Improving food security and safety through use of edible by-products from wild game

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Abstract Game harvesting in South Africa generally leaves behind edible by-products, which could be a low-cost source of protein for poor people in rural areas. Seven professional and nine recreational hunters were interviewed, a game harvest and trophy hunt attended and literature reviewed, in order to describe the food value chain for game and ways in which edible by-products could be legally channelled into the human food chain, rather than being left in the field for scavengers. Practices of informal vendors ($n = 51$) were assessed using structured interviews, observation and microbiological analysis. In an experiment, inspected game by-products (shinbones from impala and springbok) were provided to eight informal traders for cooking at an informal market and microbiological analysis was done before and after preparation. The results showed that providing edible by-products to poor consumers appears to be culturally acceptable, affordable, accessible and safe. A crossover from formal to informal marketing is recommended as it would enhance traceability and safety of the product and minimise the risk of poaching. It is suggested that methods should be developed which make the distribution of edible by-products to vulnerable rural communities feasible.

Keywords Edible by-products · Food security · Food value chain · Game harvesting · Hunting · South Africa

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1 Introduction

The South African game industry has been expanding both locally and internationally since 1969 (FAO 2010). In 2007, an estimated 19,500 Mg of game meat was marketed, corresponding roughly to half the production volume of goats (FAO 2010). South African game meat has been exported for almost a century and is popular in Europe (Field 2004; Patterson and Khosa 2005; Mostert and Hoffman 2007; La Neve et al. 2008). It is estimated that in 2005, South Africa exported the deboned meat of 160,000 game animal carcasses (Hoffman and Wiklund 2006). Moreover, up to US$ 130 million is generated annually by international trophy hunters visiting the country (Hutton and Leader-Williams 2003; Damm 2005). It has also been suggested that recreational hunting (which includes both trophy hunting and hunting for home consumption, often called "biltong" hunting) is conducted by about 200,000 South Africans on a more or less regular basis (Damm 2005; Patterson and Khosa 2005). Trophy hunting can motivate owners to maintain habitats as well as biodiversity (Bond et al. 2004). Norms and standards for the regulation of the hunting industry were drafted recently, complementing the Biodiversity Act from 2004 (Department of Environmental Affairs 2009). Hence, it was concluded that hunting done in an organised manner could be beneficial in regard to conservation (Caro et al. 2009). All foreign hunters must be supervised by a professional hunter under all circumstances (Patterson and Khosa 2005; Lindsey et al. 2007a).

In general, game ranching is the term used for a system in which selected species of ungulates are maintained on large tracts of land in a semi-wild state under private ownership and the term "game" rather than "wildlife" is used for wild animals used for hunting (Mossman 1975; Twiss et al. 1996; Radder and Le Roux 2005; Carruthers 2008). There are large areas set aside for wildlife conservation and ecotourism in South Africa, but in addition, particularly in areas of South Africa where the land is unsuitable for profitable crop or livestock production, game ranching is common (Skinner 1970; Bigalke 2000; Van der Waal and Dekker 2000; Bond et al. 2004; Cousins et al. 2008). The proportion of game animals has increased significantly in comparison with livestock on private farms (Fig. 1). There is little published data on the scope and magnitude of

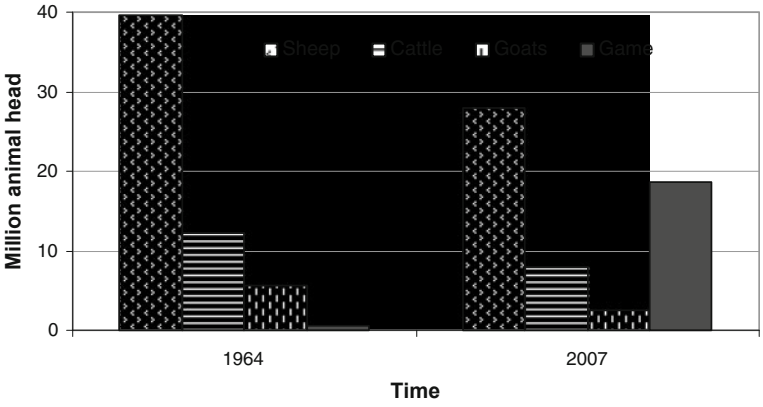

Fig. 1 Number of livestock and game animals in private farms in South Africa in 1964 and 2007. *Source*: Du Toit (2007) as cited by Carruthers (2008)

utilisation of game meat in South Africa (Barnett 2000; Damm 2005; Hoffman et al. 2004; Hoffman and Wiklund 2006; Carruthers 2008).

Game animals hunted for meat are shot in the field during the colder months (the "designated hunting season"), subject to hunters obtaining shooting permits (Gill 2007; Paulsen et al. 2011). The literature indicates that game cropping done at night results in a better meat quality (Veary 1991; Hoffman and Ferreira 2000; Kritzinger et al. 2003; Paulsen et al. 2011). Under the relevant Veterinary Procedural Notice (VPN), South African ranches producing game meat for export are required to register with the controlling authority (Department of Agriculture 2007a). If fulfilling the requirements, the farm is issued with an annually renewable registration number, which ensures traceability of game meat. The compulsory standards include the provision of a health certificate prior to harvesting, annual reports of stocks and the timely announcement of disease outbreaks on the farm. Hunters intending to take part in harvesting for export also have to apply for annual registration at the Provincial Veterinary Authority (Department of Agriculture 2007b).

In the case of game harvesting for export, another VPN proscribes a hygiene management system to monitor meat safety and hygiene control for game meat. After shooting and exsanguination, game is transported on a truck to the field depot, where it is hung and eviscerated, then inspected. Damaged as well as visibly contaminated tissue is removed, but carcasses are not skinned (Gill 2007; Paulsen et al. 2011). The primary meat inspection includes head, feet, pluck, abdominal and reproductive organs and the partially dressed game carcase with attached pluck (red offal) is sent in sealed chiller trucks to a registered game abattoir for further processing. Other offal is left in the field for predators or vultures (Department of Agriculture 2010). According to Coburn et al. (2005), microbiological hazards that could occur in wild deer include *Escherichia coli* 0157, *Salmonella* spp. and *Campylobacter jejuni*. It is expensive and impractical to culture for faecally derived organisms in meat; thus, indicator organisms are used as part of hygiene control at registered red meat abattoirs, including game abattoirs, in South Africa.

The South African game industry is a free market that can be accessed by both individual game ranchers and game meat producers (Hoffman et al. 2004). Studies on improved game meat production and marketing have documented public health concerns over the previous decade (Féron et al. 1998). Some causes for concern included inaccurate shots, the generation of excessive stress for the animal as well as inadequate cooling and bleeding, resulting in inferior quality of meat (Hoffman et al. 2004). Ntiamoa-Baidu (1997) and Féron et al. (1998) previously claimed that few food safety rules or standards were legislated for processing and marketing of South African game meat and the quality traded on the market varied widely, while handling practices were not always be satisfactory. Game meat now falls under the Meat Safety Act of 2000 (Department of Agriculture 2000), and more recently, a manual for game meat inspection has been published by the Division of Veterinary Services (Section Veterinary Public Health) of the Department of Agriculture (Bergh 2007).

Game meat from wild ungulates is consumed widely and was a traditional source of meat in Africa for both settlers and indigenous peoples (Hoffman and Wiklund 2006). Legislation to protect wildlife from poaching excludes the rural poor from direct wildlife utilisation (Kepe 1997). Management of hunting permits in South Africa is controlled by the National Department of Environmental Affairs, but permits are issued at provincial level (Department of Environmental Affairs 2009). No game may be hunted except with a permit, and methods of hunting are strictly regulated according to the species of game. Game meat, including by-products, may not be offered for sale except by a registered

butcher, and traceability is essential to prove the meat came from game that was legally hunted after application for a hunting permit. According to the Meat Safety Act, no person may sell meat (including game meat) which has not been slaughtered at an abattoir. Livestock and game may be slaughtered for own consumption (Department of Agriculture 2000). The legislation is quite broad and "biltong hunters" or "trophy hunters" may fall under the "own consumption" rule. Game meat for export must pass through a certified export abattoir after harvesting. Thus, offal from game harvested for export is inspected and may be used for human consumption in communities of South Africa.

A further constraint to supplying game meat to rural communities is the movement restrictions in place to facilitate disease control. Movement and marketing of game meat is strongly influenced by the regulations pertaining to the Animal Diseases Act of 1984, as OIE regulations are in force for the control of foot-and-mouth disease and other transboundary diseases (Department of Agriculture 1984). Many of these are endemic in game producing areas along South Africa's northern boundaries. The study area in northern KwaZulu-Natal is a controlled area for foot-and-mouth disease as it borders on Mozambique.

Rural communities therefore appear to gain few direct benefits from hunting or harvesting game, as game meat is currently marketed to affluent consumers (Hoffman et al. 2005; Lindsey et al. 2007b). It has been suggested that locally available, affordable game meat could be a valuable source of animal protein and increase food security for rural and urban poor (Child 1991; Borgerhoff-Mulder and Coppolillo 2005; Jones 2005). There is little or no scientific literature available on the utilisation of less expensive edible by-products of game such as the head, feet and offal, although these by-products are utilised in the red meat industry and are readily available to low-income consumers. A study carried out by Van Zyl and Ferreira (2004) indicated that the proportional percentage of protein in the internal offal of springbok, blesbok and impala (17.0–21.9 %) is very similar to that of sheep (16.5–23.5 %).

From the above, it can be seen that several authors motivate that food security of rural low-income communities could benefit from the consumption of game meat, but that there is currently some concern about whether there are sufficient food safety controls in place. The aim of this study was to investigate the food value pathways of game meat, to assess how the suggested role of informal marketing of by-products may fit into the existing marketing chain and to assess the risk to low-income consumers of consuming the edible by-products of game slaughter, using participatory methods.

2 Materials and methods

Structured and informal interviews with stakeholders and checklists were used to establish a flowchart for the game meat and cooked meat currently on offer at informal markets. As game was not available at the street vendors in the study area, Pongola, in northern KwaZulu-Natal, beef and chicken sales were sampled for microbiological safety.

There is an established formal marketing chain for inspected game meat products through registered butcheries (Paulsen et al. 2011). It is used as baseline in this study. Game meat is only harvested during the hunting season from May to August; thus, formal year round marketing is difficult. A trophy hunting shoot with licenced hunters and tourists was attended near Kimberley, Northern Cape. At the hunt, tourist hunters were given the opportunity to shoot first at game and the licenced hunters killed any wounded animals. Seven hunters were present with whom informal interviews were held. A structured

observation checklist that included information on prerequisites and practices of game hunting was used to record observations during the hunt. The time differences between fatal shot and throat cut for exsanguination and between throat cut and evisceration were recorded for seven animals shot. An expert opinion survey on the utilisation of edible by-products was conducted with nine so-called biltong hunters from different parts of South Africa. Biltong is a traditional food made from dried beef or game meat (Van Zyl et al. 2011). The so-called biltong hunting is a recreational rather than a commercial activity, carried out on a small scale by licenced hunters who often salt and dry the meat from game that is shot, to make "biltong." Included in this group are licenced hunters who may also escort and supervise tourists on hunting safaris, so-called trophy hunting.

The informal marketing chain (street food) for food in South Africa fills the need for affordable and accessible food for low-income commuters and rural communities (FAO/WHO 1999; Mosupye and von Holy 1999). This could be a potential domestic marketing chain for edible game meat by-products. A survey was conducted with all informal meat traders ($n = 51$) in Pongola, KwaZulu-Natal. Structured interviews dealt with vendor characteristics, food safety knowledge and perceptions, and product range. Structured observation, based on criteria established by the Food and Agriculture Organisation of the United Nations (FAO) and the World Health Organisation (WHO), was used to develop a checklist to assess the available infrastructure at informal markets in Pongola and evaluate the level of food hygiene of vendors (FAO/WHO 1999; FAO/WHO 2003; WHO 2010). The vendors were asked to answer five open-ended questions about perceived problems with their business and possible solutions, hypothetical preparation of game meat and respective sales prices.

The food value chain data generated for game meat, from interviews and direct observation, were triangulated by informal interviews with stakeholders (seven hunters) and role-players (two senior state veterinarians and a local animal health technician). Potential hazards of the informal chain to food safety and product quality were identified and characterised based on expert opinion surveys from these stakeholders and role-players, observations and literature review. Ways to improve access by informal traders or low-income communities to safe and affordable edible game by-products were suggested based on the findings.

Whether edible game by-products could be safely prepared and cooked at an informal market was tested in a pilot experiment. Game meat portions (impala and springbok shins) were purchased from a registered supplier and supplied to eight informal traders to see if they could process it by cooking so that there would be a minimal food safety risk to consumers. Samples were tested before and after cooking and serving. Each vendor was supplied with one kg of meat to prepare by stewing in iron pots over an open fire, as is usually done at the informal markets with beef or goat meat or offal. It was observed that the cooking time was in each case approximately 1.5 h. Meat was sampled for microbiology as described below before and after cooking. After cooking, the meat was tasted by researchers as well as the vendors and a focus group discussion held to indicate whether the game meat would be suitable for sale to their customers as an alternative to beef or goat meat or offal.

Microbiological testing was done using 3 M™ Petrifilm™ plates (*E. coli*/Coliform Count Plate (EC) 6414), which are recognised as AOAC INTERNATIONAL official methods of analysis for food quality. They are an affordable and appropriate way of monitoring food safety and quality that do not require expensive laboratory infrastructure and therefor are useful in developing countries. According to the WHO, the use of indicator organisms for faecal pathogens in foodstuffs has been validated. For this study, the

3 M™ Petrifilm™ plates for *E. coli*/coliform count were utilised to monitor the game meat before and after cooking, using the standard methodology for 3 M™ Petrifilm™ plates, as described on their website at http://www.3M.com/microbiology. The Petrifilm plates were obtained from 3 M South Africa (Pty.) Limited (146A Kelvin Road; Woodmead, Sandton; Private Bag X926; Rivonia 2128).

A sample of about 25 mg was excised from the raw meat and repeated with the cooked meat, using sterile precautions, and placed in a marked, sterile Whirl-pac™ bag and 225 ml buffered saline was added to give a 1:10 dilution, according to ISO method 6887. Details can be found on the 3 M website.[1] The sample was then homogenised in a Seward Stomacher Lab-Blender 400 (Merck Pty., Ltd., South Africa). According to the World Health Organization (WHO 2008), *E. coli* Type 1 is the indicator organism of choice for faecal pollution, the analysis is simple and affordable and levels of contamination can be quantified by counting colony forming units (cfu). Abattoirs are required to test for generic *E. coli* on carcasses to verify that they are preventing faecal contamination from carcasses during and after slaughter (Buzby and Crutchfield 1997; Eisel et al. 1997). The *E. coli* count tests for the presence of harmless indicator organisms that indicate the presence of pathogenic intestinal organisms such as velogenic *E. coli* strains, *Salmonella* spp. and *C. jejuni*. The presence of faecal contamination is an indicator that a potential health risk exists for individuals exposed to food or water with high coliform counts (Eisel et al. 1997). According to Codex (1997), the microbiological limits should take into consideration the risk associated with the microorganisms, and the conditions under which the food is expected to be handled and consumed. The *E. coli* test levels are expressed as colony forming units per millilitre (cfu/ml) of rinsate. They are separated into three categories for the purpose of process control verification: acceptable, marginal and unacceptable. Acceptable is below 100 cfu/ml, marginal if it is above 100 cfu/ml but not above 1,000 cfu/ml and unacceptable if above 1,000 cfu/ml in raw meat. Positive, in this study, was interpreted as samples that were above 100 cfu/ml.

3 Results

As part of the study, unpublished data were obtained from Mosstrich Abattoir in the Western Cape, the game abattoir which processed impala harvested in the study area during the study period, on the number of game carcasses and kg of game meat exported from South Arica between 2005 and 2008 (Table 1).

Two main game meat food value chains were described from the expert opinion surveys, direct observations and literature surveys. These are a commercial large-scale seasonal harvesting by professional teams, mainly for export, and smaller scale biltong or trophy hunting by registered hunters during the shooting season. Game harvesting is governed by the Meat Safety Act as well as Veterinary Procedural notices, as previously mentioned (Department of Agriculture 2000, 2010). The formal game meat value chain for export builds the backbone in the chain flowchart (Fig. 2). This food value chain is the longest, several departs from it are possible, partly already existing, partly being suggested to make productive use of edible by-products currently discarded.

During recreational (including biltong and trophy) hunting, the game animal was detected from a vehicle and if hunted by night, blinded and shot, usually through the heart. In the case of the trophy hunt attended in Kimberley, the tourist hunters wounded nearly one-third of the animals shot and these had to be killed by the licenced hunters. Wounding,

[1] http://www.3M.com/microbiology.

Table 1 Game animals harvested and kg meat exported by South Africa 2005–2008

Species	Approximate number of animals harvested for export			
	2005	2006	2007	2008
Springbok	52,000	43,000	50,000	55,706
Blesbok	7,000	6,000	8,000	11,687
Kudu	2,300	1,500	1,800	2,369
Impala	850	1,000	1,300	2,810
Wildebeest	800	1,000	1,200	3,998
Zebra	450	600	700	364
Other	1,555	930	1,260	1,579
Total	64,955	54,030	64,260	78,513
Species	Approximate kg meat exported			
	2005	2006	2007	2008
Springbok	249,422	218,594	249,074	307,465
Blesbok	81,711	74,584	97,289	130,138
Kudu	64,722	44,736	52,604	55,721
Impala	8,807	10,981	13,988	20,858
Wildebeest	22,512	29,824	35,070	106,750
Zebra	22,275	29,700	34,650	14,908
Other	27,348	17,335	23,014	28,722
Total	476,796	425,753	505,689	664,562

Source: Ramrajh (2012)

rather than instant death resulted in stress to the animal, with glycogen depletion, which could lead to poor meat quality and poor meat shelf life. Body shots were observed to result in damage to the digestive system and the contamination of carcasses with shattered bone splinters, ingesta or fragments of bullets. It was observed that the animals bled out internally when shot through the heart. However, all animals had their throats slit. The time difference in the seven animals recorded was at maximum 3:03 min (minimum 1:12 min). One respondent, however, admitted that occasionally the throat cut might occur up to 60 min after shooting, especially during trophy hunting where the trophy (head and horns and the skin) is considered more important than the use of the meat for human consumption. If the carcase is not suspended by its hind legs to drain out the blood within a short time of death, there may be insufficient exsanguination resulting in the multiplication of bacteria in the tissues. After shooting and throat slitting, the carcasses were loaded onto an open truck. As the carcasses were not skinned, dust contamination was prevented during transport to the depot. The evisceration of the recorded animals occurred between 27 and 83 min after the fatal shot. If evisceration is delayed, especially in hot weather (time–temperature hazard), gut bacteria multiply, gas may be produced, the carcase bloats and bacteria enter the tissues (Veary 1991; Paulsen et al. 2011). For private consumption after biltong or trophy hunting, the evisceration of individual animals took place in the field with almost no infrastructure. Harvesting took place during the winter when it was dry and cold. It was observed that ambient temperatures during shooting of the antelope by trophy hunters in the early morning and late evening averaged 5 °C.

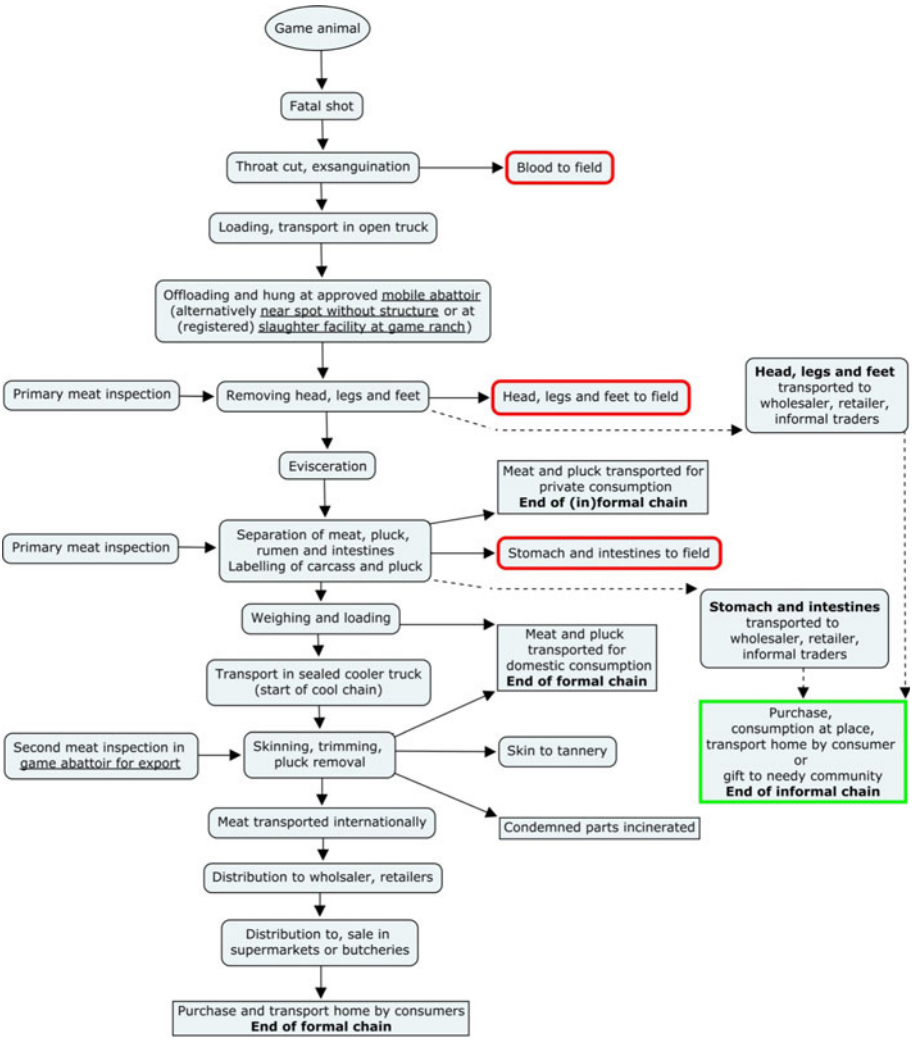

Fig. 2 Current and potential game meat chain in South Africa. *Solid line* existing chain, *dotted line* suggested extension of the existing chain

With commercial harvesting, all animals must be killed using head shots and highly trained sharp-shooters make sure death is almost instant as special ammunition is used. The VPN for export prescribes that the meat of any animal that is wounded or shot anywhere except in the head, shall be condemned. Primary meat inspection is performed in the field after evisceration. Game animals harvested for export were observed to be under the supervision of a state veterinarian, and meat inspection was done by a registered game meat inspector and a temporary mobile depot was set up on farm (Bergh 2007; Department of Agriculture 2010). It was observed that the expertise of the staff, hygienic surroundings and personal hygiene prevented contamination with soil or ingesta and minimised contamination. The carcase was skinned only when it reached the game abattoir as this kept the meat clean, and only the edges of the abdominal incision needed to be trimmed. Night

harvesting took place until 2300 hours and loading started at 0800 hours. According to the stakeholders and role-players, harvesting would be interrupted during rain or unseasonal heat.

According to the seven professional game harvesters, edible by-products were commonly left behind in the field to be consumed by predators (mainly jackals and vultures). The utilisation of edible by-products seems currently to be rather uncommon, as stated by eight of the nine biltong hunters and all seven professional hunters involved in the attended game harvest. Occasionally, the head, horns and legs are used to make ornaments, and the red offal and tripe are sometimes cooked and eaten by the cleaning staffs that accompany the hunt.

Almost all (96 %) of the informal meat traders ($n = 51$) sampled in this study derived the raw meat (beef, mutton or chicken) that they cooked and sold at informal markets, from formal marketing chains rather than locally slaughtered animals. However, in terms of game meat products, no linkages and interactions could be identified between hunters and informal traders.

Lack of knowledge and poor application of meat hygiene practices was observed during cooking and preparation in the informal markets in the study area (intrinsic factors). Also noted were poor availability or accessibility of basic prerequisites and infrastructure (extrinsic factors). It was found that in the informal markets, the vendors (98 %) in the sample did not have electricity, running water was present in only 90 % of cases; and the cold chain was not maintained for raw meat in 73 % of cases observed during the study.

Routine microbiological analyses did, however, not show severe problems in food safety. Both the analysis of meat samples taken from informal meat traders in KwaZulu-Natal as well as the cooking experiment suggest a general suitability of informally traded cooked meat products for human consumption. Only one out of 18 prepared meat samples from informal meat traders in KwaZulu-Natal tested positive for coliforms (>100 cfu/ml), none of the eight cooked game meat samples in the Pretoria cooking experiment did so. The informal traders in KwaZulu-Natal mainly traded ready-to-eat grilled or cooked products (90 %); only one sold raw meat only and the rest sold both raw and cooked meat.

The majority of biltong hunters in the study regarded utilisation of edible by-products as not profitable (7 out of 9). Nevertheless, almost all were regularly asked for offal by local communities when hunting (8 out of 9). Currently, there seem to be no incentives for game hunters and harvesters to make use of edible by-products. The environmental impacts of dumping large amounts of edible offal and by-products in the field and adverse effects on the ecosystem concerning predator–prey imbalances do not seem to be taken into account. In contrast, the majority (30 out of 51) of proposed recipients and end-users of edible by-products appeared to be generally willing to utilise them as long as they could be accessed legally and cheaply (Table 2).

4 Discussion and conclusions

The food value chain developed for game meat in this study (Fig. 2) is similar to that described by Paulsen et al. (2011). However, the focus differs in that it highlights the possibilities for utilising edible by-products. Limitations in application of best practice observed during hunting and demonstrated in some of the opinions obtained from stakeholders are in agreement with the findings of Bekker et al. (2011).

Game meat value chains that include distribution of by-products to the poor were found to be feasible, and informal markets could play a role to provide safe food from red offal

Table 2 Current trade of game meat and its' perceived acceptance amongst customers

	n	%	95 % confidence interval
Is trading game meat			
Never	49	96	87–100
Sometimes (offal)	1	2	0–10
Regularly (meat)	1	2	0–10
Would trade game meat if available legally and cheap			
Yes	30	59	44–72
No	14	27	16–42
Do not know	7	14	6–26
Customers would buy game meat if offered			
Yes	32	63	48–76
No	12	24	13–37
Do not know	7	14	6–26

The data rely on 51 informal street vendors sampled at Pongola

arising from game harvesting and hunting. Marketing channels for inspected edible offal that maintain the cold chain would need to be developed to match products with end-users. The suggested protein source shows a sporadic and seasonal nature, thus can only supplement year round provision rather than fully secure it. Finally, further developing the game industry may stimulate poaching. The latter could, however, not be tested in the present study. Extending the existing formal food chain to the informal distribution and use of formerly unused by-products may reduce the risk of poaching by reducing demand for meat killed by poachers. Moreover, the link between formal and informal chains increases the traceability of the products and maintaining the cold chain right up to the last preparation stage decreases microbiological risks. However, education of informal vendors or alternative routes of supply, for instance school or hospital feeding schemes, would be needed to maintain food safety throughout the game meat food chain from field to fork.

The microbiological analysis of the cooking experiment showed that the cooked game meat stew was safe for end-users to consume, despite the deficiencies seen in hygiene and infrastructure in informal food markets. This agrees with previous work done on street foods in South Africa (Mosupye and von Holy 1999; Kubheka et al. 2001). In 2009, the WHO published an online course on the "Five Keys to Safer Food," which could be used by the KwaZulu-Natal Health authorities to train vendors in informal markets.

Selling edible by-products locally could generate extra income for game farmers. Profitability needs still to be assessed, considering the price thresholds of customers and using larger sample populations as compared to what could be realised in the present exploratory study. The role of supporting institutions such as NGO's could also be evaluated as this could have tax benefits for game farmers.

In conclusion, a substantial underutilisation of edible by-products obtained in the course of game hunting has been shown. Game offal such as liver, kidneys, lungs, heart, and tripe, as well heads and feet, are part of the traditional diet in Africa, and it was demonstrated that they are considered as marketable by informal vendors. It was estimated during the study that each impala shot could yield approximately 3 kg of edible offal. In comparison with offal from livestock that is already marketed from red meat abattoirs, this could be considered very little. However, game farms are in rural areas where the local population is often vulnerable and long distances increase the price of meat products. Thus, if available,

edible by-products from game could increase food security in such rural communities, as well as low-income commuters that utilise informal markets. It appears feasible that edible offal from inspected game carcasses could be supplied in the same way as red meat offal, but at a cheaper cost. It is suggested that a costing exercise be done as this study has indicated that there would be benefits to both the low-income consumer as well as the environment.

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References

Barnett, R. (Ed.) (2000). *Food for thought: The utilisation of wild meat in eastern and southern Africa* (pp. 4–37). Nairobi: World Wildlife Fund.

Bekker, J. L., Hoffman, L. C., & Jooste, P. J. (2011). Knowledge of stakeholders in the game meat industry and its effect on compliance with food safety standards. *International Journal of Environmental Health Research, 5*, 341–363.

Bergh, T. (Ed.) (2007). *Meat inspectors manual—game*. Published by the Directorate of Veterinary Services, Veterinary Public Health, National Department of Agriculture, Pretoria, Gauteng, South Africa.

Bigalke, R. C. (2000). Functional relationships between protected and agricultural areas in South Africa and Namibia. In H. H. T. Prins, J. G. Grootenhuis, & T. T. Dolan (Eds.), *Wildlife conservation by sustainable use* (pp. 169–202). Boston: Kluwer Academic Publishers.

Bond, I., Child, B., De La Harpe, D., Jones, B., Barnes, J., & Anderson, H. (2004). Private land contribution to conservation in South Africa. In B. Child (Ed.), *Parks in transition: Biodiversity, rural development and the bottom line* (pp. 29–61). London: Earthscan.

Borgerhoff-Mulder, M., & Coppolillo, P. (2005). The evolution of policy. In M. Borgerhoff-Mulder & P. Coppolillo (Eds.), *Conservation: Linking ecology, economics and culture* (pp. 27–52). Princeton: Princeton University Press.

Buzby, J. C., & Crutchfield, S. R. (1997). *USDA modernizes meat and poultry inspection.* Food Safety. Economics Research Service. Washington: USDA.

Caro, T. M., Young, C. R., Cauldwell, A. E., & Brown, D. D. E. (2009). Animal breeding systems and big game hunting: Models and application. *Biological Conservation, 142*, 909–929.

Carruthers, J. (2008). Wilding the farm or farming the wild? The evolution of scientific game ranching in South Africa from the 1960s to the present. In J. D. Skinner (Ed.), *Transactions of the Royal Society of South Africa*, *63(2)*, pp. 160–181.

Child, G. S. (1991). People's participation in wildlife utilization in Africa. *Landscape and Urban Planning, 20*(1–3), 159–162.

Coburn, H. L., Snary, E. L., Kelly, L. A., & Wooldridge, M. (2005). Qualitative risk assessment of the hazards and risks from wild game. *Veterinary Record, 157*(11), 321–322.

Codex (Codex Alimentarius Commission). (1997). *Principles for the establishment and application of microbiological criteria for foods*. Document Number GL 21 (pp. 2–4). Rome: Codex Alimentarius Commission.

Cousins, J. A., Sadler, J. P., & Evans, J. (2008). Exploring the role of private wildlife ranching as a conservation tool in South Africa: Stakeholder perspectives. *Ecology and Society*, *13(2)*, online journal.

Damm, G. R. (2005). Hunting in South Africa: Facts, risks, opportunities. *African Indaba Newsletter*, *3(4)*, 1–2 and 14 and 16–19; Part II: *3(5)*, 2 and 13–21.

Department of Agriculture. (1984). *Regulations pertaining to the Animal Diseases Act 35 of 1984*. Pretoria: National Department of Agriculture, Government Printer.

Department of Agriculture. (2000). *Meat Safety Act number 40 of 2000*. Pretoria: National Department of Agriculture.

Department of Agriculture. (2007a). *Standards for the registration or re-registration of a game farm for export status*. Notice number VPN/05/2007-2. Pretoria: Department of Agriculture, National Directorate Veterinary Services.

Department of Agriculture. (2007b). *Standards for the registration of hunters for harvesting wild game intended for export of game meat*. Notice number VPN/08/2007-1. Pretoria: Department of Agriculture, National Directorate Veterinary Services.

Department of Agriculture. (2010). *Standards for the ante and post-mortem meat inspection and hygiene control at point of harvest*. Notice number VPN/09/20010-2. Pretoria: Department of Agriculture, National Directorate Veterinary Services.

Department of Environmental Affairs. (2009). National environmental management: Biodiversity Act, 2004 (Act No. 10 of 2004), *Draft norms and standards for the regulation of the hunting industry in South Africa*. General notice number 1614 of 2009. Government Gazette, Republic of South Africa, Vol. 534, No. 32798, notice 1614 of 2009.

Du Toit, J. G. (2007). *Report: Role of the private sector in the wildlife industry*, Wildlife Ranching SA/Du Toit Wilddienste, Tshwane [as cited by Carruthers, 2008].

Eisel, W. G., Linton, R. H., & Muriana, P. M. (1997). A survey of microbial levels for incoming raw beef, environmental sources, and ground beef in a red meat processing plant. *Food Microbiology, 14*, 273–282.

FAO (Food and Agriculture Organization of the United Nations). (2010). *FAOSTAT database*. Accessed November 30, 2010, from http://faostat.fao.org/.

FAO (Food and Agriculture Organization of the United Nations)/WHO (World Health Organization). (1999). *Design of control measures for street-vended foods in Africa*. Codex Alimentarius Commission (CAC/GL-22-Rev.1).

FAO (Food and Agriculture Organization of the United Nations)/WHO (World Health Organization). (2003). Assuring food safety and quality: Guidelines for strengthening national food control systems. *Food and Nutrition Paper* No. 76.

Féron, E., Tafira, J. K., Belemsobgo, U., Blomme, S., & De Garine-Wichatitsky, M. (1998). Animal resources—transforming wild African herbivores into edible meat for local communities: Sustainable use of impala (*Aepyceros melampus*) in the CAMPFIRE Program, Zimbabwe. *Revue d'Elevage et de Médecine Vétérinaire des Pays Tropicaux, 51*, 265–272.

Field, R. A. (2004). Species of meat animals—game. In W. K. Jensen (Ed.), *Encyclopedia of meat sciences* (pp. 1302–1308). Amsterdam: Elsevier.

Gill, C. O. (2007). Microbiological conditions of meats from large game animals and birds. *Meat Science, 77*(2), 149–160.

Hoffman, L. C., & Ferreira, A. V. (2000). pH decline of the *M. longissimus thoracis* of night-cropped Grey Duiker (*Sylvicapra grimmia*), short communication. *South African Journal of Animal Science, 30*(1), 16–17.

Hoffman, L. C., Kritzinger, B., & Ferreira, A. V. (2005). The effects of region and gender on the fatty acid, amino acid, mineral, myoglobin and collagen contents of impala (*Aepyceros melampus*) meat. *Meat Science, 69*, 551–558.

Hoffman, L. C., Muller, M., Schutte, De. W., & Crafford, K. (2004). The retail of South African game meat: Current trade and marketing trends. *South African Journal of Wildlife Research, 34*(2), 123–134.

Hoffman, L. C., & Wiklund, C. (2006). Game and venison—meat for the modern consumer. *Meat Science, 74*(1), 197–208.

Hutton, J. M., & Leader-Williams, N. (2003). Sustainable use and incentive-driven conservation: Realigning human and conservation interests. *Oryx, 37*(2), 215–226.

Jones, J. L. (2005). *Transboundary conservation in Southern Africa: Exploring conflict between local resource access and conservation*. Accessed March 2, 2009, from http://www.maweb.org/documents/bridging/papers/jones.jennifer.pdf.

Kepe, T. (1997). *Communities, entitlements and nature reserves: The case of the Wild Coast, South Africa*. IDS Bulletin. Accessed March 2, 2009, from http://dlc.dlib.indiana.edu/archive/00000071/00/kepe.pdf.

Kritzinger, B., Hoffman, L. C., & Ferreira, A. V. (2003). A comparison between the effects of two cropping methods on the meat quality of impala (*Aepyceros melampus*). *South African Journal of Animal Science, 33*(4), 233–241.

Kubheka, L. C., Mosupye, F. M., & von Holy, A. (2001). Microbiological survey of street-vended salad and gravy in Johannesburg city, South Africa. *Food Control, 12*(2), 127–131.

La Neve, F., Civera, T., Mucci, N., & Bottero, M. T. (2008). Authentication of meat from game and domestic species by SNaPshot minisequencing analysis. *Meat Science, 80*(2), 216–224.

Lindsey, P. A., Frank, L. G., Alexander, R., Mathieson, A., & Romañach, S. S. (2007a). Trophy hunting and conservation in Africa: Problems and one potential solution. *Conservation Biology, 21*(3), 880–883.

Lindsey, P. A., Roulet, P. A., & Romañach, S. S. (2007b). Economic and conservation significance of the trophy hunting industry in sub-Saharan Africa. *Biological Conservation, 134*, 455–469.

Mossman, A. S. (1975). International game ranching programs. *Journal of Animal Science, 40*(5), 993–999.

Mostert, R., & Hoffman, L. C. (2007). Effect of gender on the meat quality characteristics and chemical composition of kudu (*Tragelaphus strepsiceros*), an African antelope species. *Food Chemistry, 104*(2), 565–570.

Mosupye, F. M., & von Holy, A. (1999). Microbiological quality and safety of ready-to-eat street-vended foods in Johannesburg, South Africa. *Journal of Food Protection, 62*, 1278–1284.

Ntiamoa-Baidu, Y. (1997). *Wildlife and food security in Africa*. FAO Conservation Guide 33. Rome: Food and Agriculture Organization of the United Nations.

Patterson, C., & Khosa, P. (2005). *Background research paper: A status quo study on the professional and recreational hunting industry in South Africa*. TRAFFIC—the wildlife trade monitoring network, prepared for the panel of experts appointed by the Minister of Environmental Affairs and Tourism. Research Status quo of hunting industry final.doc. Accessed August 2, 2009, from http://www.environment.gov.za/HotIssues/2005/29062005/25102005/PoE.

Paulsen, P., Bauer, A., Vodnansky, M., Winkelmayer, R., & Smulders, E. (Eds.). (2011). *Game meat hygiene in focus: Microbiology, epidemiology, risk analysis and quality assurance*. Wageningen: Wageningen Academic Publishers.

Radder, L., & Le Roux, L. (2005). Factors affecting food choice in relation to venison: A South African example. *Meat Science, 71*(3), 583–589.

Ramrajh, S. (2012) Participatory risk assessment for harvesting of impala (*Aepyceros melampus*) and the distribution of by-products. Dissertation submitted for M.Med.Vet. (Hyg) degree at Faculty of Veterinary Science, University of Pretoria, South Africa.

Skinner, J. D. (1970). Game-ranching in Africa as a source of meat for local consumption and export. *Tropical Animal Health and Production, 2*, 151–157.

Twiss, M. P., Thomas, V. G., & Lavigne, D. M. (1996). Sustainable game farming: Considerations for Canadian policy makers and legislators. *Journal of Sustainable Agriculture, 9*(1), 81–94.

Van der Waal, C., & Dekker, B. (2000). Game ranching in the Northern Province of South Africa. *South African Journal of Wildlife Research, 30*(4), 151–156.

Van Zyl, L., & Ferreira, A. V. (2004). Physical and chemical carcass composition of springbok (*Antidorcas marsupialis*), blesbok (*Damaliscus dorcas phillipsi*) and impala (*Aepyceros melampus*). *Small Ruminant Research, 53*(1–2), 103–109.

Van Zyl, E., McCrindle C. M. E., Makita, K., & Grace, D. (2011). Hazard identification and characterisation to support quality control of biltong through application of appropriate microbiology and biotechnology methods. Poster presented at the International Conference on Pathogens at the Human–Animal Interface held at the International Livestock Research Institute in Addis Ababa, Ethiopia from 14–17 September, 2011.

Veary, C. M. (1991). *The effect of three slaughter methods and ambient temperature on pH and temperatures in springbok (Antidorcas marsupialis) meat*. Dissertation for the degree M.Med.Vet. (Hyg), University of Pretoria, South Africa.

WHO (World Health Organisation). (2008). *Guidelines for drinking-water quality. Third edition incorporating the first and second addenda* (Vol. 1, pp. 121–123, 142). Geneva: WHO.

WHO (World Health Organization). (2010). *Basic steps to improve safety of street-vended foods*. INFOSAN Information Note No. 3/2010 Safety of street-vended food. Accessed December 05, 2010, from http://www.who.int/foodsafety/fs_management/No_03_StreetFood_Jun10_en.pdf.