamebirds: Galliformes, Anseriformes, Columbiformes, Pterocliformes, Charadriiformes (snipes) (Viljoen 2005). Viljoen (2005) noted that all birds currently classified as gamebirds have three things in common, namely; they all have very high rates of reproduction, they exhibit a sporting behaviour which demands the necessity of a certain skill for their successful hunting and all are edible.

**Table 1** The orders classified as gamebirds and the common names of the species belonging to each order (Viljoen 2005)

| Order | Common names |
|---|---|
| Galliformes | Partridge |
| | Francolin |
| | Quail |
| | Guineafowl |
| Anseriformes | Duck |
| | Geese |
| Columbiformes | Pigeons |
| | Doves |
| Pterocliformes | Sandgrouse |
| Charadriiformes | Ethiopian snipe (*Gallinago nigripennis*) |

## The gamebird industry: International and Southern African

Initially Europe dominated the industry; however, according to Viljoen (2005) the hunting of gamebirds not only thrives in Europe but also in the USA where it has developed into an industry responsible for generating millions of dollars worldwide. The author states that in the USA more than 38 million gamebirds are shot each year and that the gamebird hunters outnumber the common hunter by far. Gamebird hunting is the major contributor to the hunting industry in the REGHAB (Reconciling Gamebird Hunting and Biodiversity) countries in Europe as gamebirds are the species predominantly being hunted (Martinez et al. 2002). In the United Kingdom (UK) this industry contributes to the economy of the country by creating 26 000 employment opportunities which are responsible for a financial revenue of R 5 billion (8.2 R = 1 U$) annually (SA Wingshooters Association 2005). According to the independent report by the Public and Corporate Economic Consultants (PACEC) (2006), approximately 19 million gamebirds were shot in the UK in 2004 alone of which the majority were incorporated into the country's food chain.

It appears that the international gamebird industry is thriving and according to Viljoen (2005) the success is accompanied by the on-going management and conservation of the bird populations. The gamebird industry in Europe is centred on family traditions, especially in countries such as France and Spain (Martinez et al. 2002).

Internationally the circumstances are very different from those experienced in southern Africa. Captive-bred birds are a key part of the international industry, especially in Europe where large numbers of gamebirds are bred on an annual basis in order to be released into the wild (put and take) (Berruti 2005; Viljoen 2005). In the UK these captive bred birds are predominantly pheasants (80 %) but Red-legged partridge (16–17 %), Grey partridge and ducks are also reared for this purpose (ADAS 2011). According to the Agricultural Development Advisory Service (ADAS 2011), the UK Game Farmers Association estimates that 20–30 million birds are reared for release into the wild each year. Apart from the financial advantage this holds for the landowners, the motivation behind the use of this method is the fact that it is believed to reduce the stress on the wild gamebird populations (Viljoen 2005). This method also offers ethical hunting and inter-breeding occurs between the released birds that survive the hunting season and the wild birds. Subsequently, the gamebird population numbers are enhanced (Viljoen 2005). Viljoen (2005), however, states that currently the captive breeding of native South African gamebirds does not seem to be feasible. This is primarily due to the low survival rate of captive-bred species in the wild and the fact that these bred birds are not fit for wingshooting as they do not have adequate sporting behaviour (Viljoen 2005). Berruti (2005), on the other hand, is of the opinion that the use of captive-bred gamebirds in South Africa could be favourable for the gamebird habitats. However, there is need for caution and the North American and European methods should only be used as guidelines.

Also, in southern Africa and in South Africa in particular, gamebird hunting has not been particularly popular and is still mainly regarded as a sporting or leisure activity (Viljoen 2005; SA Wingshooters Association 2005) even though hunting, in general, is considered to be an important part of South African culture (van Rooyen 2010). Furthermore, the potential to use the meat has not yet been recognised. The meat is mostly used for consumption by the hunters themselves while the landowner also generally receives a portion of the shootings and donations are also made to the local communities.

There is very limited information available with regard to the South African gamebird industry. Berruti (2005) in a research document, regarding recreational and professional hunting in South Africa, emphasizes this, stating that there is no specific valuation of the industry. He, nevertheless, roughly estimated the industry's total worth in 2005, based on a study of birding ecotourism in South Africa, at approximately R300-R800 million per annum. In addition, the gundog industry is estimated at R200 million per year. In 1997, 500 000 gamebirds were shot (Berruti 2005) and at present the number is estimated to be around 2 million. According to the SA Wingshooters Association the number of gamebird hunters in South Africa was believed to be 20 000 individuals in 2005.

Another important fact, recognised by Berruti (2005), which also emphasizes the value of gamebirds is their illegal poisoning which occurs on South African farms. This is estimated at between 174 000 and 428 000 gamebirds every year. The harvesting of gamebirds for their meat is believed to be the reason behind these poisonings. This, however, is not a suitable method for their use because of health concerns, illegality and effects on other wildlife (Berruti 2005).

## Popular gamebirds hunted in Southern Africa

Southern Africa has a large variety of native gamebirds. This includes; two guineafowl, six partridge, two quail, five francolin, four sandgrouse, eight pigeon and dove, one snipe, as well as 16 species of waterfowl (Viljoen 2005).

According to Berruti (2005), the Rock pigeon, Namaqua sandgrouse, Helmeted guineafowl, Swainson's francolin, Grey-wing partridge and some of the duck species, depending on the area and season, are the main gamebird species hunted in terms of the value of the birds and the population numbers in South Africa. Three out of a total of 44 gamebird species in South Africa i.e. the Yellow-throated sandgrouse (*Pterocles gutturalis*), Delegorgue's Pigeon (*Columba delegorguei*) and the African Pygmy goose (*Nettapus auritus*) cannot be used because of their distribution which is limited and their habitats which are threatened (Viljoen 2005). Table 2 indicates the gamebird species found in South Africa along with the status of the population numbers within the country.

Southern Africa's two most popular and prevalent gamebird species are the Egyptian goose and the Helmeted Guineafowl. These species are not only very familiar to the local African people but several authors have emphasized their extremely widespread distribution and high population numbers in southern Africa. In Zimbabwe for example, the guineafowl is farmed on an extensive scale by local villagers (Saina et al. 2005) and there is market potential for this species in developing countries (Madzimure et al. 2011).

## Wingshooting

Wingshooting is the term that is generally used for gamebird hunting and is profoundly different from the hunting of mammals or furred game animals (Berruti 2005). This is because of the difference in hunting techniques, habitats of the species, as well as the biological characteristics and economic (industrial) and social aspects of the two different types of hunting (Berruti 2005).

The main motivations behind the hunting and harvesting of gamebirds are the financial and recreational aspects involved. However, hunting can also be beneficial in the management of gamebird population numbers (Viljoen 2005). The harvesting of excess gamebirds for management purposes should occur in late autumn to early winter, at the beginning of the hunting season when breeding activities are at their lowest. This ensures lower population numbers before winter arrives and consequently more food sources are available. This technique allows for a greater survival rate throughout the winter months which results in the population entering the breading season in good condition and thus having an improved capability of production (Viljoen 2005).

**Table 2** Traditional gamebirds of southern Africa and their population status (adapted from Viljoen 2005; Berruti 2005)

| Common name | Species name | Status |
|---|---|---|
| Partridges | | |
| Coqui Partridge | *Francolinus coqui* | Stable |
| Crested Partridge | *Francolinus sephaena* | Improving |
| Grey-wing Partridge | *Francolinus africanus* | Stable |
| Shelley's Partridge | *Francolinus shelleyi* | Improving |
| Red-wing Partridge | *Francolinus levaillantii* | Improving |
| Orange River Partridge | *Francolinus levaillantoides* | Improving |
| Francolins | | |
| Red-billed Francolin | *Pternistis adspersus* | Stable |
| Cape Francolin | *Pternistis capensis* | Stable |
| Natal Francolin | *Pternistis natalensis* | Improving |
| Swainson's Francolin | *Pternistis swainsonii* | Improving |
| Red-necked Francolin | *Pternistis afer* | Unknown |
| Quails | | |
| Common Quail | *Coturnix coturnix* | Stable |
| Harlequin Quail | *Coturnix delegorguei* | Stable |
| Guineafowls | | |
| Crested Guineafowl | *Guttera pucherani* | Improving |
| Helmeted Guineafowl | *Numida meleagris* | Improving |
| Sandgrouse | | |
| Namaqua Sandgrouse | *Pterocles namaqua* | Stable |
| Burchell's Sandgrouse | *Pterocles burchelli* | Improving |
| Yellow throated Sandgrouse | *Pterocles gutturalis* | Unknown |
| Double-banded Sandgrouse | *Pterocles bicinctus* | Stable |
| Pigeons and Doves | | |
| Rock Pigeon | *Columba guinea* | Improving |
| Rameron Pigeon | *Columba arquatrix* | Improving |
| Red-eyed Dove | *Streptopelia semitorquata* | Improving |
| Delegorgue's Pigeon | *Columba delegorguei* | Declining |
| Laughing Dove | *Streptopelia senegalensis* | Improving |
| Cape Turtle Dove | *Streptopelia capicola* | Improving |
| Mourning Dove | *Streptopelia decipiens* | Stable |
| Green Pigeon | *Treron calva* | Improving |
| Ducks and Geese | | |
| White-faced Duck | *Dendrocygna viduata* | Improving |
| Egyptian Goose | *Alopochen aegyptiacus* | Improving |
| South African Shelduck | *Tadorna cana* | Improving |
| Yellow-billed Duck | *Anas undulata* | Improving |
| African Black Duck | *Anas sparsa* | Stable |
| Cape Teal | *Anas capensis* | Stable |
| Hottentot Teal | *Anas hottentota* | Stable |
| Red-billed Teal | *Anas erythrorhyncha* | Improving |
| Cape Shoveller | *Anas smithii* | Improving |
| Southern Pochard | *Netta erythrophthalma* | Stable |
| Spurwing Goose | *Plectropterus gambensis* | Improving |
| Fulvous Duck | *Dendrocygna viduata* | Improving |
| White-backed Duck | *Thalassornis leuconotus* | Stable |
| Knob-billed Duck | *Sarkidiornis melanotos* | Improving |
| African Pygmy Goose | *Nettapus auritus* | Declining |
| Moccoa Duck | *Oxyura maccoa* | Unknown |
| Snipes | | |
| Ethiopian Snipe | *Gallinago nigripennis* | Unknown |

The period (season) each gamebird species may be hunted is dependent on the breeding season and the population numbers in each region. The amount of gamebirds that may be shot is also regulated by daily bag limits. In the Western Cape province, species such as Egyptian geese, with an improving population status, can be hunted throughout the year and has a bag limit of 10 geese per day (Western Cape Nature Conservation Board 2010).

The techniques involved in gamebird hunting vary according to the specific type hunted e.g. upland gamebirds (terrestrial) vs. waterfowl. Waterfowl are generally shot on flight routes into or out of feeding areas such as croplands where they feed on grain (Mangnall and Crowe 2001) whereas the technique of pointing and flushing by gundogs is often used for terrestrial gamebird hunting. The flushing method forces terrestrial gamebirds, often found in trees, shrubs or long grass, to rapidly take-off and fly for short distances which provide hunters with the opportunity to shoot them in-flight. A double-barrelled shotgun (12-gauge) is mainly used for hunting purposes as most gamebirds have to be shot in-flight.

## Factors that influence the eating quality of gamebird meat

The term meat quality is based on preference and characteristics required by consumers. It is influenced by several factors such as animal genetics, *pre* and *post* slaughter conditions, nutritional characteristics and environmental conditions (Lefaucheur 2010) as well as measures taken to ensure meat safety. More specifically, the eating quality of meat involves three main attributes namely; tenderness, juiciness and flavour which are the major contributors to its acceptability by consumers (Risvik 1994; Warriss 2000). However, nowadays consumers also demand that meat is lean and provides adequate nutritional requirements (Hoffman and Wiklund 2006).

### Physical activity, carcass portions and fibre types

Similar to all game species, gamebirds are very active. The levels of physical activity do, however, vary from species to species. For example, Egyptian geese are waterfowl which are accustomed to various types of exercise such as terrestrial (walking/running), aquatic (swimming and diving) and aerial (flying long distances to forage). As Shewell (1959) noted, they will rather move into water when threatened and will only fly away when they are caught by surprise. This combination of the different types of activities compared to that of terrestrial birds such as Guineafowl and Pheasants ensure that the muscles of the breast and leg of Egyptian geese are different in terms of the muscle fibre composition.

Muscles responsible for long-term, systematic activity (such as retaining posture) are comprised of red, type I, slow oxidative (SO) fibres that contract slowly and continuously whereas those responsible for locomotive behaviour consist of fast twitch fibres. The muscles which are used during rapid movements/locomotive behaviour and bursts of activity consist of white, type IIb fast glycolytic (FG) fibres, but this type is very easily fatigued (George and Berger 1966; Warriss 2000). Type IIa, fast oxidative glycolytic (FOG) muscle fibres are resilient to fatigue and are used during locomotion because of their fast contracting ability – these would typically be dominant in birds that fly long distances such as pigeons. George and Berger (1966) states that intermediate fibres (Type 11a) become more prevalent when there is an increase in the sustainability of the rapid movements.

*Breast*

The breast portion (*Musculus pectoralis* and *Musculus supracoracoideus*) is situated in the front breast area of the carcass where the sternum provides a surface for this muscle. In poultry, this is sold with the sternum intact (whole breast) or the muscle can be removed and sold as a deboned portion. The large breast muscle (M. *pectoralis*) is mainly used during flying when it is responsible for the downward movement of the wings and the *M. supracoracoideus* is the muscle which raises the wing during the upward movement (Poore et al. 1997; Dial 1992; Swatland 2000; Biewener 2011). The breast muscle of gamebirds such as Egyptian geese which fly long distances will therefore endure a higher level of activity compared to that of terrestrial gamebird species. This *M. pectoralis* in volant species mainly consists of red, type IIa, fast oxidative glycolytic (FOG) fibres and a small amount of white, type IIb, fast glycolytic (FG) fibres (Butler 1991). Although George and Berger (1966) claim that ducks have a combination of FG, FOG and SO in the *M. pectoralis*, the study by Rosser and George (1986) found that the *M. pectoralis* in Anseriformes (ducks and geese) consists of red, FOG fibres and white, FG fibres. This is believed to be a result of the fast muscle contracting requirements for movement of the wings (Rosser and George 1986). Baeza et al. (2000) also reported that the breast muscle of Mule ducks consisted of type IIa (88 %) and type IIb (12 %) muscle fibre types. The breast muscle's fibre composition of terrestrial gamebirds (Galliformes) such as Guineafowl and Pheasant will be very different from that of volant bird species. Terrestrial gamebirds will run rather than fly but, if required, they will rapidly take off but only fly for a very short distance (Kaiser and George 1973). Kiessling (1977) reported that the breast muscle of Guineafowl hens consisted of only 10 % red fibres. Similarly for pheasants, Kiessling (1977) also noted that their breast muscle consists of 17 % red fibres and Hofbauer et al. (2010) emphasizes the fact that this muscle is primarily comprised of white, type II, glycolytic fibres. This high amount of white fibres is responsible for the rapid take off and flight acceleration while the low red fibre count suggests that the movement/flapping of the wings can only be sustained for a short period (Kaiser and George 1973).

*Leg*

The leg consists of two portions; the thigh is the proximal part (closer to the body) situated at the top of the leg and the drumstick which is the bottom or distal part (away from the body) (Swatland 2000). The leg muscles are locomotive and are used during activities such as walking by terrestrial gamebirds; waterfowl species also use these muscles when swimming and diving (Butler 1991; Turner and Butler 1988). Leg muscles consist of different combinations of slow oxidative (SO), FOG and FG fibre types depending on the muscle and its activity.

The thigh, containing the femur bone, is removed at the hip joint of the carcass and separated from the drumstick, containing the tibia bone, at the knee joint (Swatland 2000). The main lateral muscles of the thigh are the *sartorius*, *iliotibialis*, *semitendinosus*, *biceps femoris* and *semimembranosus* and the main medial muscles are the *ambiens*, *adductor longus*, *piriformis* and the *obturator internus* (Swatland 2000). Main muscles of the drumstick are the *gastrocnemius* and *peroneus longus* (Swatland 2000).

*Fibre types and meat quality*

The composition of the muscles/portions regarding the types of fibres they are composed of is a vital determinant of meat quality (Lefaucheur 2010). Muscle fibre type can affect the colour, tenderness, juiciness and even the flavour of meat and as such, may have a detrimental effect on the consumer acceptability of meat.

Tenderness is probably the attribute which is most affected by muscle fibres. The total number of fibres, the cross sectional area and diameter of the fibres (size) as well as the composition of the muscle fibre types play significant roles in the tenderness of meat (Lefaucheur 2010). Several studies have found correlations between fibre size and shear force/-tenderness of meat (Hiner et al. 1953; Tuma et al. 1962; Crouse et al. 1991). It is suggested that muscle comprised of larger fibres produce meat (pre-maturation) that is less tender while more tender meat generally contains smaller fibres (Crouse et al. 1991). Red, Type I, oxidative muscle fibres have the smallest size whereas Type IIa, oxidative-glycolytic muscle fibres have an intermediate size and white, Type IIb, oxidative muscles have the largest fibre size (Oshima et al. 2009; as cited by Lefaucheur 2010). Muscle fibre diameter is also related to sarcomere length. Herring et al. (1965) reported that a decrease in sarcomere length, due to the shortening of the muscle, results in a larger muscle fibre diameter and therefore less tender meat. Several other studies are in agreement with Herring et al. (1965) regarding the influence of sarcomere length on the tenderness of meat (Locker and Hagyard 1963; Purchas 1990). Furthermore, literature also indicates a negative relationship between the amount of fibres present in muscle and the tenderness of meat. Ryu and Kim (2005) found the number of muscle fibres to be positively correlated with shear force (low tenderness). Carpenter et al. (1963) explained that a decrease in the muscle fibre size results in a possible increase in the number of muscle fibres present therefore more connective tissue and ultimately less tender meat. This also clarifies the inverse relationship between total fibre number and cross-sectional area (size) of fibres as reported by several studies (Larzul et al. 1997; Ryu and Kim 2005).

The tenderization (ageing) of meat is another aspect in which consideration of muscle fibres is important (Huff-Lonergan et al. 2010). Variation in the activity of the proteolytic enzymes calpain/calpastatin and cathepsin activity within different fibres affects the toughness of meat. It is believed that type IIb muscle fibres (fast twitch) have higher amounts of calpains compared to the inhibitor for this proteolytic enzyme, calpastatin (Ouali and Talmant 1990). Therefore a higher rate of tenderization exists in muscles containing greater amounts of type IIb fibres (Ouali and Talmant 1990; Lawrie and Ledward 2006). Alternatively, type I, red muscle fibres contain higher concentrations of calpain II and calpastatin but they are less susceptible to proteolysis because of the lower *post mortem* calcium concentrations in the red muscles which favour the activity of the proteolytic enzymes. However, both Ouali and Talmant (1990) and Sazili et al. (2005) noted that type I muscle fibres contain higher concentrations of calpastatin promoting inhibition of the proteolytic activity of calpain leading to less tenderization taking place in muscle with high levels of type I fibres. An additional aspect where fibre composition is involved is the occurrence of cold shortening in muscles. Oxidative muscle is prone to cold shortening as there is a more rapid loss in the ability of the sarcoplasmic reticulum to sequester calcium (Lawrie and Ledward 2006; Huff-Lonergan et al. 2010). There is also variation in the collagen content of different muscle fibre types. It has been found that type I, oxidative fibres have a higher collagen content compared to type IIb glycolytic fibres (Kovanen et al. 1984; Rodrigues et al. 1996; Nakamura et al. 2003). This is also linked to the fact that there is an increase in the concentrations of intramuscular collagen in the muscles of animals that are physically more active pre-slaughter (Lewis et al. 1989).

The fibre composition is not only involved in the tenderness of meat but can be linked to the flavour of meat as well. Type I, oxidative fibres have a high proportion of phospholipids (Lefaucheur 2010) and it is widely accepted that these predominantly long chain polyunsaturated fatty acids play a significant role in the flavour formation process (Wood et al. 2003). Due to their susceptibility to oxidation, these fatty acids may also cause negative flavour characteristics. However, muscles comprised of type I fibres also have a higher intramuscular fat content as oxidative fibres use fat as an energy source during metabolism (Wood et al. 2003; Lawrie and Ledward 2006). Therefore it is postulated that these muscles may produce meat with a more prominent flavour as fat is responsible for conveying flavour during mastication (Melton 1990).

Intramuscular fat being greater in red muscles may also have a possible effect on juiciness. This is attributable to the stimulation of saliva secretion by intramuscular fat during mastication of the meat (Lawrie and Ledward 2006). Meat composed of high levels of type I fibres are also susceptible to producing DFD (dry, firm, dark) meat if the animals are subjected to stress pre-slaughter (Lawrie and Ledward 2006). The low concentration of stored glycogen in the red muscles results in the rapid depletion of glycogen and therefore meat with a high ultimate pH. The high ultimate pH causes the meat to have a very high water holding capacity which reduces the juiciness of the meat upon cooking; a negative aspect for consumer acceptability.

## Season

The seasonal changes that generally have an influence on meat quality are linked to variation in the diet as well as the breeding periods and winter months. Concerning gamebirds, these are elements that cannot be controlled as they are not raised within a domestic environment. It is therefore essential to consider season in terms of the possible use of wildfowl meat.

### *Variation in the diet*

In regions where croplands are abundant, the diets of certain gamebirds vary on account of the grain season. Guineafowl is one of the gamebird species which depend on harvested grains and maize as part of their dietary intake (Little and Crowe 2011). In South Africa, it has also been reported that pigeons cause huge economic losses to sunflower crops, however this period is also when large numbers are hunted for sport. The meat derived normally goes to the local population for consumption. Egyptian geese are another species relying heavily on the grain season. Although they mainly feed on aquatic plants, aquatic invertebrates and green terrestrial plant materials, seedlings and growing crops also form part of their diet (Maclean 1988; Viljoen 2005). Halse (1984) reported that during certain periods they also rely on Bermuda grass, algae and pondweeds as food sources. This diet, however, is very different during the grain harvesting season. The geese travel long distances in order to forage for grain seeds found on croplands in the harvesting period (November), especially in the Western Cape where a considerable number of farms are present (Mangnall and Crowe 2001, 2002). The difference in diet during these periods compared with periods when they are dependent on other sources of food may result in differences in the fatty acid profile of the meat.

In monogastric birds, dietary lipids are directly incorporated into tissues with minimum modification and therefore can have an effect on the fatty acid profile of the meat (Wood and Enser 1997; MacRae et al. 2005). The fatty acid profile is one of the major determinants of the characteristic aroma and flavour profile of meat, as the thermal degradation of the lipids is one of the key processes in producing the aroma volatiles (Mottram 1998). Not all fatty acids influence the flavour of meat to the same extent. Unsaturated fatty acids, particularly polyunsaturated fatty acids, produce a wide range of aroma or flavour volatiles because of their high susceptibility towards oxidation (Mottram and Edwards 1983). This is important in flavour development during cooking (Wood et al. 2003), a process which, to date, has not been investigated in gamebird meat and an area of research which is vital in order to correlate flavour of the meat with the seasonal diets of the birds.

### *Breeding season*

The annual breeding periods of wild birds have a large impact on their overall body condition, especially with regard to the females (Raveling 1979; Reinecke et al. 1982). For example; the peak breeding season of Egyptian geese in the Western Cape are between late winter and early summer during the months of August and October (Viljoen 2005). It is therefore postulated that regardless of the difference in diet, the geese will have the best possible body condition, with high energy reserves, by the end of July as they have prepared for the breeding season. During the breeding period the energy reserves will be depleted but by the end of October/early November Egyptian geese start to forage on grain seeds, a high energy source, during the harvesting season and the energy reserves are gradually restored. Consequently, the breeding season may not only have a significant influence on the body size and mass but also on the intramuscular fat content of Egyptian goose meat. Similar theories concern the fluctuations in the body condition due to the annual cycle of Black ducks (Reinecke et al. 1982) and Canada geese (Raveling 1979). It is therefore essential that breeding periods of gamebirds are considered in relation to meat quality.

## Age and gender

The influence of animal age on the eating quality of meat is mainly restricted to two factors; collagen content and intramuscular fat which may have an effect on the tenderness, juiciness and flavour attributes. There is a tendency for meat originating from older animals to be juicier, to have more flavour but to be less tender (Lawrie and Ledward 2006), owing to an increase in polypeptide cross-linking of the collagen as well as a decrease in its solubility upon heat treatment or cooking. This has been verified by numerous studies which correlate age with the tenderness of meat (Xiong et al. 2007; Schönfeldt and Strydom 2011). Along with the changes in the connective tissue with age there also seems to be an increase in flavour intensity (Lawrie and Ledward 2006). This is associated with an increase in the intramuscular fat deposition as the animal matures. As fat is involved in conveying flavour during mastication, a higher intramuscular fat content ensures better transmission of flavour and therefore increases the flavour intensity (Melton 1990). Chartrin et al. (2006) noted a more prominent flavour in the breast portion of Mule ducks with higher intramuscular lipid levels. However, Lawrie and Ledward (2006) state that there is not only an increase in the intramuscular fat content of the meat but an alteration in the composition of the fatty acid profile, which becomes more saturated and is associated with an improved flavour. Intramuscular fat is also involved in the sustained juiciness of meat (Lawrie and Ledward 2006).

The most significant difference regarding meat quality and gender is the variation in fat deposition between male and female animals. It is generally accepted that female animals tend to store fat more readily (Lawrie and Ledward 2006). Baeza et al. (2001) reported that Guineafowl meat from female fowl was more tender and less stringy than that from male fowl by a sensory panel.

During the slaughter process, the gender of gamebirds can be determined without difficulty but limited literature is available regarding determination of the age of wild birds. This makes the incorporation of age, as a factor of influence, in research investigating meat quality difficult if not impossible.

## Stress and meat quality

The quality of meat is determined by several factors of which *post-mortem* metabolism is one of the key aspects. The rate and extent of the pH decline in *post-mortem* muscle is fundamental in the transformation of muscle into meat. *Post mortem* acidification is directly linked to the amount of glycogen available in the muscle which can be influenced by several intrinsic factors (species, muscle type and variability between individuals) and extrinsic factors (environmental temperature and stress) (Lawrie and Ledward 2006). *Ante-mortem* stress is one of the extrinsic elements that has a major effect on the glycogen metabolism and ultimate pH of the muscle (Remignon et al. 1998; Lawrie and Ledward 2006), consequently defining meat quality attributes such as tenderness, juiciness and colour. Chronic and acute stress may result in meat that is dry, firm and dark (DFD) or pale, soft and exudative (PSE).

DFD meat is characterised by a high ultimate pH (pH> 6), a result of very low levels of available muscle glycogen *post mortem* which is a consequence of chronic stress. DFD meat has an increased water binding capacity and therefore the absorption of light is high, resulting in very dark, firm and dry meat (Hoffman 2000). This condition is also known to have a detrimental effect on the tenderness of meat as the high pH creates a very rigid structure. The research by Purchas (1990) also concluded that the tenderness of meat decreases as the ultimate pH increases from 5.5 to 6.2 while Yu and Lee (1986) found that at an ultimate pH between 5.8 and 6.3, tenderness is at its lowest. This is mainly related to the influence of the ultimate pH on the activity of the proteolytic enzymes which, at these higher values, is not optimum for their activity. According to Remignon et al. (1998) the ultimate pH of muscle from Japanese quail is highly correlated with stress pre-slaughter. This results in depletion of glycogen levels *ante-mortem*, causing low lactic acid production. It is thus expected that the meat from gamebird species will also have a tendency towards DFD, especially as most birds are shot in flight.

PSE meat occurs because of a rapid *post mortem* decline in the pH of the muscle which is induced by acute, *ante-mortem* stress (Warriss 2000). The rapid decrease and low ultimate pH of the muscle, together with temperatures that are still fairly high, produces the following characteristics of PSE meat: denaturation of the proteins, low water holding capacity and a pale colour due to an increased scattering of light. In general, the PSE condition is well-known in meat from genotypes of pigs which are very susceptible to stress. However, characteristics that suggest the occurrence of PSE have also been reported in poultry (Barbut 1997; Woelfel et al. 2002; Zhu et al. 2011) and turkey meat (Barbut 1996; Molette et al. 2003). The high content of white, glycolytic fibres present in the muscles of poultry, turkey and other Galliformes birds, with high amounts of available glycogen, have the tendency to rapidly acidify post mortem (Warriss 2000; Taylor 2004). It is thus postulated that if these gamebirds are wounded during the hunt there is a possibility that the PSE condition may be found in the meat.

Research quantifying the impact of stress on meat quality of southern African wildfowl is restricted and is therefore an area requiring extensive investigation. An understanding of the *pre* and *post* mortem biochemical activities, relating to stress, will be beneficial in terms of improving or adapting shooting procedures in order to ensure the best possible quality of the meat.

## Safety

The production of game meat for the commercial market varies a great deal from the use of domestic livestock for meat production. The manner in which the animals are killed, the evisceration process as well as the cooling procedures are elements of concern with regard to the safety of the meat (Gill 2007). During production of game meat these elements are more difficult to control as the environment in which the meat is sourced provides for certain challenges. This particularly applies to gamebirds where the method of killing is the factor causing the greatest concern regarding safety. Shotgun shells may damage the intestinal cavity resulting in microbial contamination of the meat; Paulsen et al. (2008) investigated the effect of shotshell wounding on hunted, uneviscerated Pheasant and found a loss of hygienic quality only at day 7 (stored at 0–4 °C) caused by the presence of *Escherichia coli* (>1 $\log_{10}$ cfu/g). Alternatively, emphasis can also be placed on disposing gamebird carcasses where gunshot damage to the intestinal cavity has occurred so as to ensure that contaminated meat is not consumed. Immediate cooling of shot birds is also an area of concern, especially in Southern Africa where ambient temperatures are high. To ensure effective cooling of the birds in the field is a challenge and it is thus essential that a practical approach is adopted in order to overcome this challenge (refer to section “Post mortem handling”).

It is, however, not only safety in terms of microbial contamination that needs to be considered but also contamination by lead shot - another controversial topic. Lead is toxic and affects several systems within the human body (WHO 2010). The major source of lead intake by humans is the ingestion of lead pellets or fragments of pellets that are embedded in the tissue of hunted gamebirds (Scheuhammer et al. 1998; Johansen et al. 2004; Mateo et al. 2007). Furthermore, it is also believed that residual lead, originating from hunting activities, is ingested by gamebirds as they confuse the pellets for seeds or other food (Mateo 2009; Thomas 2010). This results in secondary lead intake by humans when the tissue is consumed. For this reason certain countries such as Denmark, Norway and The Netherlands have banned the use of lead shot for hunting purposes. In other countries, the use of lead-free shot is compulsory for all waterfowl hunting as extensively discussed by Mateo (2009) and Thomas and Guitart (2010). However, the process of implementing the use of non-toxic, lead-free shot as alternatives is progressing slowly.

Legislation regarding meat safety in South Africa does not provide for hunted, wild gamebirds but only for those that have been domesticated such as Guineafowl, Pheasant and Partridge (Anonymous 2000). This Act also currently prohibits the acceptance and processing of dead animals in an abattoir. It is therefore vital that the legislation is altered so as to provide for the commercial use of gamebird meat.

## Traditional ageing of wildfowl

The traditions and ethics involved in gamebird hunting also include the preparation and handling of the birds before consumption. By tradition, particularly in Britain and several other countries, gamebirds are usually hung uneviscerated without being plucked in a cool environment for some time before further preparation and consumption (Barnes 1976). It is believed that this procedure not only increases tenderness of the meat owing to muscle autolysis but is also involved in development of flavour (Barnes 1980). Gamebirds are hung for different times according to species (see Table 3 for gamebirds shot in Britain). Ambient temperatures, which vary seasonally, as well as the age of the gamebird are also influential factors (Barnes 1980).

Theoretically, the term ageing or conditioning is defined as the *post rigor* storage of unprocessed meat, without any microbial deterioration, above the point of freezing and is therefore a natural process of tenderisation (Warriss 2000; Lawrie and Ledward 2006). The biochemical changes, involved in tenderisation during the ageing of gamebird meat, are very complex and interrelated. The two main tenderisation processes occurring in *post rigor* muscle are denaturation and proteolysis (Lawrie and Ledward 2006). As the oxygen supply to the muscle is terminated after death, there is no energy available to preserve the muscle structure and denaturation of the proteins follow. However, tenderisation mainly results from proteolysis by the protease systems present in the muscles which are responsible for the breakdown of the protein structure. There are four systems identified thus far which include calpains, cathepsins, proteasomes and caspases (Kemp and Parr 2012). Of these systems, the calpains and cathepsins are the two which have been studied most extensively and their involvement in tenderisation have been recognised widely (Ouali 1992). Koohmaraie (1996) reported that μ-calpain is the most important factor in the post mortem proteolytic tenderisation of meat. The biochemical process of tenderisation can be significantly influenced by factors such as pH, temperature, muscle fibre composition, ionic strength and protein oxidation (Huff-Lonergan et al. 2010).

**Table 3** Methods of handling and hanging of some British gamebirds (adapted from Barnes 1980)

| Gamebird | Hanging technique |
|---|---|
| Partridge | Young birds, 3–5 days; older birds, 10 days or more |
| Pheasant | 13–14 days according to age and weather conditions |
| Wild duck | Eaten fresh or hanged for up to 2 days |
| Grouse | 3 – 10 days according to age and weather conditions |

The temperature of *pre* and *post rigor* muscle determines the rate of the pH decline and the degree of muscle shortening (Huff-Lonergan et al. 2010) while it is suggested that pH regulates both the activation and inactivation of the proteolytic enzymes (Maddock Carlin et al. 2006; Melody et al. 2004). However, it is not only temperature and pH that may affect the ageing process but, as mentioned, fibre type can also be linked to tenderisation as there is variation in the content of proteolytic enzymes within oxidative and glycolytic muscle fibres (Ouali and Talmant 1990; Sazili et al. 2005). It is also believed that protein oxidation may interfere with the tenderisation process and should also be considered. Protein oxidation leads to the denaturation and aggregation of the myofibrillar proteins together with the inactivation of the proteolytic enzymes and consequently may influence the ability of meat to become more tender over time (Rowe et al. 2004; Huff-Lonergan et al. 2010).

As Barnes (1980) noted, an alteration in the flavour during hanging/ageing of gamebirds may also arise. It is suggested that ageing enhances the desirable gamey flavour of the meat. In 1972, Wasserman gave emphasis to the influence of ageing on the precursors of flavour in beef and stated that both microbial and enzymatic changes are responsible for this phenomenon. The proteins become more susceptible to enzymatic protease due to denaturation *post mortem* and this leads to the formation of peptides as well as free amino acids. The formation of other substances such as ammonia, $H_2S$, carbonyls and ribose also contribute to flavour alteration. Several authors have found that ageing of beef has a positive effect on flavour, increasing its intensity (Miller et al. 1997; Daszkiewicz et al. 2003) and, as Campo et al. (1999) reported, specifically enhancing a livery flavour. Although ageing, in general, increases the desirable sensory characteristics of meat, negative consequences can also occur. Lipid oxidation has a major influence on meat quality and may ultimately cause a rancid flavour (Elmore and Mottram 2009).

It is important to note that these aspects, specifically concerning gamebird meat, have not yet been investigated. Therefore, measuring the post mortem pH profile and enzyme activity of the muscles as well as the fibre typing of the main portions of the meat will provide information which could clarify certain textural aspects of gamebird meat such as tenderness. By investigating the ageing process, especially the role of the enzymes involved and the effect on flavour, a method for the production of gamebird meat with optimum quality could be developed. This would indirectly increase the commercial acceptability of the meat and the commercial use of these birds. Such a development would not only benefit the South African gamebird industry, but could also assist in improving the situation regarding gamebirds, the damage they cause to croplands and the consequent financial implication for farmers. Ultimately, this is also an opportunity to use new sources of meat in attempting to alleviate the problems regarding food security in southern Africa.

## Gamebirds: a sustainable food source?

### Utilisation in Southern Africa

According to Berruti (2005) the African Gamebird Research, Education and Development Trust (AGRED) believes that South African Gamebirds are definitely a natural and underused resource and this organisation is of the opinion that they should be used in an ethical and sustainable manner as this will be beneficial for South Africa. Berruti (2005) defines sustainable use as being able to make use of gamebirds by means of the continuous, successful harvesting/hunting of this group of birds. The author also answers the question of the ability of gamebirds to be a sustainable resource by stating that, with adequate management of the population numbers, the use of these species is viable. This is especially because of the high reproduction rate of gamebirds and the fact that the use should be based upon removal (harvesting) of the surplus gamebirds from the populations (Berruti 2005). Furthermore, gamebird hunting is legal in South Africa with regard to species that are extensively found throughout the country (Berruti 2005). Berruti (2005) does, however, state that for sustainable use and the development of the gamebird hunting industry, it is vital to have the appropriate policies and legislations for this type of hunting.

Viljoen (2005) emphasizes the fact that, in general, the feasibility of using gamebirds as a resource in South Africa has not been realised. Most farmers, for example, do not realise that gamebird hunting can provide additional income. This is because it is either considered to be a mediocre sport compared to big game hunting or the farmers are oblivious of the fact that there are gamebird species on their land. Furthermore, in the past, large numbers of gamebirds have been poisoned in order to eliminate them as they are generally regarded as pests (Viljoen 2005). According to Berruti et al. (2004), an estimated 176 000 to 470 000 gamebirds in South Africa are illegally poisoned annually. However, gamebirds are not only killed because they are pests but also for consumption by farm workers (Maphasa 1966; Berruti 2005). If gamebirds could be harvested in a sustainable manner this would lead to a radical decline in the numbers poisoned (Berruti 2005). Currently gamebird hunting in South Africa is on the rise as the hunting of other game species is becoming more expensive (Viljoen 2005). This is a welcome development as the hunting of gamebirds on farms and the availability of their meat could definitely lead to some major benefits for the South African economy and the meat industry.

### Gamebirds regarded as agricultural pests

In general, farmers in South Africa seem to have a negative view of certain gamebird species because of the perceived damage that they do to crops. However, there have been limited studies of the amount of damage caused or its financial implication for farmers (Mangnall and Crowe 2002). Various gamebird species are considered to be agricultural pests of which the Rock pigeon (*Columba guinea*) and the Egyptian goose (*Alopochen aegyptiacus*) are the two species most often referred to as being agricultural problems (Berruti 2005). Van Niekerk and Ginkel (2004) reported that Rock Pigeons and Red-eyed doves feed on ripening sunflower seeds and were responsible for 20–30 % sunflower seed losses in the year 2000 in the Highveld region of South Africa. In another similar study, the annual national damage caused by these two species was estimated at 8.4 % of the potential crop income (R197 million; van Niekerk 2009).

Similarly, crop farmers in the Western Cape consider Egyptian geese to be very serious agricultural pests, causing a negative impact on the agricultural economy of this region. This problem, however, creates an opportunity to improve food security which has been overlooked by farmers (Viljoen 2005). The Egyptian goose is one of the leading gamebirds hunted in southern Africa (Viljoen 2005). As a result there is enormous potential, as the wingshooting of this gamebird could provide farmers with an additional income if the meat were sold (Mangnall and Crowe 2001).

Mangnall and Crowe (2001, 2002) quantified the damage caused by geese to grain fields in the Agulhas plain region of the Western Cape of South Africa by studying their population dynamics and their physical and financial impact on cereal crops over the years 1997 and 1998. The geese cause damage during three stages of crop production: shortly after sowing (April) when the surface seeds are still in the ground, early stages of growing - April to July (germination); and when the crops have been cut - October to November and are ready to be harvested (windrows) (Mangnall and Crowe 2002). The largest number of geese was found during June and July when they foraged on the growing plants (< 25 cm tall). During October and November the geese return to the croplands and feed on barley and wheat seeds in the windrows. The geese are also responsible for damage due to the loss of grains as a result of stepping on the windrows (Mangnall and Crowe 2002). Mangnall and Crowe (2001, 2002) reported that there was a substantial increase in the numbers of Egyptian geese in the late 1980s and early 1990s. This is believed to be a result of the establishment of the Caledon Southern Association Malters factory in the 1970s which was responsible for a substantial increase in crop production in the region (Mangnall and Crowe 2002). Mangnall and Crowe (2002) emphasize that with the increase in numbers of geese, farmers will continue to suffer damage and financial losses until measures are taken to reduce them. Therefore, it is suggested that when flocks of geese larger than 150 birds remain on viable crops for more than a week, farmers should resort to wingshooting in order to decrease their numbers (Mangnall and Crowe 2001). It should also be noted that if the meat from these culls were sold it could offset the financial losses due to the damage (Berruti 2005).

## Challenges and the way ahead

It is evident that there is an enormous potential to use certain southern African wildfowl species as a food source and to assist the current state of food security in the area. Sustainable use will not only benefit the development of the South African gamebird industry, but may also assist in improving the situation regarding the damage specific gamebird species cause to croplands and the consequent financial implication for farmers. However, before the sustainable use of gamebird meat can be a success, there are several challenges, which are essential to overcome in order to ensure the availability of gamebird meat with the best possible quality.

### Limited information on the meat quality of southern African wildfowl

Limited research is available regarding the meat quality of southern African gamebird species. The information available is mainly centred on culinary customs rather than scientific investigations (Hofbauer and Smulders 2011). The gamebird industry in South Africa is becoming more popular and information on the overall meat quality of the birds hunted is vital.

It is generally accepted that consumers prefer meat to be tender, juicy and flavourful (Risvik 1994; Warriss 2000; Wiklund et al. 2003); attributes which are determined by several intrinsic and extrinsic factors. Although these characteristics are those that the general public look for when purchasing meat, it is always a challenge for the meat industry to provide them. As stated by Wiklund et al. (2003) the views or opinions of consumers in terms of the acceptability and eating quality of meat vary from population to population. However, an essential aspect of consumer acceptability is the overall uniformity in terms of meat quality; i.e. the product should have a consistent eating quality at all times (Wiklund et al. 2003). This is where the challenge lies with meat originating from gamebirds.

Therefore, an aspect that warrants research is quantifying the perception or attitude of consumers towards gamebirds as a meat source. At the same time, there is a need to scientifically evaluate those biochemical activities as well as the effect of the interventions performed on domesticated fowl to ensure an acceptable quality of gamebird meat. As very little scientific knowledge exists about the extrinsic (e.g. season/diet, gender) and intrinsic (muscle portion, fibre types, development of rigor mortis, activation of enzymes) factors that influence meat quality (e.g. yield, organoleptic attributes, and chemical composition) of gamebirds, these also need to be quantified. This will allow insight into certain aspects of meat quality which may require improvement. Subsequently, it will be possible to provide consumers with a product of the best possible quality.

### Post mortem handling

Another ambiguous area with regard to possible wildfowl use is the handling of the shot gamebirds during/after wingshooting activities. In South Africa, the handling of gamebirds is somewhat different from traditional European customs. Generally the birds are not handled correctly in order to ensure meat with the best possible quality. For example, there are delays in transporting shot birds to cold storage as they are placed on the back of the transporting vehicle, at ambient temperatures, for 3–6 h until the hunt is finished.

Concerning the slaughtering and storage of gamebirds, it is believed that several different methods are currently used during organised shoots. The birds are normally eviscerated by the staff and given to the hunters at the end of the day. The carcasses are then either placed in a freezer, usually with the feathers intact or kept fresh in the refrigerator for immediate use. Less often the gamebirds are kept uneviscerated and refrigerated. If proper use of the meat for incorporation into the commercial market is a possibility, serious measurements will have to be taken in order to establish the appropriate post mortem handling and slaughtering methods for these hunted fowl. Research on the general handling practices during the hunt and thereafter as well as the microbiological quality of the hunted birds in the Southern African context is an area that warrants more research.

### Potential farming with wildfowl species for meat production

The raising of wildfowl within a farming environment is not a modern activity and dates back to ancient times when settlers and explorers transported wild birds back to their home countries to be used for meat and egg production (Ratcliffe and Crowe 1999; Cooper 1995). Today, the domestic production of gamebird species is applied globally and countries such as those in Europe and Asia as well as the USA are leaders in this industry (Leech et al. 2003).

Domestic production of gamebirds in southern Africa is less successful. Nonetheless, there has been some domestication of Guineafowl originating in West Africa (Ratcliffe and Crowe 1999; Little 1997). Guineafowl farming has also taken off in certain other developing countries such as Botswana (Moreki and Seabo 2012), Zimbabwe (Saina et al. 2005) and Nigeria (Obike et al. 2011). This is in an attempt to increase meat production and therefore human protein consumption by means of farming this species which is more resilient than poultry (Agwunobi and Ekpenyong 1990).

Domesticating wildfowl species may not only contribute to the food security situation in Africa but may also be beneficial to the economy. According to Moreki and Seabo (2012), the domestication of Guineafowl in Botswana will potentially create new employment opportunities and therefore assist in reducing poverty in the country. It is therefore postulated that increasing gamebird farming in southern Africa by applying the appropriate scientific knowledge, will lead to the successful incorporation of meat from new species into the commercial market.

Gamebird species which show potential for domestication are mainly from the orders Galliformes and Anseriformes (Cooper 1995). Amongst these identified species is the Hartlaub's duck (*Cairina hartlaubi*) and the Egytpian goose (*Alopochen aegyptiacus*) both found in Africa. Regarding Egyptian geese, Mongin (1991) reports that this fowl has a semi-domesticated status as it has been partially domesticated in some parts of Africa, but this species has not been intensively bred.

## Conclusions

In attempting to emphasise the vast potential of southern African wildfowl as a food source, this review has provided information detailing both the international and South African gamebird industries. It has revealed the major factors of influence in terms of the eating quality of gamebird meat, which involve the physical activity of the different portions and muscle fibre types, diet, breeding, age and gender as well as the post mortem handling/ageing of the meat. The safety issues i.e. shot contamination, involved in producing gamebird meat are also discussed. The question of using gamebirds in a sustainable manner is answered by providing substantial arguments to prove the viability of this resource. Certain gamebirds, i.e. Egyptian geese and Guineafowl, are identified as having particular potential as a food source and could be used in an attempt to alleviate the current food insecurity issue in Africa. The fact that there is such limited information on the meat quality of gamebirds, the handling practices during and after the shooting activities as well as potential farming possibilities are recognised as the challenges that are essential to overcome before wildfowl can successfully contribute to food security.

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