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Sensory perception of boar odour

by

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Submitted in partial fulfilment for the degree Philosophiae Doctor
in the Faculty of Natural and Agricultural Sciences
University of Pretoria

January 2000

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I declare that the thesis herewith submitted for the PhD degree at the University of Pretoria, had not been previously submitted by me for a degree at any other University.

Acknowledgements

I would like to thank the following persons and institutions for their contributions to the completion of this research:

Prof. Amanda Minnaar of the Department of Food Science, University of Pretoria for her very able guidance, positive criticism and encouragement throughout the duration of the research and the write-up of this thesis.

Prof. Garmt Dijksterhuis, formerly of DLO Institute of Animal Science and Health, The Netherlands (ID-DLO) and currently associated with KVL Royal Veterinary and Agricultural University of Kopenhagen, as well as Dr Paul Heinze of the ARC Animal Nutrition & Animal Products Institute for fruitful discussions, positive criticism and guidance throughout the study.

The Board of the Agricultural Research Council (ARC), Dr Heinz Meissner, the Director of the ARC Animal Nutrition & Animal Products Institute (ARC-ANPI) and Dr Gerhard Nortjé, former Head of the Meat Industry Centre, ARC-ANPI, for allowing the research to be used for degree purposes.

The former South African Meat Board, the Red Meat Research and Development Trust (RMRDT), the South African Pork Producers' Organisation and Department of Trade and Industry's Technology and Human Resources for Industry Programme for providing funding for the research.

Other colleagues at ANPI and the Dept of Food Science, particularly Ina van Heerden, Tienie Potgieter, Jocelyn Anderson and Nandi Dersley for major contributions in providing technical assistance during this research. In addition Ilse Smuts, Retha Jacobs, Andries Mtsweni, Freddie Tswale, Rodney Martin, David Nchabaleng and Cabby Magongwa are thanked for assistance during the collection of samples or execution of sensory tests.

Prof. John Taylor, Head of the Dept of Food Science, University of Pretoria and colleagues for encouragement and support.

Ms Nina Muller, Dept of Consumer Studies, University of Stellenbosch for making arrangements for the use of facilities in Stellenbosch.

Mr Jackie Grimbeek of Statomet, University of Pretoria for assistance on the statistical handling of the data.

The dedicated members of the trained sensory panel who did not miss a single evaluation session.

All consumer panellists who provided valuable information on the hedonic character of the samples.

My family for their encouragement and assistance in various ways.

My husband André and daughters Leandri and Mariëtte for their love and support.

Abstract

Sensory perception of boar odour

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The research focussed on the sensory perception of boar odour; an odour problem that is sometimes present in the meat of entire male pigs and associated with two compounds namely skatole and androstenone. Researchers differ on the issue of the relative contributions of skatole and androstenone to the sensory perception of boar odour. The first objective of the research was to investigate the relative contribution of different concentrations of skatole and androstenone to the temporal perception of boar odour in boar fat.

In South Africa, the potential for boar odour was regarded to be considerable should it be decided to discontinue the policy of castrating boars. However, the economic advantages associated with boar production on the other hand necessitated an investigation into consumer reactions to boar odour. The second objective was therefore to determine the effects of gender and ethnicity on consumer reactions to boar odour in boar fat samples with different concentrations of skatole and androstenone.

Pork fat samples from 50 boars slaughtered at a commercial abattoir were analysed for skatole and androstenone concentrations and grouped within a 3 x 3 matrix representing low, medium and high levels of the odour compounds. A 10-member sensory panel, screened and trained to recognise and quantify skatole and androstenone odour intensities, was used to verify the human perception of boar odour in these pork fat samples immediately after heating (± 65 °C) and following a cooling period of ten minutes (± 25 °C). Consumers (n = 300) including equal numbers of males and females and from three ethnic groupings, namely blacks, whites and coloureds, were used to determine the effects of gender and ethnicity on consumer reactions towards boar odour compounds. Each consumer evaluated how much they would like to eat pork or pork products that smelled like the odour of each of 7 boar fat samples (65 °C) with different combinations of known concentrations of skatole and androstenone. The consumers were recruited on two university campuses and the results can therefore not be extrapolated to the general South African population since the majority of the participants were young (18 – 35 years) and representing living standards measures (LSM) groups 6 to 8, i.e. the higher income groups.

It was shown that the trained sensory panel differentiated the odour of the pork fat samples first and foremost on the basis of the presence or absence of androstenone and/or skatole odours and secondly on the character of the androstenone or skatole odour. Sensory perception of boar odour seems to have a temporal character which can be explained by differences in volatilisation (involving both odourant release and retention) of skatole and androstenone, possibly enhanced by differences in the properties of the fat matrixes of different samples. The temperature and time at which the samples were evaluated influenced both the intensity and the character of the perceived odour profiles. For samples with skatole concentrations above 0.25 μg/g and served warm, skatole was predominant while the influence of androstenone at levels above 0.5 μg/g and other odour components became increasingly important after samples had cooled down and skatole volatiles were less evident.

The results showed that females compared to males would be less willing to consume pork and pork products with detectable levels of boar odour pertaining to both skatole and androstenone. All groups would be less willing to consume pork and pork products with detectable concentrations of skatole or skatole and androstenone in combination.

An apparent liking for samples with medium levels of androstenone (0.5 to 1.0 μg/g) was found for some consumers, especially males, and can be partly attributed to the inability of some consumers to smell this component or a genuine liking for the odour of androstenone.

Significant differences ($p < 0.05$) in the sensitivity of consumers from different ethnic groups were found with white females responding more negatively than white males and blacks. However, significant ethnic group effects were confounded by gender effects. The age of individuals, socio-economic factors and gender-linked personality factors may have influenced these differences. Although it was not possible to compare responses directly with the white and black groups because the samples were not identical, it was found that a higher percentage of coloureds responded negatively to boar odour compounds. Coloured males responded particularly negatively towards samples with detectable skatole, while black males, in general, were found to be more critical than black females.

It was concluded that boar odour whether due to skatole, androstenone or both compounds in combination at the levels as currently found in South Africa, will contribute to negative consumer reactions, at least for the subsection of the population represented in the study. It was predicted that the majority of these consumers would be less willing to consume pork meat exhibiting detectable levels of boar odour. It was recommended that the policy of castration be continued until such time as methods have been developed to ensure reduction in both skatole and androstenone concentration levels of boars to levels that would not be detectable even to the most discerning of consumers.

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Chapter 1

Introduction

A consumer's decision to repeatedly purchase a meat product is strongly influenced by the sensory quality characteristics of the product, particularly at consumption (Hovenier, Kanis, Van Asseldonk & Westerlink, 1993). A negative experience in this context can easily affect sales and consumption, making effective and consistent quality assurance an essential component to successful production and marketing.

For economic reasons, pork producers would like to produce boars or entire males due to better growth characteristics, essentially meaning a better efficiency at converting protein and energy to muscle development and producing leaner carcasses. However, the practice of castration continues in many countries largely because of concern about the possible presence of an abnormal odour and flavour called boar odour or boar taint (Squires, 1993). When present, the odour/flavour is characterised by an undesirable, often intense, faecal, urine-like off-odour or off-flavour. The problem predominates in the meat of boars and the two compounds regularly identified with this problem are 3-methyl indole (skatole) and the 16-androstenone steroids, particularly 5α-androst-16-en-3-one (androstenone) (Squires, 1993; Bonneau, 1998). The economic benefits of raising boars for meat production are dependent on the proportion of carcasses with unacceptably high levels of boar odour and whether or not these carcasses can be utilised efficiently. Boar odour is most frequently associated with the fatty tissues of mature boars but the variation from animal to animal is considerable. The problem is clearly expressed in about 5-25% of entire male pigs and particularly noticeable when the meat or fat is heated. Boar odour is considerably reduced following castration (Brooks & Pearson, 1986).

Two different but related issues were identified as limitations for answering the questions that were formulated during a workshop on boar odour (Heinze & Viljoen, 1994) held in South Africa involving pork producers, processors and researchers: Can the South

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African pork industry tolerate boar odour? And will pork producers and processors be assured of a sustained, profitable market share using boars for production or should the practice of castration be maintained?

Several countries, including Denmark, Britain, Spain and Australia raise entire male pigs (Squires, 1993) with limitations on slaughter weights. In several countries there are no prohibitive regulations with respect to boar meat without boar odour, for the home market, but regulations on boar odour exists for countries wishing to export, especially to Europe (Moerman, 1982; Claus, 1993). In South Africa, interest was therefore also focused on the possibilities of including entire male pigs in the general pork production system for both fresh and processed meat. However, there were also indications that boar odour may be negatively perceived by South African consumers (De Jong, 1994a). A survey of three commercial pig abattoirs in South Africa (Potgieter, Anderson, Heinze & Muller, 1998) showed that 39 % of the boar carcasses supplied had high androstenone levels i.e. exceeding 1.0 μg/g in fat and 17 % had high skatole levels (> 0.25 μg/g). These numbers were 9 % and 6 % respectively higher than % carcasses reported for a multinational survey in Europe (Walstra, Claudi-Magnussen, Chevillon, Von Seth, Diestre, Matthews, Homer & Bonneau, 2000). The potential for high levels of boar odour in boars raised under South African pork production conditions was therefore regarded to be considerable.

Some 25 years ago, Walstra (1974) mentioned that there was much prejudice against the occurrence of boar odour. It was then stressed that it was important to know the reaction of the consumer population to boar meat. It was therefore regarded as a priority to assess South African consumers' reactions to boar odour before making a decision on the unrestricted utilisation of boar carcasses (Heinze & Viljoen, 1994).

A South African study was necessary because it was impossible to generally apply results of studies from other countries (examples are Walstra, Engel & Mateman, 1986; Sather, 1995; Godt, Kristensen, Poulsen, Juhl & Bech, 1996; Matthews, Homer, Punter, Béague, Gispert, Kempster, Agerhem, Claudi-Magnussen, Fischer, Siret, Leask, Font i Furnols, & Bonneau, 2000) to the South African situation. This was because the *per capita* consumption of pork is much lower compared to most of the countries where boar odour studies have been done (Landbouweekblad, 1993), especially for different ethnic

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groupings of the South African population. The ethnic groups representing the South African population have different cultural eating habits and attitudes towards pork in general (Viljoen, 1996). Climatic conditions, pig housing systems and herd management strategies are also different from Europe and that could influence the levels of malodorous compounds and meat properties (De Jong, 1994a).

A second issue was related to the differences in opinions on the relative contributions of skatole and androstenone to boar odour. Some studies have shown that skatole has a greater effect (Bejerholm & Barton-Gade, 1993; Andresen, Frøystein, Rødbotten, Mortensen, Eik-Nes & Lea, 1993; Lundström, Malmfors, Malmfors, Stern, Petersson, Mortensen & Sørensen, 1988 and Støier & Olsen, 1998) while others found the same for androstenone (Squires, Gullett, Fischer & Partlow, 1991; Bonneau, Le Denmat, Vaudelet, Velosi Nunes, Mortensen & Mortensen, 1992a and Xue, Dial, Holton, Vickers, Squires, Lou, Godbout & Morel, 1996). Most investigations have concluded that predictions of the perception of boar odour were improved when the contributions of both compounds were considered. This argument is important because various strategies have shown potential for reducing concentrations of either one or both compounds. These strategies range from ensuring control over certain environmental conditions to castration (Bonneau, 1998). The advantages and disadvantages of the various strategies would obviously affect their usefulness. In addition, on-slaughter line screening techniques have been developed for skatole but not effectively for androstenone (De Jong, 1994b). It has also has proven to be more difficult to develop techniques for effectively monitoring both compounds simultaneously in a relatively short time, in order to classify boar carcasses as acceptable or unacceptable.

The reasons for the differences in findings on the contributions of skatole and androstenone are not clear cut and are attributed to animal husbandry practices (e.g. variations in breeds, animal diets), carcass positions or cuts used and the composition of the sample material (meat, meat and fat, fresh or processed products). Other explanations are related to differences in the methodology used for the sensory evaluation of meat odour and flavour, including cooking and sensory evaluation procedures, differences in meat consumption habits and differences in individuals' sensitivities particularly towards androstenone (Bonneau, Kempster, Claus, Claudi-Magnussen, Diestre, Tornberg, Walstra, Chevillon, Weiler & Cook, 2000).

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Harrison, Campbell & Hills (1998) stated that the perception of volatile compounds depends on the concentration of the compounds, threshold levels of the individual and duration of exposure. To this effect an individual's perception of a particular food product will therefore primarily depend on the amounts and rates of volatiles released from the food matrix when consumed. The effect of concentrations of the compounds skatole and androstenone has been the focus of many sensory studies on boar odour (Judge, Mills, Orcutt, Forrest, Diekman, Harmon, Lin & Nicholls, 1990; Bejerholm & Barton-Gade, 1993; Annor-Frempong, Nute, Whittington & Wood, 1997b; Annor-Frempong, Nute, Whittington & Wood, 1997c; Dijksterhuis, Walstra, Agerhem, Font I Furnols, Oliver, Siret, Béague, Claudi-Magnussen, Fischer & Cook, 1997).

Threshold levels of individuals to skatole and androstenone and the link to perception of boar odour have been dealt with to a limited extent in both consumer (Weiler, Font I Furnols, Fischer, Kemmer, Oliver, Gispert, Dobrowolski & Claus, 2000) and analytical sensory studies (Sather, 1995; Annor-Frempong, Nute, Whittington & Wood, 1997a). The duration of exposure to boar odour and its effect on perception has not been dealt with in sensory studies.

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Chapter 2

Literature review

2.1 What is boar odour or boar taint?

Boar odour or boar taint refers to the undesirable, often intense, faecal, urine-like off-odour or off-flavour sometimes characteristic of pork. Patterson (1968) found the pheromone 5α-androst-16-ene-3-one (androstenone) (Figure 1) present in boar fat to be responsible for boar odour. Two years later, Walstra & Maarse (1970) and also Vold (as cited by Walstra, 1974) found that 3-methyl indole (skatole) (Figure 2) was present at higher concentrations in boars compared to barrows, causing an abnormal odour and flavour. In literature the odour or flavour is often referred to as boar *taint*. However, a taint is defined as "a taste or odour *foreign to the product*" (International Standards Organisation (ISO), 1992). This implies that naturally occurring compounds such as skatole and androstenone should not strictly speaking be considered taints, therefore the term *boar odour* is preferred.

2.1.1 C_{19}-Δ^{16}-steroids

Boar odour relates firstly to the presence of the C_{19}-Δ^{16}-steroids (Brooks & Pearson 1986; Claus, 1993) and more specifically androstenone. The C_{19}-Δ^{16}-steroids (5,16-androstadien-3β-ol, 4,16-androstadien-3-one, 5α-androst-16-en-3-one, 5α-androst-16-en-3β-ol and 5α-androst-16-en-3α-ol) are synthesised in the testes, released into the blood circulation via the spermatic vein and stored in the adipose tissue (Brooks & Pearson, 1986). 5α-androst-16-en-3-one is the most lipophilic of the C_{19}-Δ^{16}-steroids and is the predominant form of storage notably in the range of 0.08 to 7.00 μg/g fatty tissue (Potgieter *et al.*, 1998). The other C_{19}-Δ^{16}-steroids is detectable in boar fat in lesser concentrations (Claus according to Brooks & Pearson, 1986; Garcia-Requeirio & Diaz, 1989).

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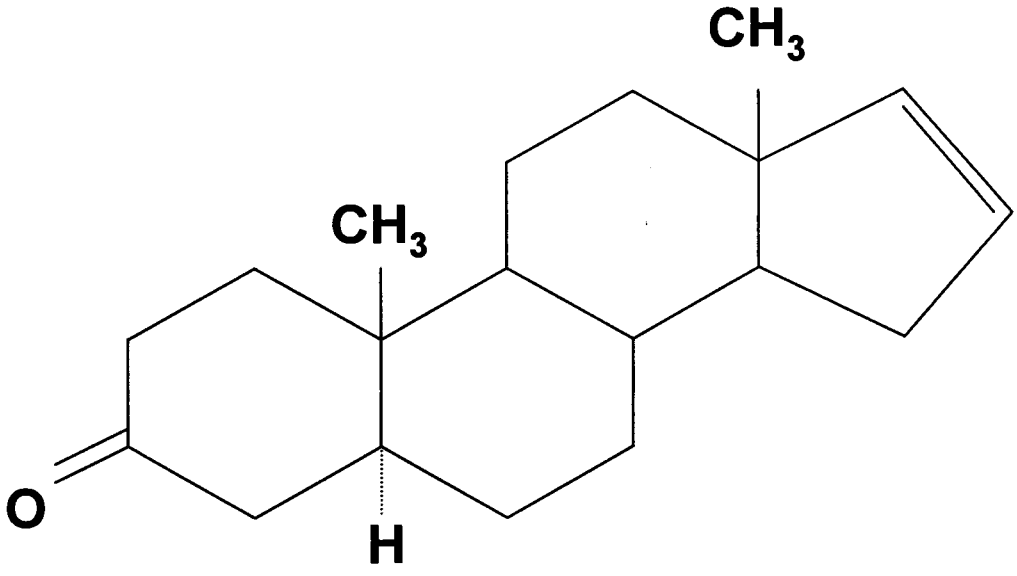

Figure 1: The chemical structure of 5α-androst-16-ene-3-one (androstenone)

(Patterson, 1968)

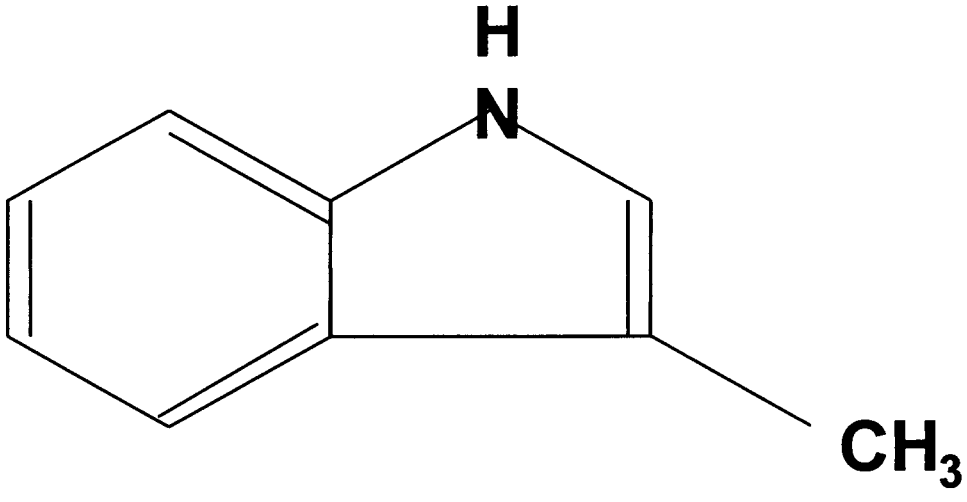

Figure 2: The chemical structure of 3-methyl indole (skatole)

(Walstra & Maarse, 1970)

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2.1.2 Indoles

Linked to androstenone is the effect of skatole and possibly also indole (Walstra & Maarse, 1970; Thomson, 1985; Garcia-Requeirio & Diaz, 1989; Bejerholm & Barton-Gade, 1993). Skatole and indole are metabolites formed by the microbiological break down of tryptophan in the hindgut, where it is absorbed from the gut, metabolised in the liver, partially excreted in the urine and partially stored in the adipose tissue (Brooks & Pearson, 1986, Claus, Dehnhard, Herzog, Bernal-Barragan & Gimenez, 1993). Deposition of skatole and indole in the adipose tissue of pigs apparently occurs in many other ways as well, ranging from absorption through the skin to inhalation (Hansen, Jensen, Hansen-Møller & Barton-Gade, 1994). The presence of skatole and indole is not specific to boar fat but higher skatole concentrations are found in boars compared to barrows and gilts (Hansson *et al.* cited by Brooks & Pearson, 1986; Potgieter *et al.*, 1998).

2.2 Factors affecting the concentration of androstenone and skatole in boars

The factors responsible for varying concentrations of androstenone, skatole and indole in pork carcasses have been reviewed extensively (Squires, 1993; De Jong, 1994a; Sather, Tong, Jeremiah, Squires & Jones, 1995; Babol and Squires, 1995; Babol, Squires & Gullett, 1996, and Bonneau, 1998). Large variations in skatole concentrations ranging from none to 1.7 μg/g fat (mean = 0.149 μg/g fat), were observed among individual boars (n = 300) in a South African survey (Potgieter *et al.*, 1998). The same survey reported variations of between none and 9.5 μg/g fat (mean = 1.08 μg/g fat) for androstenone concentrations in boars. The concentrations of androstenone in boars are genetically controlled and are either related to difference in sexual maturity or differences in the potential for androstenone development. Variations in fat skatole levels are not fully understood but rearing factors including feed properties and housing conditions and perhaps also a genetic link are involved (Bonneau, 1998).

Boar odour is associated with adipose tissue. Androstenone and skatole are concentrated in the fatty tissue and it would therefore be reasonable to assume that the intensity of the odours/flavours would be higher in food samples containing fatty tissue

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compared to leaner products. As with protein and moisture, intramuscular lipid content and fatty acid composition varies characteristically between muscles and also between pigs which will influence the concentrations of androstenone and skatole (Walstra, 1974; Agerhem & Tornberg, 1994; Agerhem & Tornberg, 1995b). That implies that depending on which cut/s are used for testing purposes, one may expect varying boar odour results (Walstra, 1974). Water content and protein content are often higher and lipid content lower in back fat of boars compared to gilts and castrates (Babol & Squires, 1995; Potgieter *et al.*, 1998). Note also that the lipid fractions of boars often contain comparatively more unsaturated fatty acids than castrates with gilts being intermediate. However, variations may occur since fatty acid composition is very dependent on diet (Lundström *et al.*, 1988).

Various strategies are proposed for reducing the concentrations of these compounds in pig carcasses. Proposals related to housing conditions and environment management, feeding requirements, genetic manipulation or non-traditional castration policies (e.g. immunocastration) have all shown some decreasing effects on androstenone and/or skatole concentrations (Bonneau, 1998).

2.3 Factors affecting the perception of boar odour

Food aromas are perceived when volatiles are released from food samples and carried to the *olfactory epithelium* in the nose. The pathway can be orthonasally or retronasally. Flavour involves the complex combination of the olfactory, gustatory and trigeminal sensations perceived during tasting (Doty, Brugger, Jurs, Orndorff, Snyder & Lowry, 1977) and involve both volatile and non-volatile compounds (Harrison, 1998). It would be reasonable to expect that the perception of androstenone and skatole odours would be influenced by the concentration and properties of the volatiles reaching the *olfactory epithelium* in the nose and the subsequent interpretation of the information in the brain. Processing of the information would involve recognising the character and intensity of the odour as well as deciding on the hedonic (like/dislike) character of the odour.

To study the recognition (description) and measure the intensity of odour and flavour perception of boar odour would necessitate an analytical sensory approach. The hedonic character can best be assessed using a consumer approach. It was noted in

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various studies that trained panellists were sometimes used to measure pleasantness (Lundström *et al.*, 1988, Bonneau *et al.*, 1992a, Bonneau, Le Denmat, Vaudelet, Velosi Nunes, Mortensen & Mortensen 1992b, Zondagh, Bruwer, Illsley, Van Heerden, Smith, Müller & Naudé, 1994, Annor-Frempong *et al.*, 1997c). The validity of these results in as far as predicting consumer responses is questionable due to the analytical approach of trained panellists to sensory assessment. In contrast, results are also reported on analytical description of boar odour by untrained consumers (Thomson, 1985). The reliability of these results is also questionable because of the potential lack of sensitivity of the individual panellists to the compounds and familiarity with the descriptive terms and task in general.

Annor-Frempong *et al.* (1997c) stated that the detection of boar odour on consumption was related to the "concentrations of the compounds androstenone and skatole present in pork, culinary procedures and olfactory sensitivity of the assessors". The same authors hypothesised on the reasons for the inconsistencies of results from studies that attempted to relate androstenone and skatole concentrations with sensory attributes. The inherent difficulty in panel assessment and interpretation; the wide variation in sensitivities of different panellists and the fact that the effects of skatole and androstenone were influenced by the presence of other compounds present in pork meat and fat, were identified as the main factors affecting the results. However, no study has specifically considered the potential time-intensity or temporal profile of boar odour perception.

2.3.1 The sensory character and physico-chemical properties of androstenone and skatole

Reports that describe the sensory quality of androstenone and skatole have shown very different odour qualities as summarised in Table 1. Many researchers have attempted with varying results to establish descriptive sensory profiles for boar odour and flavour with different concentrations of skatole and androstenone (Agerhem & Tornberg, 1995a; 1995b; Annor-Frempong *et al.*, 1997a, 1997b, Dijksterhuis, Engel, Walstra, Font I Furnols, Agerhem, Fischer, Oliver, Claudi-Magnussen, Siret, Béague, Homer & Bonneau, 2000). Annor-Frempong *et al.* (1997b) and Diksterhuis *et al.* (2000) found that even trained panellists experienced some degree of confusion between the odours of

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skatole and androstenone. A reason for this was that different concentrations of the compounds, in particular of skatole, could smell differently.

Table 1: Summary of the odour qualities of compounds that are reported to be responsible for boar odour

Description	Reference
Androstenone	
Urinous, animal, sweaty or ammonia	Amoore (1977) Griffiths & Patterson (1970)
Sweet, fruit and perfume-like	Griffiths & Patterson, 1970
Sweaty	Annor-Frempong *et al.* (1997a)
5α-androst-16-en-3β-ol and 5α-androst-16-en-3α-ol	
Musk like character	Prelog & Ruzicka according to Brooks and Pearson (1986)
Sweaty, animal, urinous and putrid	Thomson (1985)
Skatole	
Faecal, mothball, musty	Annor-Frempong *et al.* (1998)
Mothball & musty	Annor-Frempong *et al.* (1997a)
Characteristic faecal odour at high levels, becoming pleasant, sweet, and warm at very low levels; warm, over-ripe fruity flavour below 0.1 ppm	Furia & Bellanca (1981)
Mothballs, faecal, musty, putrid and camphor	Harper *et al.* cited by Thomson (1985)
Faecal, naphthalene/mothball	Diksterhuis *et al.* (2000)
Indole	
Mothballs, musty/earthy, paint, animal, sweaty and camphor	Harper *et al.* cited by Thomson, 1985
Septic	Khiari (1997)
Non-specific to whether related to skatole or androstenone	
Sweet, fruity, ammonia-like and animal like	Griffiths & Patterson (1970)
Other odours noted in boar fat volatiles resemble perfume, wood, musk, 'Ivory' soap	Beery, Sink, Patton & Ziegler (1971)
Onion-like, perspiration-like and urine-like	Self as cited by Gardze *et al.* (1979)

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Androstenone is a steroid ketone with a molecular weight of 272.4 (Figure 1). The odour of pure androstenone in model systems has mostly been described as urine or ammonia-like or sweaty (perspiration-like) (Table 1). However, Griffiths & Patterson (1970) found that 40 % of untrained panellists described the odour of androstenone as sweet, fruity and perfume-like at the first concentration level where they could positively identify the odour, but used the terms sweaty, animal and urine at the higher concentrations. The term "wild meat " has also been used as a description for androstenone (Sather, 1995). The stale-urine odour of certain steroid ketones and synthetic analogs was first identified as compounds to which a substantial proportion of people are anosmics by Beets & Theimer in 1970 (Amoore, 1977). They demonstrated that as much as half of all people tested could not perceive the unpleasant urinous odour. The same people are anosmic both to androstenone and to several synthetic ketones with totally unrelated carbon skeletons, but having very similar external molecular dimensions (O'Connell, 1991). Another important property of androstenone is its strong lipophilicity (Lundström *et al.*, 1988).

The indole, skatole, with a molecular weight of 131.2 is soluble in hot water, alcohol, benzene and ether. Its solubility in water is much higher (0.45 g/l) (Windholz, Budavari, Blumetti & Otterbein, 1983) than that of androstenone (0.00023 g/l) (Amoore, 1977). The odour of pure skatole has been described as faecal, mothball-like and musty (Annor-Frempong *et al.*, 1997a, Annor-Frempong, Nute, Wood, Whittington & West, 1998) and by panellists using the Flavour Profiling method as barnyard (Sather, 1995).

Using a trained sensory panel and a model oil system, Annor-Frempong *et al.* (1997a) found the term 'sweaty' to be the only odour descriptor, out of a total of seven terms (sweaty, ammonia, dirty, parsnip, silage, nosefeel and acrid) associated with androstenone, to significantly discriminate between pure samples of androstenone and skatole. Discrimination was similarly achieved based on the terms mothball and musty that were significantly associated with skatole. Other odours noted in boar fat volatiles have been described as perfume, wood, musk and Ivory soap (Gardze, Bowers, Craig & Allee, 1979).

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2.3.2 The inherent difficulty in panel assessment and interpretation of boar odour

Trained sensory panels are often used and have been found to evaluate food flavours with considerable accuracy. Bett & Johnsen (1996) summarised results of studies on off-flavours and concluded that standard deviations (among panellists) associated with mean intensities of descriptors in inherently flavoured samples were rather small, whereas they increased with increases in off-flavours. The cause/s of this phenomenon had not been determined, but it was concluded that trained panellists experienced difficulty evaluating with precision intense off-flavour compounds. Panellists were however quite capable of precisely defining some natural off-flavours such as fishy while certain concentrations of other compounds such as methylisoborneol (a taint caused by algae in the fish habitat) could not be rated consistently. Bett & Dionigi (1997) contributed this to a theory that off-flavours caused by single compounds resulted in less-reproducible sensory scores compared to natural flavours that usually involve multiple compounds. The hypothesis was that variation of panellists' individual detectable threshold concentrations were more affected by single than multiple compounds. Whether this phenomenon also applied to the natural off-flavour/s caused by skatole and androstenone has not been proven.

Humans also show adaptation to certain flavours, which is a problem when dealing with sensory evaluation. Adaptation is the loss, usually for a short term, of sensitivity produced by continuous exposure to certain chemical stimuli. The regaining of the same level of sensitivity to various odourants is dependent on the compounds being tested. During adaptation the sensory system does not discontinue its function, but some compounds evoke qualitative changes during continued exposure (Bugard & Kuznicki as cited by Bett & Johnsen, 1996). An example of this phenomenon was the perception of trimethylamine, a compound like androstenone also regarded as a primary odourant by Amoore (1977), the smell of which changes from a fishy smell to ammonia-like during continuous exposure (Amerine, Pangborn & Roessler, 1965). No scientific evidence of adaptation effects or how this phenomenon may affect the perception of either skatole or androstenone or boar odour could be found.

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Fatigue causes the sensory system to become less responsive to stimuli over continuous stimulation or repeated evaluation (Bugard & Kuznicki as cited by Bett & Johnsen, 1996). It occurs when panellists become tired of concentrating. When this occurs, intensity scores normally decrease (Bett & Dionigi, 1997). Carry–over effects from one sample to subsequent samples is sometimes a problem with some flavours (Amerine *et al.* 1965). These effects are mostly overcome with the use of adequate waiting periods between samples and effective mouth cleansers or in the case of odourants, exposure to fresh air. Another method is the use of a warm-up sample (the data of which is not used) to prevent the evaluation of the first real sample to be different from those that follow (Bett & Johnsen, 1996). Agerhem & Dijksterhuis (1996) proposed an inter-stimulus waiting period of 3 minutes for boar odour samples. However, little information on the time needed for sufficient recovery of the sensory system if exposed to boar odour compounds could be found. No clear indications for the most appropriate number of samples or waiting periods between samples when evaluating boar odour compounds to prevent fatigue were available. The use of a warm up sample for boar odour studies was not specifically reported in any of the studies that were reviewed. However, this may have been a standard practice for some laboratories.

Another difficulty experienced in the field of sensory evaluation is odour or flavour enhancement or suppression. Bett & Johnsen (1996) found that similar samples of catfish spiked with methylisoborneol, presented in sequence, evoked completely different odour intensities; in fact the odour of the compound was consistently rated as less intense (Bett & Dionigi, 1997). This however, did not affect the ability of the panel to identify samples without methylisoborneol. When unspiked samples of catfish were served in combination with the spiked samples, trained panellists could adequately evaluate the controls as not being tainted. The correct identification depended on a sufficient time gap for recovery of the olfactory system. It was concluded that for methylisoborneol when the receptor sites on the olfactory epithelium were saturated, a person needed sufficient time for the system to completely recover to be able to effectively judge the intensities of such lipophilic compounds.

Odour enhancement or suppression is also caused by the effect/s on odour intensity due to the presence of two or more substances in combination (Meilgaard, Civille & Carr,

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1991). This phenomenon was reported by various researchers as important for boar odour evaluation and will therefore be dealt with in more detail.

2.3.3 Enhancement and interaction of skatole and androstenone odours/flavours

Some studies reported that the presence of androstenone enhanced the effect of skatole, therefore providing a synergistic relationship (Walstra *et al.*, 1986; Berg, Agerhem, Von Seth, Tornberg & Andresen, 1993; Agerhem & Tornberg, 1994; Sather, 1995; Xue *et al.*, 1996; Annor-Frempong *et al.*, 1997b), while others, in model systems (Thomson, 1985) and using meat/fat samples (Xue *et al.*, 1996; Støier & Olsen, 1998; Dijksterhuis *et al.*, 2000) did not find this. Annor-Frempong *et al.* (1997c) found that the synergistic relation was a partial one and affected only odour intensity and not odour quality.

Lundström *et al.* as cited by Judge *et al.* (1990) and Hanson *et al.* according to Sather (1995) reported that skatole enhanced the sensory impression of boar odour as produced by androstenone. Sather (1995) found that a trained taste panel was not responsive to high levels of skatole, unless androstenone was present. Xue *et al.* (1996) reported that a trained panel's assessment of skatole levels was higher than the predictions from measured skatole concentrations while the opposite was true for androstenone assessment. These authors suggested that the skatole effect be due to synergism in the presence of androstenone. There was no clear explanation for the androstenone effect except for possible odour masking by other compounds. Note that in this case sensory assessment was based on microwave heating of samples (40 seconds at high power) and then "judges evaluated the freshly cooked fat samples by opening the Petri dish and sniffing as soon as possible after the samples had been taken out of the microwave oven". A further complication to the results may have been the number of samples (n = 40) evaluated per panellist per day, i.e. twenty (20) samples per session.

Annor-Frempong *et al.* (1997b) observed that some individuals sometimes became completely odour blind to either skatole or androstenone when presented with a mixture of the two compounds in a neutral lipid base. Skatole intensity ratings were shown to depend not only on skatole concentrations but also on androstenone concentrations. It was inferred that the presence of androstenone had an influence by increasing the rate

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of change in the responses of individuals when they were exposed to different concentrations of skatole. Babol *et al.* (1996) and Støier & Olsen (1998) were of the opinion that the lack of interaction effect found between the aroma compounds suggested that skatole and 16-androstene steroids affected human perception independently from each other. Babol & Squires (1995) stated that the level of boar taint depends on the compound whose level is more easily detected. Dijksterhuis *et al.* (2000) later concluded that it was more difficult to perceive the odour/flavour of androstenone than that of skatole but did not elaborate on the reasons for this phenomenon.

It was also found that different combinations of androstenone and skatole in pork fat were sometimes similarly assessed (Sather, 1995, Annor-Frempong *et al.*, 1997c) or caused some degree of confusion (Xue *et al.*, 1996, Dijksterhuis *et al.*, 2000) when assessed by trained sensory panels. This phenomenon led to an investigation of response classes (e.g. normal, abnormal and doubtful) rather than concentrations of skatole and androstenone (Annor-Frempong, Nute, Wood & Whittington, 1997d, Annor-Frempong *et al.*, 1998). Response criteria were assessed using a trained sensory panel and the Neotronics Olfactory Sensory Equipment (e-nose). The e-nose was able to discriminate between different levels of boar odour in that it classified all samples, shown to be 'abnormal' by the sensory panel, correctly. However, the instrument also classified 16 % (of a total of 60 samples) of 'normal' samples as 'abnormal'. It was speculated that this might have been due to undesirable abnormal odours that were not necessarily boar odour, e.g. rancidity. It was suggested that improvements on the calibration and optimisation of sensors could improve the relationships between the e-nose and sensory panel measurements. The overall significance of the research was the exciting possibility of classifying boar odour on the slaughter line into sensory classes using sensory technology.

2.3.4 The relative contribution of skatole and androstenone to boar odour

While there is general agreement that both skatole and androstenone contribute to the undesirable odour and flavour, disagreement on which one of these compounds is the most important contributor to boar taint or more specifically affecting acceptability of boar meat and products, were found to be a major reason for sensory studies on the issue (Squires *et al.*, 1991; Bonneau *et al.*, 1992a; Bejerholm & Barton-Gade, 1993; Babol *et*

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al., 1996; Støier & Olsen, 1998; Matthews *et al.*, 2000). The lack of consistency between the results obtained in the various studies may result from differences in the androstenone and skatole characteristics of the animal populations from which the samples were drawn and also from different methodologies used for the sensory assessments e.g. selection and training of panel members and/or preparation and serving of sample material (Bonneau, 1998).

The results from some analytical sensory studies found that androstenone and not skatole was a better predictor of boar taint. Judge *et al.* (1990) were unable to identify the contributions of skatole and/or androstenone to boar odour intensity reportedly because of very low levels of both compounds detected in the sample material that was used. It was suggested that because of the poor correlation found between skatole and odour intensity, skatole was not a dependable indicator of boar odour. Stamer, Nürnberg, Kanitz & Kalm (1993) concluded similarly but ascribed the low correlations to either lack of suitability of the testing instrument (the sensory panel) or the wide variation in the sensitivities of the panel members. Judge *et al.* (1990) also predicted that when skatole concentrations were low, the correlation of androstenone concentration with odour intensity scores would also be low or non-existent. Both Squires *et al.* (1991) and Xue *et al.* (1996) found good correlations ($r = 0.82$) between androst-16-ene levels in boar fat and off-aroma and off-flavour sensory scores. The importance of androstenone was found to be particularly noticeable at heavier carcass weights or near sexual maturity of the animal as well as for certain breeds.

Bonneau *et al.* (1992a) also found that the odour of entire male fat and meat cutlets were more closely related to fat androstenone than fat skatole levels, while cooked ham odour scores and overall opinion for cooked ham were more closely related to skatole than to androstenone (Bonneau *et al.*, 1992b). Bonneau, Le Denmat, Mortensen & Mortensen (1993) concluded that androstenone and skatole both contributed significantly to off-odour and off-flavours in cooked hams prepared from boar meat. Apparently part of the androstenone "disappeared" during processing and it was found that the acceptability thresholds for both skatole and androstenone under these conditions were elevated to 0.75 and 1.50 μg/g fat, respectively.

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On the contrary, a number of studies found skatole to be principally contributing to the perceived boar odour. Bejerholm & Barton-Gade (1993) found skatole to be the primary factor responsible for boar odour and flavour explaining 58 % of variance in Danish entire male pigs with androstenone explaining an additional 8 % of the variance in the data. Lundström *et al.* (1988), under Swedish conditions, similarly found skatole ($r = 0.65$) slightly more predictive than androstenone ($r = 0.53$) but emphasised, as was done previously (Lundström & Malmfors, 1985), that both compounds seemed to be important. A Norwegian study (Andresen *et al.*, 1993) also indicated skatole as the compound affecting the occurrence of boar taint and also other sensory characteristics to a larger extent compared to androstenone. Androstenone because of its lipophilic nature was regarded as a reasonably good predictor of boar taint presence in fat while skatole, being fat as well as slightly water soluble was regarded as a predictor of boar taint in fat but also for the flavour of lean meat (Lundström *et al.*, 1988; Andresen *et al.*, 1993). Støier & Olsen (1998) confirmed the Danish results that skatole gave better indications of boar odour. Berg *et al.* (1993) also under Swedish production conditions concluded that knowledge of skatole concentrations alone may be enough to discriminate among pigs with the undesirable odour at lower carcass weights (below 75 kg), while both factors are necessary to make valid predictions at higher carcass weights.

Babol *et al.* (1996) correlated 16-androstene steroids and skatole concentrations as well as the size of accessory sexual glands and animal live weight on the development of boar taint in entire male pigs. It was concluded that factors other than 16-androstene steroids and skatole also contributed to boar odour as assessed by a trained sensory panel. These factors related to sexual maturity. A similar conclusion was reached by Bonneau *et al.* (1992a) when investigating the contributions of fat androstenone and skatole to boar taint. To guarantee untainted meat it was then shown to be not sufficient to sort carcasses only according to fat androstenone and/or skatole levels.

Most of the studies concluded that the prediction of boar odour/flavour intensity was more improved when the contributions of both skatole and androstenone were taken into account. The influence of skatole, androstenone and indole on odour perception when presented individually, and in combination, in a model lipid based was investigated by Annor-Frempong *et al.* (1997b). Boar odour intensity in the model lipid base was found

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to be linearly related to skatole and androstenone concentrations, but in pork tissue it was not a simple linear relationship but rather quadratic (Annor-Frempong *et al.*, 1997c). In addition, a significant androstenone-panellist effect was observed. In the model system correlation coefficients for odour intensity of 0.64 and 0.63 for androstenone and skatole concentrations were found, respectively. For the pork fat samples, skatole and androstenone concentrations, individually, contributed about 48 % each, while the two compounds in combination contributed 56 % to the explanation of the variation in rated abnormal odour of pork fat. The addition of indole concentration to the regression model increased this explanation to 76 %.

The disagreement on the relative contribution of androstenone and skatole to boar odour led to the recent planning and execution of a European multinational research project involving 11 research centres and 7 European countries. One of the objectives of the project was to "to reach an *international* agreement on the relative contributions of androstenone and skatole to boar taint" (Bonneau *et al.*, 2000). This was amongst others done through a comparison between countries of trained sensory panel responses (Dijksterhuis *et al.*, 2000) and consumer reactions (Matthews *et al.*, 2000) to entire male pig meat with known differences in androstenone and skatole concentrations.

In this comparative study, Dijksterhuis *et al.* (1997; 2000) assessed the odour and flavour of pig meat with known concentrations of skatole and androstenone using trained analytical sensory panels based in seven European countries. Substantial differences between the panels in the different countries were found. Clear reasons for the differences were difficult to determine. Semantic language differences, panel handling and training, panel make-up and levels of training probably contributed to these differences even though efforts were made to use similar methodology. It was shown that the perception and recognition of androstenone smell seems to be "more difficult" compared to skatole (Dijksterhuis *et al.*, 2000). No reason for this observation was furnished. Because of significant quadratic effects found for different descriptive terms, it was proposed that under the conditions of boar odour assessment, trained panellists used the descriptive terms to indicate serious negative feelings towards test samples. An interesting observation was that the British and Spanish trained panels used for this study did not regard boar odour as *abnormal*. This was explained as being due to years of exposure to the odour.

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2.3.5 Variations in sensitivities to perceive skatole and androstenone

Sensory panels are often employed and trained to analyse and rate certain characteristics of a food during the eating process. Harrison *et al.* (1998) commented on the difficulty to analyse the data produced from these assessments due to large variations among panellists. Annor-Frempong *et al.* (1997b, 1997c) reported that the effects of individual panellists as well as the interactions involving panellists were important in explaining the variations in pork odour and abnormal odour ratings. The panellist-androstenone interaction effect was shown to be the most important. Stamer *et al.* (1993) confirmed the differences in sensitivities when reporting results showing important differences between screened sensory panellists when classifying fat samples, using an olfactometer, into three classes of boar odour.

Pollack, Wysocki, Beauchamp, Braun, Callaway & Dupont (1982) and Wysocki & Beauchamp (1984) reported that the ability to detect androstenone by humans is at least partly genetically determined and predominated in females. These authors showed that a proportion of humans has a specific anosmia to the odour of androstenone. Specific anosmia is "the condition in which a person of otherwise normal olfactory acuity cannot perceive a particular compound, at a concentration such that its odour is obvious to most other people" (Amoore, 1977). In their studies, Griffiths and Patterson (1970) found that only 56 % males but 92 % of females were able to detect this substance. However, wide within-sex variations have also been noted. Amoore (1977) and Thomson (1985) did not report differences in anosmia percentages between sexes. Among adults, approximately 50 % reported no odour, even at a high concentration while approximately 15 % detected a subtle odour. However, between 25 % (Thomson, 1985) and 35 % (Wysocki & Beauchamp, 1984) of consumers were exquisitely sensitive to androstenone, detecting less than 0.002 ppm in air. Amoore (1977) mentioned that androstenone was identified in human male underarm sweat and it was presumed that it may stimulate the urinous odour sensation and may have a role as a human pheromone as it has for the boar. The concentration level of androstenone in the sweat of human males was not available.

Beauchamp (1990) reviewed the phenomenon of androstenone sensitivity revealing large changes in the ability to sense this odour as individuals grow up. Regular

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exposure to the odour by initial androstenone anosmics has also shown a change in the ability to smell the odour. Stevens & O'Connell (1995) found that exposure of individuals over an 8-week period to a compound chemically distinct to androstenone but also having a urine-sweaty type odour (O'Connell, 1991), namely pemonone, significantly reduced threshold levels for androstenone. Sather (1995) suggested that through exposure, trained panellists became more sensitive to detecting androstenone. Whether the potential increases in sensitivity levels were due to physiological reasons indicating a change in absolute sensitivity of individuals or merely because of changes in cognitive and performance factors is not clear (Beauchamp, 1990).

Much less is known about the factors which cause variation in fat skatole levels or the human perception of skatole odour (Bonneau *et al.*, 1992a). Most people were able to smell skatole to varying degrees (Griffiths & Patterson, 1970). Only one report of two individuals insensitive to the odour of skatole in model oil systems could be found (Sather, 1995). No reason for this occurrence was given.

2.3.5.1 Thresholds for androstenone and skatole

Amoore (1977) reported the detection threshold for androstenone to be 1.8×10^{-7} g/l (0.0018 μg/g) in water and 2.1×10^{-9} g/l in air while Thomson (1985) found the threshold for androstenone in aqueous ethanol to be 0.0013 μg/g. This threshold value for androstenone is several orders of magnitude less than the concentration at which it is reportedly typically found in boar fat (0.63 μg/g). Thomson (1985) similarly reported the threshold for skatole to be 0.14 μg/g and for indole 0.33 μg/g in aqueous ethanol, therefore much greater than the threshold of androstenone and in excess of concentrations typically found in boar fat (0.07 μg/g skatole and 0.04 μg/g indole). Thomson (1985) argued that since skatole and indole were often found below these threshold levels in pork, that their role in boar odour may well be through synergism with androstenone. However, the values cited by Thomson (1985) as typical for boar fat is very low and not representative of the South African situation (0.149 μg/g for skatole and 1.08 μg/g for androstenone) (Potgieter *et al.*, 1998).

Druaux & Voilley (1997) stated that, in general, the presence of lipids, proteins and polysaccharides reduced the volatility of an aroma compound with respect to its volatility

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in pure water. It can therefore be expected that thresholds for these compounds in pork tissue would be different and probably be higher than in water or aqueous ethanol. In fact, Walstra reported in 1984 that panel members had more difficulty in identifying androstenone in fat samples than in the pure condition (according to Lundström & Malmfors, 1985). However, in the presence of salts, the volatility of aroma compounds is increased (Druaux & Voilley, 1997). No results could be found to verify this effect when applied to skatole and androstenone.

The hypothesis that the boar odour problem, whether due to skatole or androstenone, can be eliminated if it was clear at what concentrations humans can detect and more importantly reject sample material, has led to various attempts to determine threshold concentrations. Moerman (1982) reported that researchers at a European Association for Animal Production Working Group on Production and Utilisation of Meat from Entire males have agreed on threshold levels of 0.5 μg/g for androstenone in fat for fresh meat and 1.0 μg/g in processed meat. These levels were regarded as an acceptable risk for preventing consumer rejection of boar meat. Many papers, some as early as 1982 (Lundström, Malmfors, Fjelkner-Modig & Szatek, 1982), referred to the proposed acceptability cut off level for skatole to be in the range of 0.20 to 0.25 μg/g fat, but the original scientific evidence on which this level was based could not be found. Moss, Hawe & Walker (1993) determined the threshold level for skatole as a cooking odour perceived on heating a model meat puree (80 % pork lean, 20 % fat) with exogenous skatole added, to be between 0.08 μg/kg meat puree mix and for aqueous solution 0.05 μg/ml. Based on this model meat puree, Moss *et al.* (1993) calculated that skatole would be detected if present, as contributed by the fat part of the model, beyond a concentration of 0.4 μg/g fat. This level was much higher than the recommended cut off point for skatole in adipose tissue, namely 0.20 μg/g or 0.25 μg/g.

Annor-Frempong *et al.* (1997c) found that a sensory panel could better discriminate between different concentrations of skatole than androstenone. The reason for this was explained as being due to the much lower detection threshold found for skatole compared to androstenone. A finding that was in contrast to Thomson (1985) who reported lower thresholds for androstenone compared to skatole in both water and aqueous alcohol. Annor-Frempong *et al.* (1997c) also argued that the effects of skatole

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and androstenone on boar odour perception in pork meat are confounded by the presence of other volatile compounds of varying concentrations. For this reason the detection thresholds and odour profiles of the pure compounds in a bland lipid base (a mixture of sunflower oil and vegetable fat) were measured (Annor-Frempong *et al.*, 1997a). Group thresholds for the trained panel were found to be 0.426 μg/g and 0.026 μg/g for androstenone and skatole, respectively. These values were much lower than the 3.10 and 1.90 μg/g for androstenone and between 0.13 and 0.22 μg/g for skatole reported by Sather (1995). The latter values were obtained from sensory tests using a similar test method (3 Alternative Forced Choice test method) but with sunflower oil as base and involving less intensive training of the panel on the nature of the odour compounds. The reduction for the group threshold for androstenone in the study by Sather (1995) was found after a second replicate assessment, while the reduction for the skatole threshold was due to the elimination of skatole insensitive panellists from the calculation. Annor-Frempong *et al.* (1997a) explained that the sensory thresholds for androstenone and skatole varied to a large extent even within a well-trained panel. It seemed as if exposure to the odour compounds and training could also play an important role in threshold levels. Assessing of thresholds for the odour compounds in model lipid systems showed much larger differences between the detection thresholds for skatole and the proposed acceptability threshold at the time (0.2 to 0.25 μg/g), compared to that of androstenone.

2.3.6 The effect of heat processing on perception of boar odour

Cooking can reduce boar odour intensity due to losses of volatiles (Malmfors & Lundström, 1983). Processing reduced the concentration of boar odour related compounds and thereby also reduced the impact of perception (Pearson, Ngoddy, Price & Larzalere, 1971; Walstra, 1974; Desmoulin *et al.* as cited by Lundström & Malmfors, 1985). Products that were cooked (Paris ham) and dried (sausage) resulted in 45 % and 26 % reduction in the androstenone content, respectively. Walstra (1974), found that skatole levels were reduced significantly more than androstenone levels after processing of smoked sausages (pasteurised). Agerhem & Tornberg (1995b) and Nute *et al.* according to Annor-Frempong *et al.* (1997a) observed the same when cooking fresh meat. Androstenone levels remained fairly consistent under these processing conditions while skatole was reduced to one fifth of the original level. Although not stated, this was probably due to the lower melting and boiling points of skatole compared to

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androstenone. Annor-Frempong *et al.* (1997a) hypothesised that the residual levels of androstenone and skatole after cooking of pork meat should give better predictions of acceptability of boar odour of specific samples.

The method of applying heat influences flavour and aroma development produced by both the lean and lipid portions of meat (Paul, 1975). Amoore & Buttery (1978) commented that some odourants, such as steroids that have extremely low aqueous solubilities, have a strong tendency to absorb on metal or glass. The container, type of energy supplied, heat transfer medium, heating time and temperature (Zondagh *et al.*, 1994 citing Fischer & Weiler), internal end-point temperature (Agerhem & Tornberg, 1995a, 1995b) and total cooking time requirement (Paul, 1975) could influence the intensity and perception of meat aroma and flavour compounds and therefore potentially androstenone and skatole odour.

Agerhem & Tornberg (1995b) investigated the importance of different end-point cooking temperatures in relationship with skatole and androstenone concentrations on the development of off-flavours in pork loins (*M. longissimus dorsi*) and ham (*M. semimembranosus*). The two cuts showed differences in sensory off-flavour development at 68 °C and 80 °C. Skatole was found to be the main contributor to off-flavour development at 68 °C for both cuts. At 80 °C, androstenone contributed mostly to off-flavour of pork loins while skatole remained the more significant contributor for boar odour in *M. semimembranosus.* When androstenone was present at high concentration (1.0 to 2.7 μg/g) and skatole concentration was low (0.1 to 0.19 μg/g) in pork loins, off-flavour due to androstenone increased significantly at 80 °C compared to 68 °C. High skatole concentrations (0.2 to 0.3 μg/g) did not show a similar temperature dependency. The fact that differences were observed in the different muscles and at different end-point cooking temperatures, were regarded to be important aspects to be considered for development of on slaughter-line techniques for screening of boar odour.

Walstra (1974) prepared products using a dilution series of boar meat with and without boar odour in different proportion inclusions (0, 6, 12, 25, 50 and 100 %) of meat and fat with boar odour. It was concluded that the potency of boar odour was not easily "diluted" during product formulation, nor was it minimised by storage and processing. When

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smoked sausages prepared from boar meat and fat, with and without boar odour, were prepared, a trained panel could discriminate between the products. The products were evaluated both cold and warm and assessed by a trained panel using a 10-point scale (presumably a hedonic rating, although this was not stated). It was then concluded that inclusion of meat and fat from boar carcasses with boar odour up to 25 % when products are to be consumed cold, and up to 6 % when products are to be consumed warm, should not present odour or flavour problems.

Pearson *et al.* (1971) went so far as to conclude that boar meat can be utilised in a variety of products so long as it is not heated in the room where it is eaten. The suggestion was based on the observation that the major objections occurred during heating of the products and not during consumption. The authors made the suggestion that boar meat products could therefore be served in public eating places where the kitchen is isolated from the dining area, a sentiment shared by Nold, Romans, Costello, Henson & Libal (1997).

Chen, Forrest, Peng, Pratt & Judge (1993) conducted a study to determine whether cooking of pre-rigor boar meat would eliminate or reduce boar odour and lipid oxidation problems. It was hypothesised that cooking induced lipid oxidation products (unless meat pH > 6.0) and other odourants of the fat not normally regarded as taints can either mask or contribute to the perception of boar odour. However, the levels of boar odour of the samples in that study made it impossible to determine whether the method would have beneficial effects.

2.3.7 The potential time-intensity profile of boar odour perception

An aspect of boar odour that has not received much attention is the temporal perception, i.e. how does the intensity and character of the odour change over time? A blend or mixture of aroma compounds, whether assessed orthonasally or retronasally, usually has a non-linear character and imparts a base note, body or middle note and top note, a phenomenon sometimes referred to by the flavour industry as the flavour triangle (McPherson & Moran, 1994). The first perceived character is the top note. Once the most volatile components have evaporated the body note is apparent. An even longer lasting base note may also follow the body note. As a consequence of this, there is a

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change in odour or flavour character and intensity with time, resulting in the perception of two or more odour or flavour characters in succession.

In the case of a food product, odour or flavour release is dependent on the physico-chemical properties of the aroma compounds involved and the properties of the food matrix that affect the diffusion of the compounds within the food (Wilson & Brown, 1997). All these factors affect the availability of the odourants to the vapour phase and therefore their affinity for the product (Druaux & Voilley, 1997). Volatility describes the equilibrium headspace concentrations for a specific odour compound or the ability of a compound to reach the gaseous phase (De Roos, 1997). Since the boar odour compounds, skatole and androstenone, have different physico-chemical properties it would be logical to expect boar odour to have a changing temporal character.

Druaux & Voilley (1997) stated that the behaviour of aromas in the food matrix is one of the most important parameters involved in their retention in a product from its preparation to its consumption. The ratios of odourant distributions of fat-soluble compounds between product and water phase, and product and air phase, are described by the respective product-to-water and product-to-air partitioning coefficients. In a product like pork fat containing aqueous and lipid phases, a flavour compound distributes over all three phases, namely fat, water and air. De Roos (1997) commented that, in general, flavour release from the lipid phase of a food product proceeds at a lower rate than that from the aqueous phase (Figure 3). This was attributed to the fact that there is a higher resistance to mass transfer in lipids compared to the water phase. It was found that the release of fat-soluble compounds is delayed and that the maximum flavour intensity of these compounds is perceived at a later moment than that of their water-soluble counterparts. This may lead to differences in opinions regarding the intensity of the perceived odour or the acceptability of the odour depending on exactly when the sample material is assessed.

In addition lipids influence both the physical and chemical stability of flavours (De Roos, 1997). As an example a reduction in fat content would result in higher flavour loss during processing and storage, due to an increase in flavour volatility. It can be evaluated by measuring the vapour pressure of a pure compound (Goubet, Le Quere & Voilley, 1998). This could mean that during processing of pork products it would be

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anticipated that androstenone volatility would be affected to a greater extent by the final product composition especially regarding the fat content of the product and fat distribution.

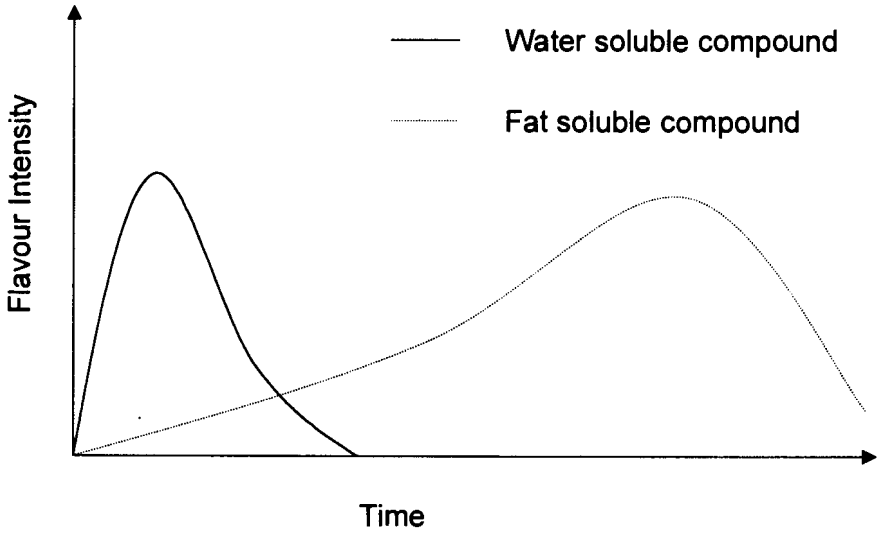

Figure 3: Time-intensity profile of flavour release from fat-containing foods

(De Roos, 1997)

Similar strongly lipophilic odour compounds e.g. methylisoborneol (an off-flavour of catfish) theoretically persists in the mouth for a length of time because it adheres to the fat of cell membranes. For such lipophilic compounds, water rinses may be ineffective for clearing it out of the mouth, a fact which may hinder subsequent evaluations (Bett & Johnsen, 1996). Although this effect has not been specifically studied for androstenone, anecdotal evidence is available that suggest that androstenone has a definite lingering ability that could affect subsequent evaluation of samples (Beery *et al.*, 1971).

2.4 Hedonic character of the odour and flavour of androstenone and skatole

Linked to the recognition of the character and intensity of androstenone and skatole, is a decision on the hedonic response. As can be expected, consumers were generally found to be less critical of differences in boar odour intensities than trained panellists (Matthews *et al.*, 2000). Malmfors & Lundström (1983) reviewed consumer studies on boar odour and reported that in general, criticisms of the flavour of boar meat were less

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common than criticisms of the odour. Matthews *et al.* (1997; 2000) reported that skatole contributed more than androstenone to the proportion of consumers which are dissatisfied with boar odour while both compounds contributed similarly to flavour.

Amoore (1977) and Thomson (1985) reported that some of the consumers who could smell androstenone were not offended by it and may even have found it pleasant. This observation was also described by Labows and Wysocki according to Babol & Squires (1995). Wysocki & Beauchamp (1984) reported that consumers that were highly sensitive to androstenone ascribed a foul odour to the steroid, usually stale urine or strong sweat. Most people are offended by the smell of skatole that has an acrid (bitter) taste, faeces-like odour, and they find it unpleasant (Griffiths & Patterson, 1970; Babol & Squires, 1995; Weiler *et al.*, 1997).

2.4.1 Ethnic differences in the hedonic reaction to boar odour

Beauchamp (1990) is of the opinion that inter-individual variation in hedonic reactions to foods is based on two interacting factors. The first is genetic differences between individuals or populations and the second is differences in experience strongly related to the individual's ethnic cuisine. Due, presumably to the reported genetic link to androstenone sensitivity, tolerance levels to boar odour have been reported to vary demographically and it can be concluded that the sensitivity to taint thus may vary dramatically between different countries and cultural groups (Squires, 1993). These differences as related to boar odour will become evident in the review of consumer studies to determine boar odour acceptability that have been conducted in different parts of the world.

It is often hypothesised that early experiences affect later preferences and aversions for particular food flavours. According to Beauchamp (1990) the complexity caused by the interaction of genetic factors and an individual's flavour exposure experiences is well demonstrated in the ability to perceive the odour of androstenone. Exposure to the odour of androstenone by some originally anosmic individuals (genetic factor) can increase the individual's ability to sense the odour, which could then affect his/her hedonic reaction to the odour. In addition, most and perhaps all very young children can smell androstenone but as they age, and particularly in the case of males, some individuals lose the ability to smell the substance. The reason for this is not clear.

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Constant or long term exposure or conditioning to boar odour has often been cited as a reason why certain population groups do not object to eating boar meat (Dijksterhuis *et al.*, 2000). These opinions are in line with powerful anecdotal evidence that constant exposure to odours appears to result in a lowered rather than a heightened sensitivity to some substances (Beauchamp, 1990).

2.4.2 Gender differences in the hedonic reaction to boar odour

Lundström *et al.* (1982) cited Elsey who reported in 1968 (at the time boar odour was linked only to androstenone) that women were more sensitive to boar taint than men. Similarly Griffiths & Patterson (1970) reported that women found androstenone to be more unpleasant than men did. Malmfors & Lundström (1983) reported that women were more sensitive to boar odour than men, although wide within-sex variations have also been noted. Matthews *et al.* (2000) confirmed the more negative responses from females compared to males. However, Godt *et al.* (1996) using sample material representative of the Danish boar production (0.00 to 0.39 μg/g skatole and 0.00 to 1.99 μg/g androstenone) reported no differences in the proportions of men and women offended by boar odour. The evaluations were performed to test the effects of both skatole and androstenone. Rhodes (1971) also did not find a significant gender effect when consumers in England evaluated bacon samples.

There are no intrinsic differences between men and women as regards olfactory sensitivity (Amoore, 1977; McPherson & Moran, 1994). However, Doty (1991) in a review of olfactory studies reported that, in general, women outperform men on tests of odour identification, detection and discrimination. A potential contributing factor for gender differences in hedonic response to boar odour might be the fact that androstenone is present in human secretions and excretions and is more abundant in males than in females. It is also reported that androstenone could alter human behaviour, act as a sexual attractant and might have special effects on emotions and sexual responses. However, Wysocki, Pierce & Gilbert (1991) regarded these assumptions as controversial and tentative. The same authors reported that a relationship existed between sensitivity to androstenone and its perceived pleasantness; those who have low thresholds generally disliked androstenone, while those with high thresholds generally were either indifferent or even inclined to like the odour. Another observation was that those who disliked the odour of androstenone tended to give higher intensity ratings to a given concentration of this

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odour. Very little information is available on gender differences, if any, with regard to the hedonic reaction towards the specific odour of skatole.

2.4.3 Other factors affecting the hedonic reaction to boar dour

Matthews *et al.* (2000) observed differences in liking of boar odour for European consumers of different age groups. The oldest group of consumers had the lowest percentage of dislike scores for both flavour and odour. It is well known that sensitivity to odours decreases with age (Beauchamp, 1990). In addition, those consumers who never were involved with the cooking process, were also less critical of boar odour than those who always did the cooking. On the other hand, consumers who ate pork less often compared to regular consumers, were more critical of boar samples for both odour and flavour perception. No study has looked at whether smokers and non-smokers differ in their hedonic rating of boar odour, but Amoore (1977) reported no intrinsic differences in the general olfactory sensitivity between smokers and non-smokers. Beauchamp (1990) summarised some general factors that could influence hedonic judgements to foods and identified momentary differences in fullness, what was recently consumed, time of day and expectations, as important.

2.5 Consumer studies on boar taint

Many consumer studies have been conducted internationally to determine consumer reactions to both processed products and fresh meat from boars. The objective of most of the studies was to determine the attitudes of ordinary consumers when preparing and eating boar meat in the normal domestic environment. These studies vary greatly in terms of the number of consumers surveyed, type of products tested and planning and design of the surveys. It is therefore difficult to compare differences in consumers' reactions as they can be attributed to many factors e.g. type of respondents, size of consumer panel, type and number of products sampled, sample materials differences, levels of boar taint in samples, preparation methods etc. Different food habits, food preparation and presentation methods may also influence the recognition of tainted pork during or prior to consumption.

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2.5.1 United Kingdom (UK) & Ireland

Consumer trials in the United Kingdom (Rhodes, 1971; Rhodes, 1972; Rhodes & Krylow, 1974; Lesser, Baron & Robb 1977, Kempster, Dilworth, Evans & Fischer, 1986 and Warkup, Dilworth, Kempster & Wood, 1990) and Ireland (Cowan & Joseph, 1981) have generally concluded that boar taint is not detected or rejected by consumers. In 1981, it was reported that in Ireland and the United Kingdom 40 % and 10 %, respectively, of young male animals are not castrated, and that this has not caused any major problems (Moerman, 1982). However, it should be noted that in the UK, pigs are usually slaughtered at 90 kg live weight while pigs in other European Community countries are slaughtered at 110 kg live weight.

Later, Warriss, Brown & Nute (1993) cited the UK Meat & Livestock Commission that reported (in 1989) that gilts were found to have better pork odour and less abnormal odour but no differences in flavour, juiciness and tenderness. These researchers also confirmed the findings using a trained panel. Matthews *et al.* (2000) found that 16 % of the UK consumers disliked a representative group of boar samples. This group showed, similar to the scores for Dutch consumers, the lowest dislike percentage of all seven of the European countries included in that study. It was concluded that the findings were supported by the reported lower sensitivity to androstenone due to anosmia of British consumers compared to other European consumers (Wysocki *et al.*, 1991).

2.5.2 Netherlands

Four consumer trials have been conducted to determine boar odour sensitivity of Dutch consumers. Walstra & Maarse (1970) found a slight negative consumer reaction to boar meat compared to gilts and the reaction was greater for fatty compared to more lean meat. However, a large variation in consumer reaction among different carcasses was observed. Walstra (1974) stated that sufficient evidence was available based on a research project involving 720 Dutch families and using pork cutlets and belly cuts, to allow the fattening of boars for local and international consumption. However, it was also concluded that boar meat with a strong odour would not be acceptable to those consumers who can detect it.

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Walstra *et al.* (1986) found that consumer reaction to boar taint was dependent on the concentration of androstenone and/or skatole. The study included 395 families consisting of a total of 1055 individuals. During eating, the percentage of negative responses for odour (all family members) was about one third lower than during cooking (cooks' responses).

Matthews *et al.* (2000) found that only a small percentage (16 %) of Dutch consumers showed a dislike for boar samples. Interestingly; this group was the only one in the European study showing significant effects for androstenone when assessing the odour of boar samples. Although consumer studies showed that boar odour should not be a problem to Dutch consumers, The Netherlands still follows a castration policy and excludes boar production for meat purposes. One reason for this is the fact that exports to Germany form a significant part of Dutch pig production and Germany does not tolerate high androstenone levels (Personal communication Dr P Walstra, Researcher ID-DLO, 1998).

2.5.3 France

Desmoulin, Bonneau, Frouin & Bidard (1982) compared the results from laboratory and consumer panels with androstenone content and found that levels of < 0.5 μg/g fat resulted in a low incidence of boar taint and unpleasant odours. An androstenone content of 1.0 μg/g in fat or higher gave a higher risk of boar taint and unpleasant odours. In contrast to Denmark, studies from France have shown that levels of 5 α –androstenone were more highly correlated to boar taint than was skatole. Resulting from this study three groups of boar meat (untainted, slightly tainted and highly tainted) were distinguished. This classification was used for meat that was suitable as pork or for processing with or without dilution.

Matthews *et al.* (2000) found that 31 % and 36 % French consumers disliked the flavour and odour of boar samples, respectively. To put these values in context it could be compared to the 19 % and 28 % of European consumers disliking the flavour and odour of gilt samples, respectively. Of all the countries included in the study, the French group of consumers was found to be the most offended by the flavour of boar samples.

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2.5.4 Sweden

The Swedish home-use consumer trial (Lundström *et al.*, 1982) also tested consumer reaction when informed that some test products could be boar meat compared with reactions from uninformed consumers. It was also concluded that odour pleasantness was of major importance regarding the impression of flavour - there were fewer negative reactions to flavour than to odour. Test products consisted of controls (gilt meat), tainted and untainted boar meat. Classification was based on trained sensory panel results. Strength of odour was found to be of no importance to consumers. This study showed that, on average, there were hardly any differences in consumer reactions between gilt meat and boar meat classified as non-tainted, but it was concluded that there might be some reaction to boar meat even when it has been pre-classified as non-tainted. Consumers informed that boar taint might occur in the product were on the whole more critical, not only to boar meat but also to gilt meat. It was recommended that if boar meat was to be introduced into the market, attention should be paid to the kind of information published, as this might result in a critical attitude to all pig meat.

Agerhem & Tornberg (1995a) did find significant differences in the percentage of consumers that did not approve of the flavour of boar and gilt meat. Acceptability of the samples was described by skatole (68 %) and androstenone (59 %), respectively. Matthews *et al.* (2000) reported that the majority of the Swedes were critical of both odour and flavour of boar samples. This was also the only group where skatole was more strongly correlated with flavour than odour. This group also showed significant flavour effects for androstenone.

2.5.5 Denmark

Mortensen, Bejerholm & Pedersen (1986) found that when boars were selected so that only those with a low content of skatole were used for producing meat for consumers, there were only a few adverse comments on meat quality compared with barrows. In Denmark entire male pigs are slaughtered when they reached the normal slaughter weight of 74 kg (Larson, Mejborn, Maribo & Bejerholm, 1995). Studies from Denmark have consistently found that skatole is the more important component of taint (Vahlun as cited by Squires, 1993, Godt *et al.*, 1996). For that reason an initial cut off level of 0.20 μg/g skatole in fat was used for screening purposes, but it was later raised to

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0.25 μg/g to reduce the number of rejected carcasses when few consumer complaints were found. Although skatole is regarded as the major contributor to boar odour under Danish conditions, Matthews *et al.* (2000) reported that the Danish consumers were one of only two groups showing a significant flavour effect for androstenone. Interestingly, Walstra *et al.* (2000) reported that the pig population of Denmark had a very low percentage of pigs with skatole levels exceeding 0.25 μg/g.

An interesting finding by Godt *et al.* (1996) was an interaction effect for consumer liking of boar odour between low concentrations of androstenone and high concentrations of skatole. Also in that study, including 539 families in four geographical locations of Denmark, no gender effect was found for evaluation of the eating quality of boar samples. The evaluation of odour while eating was found to be consistent with the odour while preparing the meat.

2.5.6 Spain

A consumer study (Diestre, Oliver, Gispert, Arpa & Arnau 1990) in Spain was prompted when the practise of castration was eliminated from commercial pig production units to increase their profitability. The meat industry and especially retailers complained about boar carcasses mainly because of the problem of boar taint. They claimed that this led to consumer rejection of pig meat and pig products. The consumer tests were planned to assess the reactions of Spanish consumers to fresh and processed meat from boars and barrows and to determine the influence of androstenone levels in fat on the consumer responses.

The home-use consumer trial (Diestre *et al.*, 1990) involving 3 boar taint level subgroups according to fat 5 α-androst-16-ene-3-one concentration (μg androstenone per g fat), [Low < 0.5 μg/g; Medium 0.5 – 1.0 μg/g; High > 1.0 μg/g] indicated that boar meat can produce an unfavourable response from Spanish consumers for fresh meat (chops) or products needing heating prior to consumption (brine-cured bellies). However, in cooked products with hot processing and cold consumption (cooked ham) no negative effects from using boar meat were observed.

They concluded that there is some justification of the criticisms and claims of retailers against boar taint, since these are supported by the consumer response obtained.

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However, there were differences in the judgements depending on the type of product that was evaluated, the type of consumer (cook or family member) and whether boar responses were analysed overall or as a particular taint-level subgroup according to androstenone concentration in the fat. Acceptability of low and medium taint levels in boars were found to be not different from barrows and that the higher proportion of unpleasant judgements was found for the high taint level.

Matthews *et al.* (2000) found the reactions of the Spanish group to be comparable to the boar odour sensitive consumers in other countries included in that study. Weiler *et al.* (2000) also showed that Spanish consumers were at least equal to Germans in as far as sensitivity to androstenone is concerned.

2.5.7 Germany

The Germans are convinced that no boars should be slaughtered for pork and they maintain that with their production system, it is also not economical to market boars (Landbouweekblad, 1993). Underestimation of androstenone sensitivity because of the unknown factor of distribution of androstenone anosmics in consumer panels, prompted Weiler *et al.* (2000) to extend the EU boar odour consumer investigation (Matthews *et al.*, 2000). The androstenone sensitivity of Spanish and German consumers was measured to be able to quantify the effect of insensitivity on the consumer responses on boar odour. It was argued that for consumers that are sensitive or highly sensitive to androstenone, assumed acceptance of boar odour obtained from consumer studies where this aspect is not considered, is inapplicable. Matthews *et al.* (2000) showed that 41 % of German consumers disliked the odour and 19 % disliked the flavour of boar samples. Weiler *et al.* (2000) found 18 % and 15 % respectively of the German group to be highly sensitive or mildly sensitive to androstenone. This may explain the lower percentage of negative reactions to flavour compared to odour.

2.5.8 Australia & New Zealand

Intact males (80 - 100 kg live weight) are raised for pork production and boar odour is a problem to some extent. Pork consumption figures for Australia for the year ending June 1995 was 18,6 kg per capita (Personnel communication Ms V Boghossian, Researcher: Australian Food Research Centre 1996). Apparently boar odour seems to be a problem for the high Asian population in Australia and she attributed this to the fact that boars are

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castrated in Asia and therefore Asians might not be conditioned to boar taint. Other Australians who are sensitive to boar taint have stopped buying pork. She was of the opinion that current pork consumers are 'conditioned' to boar taint and it does not bother them or they are just not sensitive to it. Boar taint was believed to be less of a problem in New Zealand because the boars are not reared to the same high weights as they were in Australia.

2.5.9 Canada

The risk of boar taint is regarded as even greater in Canada than in many other countries, since the desirable live market weight of pigs is in excess of 100 kg and close to 30 % of the national production of pork is exported (Sather, 1995). A consumer home-use study was conducted whereby individual families were provided with 2 loin chops each from boar, castrate or gilt carcasses. A three times higher percentage of consumers ascribed an unpleasant odour (7.4 %) and flavour (5.9 %) to cooked boar meat compared to gilts and castrates. Interestingly, a higher percentage of consumers rated the meat from boars as being pleasant provided that the unpleasant odour was not present.

2.5.10 United States of America

Judge *et al.* (1990) and Nold *et al.* (1997) mentioned that the production and merchandising of boar meat was not widely used and adopted in the USA. Pearson *et al.* (1971) concluded that products containing boar meat were not readily distinguishable from similar control (no boar odour) products. However, the conclusion was surprising in that the results presented showed that out of a total of 22 products evaluated using a triangle test, 12 of the products showed significant differences. The inappropriate practice of using an extended triangle test to determine whether two samples are significantly different and then following that with a question to determine preference for either the pair or the single sample, make the validity of the hedonic results from this study questionable. Nold *et al.* (1997) also found that most consumers were not negatively affected by the odour or flavour of boar meat and ranked it as desirable overall. Interestingly, it was concluded that meat from light to medium-weight boars may be used for institutionalised food preparation situations in which consumers are not present during the cooking of the product.

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2.5.11 South Africa

No information is currently available on the attitude of South African consumers towards pork from boars. A review of the composition of the population, pork consumption and pork production is included as background information.

In July 1994, the population of South Africa was estimated to be about 44 million. It has a heterogeneous composition in which various black ethnic groups (75 %), whites (14 %), coloureds (9 %) and Indians (2.6 %) make up the majority of the population. The black, white and coloured groups represent the South African pork eating population. Due, mainly to religious reasons, by far the majority of the Indians do not consume pork. The pork consuming groups have different meat eating habits (Viljoen, 1996) and attitudes towards pork in general (Snyman & Van Rensburg, 1990; Viljoen, 1996) which could mean their reactions to boar odour may also differ.

The black consumers in South Africa consist of four main ethnic language groups namely Nguni, Sotho, Venda and Tsonga (Hammond-Tooke according to Viljoen, 1996). Coloureds represent 9 % of the population and are a mixed-race people of a wide range of genetic backgrounds. About 85 % live in the Western Cape province of South Africa. They commonly have lighter brown or yellow skin and some Negroid features although skin colour and features vary considerably, because of the broad gene pool represented (Jenkins, 1996). Many of the white section of the population and small numbers of blacks, coloureds and Indians enjoy incomes, comforts, health and educational standards that are similar to those in Western Europe. The living standard of the rest of the population, however, is similar to developing countries (Brown, Robinson & Fischer, 1996).

South African *per capita* consumption of pork is much lower than most European countries (Table 2) and consumption of pork by different South African population groups (Table 3) varies with whites representing the highest *per capita* consumption and blacks and Indians the lowest as was measured in 1985 and 1993 (Personal communication, Mr A Azar, Economist, Meat Board, 1994). The dietary pattern of the whites and coloureds are generally regarded as a Western diet (Langenhoven *et al.* according to Viljoen, 1996).

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Table 2: Comparison of per capita consumption of pork in different countries (Landbouweekblad, 1993)

Country	*Per capita* consumption (kg)
South Africa	3,47
England	24,1
France	37,4
Denmark	64,5
The Netherlands	45,8
Germany	58,8
Australia – June 1995*	18,6

* (Personal communication, Mrs V. Boghossian, Researcher: Australian Food Research Centre 1996)

Table 3: Comparison of *per capita* consumption (kg) of pork by various ethnic groups in South Africa (Personal communication, Mr A Azar, Economist Meat Board 1994)

	Population group			
	Whites	**Coloureds**	**Blacks**	**Asians**
1985	12.68	1.43	0.55	0.08
1993	16.15	3.44	0.63	0.86

In addition to the low consumption of pork by blacks, a large section of the black community, estimated to be more than 50 %, reported that they do not serve or consume pork (Table 4). For the black groups, the pig as an animal has never had the same cultural significance and value attached to it as for example cattle and goats (Quinn, 1959). Traditionally, meat was regarded as a luxury item by blacks and pork in particular did not play a major role in the daily diet. The relatively low consumption could be attributed to various reasons as obtained from a consumer survey (Meat Board, 1987). The reasons given by white and black population groups for not serving pork are summarised in **Error! Reference source not found.** 4. Most of the reasons cited by black respondents for not serving pork refer to *cultural, religious and regional* food factors or *intrinsic* product factors, while white respondents cited *intrinsic* product factors as well as *cultural, religious, regional, educational* and *personal* factors.

Table 4: Reasons for not serving pork (Meat Board, 1987)

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Table 4: Reasons for not serving pork (Meat Board, 1987)

Reasons	*Population groups	
	% Whites	% Blacks
	26.3 % do not serve pork	56.3 % do not serve pork
Religious	4.7	19.1
Do not like pork	11.2	8.2
Health reasons	2.4	-
Too fatty/rich	2.5	-
Too expensive	1.9	-
Allergic reaction	1.6	-
Feel sick/sore throat/nauseous	-	12.3
Other	4.0	2.8

* This survey did not include Coloured and Indian population groups in South Africa

Approximately 2 million pigs are marketed annually in South Africa. Of these approximately 45 % are castrates due to the castration policy that is followed. This represents a total of about 55.8 million kg pork meat. Snyman in 1994 estimated that a change to boar production could mean a substantial saving of money, then predicted to be around ZAR 41.65 million. This saving was regarded as good enough reason to invest in the implementation of equipment, if available, at abattoirs to monitor boar odour levels of individual carcasses (according to Landbouweekblad, 1994). However, the question remained, how similar was boar odour as found in South Africa to that experienced in other countries and particularly Europe. Was it a skatole, androstenone or a combination problem and how would consumers react to boar odour?

During a Workshop on Boar Taint (Heinze & Viljoen, 1994,) involving producers, processors and researchers, it was agreed that boar odour in South Africa needed to be investigated. A survey was planned to measure the concentrations of skatole, androstenone and indole in a population of boar carcasses produced under typical South African conditions. An analytical sensory study was planned to determine the relative contribution of the odour compounds to boar odour and consumer reactions to boar taint

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had to be tested. It was foreseen that answers to these issues would be needed before making a decision on whether or not to promote the production of boars.

2.6 Summary

Boar taint has been studied by international scientists for at least the last 30 years. However, very few detailed and extensive studies have been conducted where the perception of boar odour, as perceived by the human subject, are addressed in a fully structured way. Part of the difficulty for the human subject is that the main compounds responsible skatole, androstenone and possibly indole do not occur independently. The human, unlike analytical instruments, determines the evaluation of the odour/flavour as an immediate response and then attempts to rationalise the stimulus in terms of descriptions and hedonic feelings about the odour or flavour.

Aspects that may affect the human perception of boar odour include; concentrations and interaction effects of the compounds androstenone and skatole present in pork, the physico-chemical properties of boar odour compounds, interference due to the presence of other compounds in pork fat and meat, differences in the properties of especially pork fat and meat composition (fat, water, protein ratios) that affect odour volatilisation and retention. In addition, various inherent difficulties (e.g. enhancement and interaction of odour compounds, differences in olfactory sensitivity to the compounds, the temperature at which the samples are assessed and the time period between heating and assessing pork samples) exist when applying standard sensory practices, using both trained and consumer panellists, which makes data interpretation very difficult and complex. Human perception of boar odour seems also to be affected by genetic differences between individuals and populations and experience related to traditional eating patterns.

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Chapter 3

Objectives

The first objective of the research was to investigate the relative contribution of different concentrations of skatole and androstenone to the perception of boar odour in boar fat, immediately after heating the fat and following a cooling period.

The following hypotheses were formulated:

Skatole and androstenone will contribute to the perception of boar odour in different ways that will be affected by the concentrations of the odour compounds in boar fat and the time-temperature condition of the boar fat after heating. The differences in the physico-chemical properties of skatole and androstenone will lead to differences in the rates of volatilisation as well as retention of the odours in the fat that would affect the temporal perception of boar odour. Skatole will be volatilised faster and androstenone will be retained for a longer period in the fat structure. This is due to the assumption that skatole, being more hydrophilic compared to androstenone, would be more volatile and less affected by the retention properties of the lipid base (pork fat). In a lipid environment such as pork fat, it is expected that the concentration of the more lipophilic compound, androstenone, in the aqueous and vapour phases would be lower compared to that of skatole that is more water soluble, and its odour impact may therefore also be lower.

De Roos (1997) found that the higher the proportion of a flavour compound in the lipid phase, the higher is the increase in its stability. A hypothesis for boar odour perception would thus be that skatole and androstenone odours would be more stable at higher compared to lower concentrations.

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A second objective was to determine the effects of gender (males, females) and ethnicity[1] on consumer reactions to boar odour in boar fat samples with different concentrations of skatole and androstenone.

The following hypotheses were formulated:

Females would like boar odour originating from samples with detectable concentrations of androstenone less than males. Most reports have shown that women find androstenone more unpleasant than men do. In addition more males compared to females have been reported to be anosmic to the smell of androstenone.

It is expected that the odour of samples with detectable skatole concentrations will be less liked by consumers from both genders compared to control samples with below threshold concentrations of both skatole and androstenone. This is because most individuals can smell skatole and find it unpleasant.

The different ethnic groups would have different hedonic reactions to boar odour because of different pork consumption habits and *per capita* consumption levels of pork. Possible differences in sensitivity to androstenone may also be found based on genetic differences among the ethnic groups residing in the same demographic area.

[1] Ethnic: designating or of any of the basic divisions or groups of mankind, as distinguished by customs, characteristics, language, etc. or a member of an ethnic group, especially a member of a minority or nationality group that is part of a larger community (Dept of Art & Design, 1999).

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Chapter 4

Materials and methods

4.1 Experimental design

The study was designed to include both analytical and consumer sensory assessments of various back fat samples obtained from boar carcasses. Other studies often included either samples from gilts or castrates as controls. However, it was decided to concentrate on the boar odour problem in boar carcasses and to regard samples with below threshold concentrations of both skatole and androstenone in pork meat (as indicated by most literature at the time of planning the experiment to be 0.20 μg/g for skatole and 0.5 μg/g for androstenone) as control or untainted samples. The reported differences in meat quality and especially fat quality properties (Babol *et al.*, 1996, Potgieter *et al.*, 1998) of boars, castrates and gilts were factors that motivated this decision. In addition all sensory evaluations were limited to smelling of fat samples and not consumption of meat. The reason for this was that most of the boar odour studies correlated sensory perceptions of pork meat and sometimes pork fat with concentrations of skatole and androstenone as measured in fatty tissue. Since the correlations that were found under these conditions were usually quite low, it was anticipated that correlations would improve if direct measurement of skatole and androstenone concentrations could be linked to odour perception of the same tissue material.

Figure 4 shows the conceptual framework for the research. The analytical sensory experiment was designed to determine if the human nose could effectively evaluate intensities of different concentrations of skatole and androstenone in pork fat over a period of time after the product had been heated. In addition the ability of the nose to determine the difference between skatole and androstenone in pork fat was tested. A trained sensory panel was used in order to describe the character and intensity of the odour profiles under the two time/temperature conditions.

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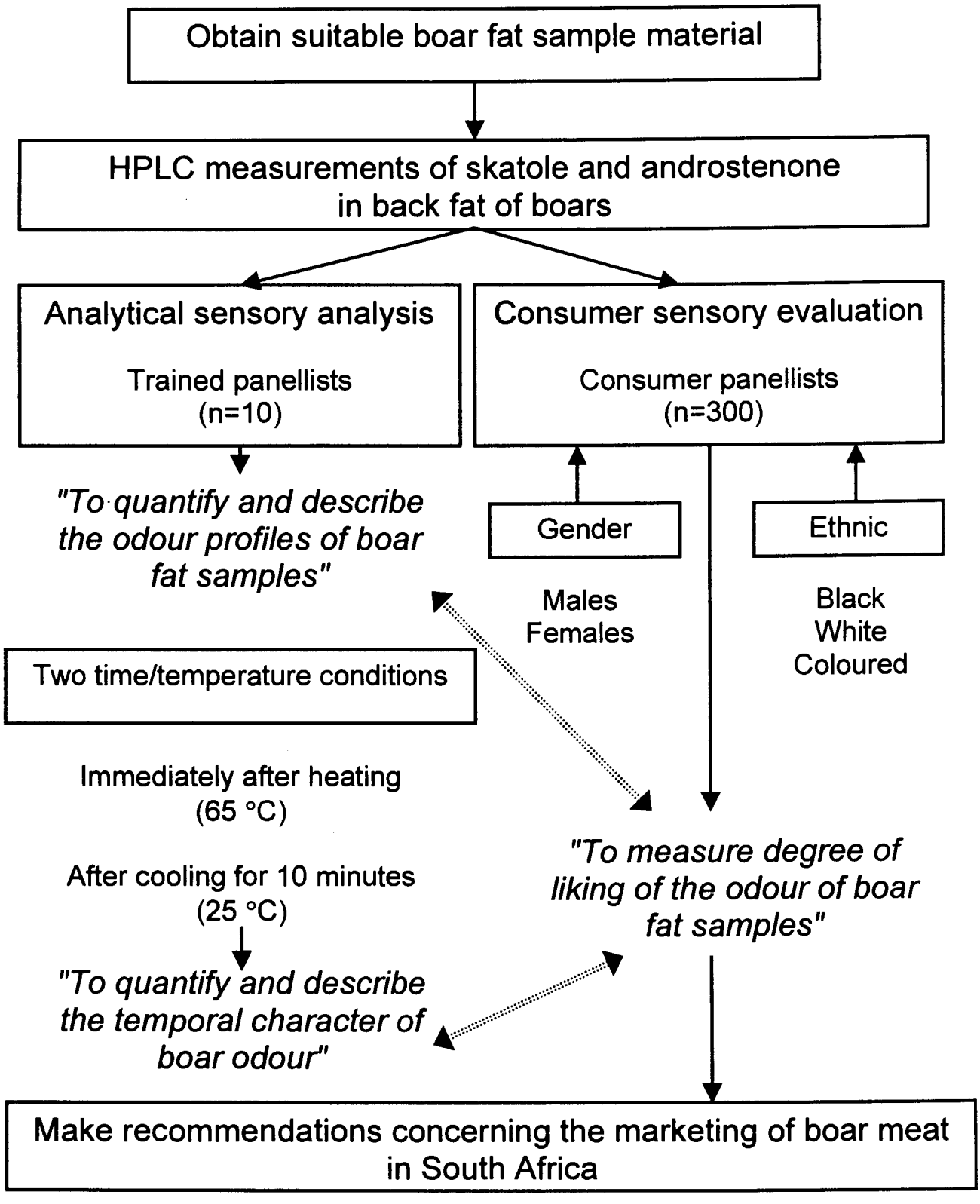

Figure 4: Conceptual framework for the research

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Pork eating consumers, including equal numbers of males and females, from three South African ethnic groups, were used to evaluate the degree of liking of the odours of boar fat samples. The consumer study was not representative of the consumer reaction to boar odour of the South African population in general since the consumers used for the study were mainly of a younger age group (18 – 35 years) and of an above average living standard level. However, it was foreseen that the information gained from the analytical sensory analysis would be useful to possibly explain and interpret the consumer responses.

4.2 Pork fat sample collection

Pork fat samples (± 50 g) were taken, immediately after slaughter, from the back fat (anterior area of the loin) of boars with an average slaughter weight of 72 kg (range 57.6 to 93.8 kg) at a commercial South African pig abattoir. The individual samples were placed in 200 X 150 mm coded plastic bags and transported to ARC-ANPI in cooler bags (± 4 °C) and analysed for skatole and androstenone concentrations within 24 hours. Analyses were performed by High Performance Liquid Chromatography (HPLC), using a C18-column (3.9 mm x 150 mm), isopropanol as extraction medium and a water/acetonitrile/tetrahydrofuran solvent gradient (a modification of the method of Hansen-Møller, 1994). The use of chromatographic methods can be advantageous in that a number of related compounds could be measured at the same time. The methods are also quite specific and are not affected by interfering compounds. Disadvantages of the chromatographic methods are related to them being time consuming, technically difficult and expensive (Squires, 1993)

From the HPLC results, specific carcasses (a total of 102 carcasses) were selected to incorporate low, medium and high skatole and androstenone concentrations in a 3 x 3 matrix. Unfortunately, in the time period available and taking into account the financial and technical resources available, it was not possible to collect equal numbers of boar carcasses to fill all the cells optimally as was initially intended. At the time of sample collection, and due to the official castration policy, information on the distribution of skatole and androstenone concentrations in South African pigs was limited. The majority of boar carcasses screened during that time had either low or very high concentrations of both compounds. It was particularly difficult to find boar carcasses with high skatole

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but low androstenone concentrations. The back fat from both the right and left loins of each of the selected carcasses was removed approximately 24 hours after slaughter, and was cut into 5 approximately equal portions. This yielded a total of 10 individual samples from each carcass, 2 samples for the analytical sensory analysis and 8 to be used for consumer evaluation. Each individual fat portion was coded, individually vacuum-packed in an impermeable nylon/polyethelene bag, frozen and stored (-20 °C) until required for the sensory tests. The fat samples were stored for a maximum of 10 months. Extra samples were collected for methodology development and sensory panel training purposes. The actual distribution, within the concentration ranges, of the fifty samples that were used during the final study is shown in Table 5 and Figure 5.

4.3 Analytical sensory analysis

4.3.1 Trained sensory panel

4.3.1.1 Screening of the panel

Sixteen people were screened for participation on the sensory panel according to the test protocol defined by ASTM Practice E 679-79 (American Society for Testing and Materials, 1991). This protocol uses the 3 Alternative Forced Choice (3-AFC) test method. A set of three samples (two blank oil samples and one oil sample spiked with skatole or androstenone) is presented and the panellist is requested to identify the spiked sample. Samples for screening were prepared by dissolving pure skatole and androstenone (Sigma-Aldrich Co Ltd, Poole) in refined poly-unsaturated pure vegetable oil (Golden Drop®, P O Box 768, East London, South Africa).

A total of seven sets of three samples each were presented to each panellist during a session. The sets (Table 6) were arranged in order of increasing concentrations of the spiked samples. Separate tests were conducted, in duplicate, to determine the sensitivity (detection thresholds) for skatole (range 0.059 to 0.675 μg/ml), androstenone (range 0.298 to 3.400 μg/ml) and skatole and androstenone in combination (Skatole/Androstenone range 0.059/ 0.298 to 0.675/ 3.400 μg/ml).

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Table 5: **Ranges and means (± standard deviation) of low, medium and high skatole and androstenone concentrations in back fat samples (n = 50 samples) that were used for sensory analysis**

		Fat Androstenone (An) level (µg/g)		
		Low (L) <0.5	**Medium (M) 0.5-1.25**	**High (H) >1.25**
Fat Skatole (Sk) level (µg/g)	**Low (L) <0.15**	**L Sk L An** n = 5 Sk = 0.08 (±0.04) An = 0.21 (±0.13)	**L Sk M An** n = 11 Sk = 0.09 (±0.04) An = 0.82 (±0.18)	**L Sk H An** n = 6 Sk = 0.08 (±0.04) An = 1.47 (±0.16)
	Medium (M) 0.15-0.25	**M Sk L An** n = 4 Sk = 0.18 (±0.02) An = 0.27 (±0.15)	**M Sk M An** n =6 Sk = 0.19 (±0.02) An = 0.79 (±0.17)	**M Sk H An** n = 3 Sk = 0.19 (±0.02) An = 3.02 (±1.05)
	High (H) >0.25	**H Sk L An** n = 2 Sk = 0.83 (±0.32) An = 0.37 (±0.07)	**H Sk M An** n = 9 Sk = 0.52 (±0.28) An = 0.84 (±0.20)	**H Sk H An** n = 4 Sk = 0.76 (±0.51) An = 3.33 (±1.46)

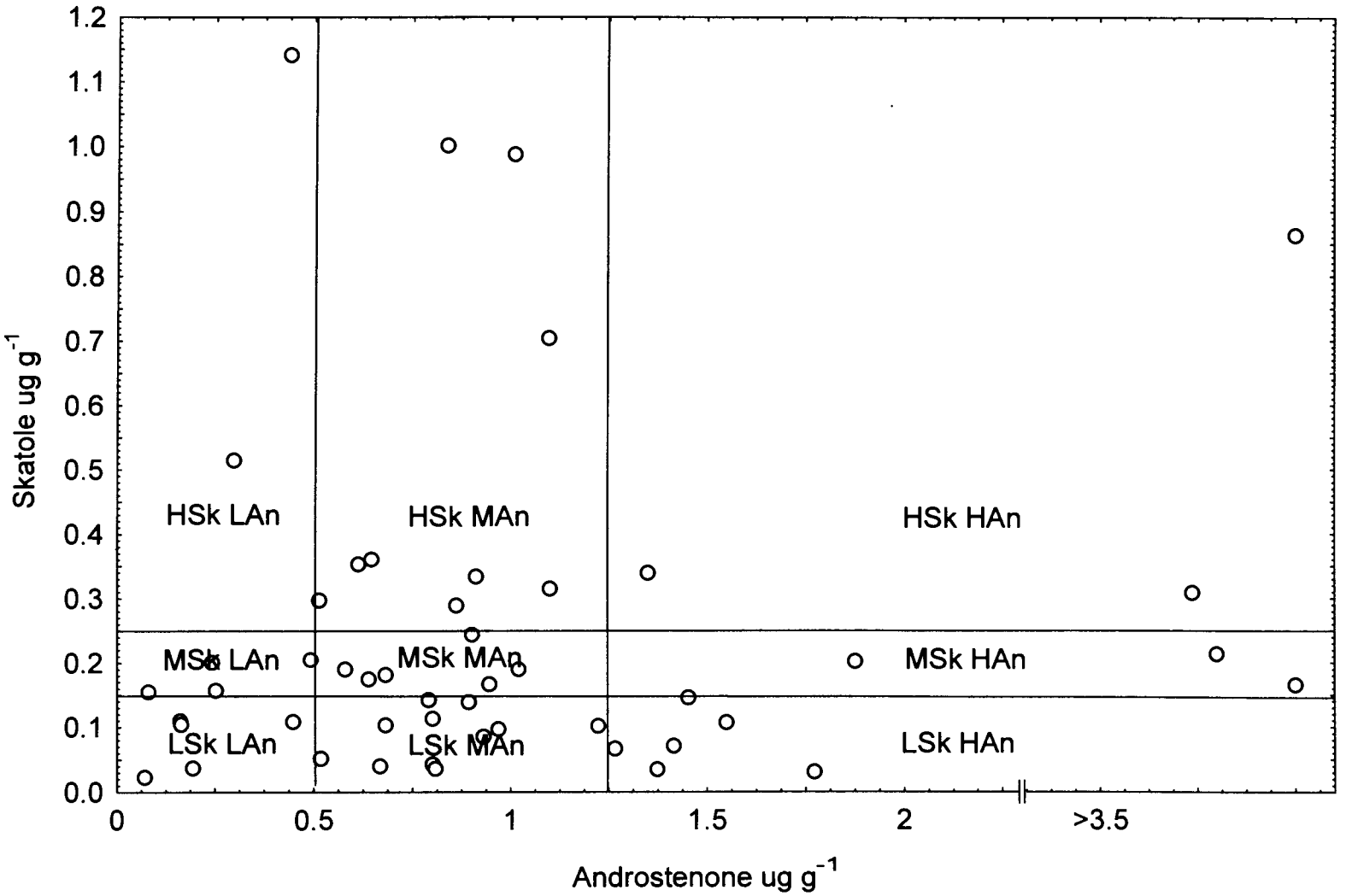

Figure 5: Distribution of carcasses with regard to skatole and androstenone concentrations

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Table 6: Description of concentration series of spiked oil samples used for panel screening

	Androstenone concentration series	Skatole concentration series	Combined skatole/androstenone concentration series	
	µg/ml oil	µg/ml oil	Skatole µg/ml oil	Androstenone µg/ml oil
1	0.298	0.059	0.059	0.298
2	0.448	0.089	0.089	0.448
3	0.672	0.133	0.133	0.672
4	1.007	0.200	0.200	1.007
5	1.511	0.300	0.300	1.511
6	2.267	0.450	0.450	2.267
7	3.400	0.675	0.675	3.400

Oil samples (3 ml) were presented to panellists in 50 ml glass polytop containers covered with Parafilm M (American National Can™, Greenwich, CT 06836). Immediately prior to heating the samples the panellists individually replaced each of the microfilm coverings with a 50 mm x 50 mm aluminium foil square. Samples for each panellist were heated in sand baths (preheated for 45 minutes in an oven at 180 °C) that were placed on individual hot plates (Estia, setting 2). A set of three samples (two blank oil samples and one spiked oil sample) was heated together for 60 seconds. Panellists then removed the samples from the sand baths, removed the foil coverings and had to identify, by smelling, the spiked sample in each set.

The results of the screening tests were used to identify the 10 most sensitive panellists from the initial group for further training. Table 7 shows the detection thresholds for skatole and androstenone for the selected 10 panellists.

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Table 7: Screening sensory thresholds for androstenone and skatole (μg/ml sunflower oil) for trained panellists

Panellist	Androstenone (μg/ml oil)				Skatole (μg/ml oil)				Overall threshold ranking[3]
	Replicate 1	Replicate 2	Average threshold[1]	Threshold ranking[2]	Replicate 1	Replicate 2	Average threshold	Threshold ranking	
A ♀	0.077	0.077	0.077	1	0.048	0.048	0.048	1	1
B ♀	0.077	0.077	0.077	1	0.048	0.048	0.048	1	1
C ♀	0.549	4.164	2.357	7	0.048	0.048	0.048	1	3
D ♂	1.234	1.234	1.234	5	0.048	0.244	0.146	4	4
E ♀	0.077	0.077	0.077	1	0.367	0.826	0.597	9	5
F ♂	1.234	0.077	0.656	4	0.163	0.048	0.187	6	5
G ♂	2.776	1.234	2.005	6	0.367	0.048	0.208	7	7
H ♀	4.164	2.776	3.470	9	0.244	0.048	0.146	4	7
I ♂	0.823	4.164	2.494	8	0.367	0.048	0.208	7	9
J ♀	2.776	4.164	3.470	9	0.367	0.826	0.597	9	10
Group	1.379	1.804	1.619		0.207	0.235	0.223		

♀ = Females, ♂ = Males

[1] The average threshold is the average of replicates 1 and 2.

2 The threshold ranking is a ranking of the ten panellists according to lowest to highest average threshold for the indicated compound.

3 The overall threshold ranking is a ranking of the ten panellists in terms of thresholds for both skatole and androstenone from lowest to highest ranking

Note that these thresholds may have decreased with the further training and exposure to test samples and the analytical nature of the sensory analysis task (Powers & Schinholser, 1988). However, it is interesting to note that panellists A and B were able to consistently identify the spiked sample at the lowest concentration levels. Panellist E was able to identify androstenone at the lowest concentration level but was one of the least sensitive panellists with regard to skatole. The three panellists with the lowest overall thresholds were all females but so was the panellist that ranked 10th in terms of overall threshold. Selection also meant that these panellists had indicated that they would be available for the entire period of evaluation.

4.3.1.2 Training of the panel

After screening, the final panel consisting of 10 members (6 females and 4 males) was further trained over a period of two weeks (a total of 10 hours). Training of the panel was done according to a generic descriptive analysis procedure as described by Einstein (1991). This implied familiarising the panellists with general sensory analysis principles, identification of terms to describe androstenone and skatole odours using pork fat samples of known skatole and androstenone concentrations and development of a suitable evaluation form. Panellists were paid R20 per day for taking part in the sensory analysis tests.

4.3.2 Evaluation of the pork fat samples

Fat samples from 50 carcasses were evaluated in duplicate by the trained sensory panel using five descriptive terms (Table 8) and 10-point intensity rating scales (Figure 6) marked at the extreme ends (none, extreme). The first replicate included samples from the left side of each carcass while samples from the right sides were used for the second replicate. A total of ten evaluation sessions were held in a controlled sensory laboratory with individual sensory booths following standard sensory practices (Stone & Sidel, 1993). Two sessions with a 20 minutes break between sessions were held per day between 10:00 and 12:00. Five blind-coded samples, selected at random from the 50 carcasses (Table 5), were presented per session i.e. a total of ten samples per day. The presentation order of samples selected on a specific day was randomised over the 10 panellists.

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Table 8: Descriptive terms and definitions used by the trained panel to evaluate boar odour

Descriptive term	Definition
Skatole intensity	Aromatics associated with skatole – barnyard, manure, faeces-like
Androstenone intensity	Aromatics associated with androstenone – urinous, sweaty
Pork fat, cooked	Aromatics associated with normal cooked pork fat
Pork fat, grease	Aromatics associated with normal cooked pork at room temperature
Other	Any other aromatics not specifically defined in this list

SAMPLE CODE ☐

	NONE									EXTREME
SKATOLE, MANURE/FAECES-LIKE	0	1	2	3	4	5	6	7	8	9
ANDROSTENONE, SWEATY, URINOUS	0	1	2	3	4	5	6	7	8	9
PORK FAT, COOKED	0	1	2	3	4	5	6	7	8	9
PORK FAT, GREASE	0	1	2	3	4	5	6	7	8	9
OTHER: SPECIFY	0	1	2	3	4	5	6	7	8	9

Figure 6: Descriptive analysis rating scales used by the trained sensory panel

The frozen pork fat portions were partially thawed for 30 minutes at room temperature (±18 °C). The rind of each fat portion was removed using a sharp knife and ten cubes (10 mm x 10 mm x 10 mm) were cut. Each cube was placed in an aluminium foil container (Hullett's 55 mm diameter, 20 mm height) and covered tightly with a 90 mm x 90 mm aluminium foil square. The samples were heated for 5 minutes in an AEG oven (Model B88.1 LFV), which had been preheated to 180 °C, and served to the panel. After removing the samples from the oven they were kept warm on heated sand baths that were placed on Estia solid hot plates (Setting 1). A one-minute waiting period was observed between smelling of successive samples allowing for recovery of the olfactory system. Samples were evaluated immediately after heating (± 65 °C) and again after allowing the then opened samples to cool (± 25 °C) for 10 minutes. The panellists left the evaluation room and went outside after evaluating the warm samples and returned after 10 minutes to evaluate the cooled samples. The evaluation forms consisted of two

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separate sheets, one sheet yellow for evaluating the warm samples and one blue sheet for recording the ratings of the cooled samples.

4.4 Consumer sensory evaluation

4.4.1 Consumer panels

A total of 300 pork eating consumers, including equal numbers of males and females from three different ethnic groups, namely black, white and coloured consumers were used to evaluate pork fat samples with different levels of skatole and androstenone. The concentrations ranged from presumably sub-threshold concentrations for both compounds (< 0.15 μg/g for skatole and < 0.5 μg/g for androstenone, i.e. L Sk L An) to presumably, if not anosmic, clearly detectable levels (> 0.25 μg/g for skatole and > 1.25 μg/g for androstenone, i.e. H Sk L An, L Sk H An or H Sk H An groups). Figure 7 indicates the overall representation of consumers from different ethnic language groups participating in the evaluation of the boar fat samples. The black group consisted mainly of Sotho or Nguni language speakers, while the majority of the white and coloured consumers were Afrikaans-speaking (Figure 7). The majority of the consumers were Afrikaans speaking with a 31 % representation of traditional black languages. The reason for the high numbers of Afrikaans speaking consumers can be attributed to the fact that the two locations namely, University of Pretoria and University of Stellenbosch, that were used for the tests and where recruiting took place were, historically Afrikaans language institutions. The respondents were recruited by advertising in the local university newspaper distributed on the university campus and by using field workers. Respondents consisted mainly of students and staff members which consumed pork or pork products regularly (at least once a week). Each respondent attended only one evaluation session.

4.4.2 Evaluation of the pork fat samples

The consumer tests with the black and white groups were conducted (12 to 15 May 1997) at the University of Pretoria (UP), Pretoria and the test with the coloured group was conducted (10 to 12 February 1998) at the University of Stellenbosch (US), Stellenbosch. Evaluation was done in a sensory laboratory fitted with 16 individual sensory booths at the UP and in a food preparation laboratory with 16 individual working stations at the US.

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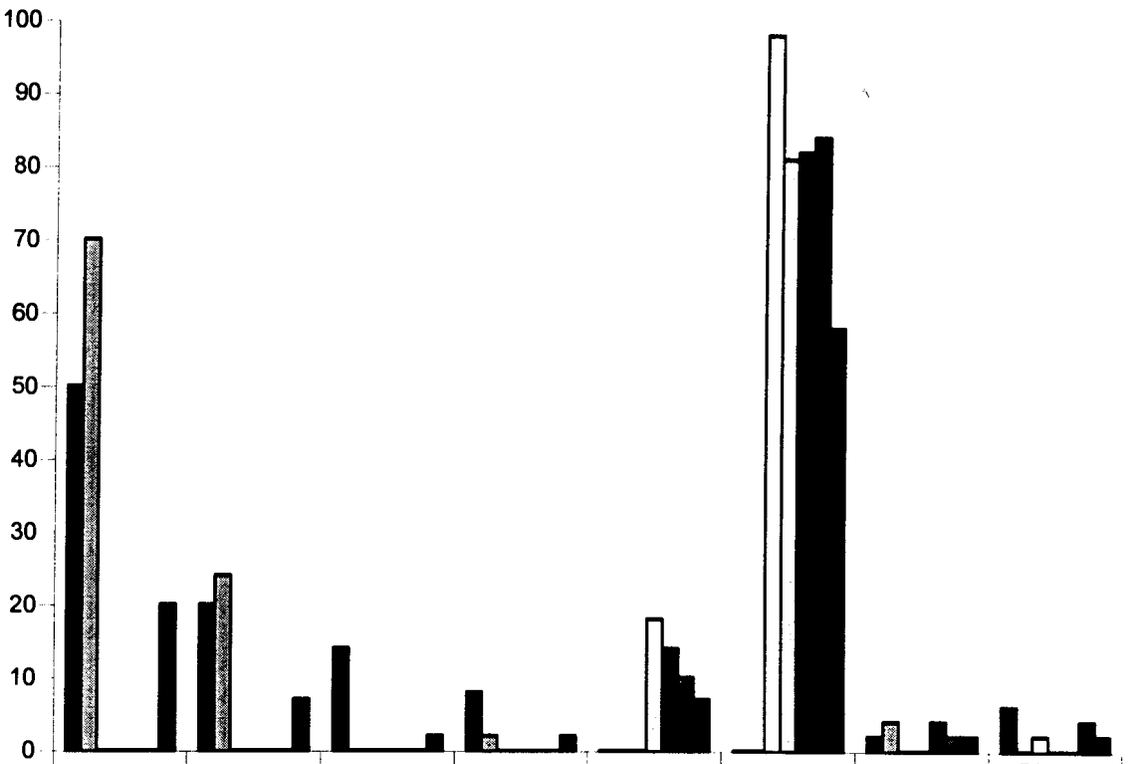

	Sotho	Nguni	Venda	Tshonga	English	Afrikaans	Other	Did not indicate
Black males	50	20	14	8	0	0	2	6
Black females	70	24	0	2	0	0	4	0
White males	0	0	0	0	0	98	0	2
White females	0	0	0	0	18	81	0	0
Coloured males	0	0	0	0	14	82	4	0
Coloured females	0	0	0	0	10	84	2	4
All consumers	20	7	2	2	7	58	2	2

Figure 7: Ethnic language profiles (%) of male and female consumers of three ethnic groups (n = 100 per ethnic group) participating in the sensory evaluation of boar fat samples

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Respondents were asked to judge seven pork fat samples in a specific order (Table 9) by responding to the question *"How much would you like to eat pork/pork products that smell like this sample?"* Samples for each respondent were coded with randomly selected 3-digit code numbers. Judgements were recorded by marking a 9-point scale with word anchors (dislike extremely and like extremely) at the extreme ends (Figure 8). The respondents were also requested to write down words to describe what they smelled. At no point were any of the respondents asked to reveal his/her identity (name or surname). It was regarded as extremely necessary for the consumers to feel totally free to respond negatively without fear of being identified taking into account the potentially undesirable nature of the samples.

Table 9: Order for presenting the samples to consumers

Presentation order	Samples
1st sample	L Sk L An
2nd, 3rd & 4th samples	Samples taken randomly excluding L Sk L An, H Sk L An, L Sk H An and H Sk H An.
5th sample	H Sk L An OR L Sk H An
6th sample	L Sk H An OR H Sk L An
7th sample	H Sk H An

After the respondents had evaluated the samples they were asked to complete a questionnaire. The purpose of the questionnaire was to gain information on gender, age, home language and smoking habits of the respondents. A separate section was included to obtain information on the living standards of each respondent. The living standards measures questions were developed by the South African Advertising Research Foundation (1995) based on the All Media and Products Survey (AMPS). This is a survey that is regularly conducted to gain information on household use of various types of products by South Africans. By means of a set of specific questions that was identified by AMPS, it is possible to group all persons forming part of the South African population into one of eight possible living standards groups.

These groups ranged from LSM 1 representing the poorest individuals to LSM 8 representing the most affluent sector of the population. The study was not designed to be representative of all or even some of the LSM groupings but it was necessary to obtain a clear picture of the consumers who took part in the study.

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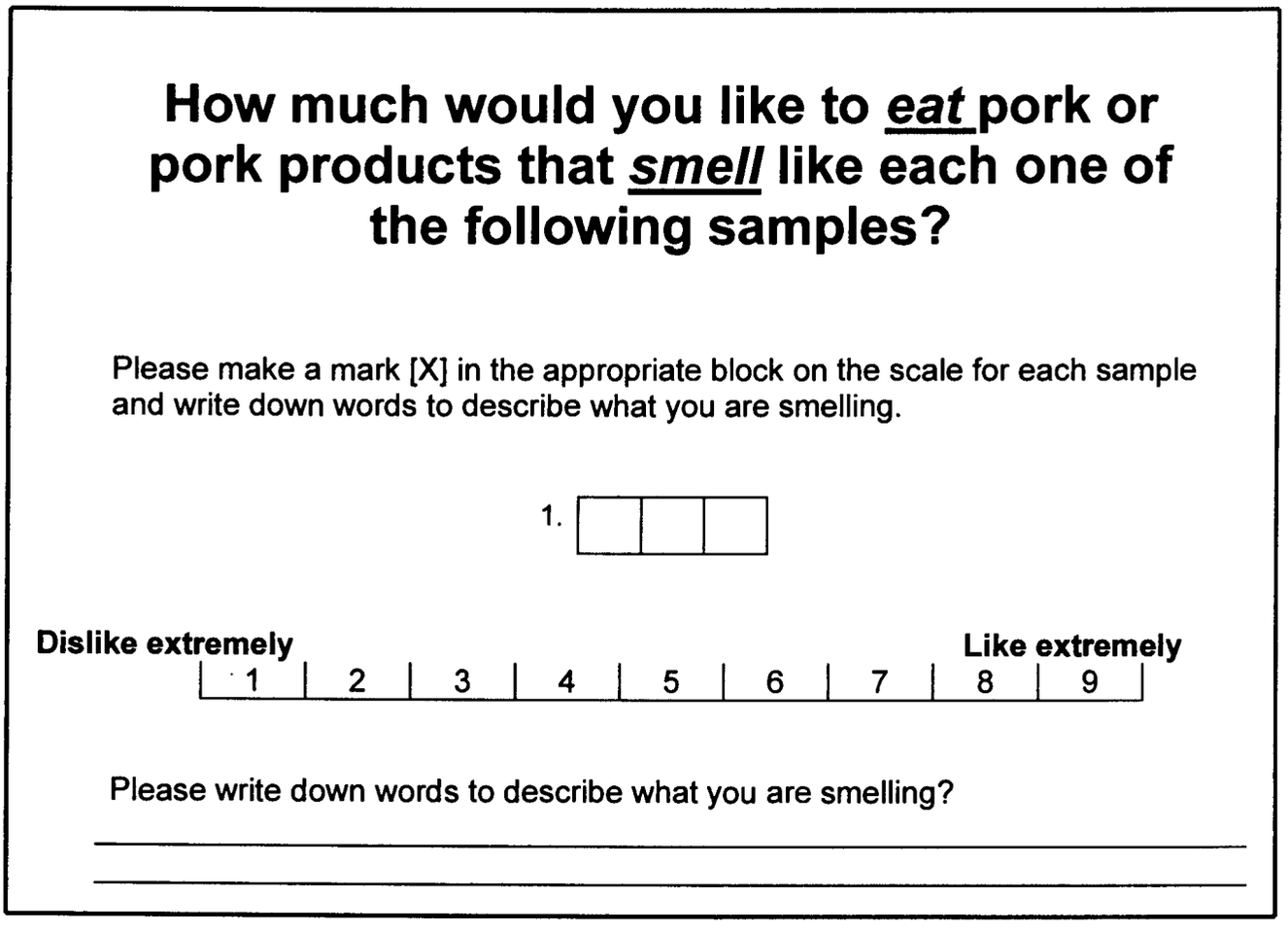

Figure 8: Example of the score sheet used for the consumer evaluation of boar fat samples

See Appendix B for a summary of the comments from consumers

If significant differences between the gender or among the ethnic groups were to be found, it was anticipated that differences in living standard measures might possibly be one of the explanatory reasons. The last section of the questionnaire asked consumers to indicate how much they liked to eat pork and to indicate how frequently they consumed pork in either the fresh or processed form. It was anticipated that pork consumption habits might potentially influence consumer perception of boar odour (Appendix A). Each consumer received a gift voucher to purchase goods at a local supermarket after completing the test and questionnaire.

Pork fat from the selected carcasses used for the consumer tests with the black and white panels could not be used for the coloured panel because of an unfortunate breakdown in the university's freezer facility causing the designated sample material to spoil. Pork fat samples from extra carcasses that were not evaluated by the

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trained panel but kept frozen at another facility were used for the evaluation by the coloured panel.

4.4.3 Sample preparation

When preparing the samples for the consumer panels, frozen pork fat portions were partially thawed for 30 minutes at 4 °C. The rind of each fat portion was removed using a sharp knife and the fat cut into the required number of 10 mm x 10 mm cubes. Each cube was placed into an aluminium foil container (Hullett's 55 mm diameter, 20 mm height) and covered tightly with a coded 90 mm x 90 mm aluminium foil square. Each consumer evaluated a total of seven samples presented in a specific order. Samples for the consumer panels were heated by the consumers themselves on Estia solid hot plates (Setting 3) for 2 minutes and then evaluated by smelling once they had removed or punctured the foil covering using the tip of a sharp pencil.

The same sampling plan (Table 9) including the same sample identity and serving order was set up beforehand and applied similarly to both the male and female participants from all three of the ethnic groups. Some deviations for the coloured consumers will be explained in detail. All consumers (n = 300) evaluated samples, served warm, from the four extreme groups of skatole and androstenone concentrations, i.e. L Sk L An, L Sk H An, H Sk L An and H Sk H An (Table 5). Fat samples from two representative carcasses per group were used. The skatole and androstenone concentrations of these specific samples are indicated in Table 10. All consumers received the control (L Sk L An) sample first. The idea was that the L Sk L An sample would serve as an untainted reference point against which the samples with detectable skatole and/or androstenone could be compared. Pork fat samples from any of the remaining 42 carcasses were randomly assigned to the second, third and four serving position for each of the 50 consumers within each group. A sample each from the L Sk H An and H Sk L An groups were served in the fifth and sixth sample positions. The order allocation for these positions was balanced over each group of 50 consumers. The seventh sample was always from the H Sk H An group.

The coloured consumers also evaluated samples from the four extreme groups but these samples were not from the same carcasses as those used for the evaluation with the black and white consumer panels. Another difference for this group was that the

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fat sample (only one was used in this case) representing the H Sk H An group had a androstenone concentration of 1.03 μg/g, therefore not > 1.25 μg/g. For these reasons the results for the coloured group will be reported separately and cannot be directly compared with that of the black and white panels.

Table 10: Skatole and androstenone concentrations (μg/g fat) of the respective boar fat samples[1] that were used to represent the extreme groups for the black and white consumer panels

	Skatole concentration μg/g fat	Androstenone concentration μg/g fat
L Sk L An		
Sample 1	0.02	0.07
Sample 2	0.04	0.20
L Sk H An		
Sample 1	0.07	1.41
Sample 2	0.03	1.77
H Sk L An		
Sample 1	1.14	0.43
Sample 2	0.51	0.29
H Sk H An		
Sample 1	0.86	4.01
Sample 2	1.55	5.24

[1] Sample 1 was evaluated by consumers 1 to 25 and sample 2 by consumers 26 to 50 in each gender/ethnic group.

4.5 Statistical analysis

All the data was collected in spread sheets using Microsoft Excel 97 and all the statistical analyses were done using Statistica 5.0 (Statsoft . Inc., 1995).

4.5.1 Analytical sensory analysis

Analysis of variance (ANOVA), Principal Component Analysis (PCA) and Correlation analysis were used to analyse the mean sensory ratings provided by the trained sensory panel for evaluation of the pork fat attributes. For ANOVA 1 (Table 11), the main effects and two-way interaction effects of androstenone and skatole concentrations, replicate (first versus second) and temperature of serving (warm

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Table 11: Guide to statistical analyses by ANOVA of analytical sensory panel results

ANOVA 1 Dependant variables for 5 separate ANOVAs: Skatole intensity, Androstenone intensity, Pork fat, cooked, Pork fat, grease, Other			
Source	**Degrees of freedom**	Significant differences by ANOVA were further analysed using Least Significant Difference (LSD) test	Results presented in Table 13
1. Androstenone concentration	2		
2. Skatole concentration	2		
3. Replicate	1		
4. Temperature of serving	1		
1x2	4		
1x3	2		
1x4	2		
2x3	2		
2x4	2		
3x4	1		
Error	180		
Total	199		

ANOVA 2 Dependant variables for 4 separate ANOVAs: Skatole intensity (warm serving), Skatole intensity (cold serving), Androstenone intensity (warm serving), Androstenone intensity (cold serving)			
Source	**Degrees of freedom**	Significant differences by ANOVA were further analysed using Least Significant Difference (LSD) test	Results presented in Table 14
1. Panellists	9		
2. Skatole concentration	2		
3. Androstenone concentration	2		
1x2	18		
1x3	18		
2x3	4		
1x2x3	36		
Error	909		
Total	1000		

The effect of individual panellists' ratings (df = 9) on the odour profiles of boar fat samples served warm and cold, respectively, with regard to the attributes *skatole* and *androstenone* intensity were also analysed (ANOVA 2 -Table 11). For these analyses, the main effects of skatole and androstenone concentrations and the relevant interaction effects were also included. Pearson product moment correlations were used to investigate linear relationships between androstenone and skatole concentrations and sensory ratings.

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4.5.2 Consumer sensory evaluation

Classification of consumers and rated liking of odour scores for all boar samples were initially compared by Kruskal Wallis ANOVA by median tests. Mean liking of odour scores for all samples were analysed by ANOVA (ANOVA 1 - Table 12) to test for the effects of smoking habits (smokers versus non-smokers), liking of pork in general (five categories ranging from "strongly dislike" to "like a lot"), frequency of consuming fresh pork (five categories ranging from "very often" to "never") and frequency of consuming processed pork (five categories ranging from "very often" to "never"). No interaction effects were included in the model. Where the p-values were < 0.05, the LSD-test was used to investigate the specific differences.

Liking of the smell of boar odour samples were analysed by ANOVA (ANOVA 2 - Table 12) for the effects of skatole concentration, androstenone concentration, gender and ethnic grouping as well as the relevant two-way interaction effects, by including all responses from black and white consumers pertaining to samples as subdivided into three concentration levels (low, medium & high) each of skatole (< 0.08 μg/g, 0.08 to 0.25 μg/g and > 0.25 μg/g) and androstenone (< 0.5 μg/g, 0.5 to 1.25 μg/g and > 1.25 μg/g). These concentrations were chosen *a priori* to represent approximately equal numbers of responses for each concentration combination of skatole and androstenone. The same ANOVA model (ANOVA 3 - Table 12) but excluding the effect of ethnic grouping was tested separately for the coloured panel.

Correlation analysis was performed using Pearson product moment correlation coefficients to determine the relation between consumer liking of the odour of samples and skatole and androstenone concentrations, as well as odour profiles by the trained sensory panel of skatole and androstenone intensities. This analysis was only done using the data from the black and white consumers.

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Table 12: Guide to statistical analyses by ANOVA of consumer panel results

ANOVA 1			
Dependant variable: Hedonic score			
Source	**Degrees of freedom**	Significant differences by ANOVA were further analysed using Least Significant Difference (LSD) test	Results presented in Table 16
1. Smoking	1		
2. Liking of pork	4		
3. Frequency of consuming fresh pork	4		
4. Frequency of consuming processed pork	4		
Error	2086		
Total	2099		

ANOVA 2			
Dependant variable: Hedonic score (black and white consumers)			
Source	**Degrees of freedom**	Significant differences by ANOVA were further analysed using Least Significant Difference (LSD) test	Results presented in Table 17
1. Skatole conc.	2		
2. Androstenone conc.	2		
3. Gender	1		
4. Ethnic group	1		
1x2	4		
2x3	2		
2x4	2		
3x4	1		
Customized error term (pooled all remaining 2-way, 3-way and 4-way interaction effects)	1354		
Total	1369		

ANOVA 3			
Dependant variable: Hedonic score (coloured consumers)			
Source	**Degrees of freedom**	Significant differences by ANOVA were further analysed using Least Significant Difference (LSD) test	Results presented in Table 18
1. Skatole conc.	2		
2. Androstenone conc.	2		
3. Gender	1		
1x2	4		
1x3	2		
2x3	2		
Error	678		
Total	691		

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Chapter 5

Results

5.1 Analytical sensory analysis

5.1.1 The effects of skatole and androstenone concentrations, time/temperature of serving and replicate sessions on the odour profiles for boar fat samples

The main effects of skatole concentration, androstenone concentration, time/temperature of serving and replicate sessions on descriptive sensory odour profiles of boar fat samples, are presented in Table 13. No significant interactions ($p > 0.05$) of the main effects were found.

The samples with skatole concentrations above 0.25 μg/g, i.e. high skatole (H Sk) samples, were perceived to have significantly higher *skatole* and significantly lower *pork fat cooked* intensities compared to samples with skatole concentrations below 0.25 μg/g (L Sk and M Sk samples). The panel could not significantly distinguish between samples in the L Sk (< 0.15 μg/g) and the M Sk (0.15 – 0.25 μg/g) groups using these descriptors. However, samples with skatole concentrations below 0.15 μg/g had significantly higher *pork fat grease* intensities than those samples with skatole concentrations above 0.15 μg/g.

The samples with androstenone concentrations above 0.5 μg/g (M An and H An) were perceived to have significantly higher *androstenone* intensities compared to samples with androstenone concentrations below 0.5 μg/g (L An). The panel could not significantly discriminate between M An (0.5 – 1.25 μg/g) and H An (> 1.25 μg/g) samples in terms of *androstenone intensity*. All the other sensory characteristics did not differ significantly for the three concentration levels of androstenone.

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Table 13: Significance, mean sensory ratings and identified differences for the effects of skatole and androstenone concentrations, time/temperature of evaluation and replicate evaluations on descriptive odour characteristics[1] of boar fat samples as obtained by analysis of variance

Sensory attributes[2]	Main effects for ANOVA (No significant interaction effects were found and these results are therefore excluded from the table)									
	Skatole concentration (µg/g)			Androstenone concentration (µg/g)			Time/Temperature of evaluation		Replicate	
	Low	Medium	High	Low	Medium	High	Warm	Cold	First	Second
	<0.15	0.15-0.25	>0.25	<0.5	0.5-1.25	>1.25	65 °C	25 °C		
Skatole intensity		P<0.001			NS		P<0.001		P<0.01	
	2.3[a]	2.6[a]	3.1[b]	2.5	2.7	2.8	3.4[b]	2.0[a]	2.9[b]	2.5[a]
Androstenone intensity		NS			P<0.01		P<0.001		NS	
	3.1	3.1	3.1	2.8[a]	3.3[b]	3.4[b]	3.4[b]	2.8[a]	3.2	3.1
Pork fat cooked		P<0.01			NS		P<0.001		NS	
	1.2[b]	1.2[b]	0.8[a]	1.2	1.0	1.0	1.2[b]	0.9[a]	1.1	1.1
Pork fat grease		P<0.001			NS		P<0.001		P<0.05	
	0.6[b]	0.4[a]	0.4[a]	0.4	0.5	0.5	0.3[a]	0.7[b]	0.5[b]	0.4[a]
Other		NS			NS		P<0.05		P<0.05	
	0.3	0.3	0.3	0.3	0.3	0.2	0.4[b]	0.2[a]	0.4[b]	0.2[a]

[1] For individual main effects, mean scores in a row with different superscripts ([ab]) differed significantly at the indicated significance level

NS = Not significantly different (p>0.05)

[2] Rating scale (0 = None, 9 = Extremely intense)

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A very important observation was that significant differences were found for the intensity of all the sensory descriptors when comparing warm to cold serving. After cooling down, the pork fat samples had significantly lower perceived *skatole*, *androstenone*, *pork fat cooked* and *other* intensities. As expected, the intensity of *pork fat grease* increased significantly after the samples had cooled down. The descriptor, *pork fat grease* referred to the aroma of untainted pork fat at room temperature.

Although no significant interaction effects for time/temperature of serving and skatole or androstenone concentrations were observed, an indication was observed when the mean scores were plotted (Figure 9). Odour profiling showed that the trained panel, overall, could mostly distinguish between low and high levels of skatole and androstenone when samples were warm and were smelled immediately after heating. However, after the samples had cooled down, the classification was not so clear anymore. When served cold, the intensity of *skatole* was found to be consistently lower than the perception of *androstenone intensity*, even at H Sk concentrations. Note specifically for the cold evaluation that for samples with H Sk concentrations the panel was unable to classify the L An, M An and H An status of these samples using the term *androstenone intensity*. After cooling, the panel did not detect the H Sk concentration of samples when combined with L An concentrations, although this was indicated when the samples were warm. When served warm and the samples were smelled for the first time, skatole contributed as expected to the odour profile. When samples cooled down, it seemed that the relative contribution of androstenone to the odour profile of all the concentration levels increased.

The panel gave significantly lower scores during the second replicate compared to the first replicate for *skatole*, *pork fat grease* and *other* intensities, while no significant differences were observed for the evaluation of *androstenone intensity* and *pork fat cooked*.

5.1.2 Effect of panellist

The main and interaction effects of panellists, skatole concentration and androstenone concentration were separately analysed by ANOVA to determine whether ratings by individual panellists influenced the perception of *skatole* and *androstenone* intensities (Table 14). Two separate ANOVAs were performed for the two time/temperature conditions, i.e. warm and cold.

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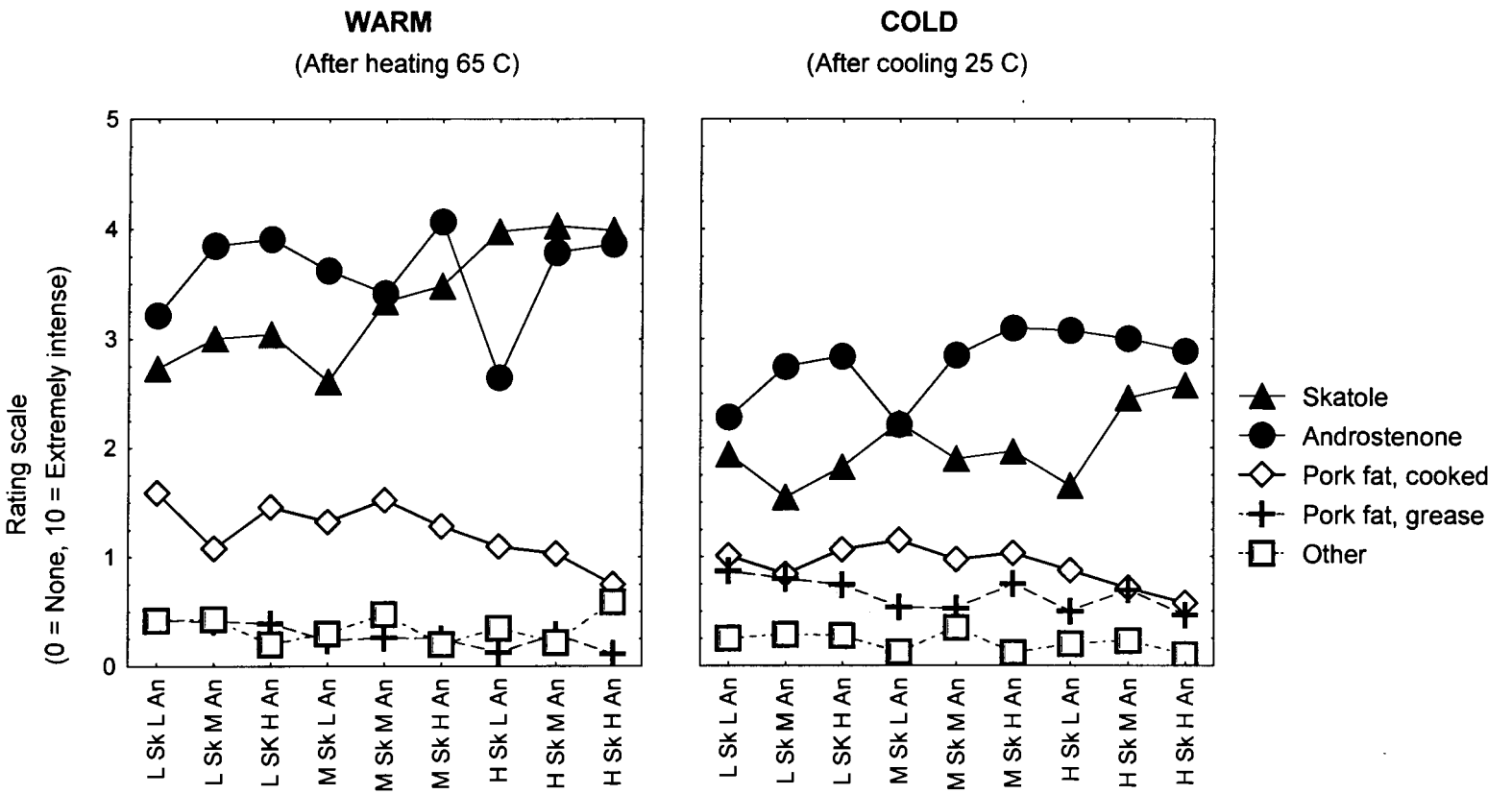

Figure 9: The plot of different average, trained panel, sensory ratings for boar fat samples with various skatole and androstenone concentrations when served warm and cold

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Table 14: P-values[1] for ANOVA to indicate the effect of panellists on the rating of skatole and androstenone intensities when samples were served warm and cold

	Skatole intensity		*Androstenone intensity*	
	Warm 65 °C	Cold 25 °C	Warm 65 °C	Cold 25 °C
Panellists	< 0.001	< 0.001	< 0.001	< 0.001
Skatole concentration	< 0.001	0.05	NS	NS
Androstenone concentration	NS	NS	0.05	NS
Panellists x Skatole concentration	< 0.001	0.01	< 0.001	0.05
Panellists x Androstenone concentration	0.01	NS	NS	NS
Skatole x Androstenone concentration	NS	NS	NS	NS
Panellists x Skatole concentration x Androstenone concentration	NS	0.05	NS	NS

1 NS = Not significantly different ($p > 0.05$)

The results showed that, when served warm and assessed immediately after the samples were heated, panellist had a significant effect on rating of both *skatole* and *androstenone* intensities. For the rating of *skatole intensity*, significant interaction effects were evident for both panellist x skatole concentration and panellist x androstenone concentration. In fact, for cold serving, a significant ($p < 0.05$) three-way interaction effect for panellist x skatole concentration x androstenone concentration was found for the rating of *skatole intensity*. This meant that the panellists were not able to use the term *skatole intensity* in the same manner under the influence of varying concentrations of both skatole and androstenone. Only the panellist x skatole concentration interaction effect had a significant influence on the perception of *androstenone intensity*.

When samples had cooled down and were evaluated for a second time, the main effect of panellist continued to influence ratings for both *skatole* and *androstenone* intensities. The interaction effects concerning panellist x skatole concentration were still influencing the perceived *skatole* and *androstenone* intensities. Under the conditions of cooled down samples no panellist x androstenone concentration interaction effects were significant.

Table 14 shows that overall skatole concentration seemed to have the greatest effect on the panellists' abilities to consistently rate perceptions of both *skatole* and *androstenone* intensities. Figure 10 to Figure 13 are included as examples to show how the individual panellists differed in their ability to rate differences in skatole concentrations in boar fat. It is clear that different panellists used different sections of the rating scale to indicate their perceptions. Most, but not all, of the panellists were able to distinguish the skatole concentrations when the samples were hot. Figure 10 shows that panellists G and I rated the samples with the highest skatole concentrations the lowest in terms of skatole intensity. When comparing Figure 10 and Figure 11 it is clear that the separation of boar fat, based on skatole concentrations were more difficult when samples were cold compared to when the samples were served warm. Figure 12 and Figure 13 show that most panellists found it difficult to rate *androstenone intensity* in the presence of varying skatole concentrations. Some panellists, notably H and I seem to have used the term *androstenone intensity* to indicate increasing concentrations of skatole.

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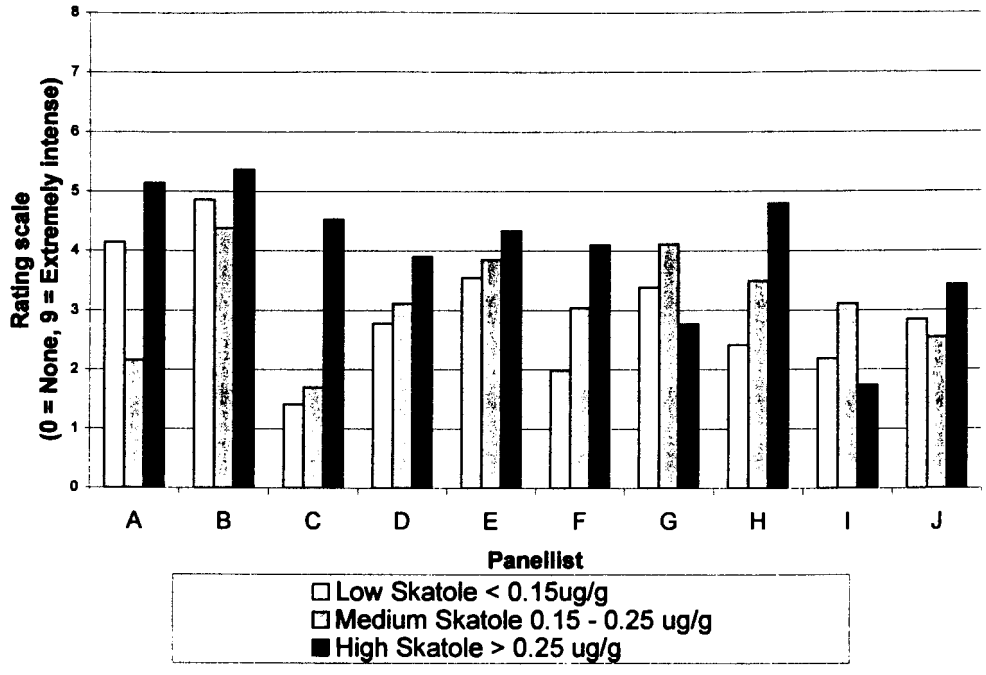

Figure 10: Means for *skatole intensity* for three skatole concentration groups in warm (65 °C) boar fat samples as rated by the individual trained panellists

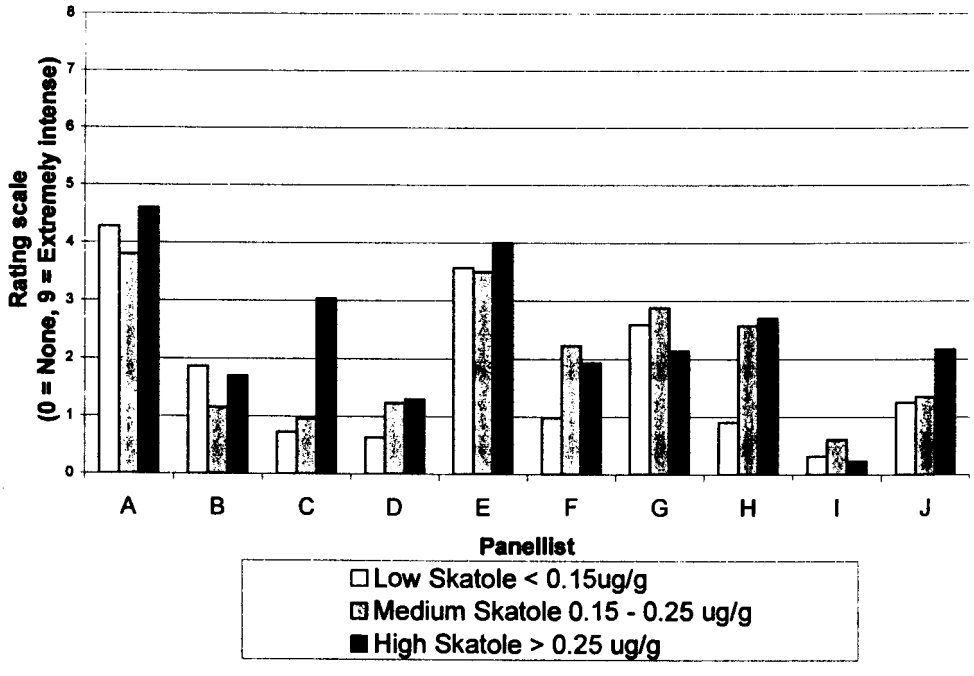

Figure 11: Means for *skatole intensity* of three skatole concentration groups in cold (25 °C) boar fat samples as rated by the individual trained panellists

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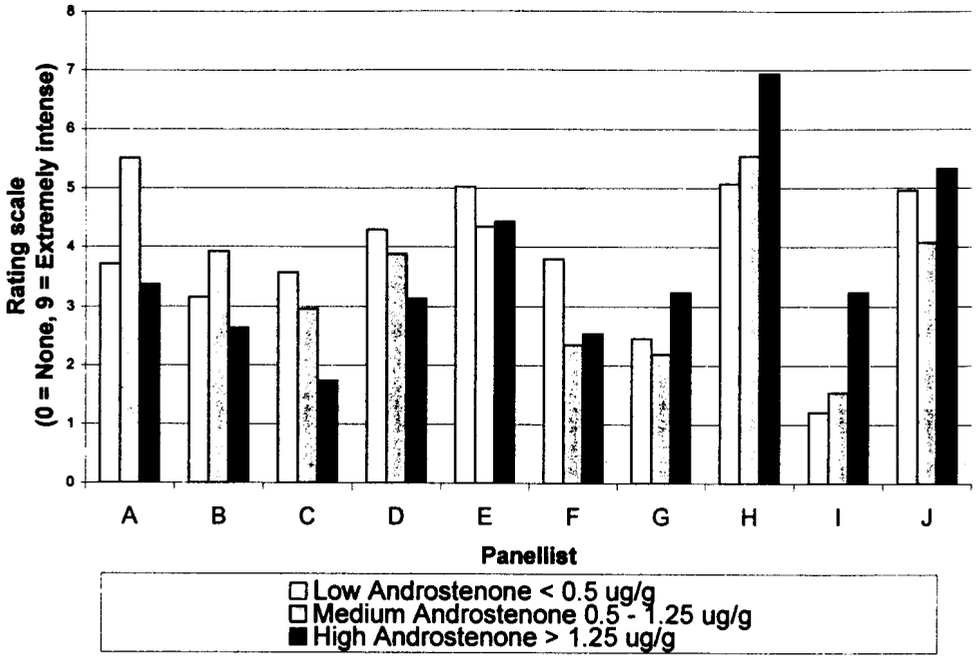

Figure 12: Means for *androstenone intensity* of three skatole concentration groups in warm (65 °C) boar fat samples as rated by the individual trained panellists

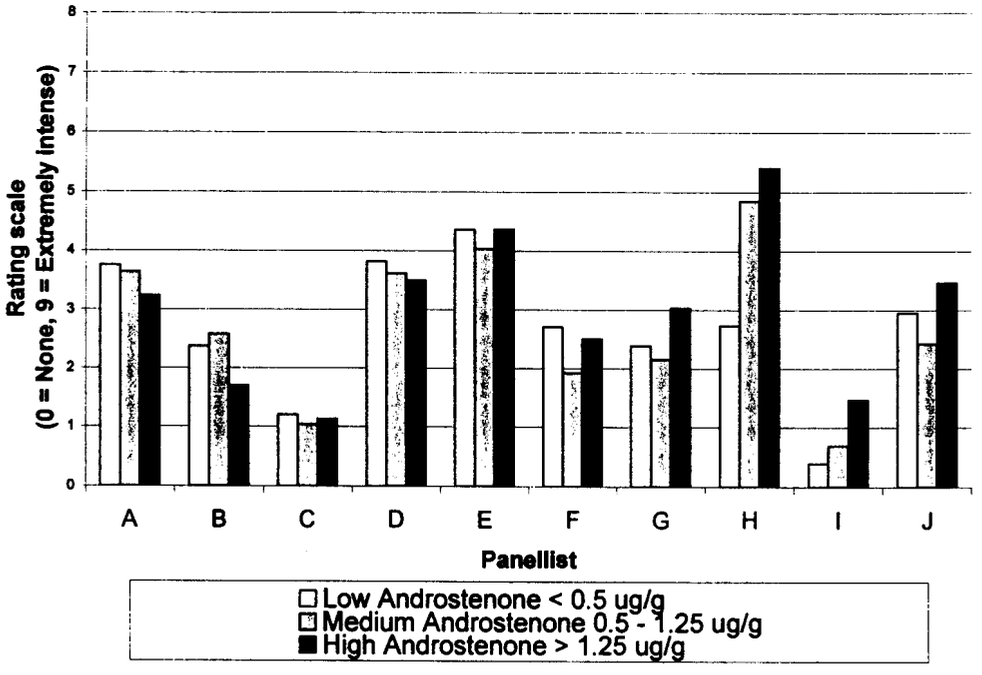

Figure 13: Means for *androstenone intensity* of three skatole concentration groups in cold (25 °C) boar fat samples as rated by the individual trained panellists

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5.1.2 The sensory odour profiles of boar fat samples as analysed by Principal Component Analysis (PCA)

The odour or aroma of a food product as perceived by humans is usually a function of several sensory qualities. Multivariate statistical techniques such as PCA are therefore useful to interpret the overall sensory impression, incorporating all the descriptive terms at the same time. PCA allowed for visual interpretations of both warm (Figure 14 and Figure 15) and cold (Figure 16 and Figure 17) sample presentations. These visual plots indicated the way in which the trained sensory panel used the five sensory descriptors, in combination, to describe the odour of the total set of 50 pork fat samples (evaluated in duplicate). For both serving temperatures, the pork fat samples were separated on the first dimension into tainted (high *skatole* and/or *androstenone* intensities) versus untainted (high *pork fat cooked* and *pork fat grease* intensities) samples. The second dimension separated samples with high *androstenone intensity* from samples with high *skatole*-like properties.

On warm serving, the first dimension explained 37 % of the variance in the data and the second dimension explained a further 22 % of the variance in the data (Figure 14 and Figure 15). For cold serving, the first dimension explained 40 % of the variance in the data and the second dimension explained an additional 23 %. In the case of the samples that were cold (Figure 16 and Figure 17), a third dimension (not shown) explained a further 20 % of the variation in the data and indicated the presence of other components designated by the use of the term *other* that had an effect. The plots for warm and cold serving were fairly similar but note that the factor loading for *androstenone intensity* became higher on the first dimension during cold serving (Figure 16 and Figure 17), showing a greater contribution from this compound. In addition, when served cold, the factor loadings for *skatole intensity* decreased and that of *pork fat grease* increased on the first dimension. The distribution of the 50 carcasses in low (L), medium (M) and high (H) concentration levels of skatole (Figure 14 and Figure 16) and androstenone (Figure 15 and Figure 17) is indicated on the perceived sensory profiling spaces. The positions of the letters (L, M and H) indicate the perceived character and intensities of the descriptive terms as perceived in the back fat of the selected carcasses when served warm and after cooling. The circles on the plots roughly indicate the distributions of L and M skatole compared to H concentration levels (Figure 14 and Figure 16) and L compared to M and H androstenone concentration levels (Figure 15 and Figure 17), respectively.

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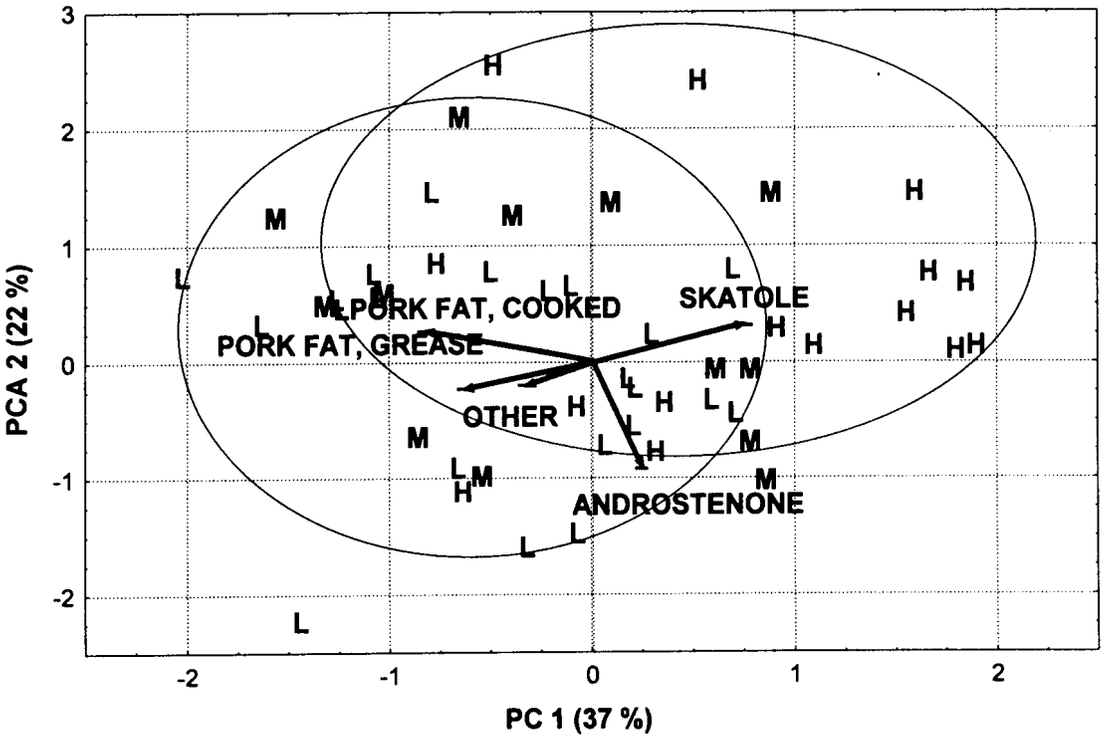

Figure 14: Principal component analysis[1] of the sensory odour profile of 50 pork fat samples with varying skatole and androstenone concentrations when evaluated warm. The plot loadings of low (L < 0.15 μg/g), medium (M = 0.15 to 0.25 μg/g) and high (H > 0.25 μg/g) skatole concentrations are indicated

1 The circles indicate the rough separation of low and medium skatole (grouped together) from high skatole concentration samples.

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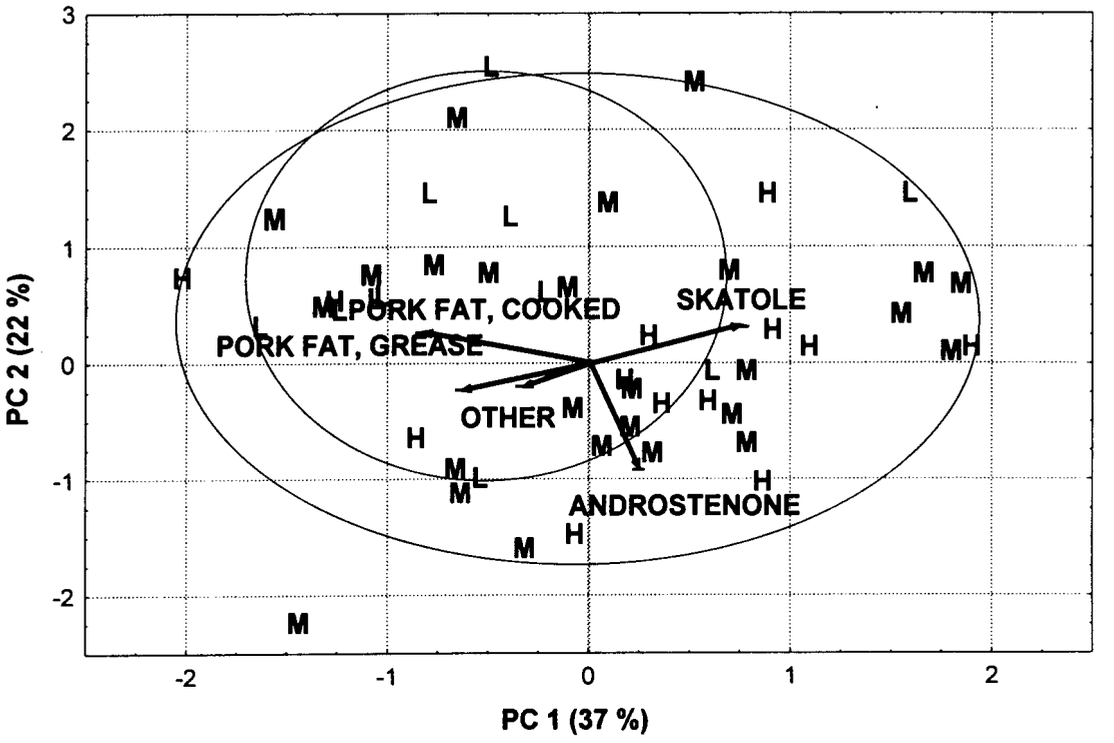

Figure 15: Principal component analysis[1] of the sensory odour profile of 50 pork fat samples with varying skatole and androstenone concentrations when evaluated warm. The plot loadings of low (L < 0.5 μg/g), medium (M = 0.5 to 1.25 μg/g) and high (H > 1.25 μg/g) androstenone concentrations are indicated

1 The circles indicate the rough separation of low androstenone from medium and high (grouped together) androstenone concentration samples.

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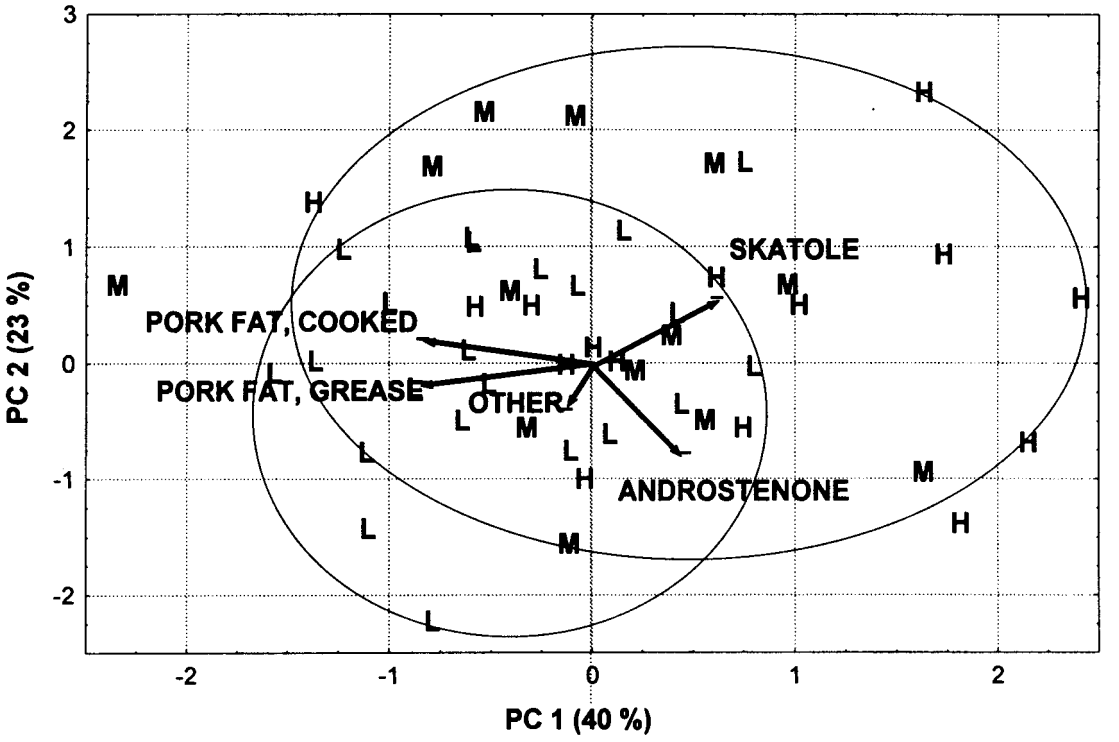

Figure 16: Principal component analysis[1] of the sensory odour profile of 50 pork fat samples with varying skatole and androstenone concentrations when evaluated cold. The plot loadings of low (L < 0.15 μg/g), medium (M = 0.15 to 0.25 μg/g) and high (H > 0.25 μg/g) skatole concentrations are indicated

1 The circles indicate the rough separation of low and medium skatole (grouped together) from high skatole concentration samples.

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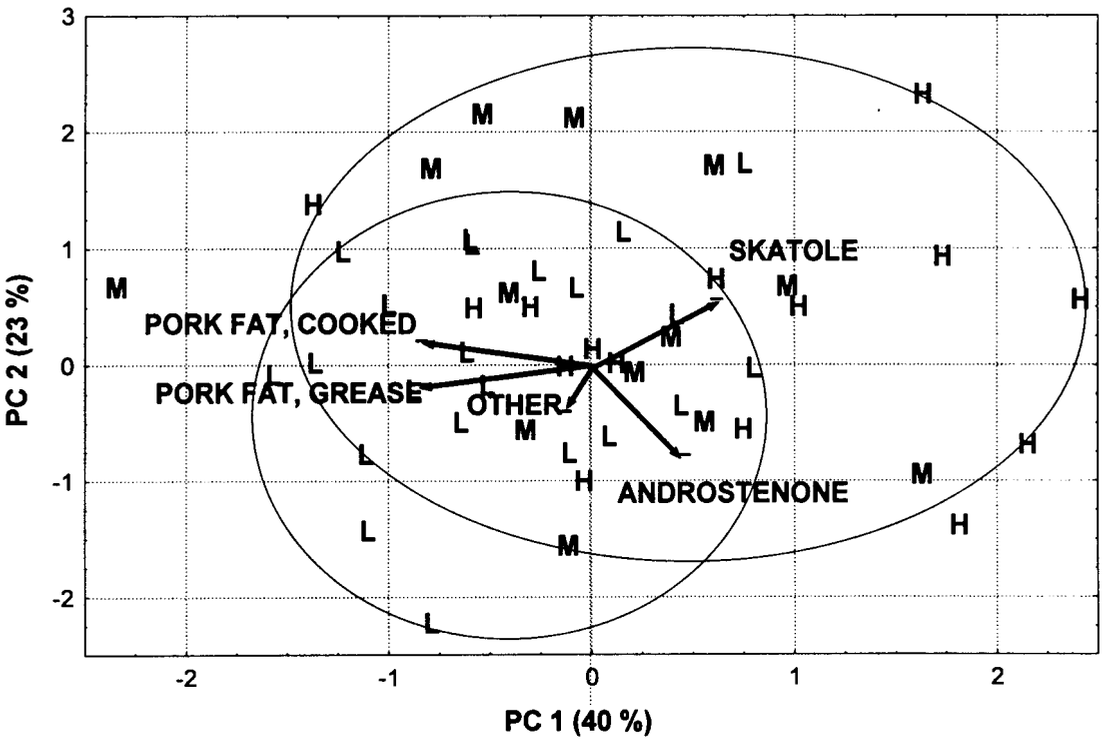

Figure 17: Principal component analysis[1] of the sensory odour profile of 50 pork fat samples with varying skatole and androstenone concentrations when evaluated cold. The plot loadings of low (L < 0.15 μg/g), medium (M = 0.15 to 0.25 μg/g) and high (H > 0.25 μg/g) skatole concentrations are indicated

[1] The circles indicate the rough separation of low and medium skatole (grouped together) from high skatole concentration samples.

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When served warm, a general presence of L and M skatole samples on the left and H skatole samples on the right side of the plot (Figure 14) is evident with some definite overlapping in the centre. The separation of different skatole concentrations was even less when samples were evaluated cold (Figure 16). No clear separation pattern was found for samples with L compared to M and H androstenone concentrations (Figure 15). However, slightly better separation can be observed for different androstenone concentrations, when evaluating the cold samples (Figure 17).

5.1.3 Correlation analysis of skatole and androstenone concentrations and odour descriptors for boar fat samples

Table 15 presents the correlation coefficients for skatole and androstenone concentrations as determined by HPLC and the descriptive sensory data.

The skatole and androstenone concentrations of the sample material (n = 50 samples) that were used were significantly positively correlated by an r of 0.42. The perceived *skatole intensity*, evaluated in the warm and the cold samples, increased significantly with increasing concentrations of both skatole and androstenone. No significant correlation between fat androstenone concentration and *androstenone intensity* when serving samples warm was found. However, when pork fat samples were evaluated cold, low but significant positive correlations between *androstenone intensity* and both increasing skatole (r = 0.29) and androstenone (r = 0.29) concentrations were evident.

The term *pork fat cooked* relating to the smell of normal untainted pork fat decreased as the perceived intensity of either *skatole* or *androstenone* increased, irrespective of the time/temperature of evaluation. In both cases the terms used for describing the desirable pork fat odours, *pork fat cooked* and *pork fat grease*, showed a significant negative correlation with skatole concentration and *skatole intensity*. For these terms, the correlations with androstenone concentration were in all instances not significant.

The *pork fat cooked* and *pork fat grease* terms were significantly positively correlated for both serving temperatures. The correlation was higher for cold serving compared to warm serving. The term *other*, relating to the perception of aromatics that were not specifically defined, was not significantly correlated to skatole and androstenone concentrations or any of the other sensory descriptive terms.

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Table 15: Correlation coefficients (r) and significance of correlation of skatole and androstenone concentrations (HPLC) and descriptive sensory profiling (trained sensory panel) of pork fat samples when served warm and cold (50 carcasses)

	Skatole concentration	Androstenone concentration	Skatole intensity	Androstenone intensity	Pork fat cooked intensity	Pork fat grease intensity	Other intensity
							Cold serving temperature
Skatole concentration		0.42**	0.60***	0.29*	-0.41**	-0.42**	-0.04 NS
Androstenone conc.	0.42**		0.29*	0.29*	-0.28 NS	-0.24 NS	-0.22 NS
Skatole intensity	0.64***	0.37**		-0.11 NS	-0.36 **	-0.45***	-0.01 NS
Androstenone intensity	-0.07 NS	0.19 NS	-0.08 NS		-0.41 **	-0.24 NS	0.03 NS
Pork fat, cooked intensity	-0.42**	-0.24 NS	-0.51***	-0.30*		0.52***	-0.01 NS
Pork fat, grease intensity	-0.43**	-0.26 NS	-0.30*	-0.01 NS	0.31*		0.18 NS
Other intensity	0.11 NS	0.02 NS	-0.16 NS	-0.02 NS	0.10 NS	0.11 NS	
	Warm serving temperature						

NS = Not significantly different at $p < 0.05$
* = Significant correlation at $p < 0.05$; ** = Significant correlation $p < 0.01$; *** Significant correlation $p < 0.001$

5.2 Consumer sensory evaluation

5.2.1 The effect of consumer profiles on the hedonic ratings of the odour of boar fat samples

The average age of the consumers participating in the evaluation of pork fat samples was 23 years (Table 16). The majority of the consumers (84 %) were enjoying high living standards indicated by LSM groups 7 and 8, with the remaining consumers from LSM groups 4 to 6. The majority of consumers (87 %) did not smoke. A small percentage (9 %) of the consumers indicated that they did not really like pork while 66 % indicated that they either liked or liked pork a lot. Overall 15 % of consumers said that they did not often consume pork in the form of fresh meat and 8 % did not consume pork often in the form of processed meat. The consumer profile (Table 16) showed that male and female groups did not differ significantly in terms of age distribution, living standards (LSM) grouping, liking of pork in general and consumption frequency of both fresh and processed pork products. More of the male respondents compared to females smoked. No difference between ethnic groups (Table 17) was found for the number of respondents that smoked.

The consumers representing the different ethnic groups differed in terms of age distribution with white consumers being slightly older than blacks and the coloured consumers was the youngest group. The LSM grouping revealed that the living standards of the black group were generally lower than that of the white and coloured groups. Pork was the least liked by the coloured group with the black group liking pork the most. No significant difference in frequency of consuming fresh pork was noted for the groups but the black group reported that processed pork was more frequently consumed compared to the white and coloured groups.

Consumers' liking of pork meat in general had a significant effect on the hedonic rating of the boar fat samples (Table 18). Those who indicated that they *liked to eat pork a lot* (5 on a 5-point scale) also gave significantly higher hedonic ratings for the boar fat samples compared to all the consumers that marked the other categories on the scale. Consumption frequency of eating pork in either the fresh or processed form, as well as smoking habits did not have significant effects on the hedonic rating of the samples. The distribution of consumers in the LSM groups and age groups was not sufficient to test the effects of these on liking of the boar fat samples.

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Table 16: Comparison[1] of the consumer profiles of males (n=150) and females (n=150) participating in the study

Age distribution (%)	χ^2 =1.0 NS				
	Average age		Minimum		Maximum
Males	22.6		17		53
Females	23.1		17		63
All consumers	22.9		17		63
Living standards measure (LSM) grouping (%)		χ^2 =0.03 NS			
	LSM 4	LSM 5	LSM 6	LSM 7	LSM 8
Males	1	6	11	47	34
Females	1	3	11	51	33
All consumers	1	4	11	49	34
Distribution of smokers and non-smokers (%)		χ^2 =7.5**			
	YES		NO		
Males	18		82		
Females	7		92		
All consumers	13		87		
Distribution by liking of pork (%)		χ^2 = 1.3 NS			
	Strongly dislike	Dislike	Sometimes	Like	Like a lot
Males	4	4	26	34	32
Females	3	6	25	39	26
All consumers	4	5	26	37	29
Frequency of consuming pork in the form of fresh meat (chops, pork roast etc.) (%)				χ^2 = 0.02 NS	
	Never	Almost never	Now & then	Often	Very often
Males	5	10	48	29	8
Females	4	10	46	32	8
All consumers	5	10	48	31	8
Frequency of consuming pork in the form of processed meat (bacon, viennas, polony, pork spare ribs etc.)		χ^2 = 0.75 NS			
	Never	Almost never	Now & then	Often	Very often
Males	5	5	27	33	30
Females	3	3	26	35	33
All consumers	4	4	27	34	32

[1] Significance level NS = Not significant ($p > 0.05$), ** = ($p < 0.01$)

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Table 17: Comparison[1] of the consumer profiles of black, white and coloured consumers participating in the study

Age distribution (%)	χ^2 =57.7 ***		
	Average age	Minimum	Maximum
Blacks	22.9	17	54
Whites	26.1	17	63
Coloureds	19.7	17	40
All consumers	22.9	17	63

Living standards measure (LSM) grouping (%)	χ^2 =43.1 ***			
	LSM 4	LSM 5	LSM 6	LSM 7	LSM 8
Blacks	3	13	32	42	9
Whites	0	0	2	46	51
Coloureds	0	0	0	58	40
All consumers	1	4	11	49	34

Distribution of smokers and non-smokers (%)	χ^2 = 2.5 NS
	YES	NO
Blacks	11	89
Whites	10	90
Coloureds	17	83
All consumers	13	87

Distribution by liking of pork (%)	χ^2 = 16.0 **				
	Strongly dislike	Dislike	Sometimes	Like	Like a lot
Blacks	1	6	20	31	42
Whites	3	3	21	44	29
Coloureds	7	6	36	35	16
All consumers	4	5	26	37	29

Frequency of consuming pork in the form of fresh meat (chops, pork roast etc.) (%)				χ^2 = 2.6 NS
Never	Almost never	Now & then	Often	Very often
Blacks	4	7	44	33	11
Whites	3	10	48	35	3
Coloureds	6	13	48	24	8
All consumers	5	10	48	31	8

Frequency of consuming pork in the form of processed meat (bacon, viennas, polony, pork spare ribs etc.) (%) χ^2 = 6.3 *				
Never	Almost never	Now & then	Often	Very often
Blacks	2	1	21	28	47
Whites	3	6	31	39	21
Coloureds	6	4	28	35	27
All consumers	4	4	27	34	32

[1] Significance level NS = Not significant ($p>0.05$); * = ($p < 0.05$), ** = ($p < 0.01$)

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Table 18: Effect of consumer profiling measurement on hedonic rating of boar fat samples as obtained by ANOVA

Consumer profile measurements	Significance[1]
Smoking	NS
Liking of pork	***
Frequency of consuming fresh pork	NS
Frequency of consuming processed pork	NS

[1] NS = No significant effect ($p \geq 0.05$); *** = Significant effect ($p<0.001$),

5.2.2 Analysis of the hedonic ratings of boar fat samples from combinations of low, medium and high levels of skatole and androstenone

It was necessary to know consumer reactions to the extreme concentrations of skatole and androstenone where it was hypothesised that the levels of boar odour would be clearly detectable. However, it was also important to know how consumers would react to intermediate concentrations of skatole and androstenone, which might not be detectable or undesirable. Comparison of hedonic scores for 3 levels each of skatole (low < 0.08, medium = 0.08 - 0.25 and high < 0.25 μg/g fat) and androstenone (low < 0.5, medium = 0.5 - 1.25 and high < 1.25 μg/g fat) are presented for the black and white consumers (Table 19) and the coloured consumers (Table 20).

Significant differences in consumer liking of boar fat samples were found between the 3 levels of skatole and androstenone concentrations, respectively. As expected, the samples were significantly less liked as the concentration of skatole increased. The black and white groups gave the highest mean hedonic rating for the samples with the lowest skatole concentration (< 0.08 μg/g fat) and liked the samples with the highest skatole concentration (> 0.25 μg/g fat) the least (Table 19). The coloured group liked the low and medium skatole samples significantly more than the high samples (Table 20). However, liking of samples with varying concentrations of androstenone followed a different trend for black and white as compared to the coloured groups.

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Black and white groups liked the low (< 0.5 μg/g) and high (> 1.25 μg/g) levels of androstenone significantly less compared to the medium (0.5 – 1.25 μg/g) level. A similar result was found for the coloured group, but in this case the high level was significantly less liked compared to the low level. No significant interaction effect was found for skatole and androstenone concentrations, but the interaction effect for gender and androstenone concentration was significant for the black and white groups but not for the coloured group.

Table 19: Comparison by ANOVA of hedonic ratings[1] for the odour of boar fat samples (n=50) with three different skatole and androstenone concentrations by the black and white panels (n=200 consumers)

Skatole concentration ***					
Low		Medium		High	
(< 0.08 μg/g)		(0.08 – 0.25 μg/g)		(> 0.25 μg/g)	
5.1 (±2.2) [a]		4.8 (±2.3) [b]		4.3 (±2.3) [c]	
Androstenone concentration **					
Low		Medium		High	
(< 0.5 μg/g)		(0.5 – 1.25 μg/g)		(> 1.25 μg/g)	
4.7 (±2.2) [b]		5.1 (±2.3) [a]		4.5 (±2.3) [b]	
Gender NS					
Ethnic group **					
Black			White group		
4.9 (±2.4) [b]			4.6 (±2.1)[a]		
Skatole X Androstenone concentration NS					
Gender X Androstenone concentration *					
Males			Females		
Low	Medium	High	Low	Medium	High
4.7 (±2.2) [b]	4.9 (±2.3)[bc]	4.6 (±2.3) [b]	4.6 (±2.2) [b]	5.2 (±2.3) [c]	4.3 (±2.4) [a]
Ethnic group X Androstenone concentration NS					
Gender X Ethnic group **					
Males			Females		
Black group	White group		Black group	White group	
4.7 (±2.4) [b]	4.8 (±1.9) [bc]		5.1 (±2.4) [c]	4.4 (±2.2) [a]	

[1] 1=Dislike extremely, 9 = Like extremely

Means in a row with different superscripts ([abcd]) differed significantly at the indicated significance level * = ($p<0.05$), ** = ($p<0.01$), *** = ($p<0.001$), NS ($p \geq 0.05$)

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Table 20: Comparison by ANOVA of hedonic ratings[1] for the odour of boar fat samples with three different skatole and androstenone concentrations by the coloured panel (n=100 consumers)

Skatole concentration ***		
Low	Medium	High
(< 0.08 µg/g)	(0.08 – 0.25 µg/g)	(> 0.25 µg/g)
4.5 (±2.4) [a]	4.6 (±2.2) [a]	3.1 (±2.3) [b]
Androstenone concentration **		
Low	Medium	High
(< 0.5 µg/g)	(0.5 – 1.25 µg/g)	(> 1.25 µg/g)
4.1 (±2.3) [b]	4.6 (±2.3) [a]	3.0 (±2.3) [c]
Gender NS		
Skatole X Androstenone concentration NS		
Androstenone concentration X Gender NS		

[1] 1=Dislike extremely, 9 = Like extremely

Means in a row with different superscripts ([abcd]) differed significantly at the indicated significance level * = ($p<0.05$), ** = ($p<0.01$), *** = ($p<0.001$), NS ($p \geq 0.05$)

The first-mentioned interaction showed that the black and white males did not rate the acceptability of the three levels of androstenone as significantly different, while the females liked the medium (0.5 – 1.25 µg/g fat) androstenone samples significantly more than the low (< 0.5 µg/g fat) concentration samples with the high (> 1.25 µg/g fat) androstenone samples being liked the least (Table 19).

A significant gender x ethnic group interaction effect was found for the black and white groups. This interaction showed that white females generally disliked the boar fat samples significantly more than all other consumer groups. No significant difference was found between the liking scores of the samples for the white and the black males. The black female group and the white male group did not differ significantly with regard to hedonic rating of the smell of boar fat samples. However, the black male group liked the samples significantly less compared to black females. No significant gender effect ($p = 0.4$) was found for the coloured group. However, the

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same trend (Table 20), as observed with the white and black group, was evident with males responding more positively towards the high androstenone samples.

5.2.3 Correlation of skatole and androstenone concentrations, hedonic ratings and descriptive profiles of boar fat samples

Table 21 shows the correlation of skatole and androstenone concentrations (HPLC), mean descriptive sensory intensity ratings as assessed by a trained sensory panel and mean hedonic ratings for all black and white consumers together, as well as for the different gender (males and females) and ethnic groups (black and white consumers), respectively, of pork fat samples (n = 50). It is clear that all the correlations were generally low. Hedonic ratings for the consumers were significantly negatively correlated with concentrations of both skatole and androstenone.

The significance of these correlations seems to be influenced more by the female than the male groups as can be seen from the higher correlation coefficients for the female groups. An unexpected finding was that the correlations between hedonic rating and skatole and/or androstenone concentrations were generally higher than those compared with *skatole* and/or *androstenone* intensities provided by the trained panel. Interestingly, the correlation coefficients for the black female group were generally higher compared to the other groups, while this was the group that responded the least negative in terms of hedonic ratings. The black male group showed no significant correlations for any of the parameters that were measured.

5.2.4 Consumer descriptions for the smell of boar fat samples

Summaries of the words used by the different gender and ethnic groups (black and white consumers) to describe the odours of the boar fat samples for the four extreme skatole and androstenone concentration groups are provided in Appendix B. These words gave some information on the terms used to describe both desirable and undesirable odours or levels of disgust. Comments ranged from very positive (e.g. well roasted pork, pleasant, delicious food etc.) to extremely negative (e.g. nauseating, rotten eggs, disgusting, not fit for human consumption). However, no clear trends were evident since samples from the same carcass often evoked both positive and negative reactions or associations.

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Table 21: Correlation coefficients[1] for mean hedonic ratings of the odour of boar fat samples (n = 50) compared with skatole and androstenone measurements by HPLC and mean skatole and androstenone intensities (samples as assessed at 65 °C by a trained sensory panel)

Consumer group	N	HPLC		Trained sensory panel (warm serving 65 °C)	
		Skatole concentration	Androstenone concentration	*Skatole intensity*	*Androstenone intensity*
All consumers	300	-0.46 ***	-0.31 *	-0.34 *	0.11 NS
Males	150	-0.22 NS	-0.20 NS	-0.19 NS	0.02 NS
Females	150	-0.48 ***	-0.28 *	-0.33 *	0.15 NS
Blacks	150	-0.36 *	-0.28 *	-0.29 *	0.10 NS
Whites	150	-0.41 **	-0.25 NS	-0.28 *	0.08 NS
Black males	50	-0.09 NS	-0.12 NS	-0.11 NS	0.10 NS
Black females	50	-0.46 ***	-0.29 *	-0.32 *	0.04 NS
White males	50	-0.32 *	-0.23 NS	-0.22 NS	-0.12 NS
White females	50	-0.31 *	-0.16 NS	-0.21 NS	0.19 NS

Significance levels NS = ($p>0.05$), * = ($p < 0.05$), ** = ($p < 0.01$), *** = ($p < 0.001$)

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Chapter 6

Discussion

The results will be discussed in three sections. The first section will deal with the analytical sensory analysis of boar odour and the second will concentrate on the results obtained from consumer evaluations. This will be followed by a discussion on possible reasons, based on the insight gained during this research, for some of the discrepancies that exist in the current understanding of boar odour perception.

6.1 The relative contribution of skatole and androstenone to the perception of boar odour

To discuss the results in this section three aspects will be dealt with namely (1) the trained panel's ability to recognise and quantify skatole and androstenone odours in boar fat samples with different concentrations of skatole and androstenone; (2) the temporal perception of boar odour based on an assessment immediately after heating boar fat and following a cooling period; and (3) the ability of the panellists to evaluate skatole and androstenone odours in boar fat.

6.1.1 Recognition and quantification of skatole and androstenone odours in boar fat samples

The acceptance threshold levels of 0.20 or 0.25 μg/g for skatole and 0.5 or 1.0 μg/g for androstenone have frequently been used as cut off levels above which consumers apparently would react negatively to meat from boars (Walstra *et al.*, 2000). It was argued that it would be important to be sure that humans could indeed discriminate between boar odour samples below and above these thresholds.

The trained sensory panel could significantly distinguish using the term *skatole intensity* between boar fat samples with skatole concentrations above and below 0.25 μg/g. It was however, not possible for the panel as a whole to identify differences in skatole odour intensities for concentrations below 0.25 μg/g, specifically for comparing samples with skatole concentrations below 0.15 μg/g to samples with skatole concentrations between 0.15 and 0.25 μg/g.

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For androstenone the identified acceptability threshold of 0.5 μg/g (Moerman, 1982) also indicated a significant concentration for distinguishing high from low *androstenone* intensities. It was also found that the panel was unable to rate the differences in the androstenone intensities of samples with androstenone concentrations above 0.5 μg/g, specifically when comparing samples with androstenone concentrations between 0.5 and 1.25 μg/g with those above 1.25 μg/g.

Overall, the trained panel demonstrated discrimination abilities for skatole and androstenone concentrations in boar fat quite similar to those reported by others (Lundström *et al.*, 1988; Bonneau *et al*, 1992a; Annor-Frempong *et al.*, 1997c). However, it seemed that panellists, even when trained, lacked the ability to discriminate between odour intensities of certain concentration ranges, notably very low concentrations of skatole (below 0.25 μg/g) and very high concentrations of androstenone (above 0.5 μg/g). This was in agreement with Dijksterhuis *et al.* (1997) who concluded that sensory analytical panels are in principle capable of distinguishing between different levels of androstenone and skatole, but not at all levels. Another reason may be that the odour compounds were more stable at the higher concentrations affecting the perceived intensities. De Roos (1997) concluded that flavour compounds were more stable at higher compared to lower concentrations.

This finding seems to be different to the situation observed in a model oil system. In support of the results of this study for skatole, Annor-Frempong *et al.* (1997a) found that panellists were unable to correctly rank increasing skatole intensities of samples with pure skatole concentrations below 0.20 μg/g in a model oil system. This was attributed to the intense impact of skatole on the mucosal membrane of the nose, causing overrating of the first samples in an increasing skatole concentration series. The same authors found that most, but not all trained panellists could, in model oil samples, recognise increases in concentrations of androstenone beyond 0.5 μg/g and up to 8 μg/g. However, one of the trained panellists in that experiment did show a terminal threshold of 0.4 μg/g for androstenone. This individual rated the intensity of samples beyond that concentration as lower compared to those below.

A possible reason for the observation in the case of androstenone may be interference of other substances at high androstenone concentrations which are normally associated with more sexually mature animals (Squires *et al.*, 1991). The

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results for skatole may be due to the fact that the overall panel's discrimination threshold for this substance was reached when comparing sample concentrations between 0.15 and 0.25 µg/g with those below 0.15 µg/g. The discrimination threshold is defined as the smallest perceptible difference in the physical intensity of a stimulus (Kilcast, 1996). However, it is well known that thresholds of individuals can vary quite considerably. Potential interference of androstenone and skatole odours at either the very low or very high concentrations may also have contributed to these results.

The descriptors *pork fat cooked* and *pork fat grease* associated with untainted pork generally decreased with increased concentrations of skatole, while increasing concentrations of androstenone did not have a significant effect on the ratings for these terms. This may be due to the finding by Annor-Frempong *et al.* (1997c) that androstenone contributed more to normal pork odour than skatole.

Annor-Frempong *et al.* (1997c) found that a trained panel was better able to differentiate between low and high levels of skatole than between low and high levels of androstenone, a finding attributed to the fact that the detection threshold for skatole is much lower than androstenone. Another reason was the significant androstenone-panellist interaction effect found during that study. This finding was not confirmed during this study. The differences in panel ratings for low and high levels of skatole and androstenone, respectively, were quite similar. A possible reason for the different finding could be that in this case the skatole-panellist interaction effect and not the androstenone-panellist effect as shown by Annor-Frempong *et al.* (1997c), was found to be more important. It was however noted that mean androstenone intensity ratings were comparatively higher compared to skatole intensity ratings in all samples except those with skatole concentrations higher than 0.25 µg/g (when evaluated warm). When samples were evaluated cold, the mean intensity ratings for *androstenone* were consistently higher compared to those for *skatole*.

The correlation coefficients between the concentrations of the boar odour compounds and the sensory properties were generally low as was similarly found by Annor-Frempong *et al.* (1997c). Differences in findings between the two studies are, however, the higher correlations coefficients reported here between skatole intensity and skatole concentration (0.64 compared to 0.53) and between skatole intensity and

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androstenone concentration (0.37 compared to 0.22). In addition this research did not find a significant correlation between androstenone intensity and androstenone concentration when samples was served warm while Annor-Frempong *et al.* (1997c) found a significant correlation coefficient of 0.43. However, significant correlation coefficients of 0.29 were found for androstenone intensity and androstenone concentration as well as for skatole intensity and androstenone concentration, when the samples were reassessed after 10 minutes, i.e. cold.

The reason for these differences can probably be ascribed to the comparably higher numbers of samples with much higher skatole concentrations used as sample material for this study. In fact, the majority of samples use by Annor-Frempong *et al.* (1997c) had zero μg/g skatole in fat. In that study no samples with both high skatole and low androstenone concentrations were included, while at least two such samples were used here. These differences in findings confirm the statement by Bonneau (1998) that differences in the skatole and androstenone characteristics of the animal population from which samples are drawn is a reason for the lack of consistency in sensory studies on boar odour.

To put sensory boar odour results in perspective it is important to be aware of the nature of the sample material. The concentration of skatole (determined by HPLC) in the boar fat samples for this study was significantly correlated with the levels of androstenone. The correlation coefficient of 0.4 found during this study is similar to that reported by Andresen *et al.* (1993) and Lundström *et al.* (1988) but different from the much higher correlation ($r = 0.7$) reported by Bonneau *et al.* (1992b) and the lower values (0.3) found by Annor-Frempong *et al.* (1997c) and Walstra *et al.* (2000) or the non-significant correlation (-0.02) of Judge *et al.* (1990). The high correlation found by Bonneau *et al.* (1992b) was reportedly due to over-representation of high skatole samples in the group of boars. In fact, Walstra *et al.* (2000) cited correlation coefficients for skatole and androstenone for various studies ranging from 0.3 to 0.55 and then also the high value 0.7 reported by Bonneau *et al.* (1992b). Although the relationship between the two compounds in selected sample material generally remains to be moderate (Walstra *et al.*, 2000), it may explain some of the differences in the sensory results as found for different studies.

However, an interesting finding of this research was that overall no significant interaction effects were observed for any one of the descriptors used and particularly

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not for interactions with skatole and androstenone concentrations (each grouped into three concentration levels). A reason for this may be the limited number of descriptors, namely four real descriptors plus the term *other* that were used during this study possibly contributing to less confusion of odours and terms. This is in contrast to ten and seven descriptors used by Annor-Frempong *et al.* (1997c) and Dijksterhuis *et al.* (2000), respectively. Annor-Frempong *et al.* (1997c) reported a quadratic effect for pork odour and abnormal odour with skatole and androstenone levels while Dijksterhuis *et al.* (2000) also reported quadratic effects in the assessment of odour and flavour attributes. The effects differed for the various trained panels used in the EU boar odour study with some panels reporting hardly any quadratic effects while others reported various.

6.1.2 The temporal perception of boar odour

A major finding of this research was a quantification of the differences that can be expected for perception of skatole and androstenone odours immediately after heating boar fat samples and when evaluating the odour/s of the same samples following a cooling period of 10 minutes. This time period was long enough to allow for a decrease in temperature from ± 65 °C to ± 25 °C. The results showed that the temporal perception of boar odour is an important aspect that could influence the recognition and quantification of boar odour quality and intensity and potentially also contribute to the hedonic reaction to boar fat samples. The perception of different concentrations of skatole and androstenone in boar fat as evaluated by a trained sensory panel differed when samples were assessed immediately after heating and following a cooling period. At the lower temperature (25 °C) after cooling, the intensities of all the odour attributes, except *pork fat grease,* were less intense. This was due to two aspects, namely the reduced temperature affected volatilisation and a loss of volatiles occurred after samples had been heated. The increase in the intensity of *pork fat grease* was expected because this term described the odour of untainted cooked pork fat at room temperature. Bonneau *et al.* (1993) found that human perception of boar taint related off-odours was more difficult at room temperature than in heated products.

The analytical sensory results indicated that when boar fat samples were served warm and the samples were smelled for the first time, skatole seemed to have a faster rate of odourant release and was therefore perceived to be the initial contributor to the overall odour. However, the relative contribution of androstenone to

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the odour profile, after some of the skatole was released together with the water vapour, became more evident. This change in total odour profile affected the identification of the individual odour compounds. After cooling, the classification of samples using the terms *skatole intensity* and *androstenone intensity* was not clearly according to skatole and androstenone concentrations anymore.

This finding is in agreement with Sather (1995) who reported that an aromatic described as barnyard relating to skatole was perceived as one of the first sensations in a large number of boar samples evaluated by a trained sensory panel using the Flavor Profile technique (Caul, 1957). For this technique the panellists are expected, in addition to rating the intensities of characteristics, to also indicate the order in which different odour or flavour qualities become evident. Dijksterhuis *et al.* (1997), assessing the odour of heated fat samples, also found that skatole seemed to "overrule" androstenone perception especially at high concentrations. No reports on the increasing contribution of androstenone to the overall odour profile over time after fresh meat samples had been cooked, could be found. The good discrimination between smoked sausages with and without boar odour that Walstra (1974) found, is in agreement with the results from the time/temperature effect of boar odour perception. In that study it was found that the boar odour could be differentiated even when the sausages were consumed cold. The results was supported by the analytical measurements of androstenone and skatole which showed that the amount of androstenone retained in the products after processing was comparable to that in uncooked back fat, while the concentration of skatole was reduced to one-fifth of the original value.

Walstra (1974) mentioned that a taste panel found the detection of boar odour using a hand sealer (a method similar to the soldering iron method reported by Jarmoluk, Martin & Fredeen, 1970) more discriminating than a cooking procedure. This was probably because the influence of temporal aspects did not come into play with the immediate heating and evaluating procedure. It is also possible that when assessing the odour immediately after heating, skatole was the predominant contributor. A conjecture is that a longer time heating process would allow the multi-dimensional perception, including both skatole and androstenone, to make the perceived odour more complex.

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No interaction effects for skatole and androstenone intensities were found with increasing concentrations of either or both of the odour compounds. The existence of a synergistic effect could therefore not be concluded unequivocally from the results as was reported by others (Walstra *et al.*, 1986; Berg *et al.*, 1993; Agerhem & Tornberg, 1994; Sather, 1995; Xue *et al.*, 1996; Annor-Frempong *et al.*, 1997b) on odour synergism or enhancement. When serving samples warm, Annor-Frempong *et al.*, (1997b) found that the effect of skatole was enhanced by the presence of androstenone, i.e. the higher the androstenone concentration, the more intense the skatole component was perceived.

Although not supported by statistical evidence, a trend was observed that the *skatole intensity* of samples with skatole concentrations above 0.25 µg/g, after cooling, increased as androstenone concentrations increased. The results showed that when samples were evaluated cold, the effect of androstenone, measured here as *androstenone intensity*, may also be slightly enhanced by the presence of skatole. Evidence of enhancement of androstenone intensity by increasing skatole concentration was reported by Sather (1995) and Xue *et al.* (1996). However, these may purely be a result of the variations among ratings by the different panellists demonstrated by significant panellist X skatole concentration and panellist X skatole concentration X androstenone concentration interaction effects.

During this study correlation coefficients of 0.64 and 0.60 found between fat skatole concentration and *skatole intensity* on warm and cold serving, respectively, were well within the range normally reported (Bonneau, 1998). Coefficients of correlation between fat skatole and androstenone concentrations and boar odour intensity as reported in other studies ranged between 0.4 and 0.8. However, it should be noted that in most of these studies the term 'boar odour intensity' was measured and perceptions were therefore not specified as being skatole or androstenone-like as was the case here. A reason for the relatively low correlation with androstenone concentration could be that the sample preparation and serving method was not ideal for the release of the less volatile androstenone or because of masking by the more volatile skatole. Agerhem & Tornberg (1995b) found that, in general, androstenone contributed more to off-flavour at higher (80 °C) compared to lower (60 °C) internal end-point cooking temperatures. The higher temperature probably contributed to greater volatilisation of androstenone.

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An important observation is the fact that the correlation between androstenone intensity and androstenone concentration was significant only when the samples were assessed for the second time (i.e. after cooling), confirming the increasing contribution of this compound over time after heating. It seems as if it was relatively easier to detect androstenone once the samples were left to cool for a while after heating. Babol & Squires (1995) noted that the response to boar taint depended on the compound which is more easily detected.

The complexity of boar odour perception caused by the different interacting odour qualities and intensities was illustrated using a multivariate statistical technique enabling the plotting of samples in relation to all of the sensory descriptors that were available for profiling purposes. It was found that panellists classified boar fat samples firstly as tainted (i.e. with detectable skatole and/or androstenone odours present) or untainted (i.e. with the normal pork fat cooked and/or pork fat grease odour qualities). A secondary aspect was the analysis of the character of the odour that was classed as either tainted or non-tainted. Those samples classified as tainted were separated as either possessing skatole or androstenone character. The non-tainted samples were not separated further and it was noted that the two descriptors for normal untainted pork fat were closely associated on the plots indicating that they probably described the same qualities.

An important observation was that multivariate analysis of the sensory analysis ratings of the cold samples contributed to a higher percentage explanation of the variation in the data. This was probably because the perception of androstenone was more clear in the cold samples compared to the warm samples were skatole seemed to be the most important contributor to the perceived odour profile. Although using different sensory descriptors, Dijksterhuis *et al.* (1997) showed a Principal Component Analysis plot for boar odour perception by a trained sensory panel where the distribution of descriptors was fairly similar to the plots reported during this research. On the plot the descriptors naphthalene/mothballs (relating to skatole) are clearly separated from the descriptors for gilt samples considered being untainted, namely sweet. Similarly a second dimension separation of the terms naphthalene/mothball and urine and sweat (normally associated with androstenone) was found. However, Dijksterhuis *et al.* (1997) pointed to the more significant unidimensional nature of the plot and did not emphasise the second dimension, i.e. the separation of the skatole and androstenone characters. The plots shown by the authors were from the trained panel (EU boar taint project) which had the highest fit

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for Generalised Procrustes Analysis (GPA). This meant that the panellists in this panel showed the highest agreement of the seven trained panels that were compared.

The distribution of carcasses on the multivariate plots again illustrated that skatole and androstenone concentrations were not the only factors affecting the odour and flavour perception of pork meat/fat. Samples were not clearly separated into concentration classes of skatole and androstenone (low, medium or high). This is similar to results by Lundström *et al.* (1982), Dijksterhuis *et al.* (1997) and supports the theory of classification of samples based on response classes as was suggested by Annor-Frempong *et al.* (1997c). This idea is illustrated by the fact that the samples that were the most liked by the consumers in the present study were all clustered on the side of the PCA plots relating to the normal untainted pork fat sensory descriptors. Samples that were the least liked by consumers were clustered to the right of the plots associated with the descriptors *skatole* and *androstenone* although these terms were not necessarily associated with samples containing high concentrations of skatole and/or androstenone.

The findings related to the temporal perception of boar odour can in part be attributed to different odour partition (release), adaptation and retention properties for the two odour compounds.

Flavour perception and especially aroma, is controlled by the way aroma molecules are distributed over various phases (Bruin, 1999). The composition of the sample headspace depends on the partitioning of volatiles among the air phase and the different phases present in the food (e.g. fat and water). Odour or flavour release and retention depends on the availability of odourants to the vapour phase and therefore on their affinity to the product. Most aroma compounds, including skatole and androstenone, are lipophilic which means that the composition of the product will influence the transfer across interfaces such as lipid-aqueous or aqueous-vapour phases. The transfer rate of an aroma compound at the lipid-water interface mainly depends on its affinity for the phase containing the aroma compound originally (Druaux & Voilley, 1997). Other factors such as product surface area and temperature also influence the headspace composition (Taylor & Lindforth, 1996).

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Compared to skatole, androstenone is more lipophilic, has a higher molecular weight (272.4 g/mol compared to 131.18 g/mol), and higher melting (143 °C compared to 95 to 97 °C for skatole) and boiling points (Windholz *et al.*, 1983). The water solubility of androstenone is 0.00023 g/l at 25 °C (Amoore & Buttery, 1978), much lower compared to that of skatole (0.45 g/l at 20 °C, Windholz *et al.*, 1983). The partitioning coefficients of androstenone are therefore higher (Pc air/water = 0.012 at 25 °C) meaning that the substance is released more slowly and for this reason it can be expected that androstenone would have a lower but more lingering odour impact compared to skatole. This is probably one of the reasons why Dijksterhuis *et al.* (2000) concluded that it was more difficult to smell androstenone compared to skatole and was confirmed in the assessment of samples when served warm during this study.

Androstenone is retained for longer in the fat matrix and it is therefore expected that it could provide a more stable, longer lasting odour/flavour. Retention of aroma compounds by a fat matrix depends on the physico-chemical interactions (Druaux & Voilley, 1997) affected amongst others by the functional groups of the aroma compounds. It increases with molecular weight and decreases with the polarity and the relative volatility of the aroma compounds (Goubet *et al.*, 1998). Skatole, theoretically has lower phase partitioning coefficients and is therefore more readily released from the fat matrix into both the aqueous and gaseous phases. The greater solubility of skatole in water due to its more polar nature mean that it would diffuse more easily through the matrix during heating compared to more apolar compounds such as androstenone. The higher rate of volatilisation for skatole could mean that the nose would detect it first or more easily as was demonstrated by the results of this research and observed by Dijksterhuis *et al.* (2000).

The results showed that the contribution of androstenone, relative to skatole, was more noticeable during cold serving of samples. A contributing reason for this phenomenon is the fact that androstenone partitions more readily into the aqueous than the gaseous phase. It takes longer to become volatile, as this compound prefers to volatilise via an aqueous medium. This also mean that retronasally perceived flavour of androstenone, such as when a pork sample is chewed and in contact with watery saliva, should lead to an increase in the rate of volatilisation of this compound. This is aided by the fact that mastication breaks down the fat or fibre matrix of a meat samples which increases the surface area by spreading the product

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throughout the mouth and releases juices and volatile aroma compounds into the mouth (De Roos, 1997). Although flavour during eating of pork fat was not evaluated during this study, it has been found in several boar odour studies reviewed by Bonneau (1998) and again confirmed by Dijksterhuis *et al.* (2000) that androstenone has a greater contribution to flavour (retronasal perception) than to smell (orthonasal perception). This finding is to be expected when the physico-chemical properties of this substance is taken in consideration.

The time delay between perceiving the initial skatole and the androstenone odours as was shown in this research, would mean that individuals that are sensitive to the odour of androstenone, would become more aware of its presence when the product has cooled down sufficiently for it to, for example, be put in the mouth and eaten. The chewing action in the mouth would also aid volatilisation of androstenone. The temporal aspect involved in skatole and androstenone perception also means that the character of the odour that is perceived would be affected by whether a sample is assessed immediately after heating, cold or after re-heating.

6.1.3 Ability of the trained sensory panel to evaluate boar odour compounds

A descriptive panel that is sufficiently trained and operating under suitable conditions for sensory evaluation should be able to consistently evaluate the characteristics of a sample that is presented twice (in either the same or different evaluation sessions). Skatole intensity of samples was significantly lower during the second replicate compared to the first. The differences for *skatole intensity* that were found over the two replicates may therefore suggests insufficient panel training or adaptation (a decrease in responsiveness) of the nose to the odour of skatole on repeated exposure over a period of time. The rating of the terms *pork fat grease* and *other* also decreased and was probably an effect of the decrease in the perception of *skatole intensity*.

No significant differences over the two replicates were found for any of the other descriptive terms and notably not for androstenone, which could mean that inadequate panel training, did not necessarily play a role. Annor-Frempong *et al.*, (1997a) reported inconsistent skatole thresholds for trained panellists over six replicates. In contrast, threshold values for androstenone remained similar over the replicates. The low repeatability of skatole thresholds was ascribed to a more narrow range of detection during heating (Annor-Frempong *et al.*, 1997a). This may mean

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that the off-flavour of *skatole* can not be precisely evaluated in separate panel sessions even by a properly trained sensory panel. Another conjecture could be that the panellists became more used to the odour and were less offended by it. Dijksterhuis *et al.* (2000) mentioned that it seemed as if panellists used the descriptors to indicate serious negative feelings towards the samples tested.

A general observation was the relatively low sensory intensity ratings that were given overall by most of the panellists. This may point to lack of sufficient training on the possible intensities of skatole and androstenone that were to be expected. However, the results of the distribution of sample material shown by the PCA plots and the relatively low correlations of panel responses with skatole and androstenone concentrations, meant that panel training according to these theoretical high and low intensities may not have served as sufficient standards for anchoring the rating scales. It was also found that the individual trained panellists differed in the ability to accurately and precisely evaluate the odours of skatole and androstenone in pork fat especially once the samples had cooled. Individual panellists differed significantly in as far as perception of the intensities of both *skatole* and *androstenone*. This was expected since differences in sensitivities to skatole and androstenone among the panellists were already demonstrated during the screening sessions. With both the descriptors skatole and androstenone intensity on the ballot, some of the panellists were unable to correctly differentiate between skatole and androstenone. This is in accordance with a finding by Bett & Johnsen (1996) who previously showed that trained panellists experienced difficulty evaluating with precision intense off-flavour compounds. Aubry, Schlich, Issanchou & Etiévant (1999) showed that individual differences among trained panellists may sometimes have a greater influence on sensory ratings of wine than differences among products.

Various panellist interaction effects were observed, the effects of which were limited by using panel averages. Overall, for these evaluation conditions it seemed as if skatole had the greatest effect on the panellists' abilities to rate *skatole* and *androstenone* intensities irrespective of time/temperature conditions. This is in contrast to Annor-Frempong *et al.* (1997c) who found that the most important panellist interaction was the panellist-androstenone interaction. Dijksterhuis *et al.* (2000) found that trained panellists were less able to perceive and recognise the smell of androstenone, even when people anosmic for androstenone were selected out of the panels.

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Many researchers have tried to establish descriptive sensory profiles for the odour and flavour of meat, fat and/or model samples with different combinations of skatole and androstenone concentrations (Agerhem & Tornberg, 1995b; Annor-Frempong *et al.*, 1997a; Annor-Frempong *et al.*, 1997b; 1997c, Dijksterhuis *et al.*, 1997; 2000). They used various descriptive terms to describe components of boar taint. During the training phase for the sensory panel for this study, the individual panellists used different words and associations to describe the odour of skatole and androstenone. The individual panellists found it impossible to reach consensus on the descriptions for skatole and androstenone, even when the compounds were presented in the pure form. The use of the ballot training technique (Einstein, 1991) where a lexicon including terms and definitions for descriptors used in other studies was provided did not prove to be effective for reaching consensus. It was concluded that the panellists could reliably only use the terms *skatole intensity* and *androstenone intensity* to label each person's personal impressions or descriptions of pure skatole and androstenone.

The use of different terms by individuals to describe the odours of skatole and androstenone has been described before (Annor-Frempong *et al.*, 1997a; Dijksterhuis *et al.*, 1997; 2000). In addition, the panel consisted of persons from different ethnic groupings speaking different home languages (i.e. Afrikaans, English and Sotho) which may have affected their familiarity with some of the English terms. This phenomenon was described, to a certain extent, also by Dijksterhuis *et al.* (2000). Differences between trained panels in different European countries evaluating similar samples were influenced by subtle changes caused by translations and cultural uses of different descriptive terms. Stevens and O'Connell (1996) concluded that differences in culture, context, social conventions and semantics are known to influence in the labelling of odours.

The use of the Free Choice Profiling method (Williams & Arnold, 1985) where each individual panellist uses a personal list of descriptors might perhaps be useful for boar odour sensory description.

6.2 Consumer perception of boar odour

Overall, it is clear that the majority of consumers responded more negatively towards samples with high concentrations of skatole or high concentrations of skatole and androstenone in combination, compared to low skatole and high androstenone

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concentrations. These results are consistent with those obtained by Annor-Frempong *et al.* (1997b) with regard to odour intensity of skatole/androstenone concentrations in model systems assessed by a trained panel, Godt *et al.* (1996) and Matthews *et al.* (2000) using consumer panels. By far the highest majority of consumers disliked the odour of samples with high skatole and androstenone concentrations in combination. This is in agreement with results found by Walstra *et al.* (1986).

Surprising results were found for the differences in hedonic ratings of the consumer panels when comparing skatole and androstenone concentrations at three different levels. While the trained panel was unable to discriminate between the odour intensities of samples with skatole concentrations below 0.15 and samples between 0.15 and 0.25 μg/g, the consumers showed significant differences in degree of liking of samples below 0.08 μg/g compared to those between 0.08 and 0.25 μg/g. Similarly significant differences were found in the consumer liking of samples with androstenone concentrations below 0.5 μg/g compared to those with concentrations between 0.5 and 1.25 μg/g, a result not expected from the trained panel responses. Whether the reasons for the significance of the results of the consumers were real effects of the concentrations or due to higher degrees of freedom or limitations of the distribution of the samples (skatole and androstenone concentrations) in the case of the consumers is not clear.

6.2.1 Effect of gender and ethnicity on consumer perception of boar odour

Females, in general, but particularly the white females seemed to be more sensitive or perhaps more critical to boar odour where androstenone is concerned. However, the gender difference seemed to be less evident for the coloured and black consumer groups. Possible reasons why the white females were more sensitive to androstenone would be merely speculative but could possibly be linked to the slightly higher age of this particular group. The higher age and living standard may give this group perhaps more freedom to choose products and maybe to be more critical towards quality. Matthews *et al.* (2000) found that those consumers who never cooked pork were less critical of boar odour than those who always did the cooking. In addition, those eating pork less often were generally more critical of boar odour or boar flavour. In this study it was found that those consumers that liked pork less also gave lower hedonic ratings for the boar fat samples.

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Ethnic group differences were demonstrated by the comparison for low, medium and high concentration levels for both odour compounds as well as the correlation coefficients for the different groups. The fact that the white group was older and of a higher socio-economic group compared to the black group could have contributed to the more negative attitude towards boar fat samples, although this theory was not true for the white male group which did not like the samples any less than either the black male or female groups.

An interesting finding was that the black female group gave significantly higher hedonic ratings for boar fat samples compared to most of the other consumer groups. A conclusion could therefore be made that this group was less offended by boar odour. However the hedonic rating should be interpreted in relation to results for correlation analysis. The correlation of hedonic ratings for this specific group and both skatole and androstenone concentrations as well as the correlation with intensity of skatole as assessed by a trained sensory panel, was higher for this group compared to the others. The higher correlations and more consistent significance of the correlations found for the black female group, may show that this group used the hedonic scale more conservatively but in a more linear way. Compared to the other groups this group probably gave slightly lower hedonic ratings as the concentrations of skatole or androstenone increased but avoided the extreme ends of the scale. The white females perhaps also the white males and particularly the black male groups probably used the extreme ends and particularly the negative side of the scale more often, irrespective of subtle differences in odour concentrations. In other words, when an off-odour was detected, the extreme negative end of the scale was marked but when that off-odour was more intense in another sample no more negative scale categories were available to indicate an even further decrease in liking for a sample.

This phenomenon of differences in the use of the scales may be due to the age and socio-economic differences in the case of the white females compared to black females. For the males, in general, it might be due to differences in personality or gender related issues in general.

The apparent liking by some consumers for the smell of androstenone may be attributed to anosmia towards the odour of androstenone by some individuals. Weiler *et al.* (2000) showed that the sensitivity for androstenone had a significant influence on the perceived hedonic rating (odour and flavour) of boar samples for

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highly sensitive compared to mildly sensitive and insensitive Spanish and German consumers. A reason could be a genuine liking for the odour of androstenone by some consumers. Pearson *et al.* (1971) reported apparent consumer liking and even preference for some products made from boar meat. In attempting to explain this, reference was made to Wismer-Pedersen who suggested in 1969 that the compound/s responsible for boar odour is/are desirable up to a certain level, but after exceeding that level they are regarded to be objectionable. Walstra (1974) also showed that a percentage of consumers regarded some samples with boar odour as better than normal and related this finding to the level of boar odour present (presumably that of androstenone odour).

Amoore (1977) reflected that a small amount, or an amount in a balanced proportion of a primary odour, of which androstenone was typically an example used to represent the urinous primary group, can be appetising. The same odour in high concentrations may be repulsive. The finding that medium level androstenone samples were liked significantly more than low and high samples in this study, especially by females may indeed demonstrate a real liking for the odour if present at detectable but relatively low concentrations. It may perhaps also indicate masking or fixating of the odour of skatole resulting in a balanced proportion at certain concentrations which is not possible at low androstenone levels. O'Connell (1991) remarked that the urinous, sweaty odour compounds were remarkable in that the sensory experiences of individuals may differ on each of the three descriptive dimensions of olfactory sensory experience. This meant that differences were found among individuals for perceptions of the intensity of the odour, its quality and the hedonic responses that it evoked.

The South African consumer study was limited to smelling of samples and the samples were only evaluated immediately after heating. The results from the consumer panels should be interpreted in the light of the trained panel results demonstrating the influence of temperature of samples and temporal aspects related to the perception of androstenone. Sensory perception of boar odour seems to have a temporal character which can be explained by differences in volatilisation properties (involving both odourant release and retention) of skatole and androstenone, odour synergism and also differences in the properties of fat matrices of different samples. This could in part explain the dissatisfaction with samples containing detectable levels of skatole and the apparent satisfaction, especially for

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It is possible that the high androstenone samples would also be less liked had consumers re-smelled the samples after it had cooled down or evaluated flavour i.e. eating the samples, when the contribution of androstenone to the flavour profile seem to be higher (Bonneau, 1998).

A concern is the relatively high percentage of respondents that were rejecting the L Sk L An class, thought to be the 'untainted' or control group. A possible explanation can be that to eliminate carry over effects of the taint compounds it was decided to serve the L Sk L An sample (control) first. However, Annor-Frempong *et al.* (1997a) have shown that panellists often overrated the first sample in an increasing skatole concentration series. This phenomenon was apparently due to skatole having an intense initial impact on the nasal mucosal membrane. This 'first sample effect' could have led to overrated negative responses towards the first sample in the series.

A second reason could be that the acceptance thresholds for androstenone and skatole for some individuals, are lower than that which is generally taken as a guideline (i.e. EU 0.5 to 1.0 µg/g for androstenone and 0.20 to 0.25 µg/g for skatole (Bonneau, 1998) and the L Sk L An sample could therefore be perceived as being tainted or unacceptable by some consumers. The low acceptability of the control or supposedly untainted samples may also be due to blandness (lack of flavour) as was described by Matthews *et al.* (2000) as a reason for the general dissatisfaction with the pork test samples used in their study. The idea of smelling heated pork fat, albeit with 'normal' pork fat odour was not a normal consumption situation. The lack of association with eating could have influenced perceptions negatively. One should therefore rather interpret the size of the differences in percentages of negative responses for different concentration classes.

6.2.2 Consumer descriptions for the smell of boar fat samples

A summary of the words used by the different gender and ethnic groups to describe the odours of the boar fat samples provided some information on the terms used to describe undesirable odours or levels of disgust. However, no clear trends were evident since samples from the same carcass often evoked both positive and negative reactions or associations. The results confirmed that consumers mostly know and can say what they like and dislike but they find it difficult to accurately

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describe why (Kilcast, 1996). Consumers generally lack the analytical judgement and training to consistently describe food odours and flavours and therefore the validity of the odour quality reports given by human subjects is often questionable. In addition, social conventions can influence the labelling of odourants, especially those that have a putrid or uncommon odour quality.

There are also semantic differences that exist for odour descriptors among individuals (Stevens & O'Connell, 1996) and behavioural responses to the same flavour can vary within and between individuals depending on attitude, memory, expectations, experience and physiology (Acree according to Leland, 1997). Lawless (1997) mentioned that olfaction is poorly connected to verbal processing and emotional tone and physical reactions (e.g. a frown, a verbal expression etc.) that are difficult to measure, are often used as responses to odours. For this reasons Lawless adapted a non-verbal multidimensional scaling technique that was used by Stevens and O'Connell (1996) to study the similarity of putrid odourants including androstenone.

6.3 Contribution of this research to the current understanding of boar odour perception

The purpose of this section is to discuss two theories that were formulated as a result of the research. These may contribute to the current understanding of boar odour perception. There are many factors that could contribute to the perception of boar odour. However, a very important contribution of this research is the evidence that the perception of boar odour is influenced by the differences in volatilisation rates of skatole and androstenone from boar fat. Researchers should therefore also take into account the physico-chemical properties of the odour compounds as well as the properties of the fat or fat-meat matrix when studying boar odour perception.

Druaux & Voilley (1997) reflected that a better understanding of the phenomena that occur in the perception of complex flavours in food products would be gained if the nature of both the food matrix and the aroma compounds were taken into account. Some physico-chemical properties of pork fat that could influence boar odour perception might include: the physical form (e.g. whole pieces, comminuted etc.), its distribution (i.e. whether it is emulsified or not), temperature, especially near the melting point of fat, fatty acid chain lengths and degree of unsaturation. Land as cited by Leland (1997) commented that when vapour pressures of lipophilic flavour

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compounds are decreased the thresholds for the compounds are increased. This means that the odour compounds would only be detectable at higher concentrations. Vapour pressures for aroma compounds decrease as fat hardness decreased. Fat hardness decreased with increases in fat unsaturation or decreases in fatty acid chain length.

Druaux & Voilley (1997) and Bruin (1999) stated that sensory properties are strongly dependent on the food microstructure and how this breaks down during mastication. In fact, Baek, Lindforth, Blake & Taylor (1999) found that different rates of volatile release from a model food system was the effect of different rates of breakdown of the gel structure in the mouth. In their study there were no significant differences in the maximum in-nose volatile concentrations for model food samples with variations in gelatine concentrations causing differences in stiffness of the different gels. It was concluded that the rate of volatile release and not the amount of volatile present correlated better with sensory data. A similar observation was found by Lee (as cited by Druaux & Voilley, 1997) showing that when the concentration of high-boiling point lipids was increased in emulsions, the total release of the odour compound diacetyl was reduced.

This would suggest that the perception of skatole and androstenone in pork fat could, amongst other factors, also be influenced by the properties of the fat especially those affecting the melting point of the fat and the moisture content. Malmfors, Lundström & Hansson (1978) noted that fatty acid composition contributed to boar odour and Wismer-Pedersen according to De Jong (1994b) measured a correlation (r=0.65) between iodine value (i.e. fat unsaturation) and androstenone content. Desmoulin in 1984 (according to Lundström & Malmfors, 1985) reported that the fatty tissue (content of intramuscular fat, level of unsaturation) and content of androstenone (which was at the time regarded as the main contributing factor to boar odour) were responsible for differences in the limiting factors responsible for acceptability of boar meat. Indications were that high unsaturation levels had positive effects on the aroma and taste of fresh meat. In dried processed meat high unsaturation levels of fat had, in contrast to fresh meat, a negative effect on odour and taste. For dried cured hams, the unpleasant rating on aroma was higher in product from high unsaturation levels (e.g. maize diets). For these processed products the findings were probably attributed to higher degrees of fat hydrolysis and oxidation.

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Another possible contributing factor to boar odour perception is that compared to androstenone, the head space concentration of skatole, being slightly water-soluble and therefore a more polar compound should be less affected by the fat content and properties of the fat matrix of a product. Brossard, Rousseau & Dumont (1998) mentioned that water vapour indirectly contributes to apparent partition coefficients of odourants by enhancing sensory responses of more polar compounds. Differences in moisture content of the fat matrix could therefore influence the rate and extent of phase partitioning of the odourants as well as contribute to uneven volatilisation. In addition, Taylor & Lindforth (1996) stated that the melting point of fat which is based on the saturation level of the fat, could cause substantial differences in the rates of volatile release. The fat content has been shown to affect not only the perceived intensity of odourants but also the temporal profile of flavours.

Very few reports on the correlation of sensory data on boar odour and fatty acid composition of fat samples or indeed any fat properties were found. It was however reported previously (Annor-Frempong *et al.*, 1997c; Dijksterhuis *et al.*, 2000) and in this study confirmed that fat samples from different carcasses within the same skatole/androstenone grouping were often differently assessed. The irregular distributions of carcasses in the descriptive sensory spaces created by PCA re-emphasised the fact that boar odour is not a simple matter of concentrations of androstenone and skatole (Annor-Frempong *et al.*, 1997c; Bonneau *et al.*, 1992b). It is proposed that the fat properties and moisture content of the fat could contribute to these differences. When odour profiles and sensory thresholds of skatole and androstenone are determined in pure lipid bases consisting of mineral oil (Sather, 1995) or a mixture of sunflower oil and vegetable fat (Annor-Frempong *et al.*, 1997a), it would therefore not necessarily reflect the influence of typical matrix properties (saturation level, melting point and fatty acid composition) of pork fat on the volatilisation and retention of odour compounds.

Unfortunately fat properties such as saturation levels, moisture content and fatty acid composition were not measured during this study which could potentially have aided in the explanation of the variation in sensory perceptions of boar odour for the fat samples. It is recommended that these factors be taken in consideration in future studies on boar odour perception.

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A second issue refers to the odour synergism that is often reported. Annor-Frempong *et al.* (1997b) stated that the rate of change in the intensity of skatole depended on the presence of androstenone. This implies that when androstenone is present, skatole perception tends to be retained for a longer period, that is, it lasts longer. A possible explanation for the phenomenon of odour synergism between androstenone and skatole might be the fixative capacity of androstenone based on its chemical properties. This mechanism could be similar to the use of fixative agents like musk, civet and ambergris in the perfume industry that influence the retention properties of odours. Fixatives are oily or waxy materials with very low air-oil partition coefficients and can therefore retain a large proportion of odourants and release them slowly over time (Amoore, 1982).

The differences in volatilisation properties of skatole and androstenone and specifically the fixative odour retention property of androstenone may therefore further explain odour intensity synergism since odour intensity is perhaps linked to temporal integration, that is the longer an odour lasts the more intense it may seem. Beery *et al.* (1971) and Patterson (1968) commented that androstenone has a long retention time and is apparently absorbed in the mucosal layer in the nose and due to its low odour threshold can be smelled for hours.

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Chapter 7

Conclusions and recommendations

Skatole and androstenone contribute to the perception of boar odour in different ways that are affected by the concentrations of the odour compounds in boar fat and the time-temperature condition of the boar fat after it is heated. A trained sensory panel differentiates boar fat samples first and foremost on the basis of whether androstenone and/or skatole odours are present or absent, and secondly based on the inherent character of the androstenone or skatole odour. The temperature and time at which the samples are evaluated influence the intensity but also the character of the perceived odour profiles. For samples with skatole concentrations above 0.25 μg/g and served warm, skatole is the predominant odour while the influence of androstenone at levels above 0.5 μg/g and other odour compounds become increasingly important after samples had cooled down and skatole volatiles are less evident. Androstenone clearly has a more lingering odour impact compared to skatole.

The temporal perception of boar odour is an important aspect that could affect the recognition of the character of the odour, quantification of the intensity of the odour and also influence the hedonic response of an individual. Immediately after heating pork fat, the contribution of skatole to the odour profile seem to be relatively more important compared to when the samples are left to cool. At this stage the relative contribution of androstenone to the overall odour is more easily detected. This can, in part, be attributed to the differences in physico-chemical properties of skatole and androstenone that mainly affect the rates of volatilisation of the compounds.

Sensory perception of androstenone and skatole odours in fat samples therefore seems to have a temporal character. A conjecture would be that the odour perception of androstenone and skatole consists of a top note, body note and base note. Skatole, being most volatile and perceived first, represents the top note. The relative contribution of androstenone to the odour profile becomes more evident after volatilisation of skatole such as after cooling. Androstenone can be seen as the body note and the fat matrix as the base note. The body and base notes both having

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retention capacities. At what stage the respective character notes is perceived will depend on the temperature of heating and potentially the properties of the fat matrix.

Panellists, even when trained, lack the ability to discriminate between odour intensities of certain concentration ranges, notably very low concentrations of skatole and very high concentrations of androstenone. A trained sensory panel can differentiate between skatole and androstenone concentrations but significant panellist interaction effects can be expected. Individual panellists' ratings of various descriptive terms are affected by their perception of skatole in general and to a lesser extent by androstenone, more so when assessing the samples at lower temperatures.

The temporal aspect of boar odour could possibly explain some of the inconsistencies from sensory studies on boar odour. Based on the results it is recommended that factors that could influence the volatilisation of skatole and androstenone in pork meat should also be considered when attempting to predict sensory responses to pork with varying skatole and androstenone concentrations. These factors include measurements of the fat properties of a sample such as melting point, level of saturation, fatty acid composition and moisture content. In addition it is recommended that temporal effects including time and temperature of assessment should be investigated. This should first be done in model systems with pure skatole and androstenone and then using pork fat with varying skatole and androstenone concentrations to determine the influence of using different time-temperature parameters. Assessment should be done using trained sensory panels and Time-Intensity sensory methodology.

The second part of the research dealt with the effects of gender and ethnicity on the consumer reactions to boar odour. The consumers were recruited on two university campuses and the results can therefore not be extrapolated to the general South African population since the majority of the participants were young (18 – 35 years) and representing living standards measures (LSM) groups 7 and 8, i.e. the higher income groups.

The majority of consumers are dissatisfied with pork meat exhibiting detectable levels of skatole. Boar meat with skatole and androstenone odours at detectable concentrations are the least liked. In general, more females compared to males will

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also respond more negatively towards samples with detectable levels of androstenone. This gender difference is clear for the white consumer group but less evident for the coloured and black female groups. In addition, it is possible that a section of the pork-consuming public may prefer pork products with detectable but low levels of androstenone. This apparent liking of the odour of androstenone can be partly attributed to the inability of some consumers to smell this compound or a genuine liking for the odour of androstenone.

It can be expected that some differences will exist in the hedonic reactions to boar odour of South African black, white and coloured consumers. However, any significant ethnic group effects may be confounded by gender and age effects. White females generally respond more negatively towards boar odour than white males and blacks. These differences may have been influenced by age, socio-economic and gender-linked personality factors. Coloured consumers generally responded very negatively to boar odour compounds. Coloured males respond particularly negatively towards samples with detectable skatole, while black males, in general, are more critical in their responses to boar odour compared to black females.

Boar odour whether due to skatole, androstenone or both compounds in combination at levels as currently found in South Africa, will potentially contribute to negative consumer reactions at least for the subsection of the population represented in this study. Discerning consumers that purchase pork with a detectable and unacceptable boar odour may stop purchasing the pork and pork products, spread their opinions to others and possibly hurt the future of the pork industry. It is therefore recommended that the policy of castration be continued until such time as methods have been developed to ensure reduction in both skatole and androstenone concentration levels of boars to levels that would not be detectable even to the most discerning of consumers.

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YUNIBESITHI YA PRETORIA

Chapter 8

References

AGERHEM, H. & DIJKSTERHUIS, G. B., 1996. EU boar taint project: Sensory evaluation by trained panels. Final proposal based on the demonstration meeting held at the S.M.R.I. in Kävlinge, Sweden, 7 September 1995 and some changes suggested at the meeting at the M.L.C. in Milton Keynes, UK 11 & 12 September 1995.

AGERHEM, H. & TORNBERG, E., 1994. A comparison of the off-flavour of shoulder butts from entire male and female pigs using expert and consumer panels. *Proceedings of the 40th International Congress of Meat Science and Technology,* The Hague, The Netherlands 29 August – 2 September.

AGERHEM, H. & TORNBERG, E., 1995a. A comparison of the off-flavor of shoulder butts from entire male and female pigs using trained and consumer panels. *2nd Pangborn Sensory Science Symposium,* Univ. of California, Davis, 30 July - 3 August.

AGERHEM, H. & TORNBERG, E., 1995b. A comparison of the off-flavour of meat from entire male pigs cooked to two different internal end-point temperatures. *Proceedings of a meeting of the EAAP Working Group. Production and Utilisation of Meat from Entire Male Pigs.* 27 -29 September.

AMERICAN SOCIETY FOR TESTING AND MATERIALS, 1991. Standard practice for determination of odor and taste thresholds by a forced-choice ascending concentration series method of limits E679-79. Philidelphia: ASTM.

AMERINE, M. A., PANGBORN, R. M. & ROESSLER, E. B., 1965. *Principles of Sensory Evaluation of Food.* New York: Academic Press.

AMOORE, J. E., 1977. Specific anosmia and the concept of primary odors. *Chemical Senses and Flavor* 2, 267-281.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

AMOORE, J. E., 1982. Odor theory and odor classification. *In*: Theimer, E.T. (Ed.) *Fragrance Chemistry: The Science of the Sense of Smell.* pp.28 - 76.

AMOORE, J. E. & BUTTERY, R. G., 1978. Partition coefficients and comparative olfactometry. *Chemical Senses and Flavor* 3, 57-71.

ANDRESEN, Ø., FRØYSTEIN, T., RØDBOTTEN, M., MORTENSEN, H. P., EIKNES, O. & LEA, P., 1993. Sensoric evaluation of boar meat with different levels of androstenone and skatole. *In:* Bonneau, M. (Ed.) *Measurement and Prevention of Boar Taint in Entire Male Pigs* 12-14 October 1992, Roskilde, Denmark. Paris: INRA Editions. pp. 69-74.

ANNOR-FREMPONG, I. E., NUTE, G. R., WHITTINGTON, F. W. & WOOD, J. D., 1997a. The problem of taint in pork: I. Detection thresholds and odour profiles of androstenone and skatole in a model system. *Meat Science* 46 (1) 45-55.

ANNOR-FREMPONG, I. E., NUTE, G. R., WHITTINGTON, F. W. & WOOD, J. D., 1997b. The problem of taint in pork: II. The influence of skatole, androstenone and indole, presented individually and in combination in a model lipid base, on odour perception. *Meat Science* 46 (1) 49-61.

ANNOR-FREMPONG, I. E., NUTE, G. R., WHITTINGTON, F. W. & WOOD, J. D., 1997c. The problem of taint in pork: III. Odour profile of pork fat and the interrelationships between androstenone, skatole and indole concentrations. *Meat Science* 46 (1) 63-76.

ANNOR-FREMPONG, I. E., NUTE, G. R., WOOD, J. D. & WHITTINGTON, F. W., 1997d. The development of 'response classes' for boar taint based on sensory assessment. *Proceedings of a meeting of the working group "Production and Utilisation of Meat from Entire Male Pigs" of the EAAP.* Royal Swedish Academy of Agriculture and Forestry, Stockholm, Sweden, 1 - 3 October.

ANNOR-FREMPONG, I. E., NUTE, G. R., WOOD, J. D., WHITTINGTON, F. W. & WEST, A., 1998. The measurement of the responses to different odour intensities of 'boar taint' using a sensory panel and an electronic nose. *Meat Science* 50 (2) 139-151.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

AUBRY, V., SCHLICH, P., ISSANCHOU, S. & ETIÉVANT, P., 1999. Comparison of wine discrimination with orthonasal and retronasal profilings. Application to Burgundy Pinot Noir wines. *Food Quality and Preference* 10, 253-259.

BABOL, J. & SQUIRES, E. J., 1995. Quality of meat from entire male pigs. *Food Research International* 28(3) 210-212.

BABOL, J., SQUIRES, E. J. & GULLETT, E. A., 1996. Investigation of the factors responsible for the development of boar taint. *Food Research International* 28(6) 573 -581.

BAEK, I., LINDFORTH, R. S. T., BLAKE, A. & TAYLOR, A. T., 1999. Sensory perception is related to the rate of change of volatile concentration in-nose during eating of model gels (Abstract). *Chemical Senses* 24 (2) 155-160.

BEAUCHAMP, G., 1990. Research in chemosensation related to flavor and fragrance perception. *Food Technology* 58 (1) 98–100.

BEERY, K. E., SINK, J. D., PATTON, S. AND ZIEGLER, J. H., 1971. Characterization of the swine sex odor (SSO) components in boar fat volatiles. *Journal of Food Science* 36, 1086-1090.

BEJERHOLM, C. & BARTON-GADE, P., 1993. The relationship between skatole/androstenone and odour/flavour of meat from entire male pigs. *In*: Bonneau, M. (Ed.) *Measurement and Prevention of Boar Taint in Entire Male Pigs* 12-14 October 1992, Roskilde, Denmark. Paris: Inra Editions. pp. 75-80.

BERG, H., AGERHEM, H., VON SETH, G., TORNBERG, E. & ANDRESEN, Ø., 1993. The relationship between skatole and androstenone content and sensory off-odour in entire male pigs. *In*: Bonneau, M. (Ed.) *Measurement and Prevention of Boar Taint in Entire Male Pigs* 12-14 October 1992, Roskilde, Denmark. Paris: Inra Editions. pp. 55–61.

BETT, K. L. & JOHNSEN, P. B., 1996. Challenges of evaluating sensory attributes in the presence of off-flavours (geosmin and 2-methylisoborneol). *Journal of Sensory Studies* 11, 1-17.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

BETT, K. L. & DIONIGI, C. P., 1997. Detecting seafood off-flavors: Limitations of sensory evaluation. *Food Technology* 51 (8) 70–79.

BONNEAU, M., 1998. Use of entire males for pig meat in the European Union. *44th International Congress of Meat Science & Technology*, Barcelona, Spain. pp. 192-205.

BONNEAU, M., KEMPSTER, A. J., CLAUS, R. CLAUDI-MAGNUSSEN, C. DIESTRE, A., TORNBERG, E., WALSTRA, P., CHEVILLON, P., WEILER, & COOK, G. L., 2000. An international study on the importance of androstenone and skatole for boar taint: I. Presentation of the programme and measurement of boar taint compounds with different analytical procedures. *Meat Science* 54 (3) 251-259.

BONNEAU, M., LE DENMAT, M., MORTENSEN, A. B. & MORTENSEN, H. P., 1993. Relationships between fat androstenone and skatole levels and the organoleptic assessment of pork and cooked ham. *In*: Bonneau, M. (Ed.) *Measurement and Prevention of Boar Taint in Entire Male Pigs* 12-14 October 1992, Roskilde, Denmark. Paris: Inra Editions. pp. 81-86.

BONNEAU, M., LE DENMAT, M., VAUDELET, J. C., VELOSI NUNES, J. R., MORTENSEN, A. B. & MORTENSEN, H. P., 1992a. Contributions of fat androstenone and skatole to boar taint: I. Sensory attributes of fat and pork meat. *Livestock Production Science* 32, 63-80.

BONNEAU, M., LE DENMAT, M., VAUDELET, J. C., VELOSI NUNES, J. R., MORTENSEN, A. B. & MORTENSEN, H. P., 1992b. Contributions of fat androstenone and skatole to boar taint: II. Eating quality of cooked hams. *Livestock Production Science* 32, 81-88.

BROOKS, R. I. & PEARSON, A. M., 1986. Steroid hormone pathways in the pig, with special emphasis on boar odor: A Review. *Journal of Animal Science* 62,632-645.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

BROSSARD, C. ROUSSEAU, F. & DUMONT. J-P., 1998. Perceived intensity of odorants: Far from being related to their concentration in the air! (Abstract). *Proceedings of the Sense & Sensibility Rose Marie Pangborn Memorial Symposium,* Ålesund, Norway, 9-13 August.

BROWN, J. Y., ROBINSON, S. & FISHER, M., 1996. South African Demographics. http://www.micds.pvt.k12.mo.us/.

BRUIN, S., 1999. Phase equilibria for food product and process design. *Fluid Phase Equilibria* 158 (1) 657-671.

CAUL, J. F., 1957. The profile method of flavor analysis. *Advanced Food Research* 7,1.

CHEN, W., FORREST, J. C., PENG, I. C., PRATT, D.E. & JUDGE, M. D., 1993. Palatibility of pre-rigor cooked boar meat. *Journal of Animal Science* 71, 645-650.

CLAUS, R., 1993. Die unendliche geschichte der ebermast. Eine historisch-physiologische analyse. *Fleischwirtschaft* 73 (4) 449-453.

CLAUS, R., DEHNHARD, M., HERZOG, A., BERNAL-BARRAGAN, H. & GIMENEZ, Z., 1993. Parallel measurements of indole and skatole (3-methylindole) in faeces and blood plasma of pigs by HPLC. *Livestock Production Science* 34, 115-126.

COWAN, C. A. & JOSEPH, R. L., 1981. Production and quality of boar and castrate bacon. Consumer and panel response to bacon and fat samples. *Irish Journal of Food Science and Technology* 5,105-116.

DE JONG, S. M., 1994a. Boar taint - an introduction. *Proceedings of the Workshop on Boar Taint and PSE Pork.* Meat Industry Centre, Irene Animal Production Institute, Irene, South Africa. 10 March.

DE JONG, S. M., 1994b. Boar taint - South African research needs. *Proceedings of the Workshop on Boar Taint and PSE Pork.* Meat Industry Centre, Irene Animal Production Institute, Irene, South Africa. 10 March.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

DEPT. OF ART & DESIGN, 1999. Glossary. Iowa State University. http://www.design.iastate.edu/ART/NAB/Glossary.html.

DE ROOS, K. B., 1997. How lipids influence food flavor. *Food Technology* 51(1) 60-62.

DESMOULIN, B., BONNEAU, M., FROUIN, A., BIDARD, J. P., 1982. Consumer testing of pork and processed meat from boars: The influence of fat androstenone level. *Livestock Production Science* 9 (6) 707-715.

DIESTRE, A., OLIVER, M.A., GISPERT, M., ARPA, I. & ARNAU, J., 1990. Consumer responses to fresh meat and meat product from barrows and boars with different levels of boar taint. *Animal. Production* 50, 519-530.

DIJKSTERHUIS, G. B., ENGEL, B., WALSTRA, P., FONT I FURNOLLS, M., AGERHEM, H., FISCHER, K., OLIVER, M. A., CLAUDI-MAGNUSSEN, C., SIRET, F., BÉAGUE, M. P., HOMER D. B., & BONNEAU, M., 2000. An international study on the importance of androstenone and skatole for boar taint: II. Sensory evaluation by trained panels in seven European countries. *Meat Science* 54 (3) 261-269.

DIJKSTERHUIS, G. B., WALSTRA, P., AGERHEM, H., FONT I FURNOLS, M., OLIVER, M. A., SIRET, F., BEAGUE, M. P., CLAUDI-MAGNUSSEN, C., FISHER, K. & COOK, G., 1997. EU research programme on boar taint: preliminary analyses on the results of the sensory evaluations by test panels. *Proceedings of a meeting of the working group "Production and Utilisation of Meat from Entire Male Pigs" of the EAAP*. Royal Swedish Academy of Agriculture and Forestry, Stockholm, Sweden, 1 - 3 October 1997. Wageningen: Wageningen Pers. pp. 20-28.

DOTY, R. L., 1991. Olfactory system. *In*: Getchell, T. V. *et al.* (Ed.) *Smell and Taste in Health and Disease*. New York: Raven Press. pp. 175-203.

DOTY, R. L., BRUGGER, W. E., JURS, P. C., ORNDORFF, M. A., SNYDER, P. J. & LOWRY, L. D., 1977. Intranasal trigeminal stimulation from odorous volatiles: Psychometric responses from anosmic and normal humans. *Physiology & Behavior* 20,175-185.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

DRUAUX, C. & VOILLEY, A., 1997. Effect of food composition and microstructure on volatile flavour release. *Trends in Food Science & Technology* 8,364-368.

EINSTEIN, M. A., 1991. Descriptive techniques and their hybridization. *In:* Lawless, H. T. & Klein, B. P. (Eds.) *Sensory Science Theory and Applications in Foods.* New York: Marcel Dekker, Inc.

FURIA, T. E. & BELLANCA, N., 1981. *Fenaroli's Handbook of Flavor Ingredients* Volume 2. 2nd Edition. Cleveland, Ohio: CRC Press. p 518.

GARCÍA-REGUEIRIO, J. A. & DIAZ, I., 1989. Research note: Evaluation of the contribution of skatole, indole, androstenone and androstenols to boar-taint in back fat of pigs by HPLC and Capillary Gas Chromatography (CGC). *Meat Science* 25, 307-316.

GARDZE, C., BOWERS, J. A., CRAIG, J. & ALLEE, G., 1979. Sensory evaluations of roast from boars, barrows, gilts and ovariectomized gilts. *Journal of Food Science* 44(2) 617-618, 621.

GODT, J., KRISTENSEN, K., POULSEN, C. S., JUHL, H. J. & BECH, A. C., 1996. A consumer study of Danish entire male pigs. *Fleischwirtschaft* 76 (5) 518-520.

GOUBET, I., LE QUERE, J.-L. & VOILLEY, A. J., 1998. Retention of aroma compounds by carbohydrates: Influence of their physico-chemical characteristics and their physical state. *Journal of Agriculture and. Food Chemistry* 46, 1981-1990.

GRIFFITHS, N. M. & PATTERSON, R. L. S., 1970. Human olfactory responses to 5-androst-16-en-3-one principle component of boar taint. *Journal of the Science of Food and Agriculture* 21, 4-6.

HANSEN, L. L., JENSEN, B. B., HANSEN-MØLLER, J. & BARTON-GADE, P., 1994. Influence of stocking rate and faeces deposition in the pen at different temperatures on skatole concentration (boar taint) in subcutaneous fat. *Animal Production* 59, 99-110.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

HANSEN-MØLLER, J., 1994. Rapid high-performance liquid chromatographic method for simultaneous determination of androstenone, skatole and indole in back fat from pigs. *Journal of Chromatography B,* 661, 219-230.

HARRISON, M., 1998. Effect of breathing and saliva flow on flavor release from liquid. *Journal of Agriculture and Food Chemistry.* 46, 2727-2735.

HARRISON, M., CAMPBELL, S. & HILLS, B. P., 1998. Computer simulation of flavor release from solid foods in the mouth. *Journal of Agriculture and Food Chemistry* 46, 2736-2743.

HEINZE, P. H. & VILJOEN, H., 1994. Trends regarding boar taint. *In.* Heinze, P. H. (Ed.) *Proceedings of the Workshop on Boar Taint and PSE Pork.* Meat Industry Centre, Irene Animal Production Institute, Irene, South Africa. 10 March.

HOVENIER, R., KANIS, E., VAN ASSELDONK, T. & WESTERLINK, N. G., 1993. Breeding for pigmeat quality in halothane negative populations - a review. *Pig News & Info* 14, 17N-25N.

INTERNATIONAL STANDARDS ORGANISATION (ISO), 1992. Sensory Analysis – Vocabulary. Ref. No. ISO 5492:92. Geneva.

JARMOLUK, L., MARTIN, A. M. & FREDEEN, H. T., 1970. Detection of taint (sex odor) in pork odor. *Canadian Journal of Animal Science* 50, 750-752.

JENKINS, O. B., 1996. The Coloureds of Southern Africa. http://www.calebproject.org/obj08.htm.

JUDGE, M. D., MILLS, E. W., ORCUTT, M. W., FORREST, J. C., DIEKMAN, M. A., HARMON, B. G., LIN, R. S. & NICHOLLS, L. L., 1990. Utilization of boar meat: Composition, quality and odor incidence in relation to androstenone and skatole. *Journal of Animal Science* 68, 1030-1033.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

KEMPSTER, A. J., DILWORTH, A. W., EVANS, D. G. & FISCHER, K. D., 1986. The effects of fat thickness and sex on pig meat quality with special reference to problems associated with overleanness. Butcher and consumer panel results. *Animal Production* 43, 517-533.

KHIARI, J., 1997. Identification of taste-and-odor compounds in drinking water. Thesis. Drexel University, Philadelphia. *Dissertation-Abstract-International*.

KILCAST, D., 1996. Sensory evaluation of taints and off-flavours. *In.* Saxby, M. J. (Ed.) *Food Taints and Off-flavors*. 2nd Ed. London: Blackie Academic & Professional.

LANDBOUWEEKBLAD, 1993. Beergeur bring geskarrel in Europa. 20 Augustus, 16-17.

LANDBOUWEEKBLAD, 1994. Beergeur in varkvleis nou ondersoek. 24 Junie, 90.

LARSON, E., MEJBORN, H., MARIBO, H. & BEJERHOLM, C., 1995. The production of entire male pigs in Denmark: The causes of boar taint and sensory assessment. *Proceedings of the. 41st International Congress of Meat Science and Technology*, San Antonio, USA.

LAWLESS, H. T., 1997. The sense of smell. http://www.nyasaes.cornell.edu/fst/faculty/acree/fs430/lectures/htl17olfaction.html.

LELAND, J. V., 1997. Flavor interactions: The greater whole. *Food Technology* 51 (1) 75-80.

LESSER, D., BARON, P. J. & ROBB, D., 1977. Boar bacon: A consumer survey. *Journal of the Science of Food and Agriculture.* 28, 1120-1131.

LUNDSTRÖM, K. & MALMFORS, B., 1985. Recent research on the use of boars for meat production - Report from the EAAP Working group meeting in Denmark, 1984. *Livestock Production Science* 13, 303 - 309.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

LUNDSTRÖM, K., MALMFORS, B., FJELKNER-MODIG, S. & SZATEK, A., 1982. Consumer testing of boar meat in Sweden. *Swedish Journal of Agricultural Research* 13, 39-46.

LUNDSTRÖM, K., MALMFORS, B, MALMFORS, G., STERN, S., PETERSSON, H., MORTENSEN, A. B. & SØRENSEN, S. E., 1988. Skatole, androstenone and taint in boars fed two different diets. *Livestock Production Science* 18, 55-67.

MALMFORS, B. & LUNDSTRÖM, K., 1983. Consumer reactions to boar meat - a review. *Livestock Production Science* 10(2) 187-196.

MALMFORS, B. & LUNDSTRÖM, K. & HANSSON, K-E., 1978. Interrelations between boar taint, 5α-androstenone and fatty acid composition in pigs. *Swedish Journal of Agricultural Research* 8, 161-169.

MATTHEWS, K. R., AGERHEM, H., BEAGUE, M-P., CLAUDI-MAGNUSSEN, C., COOK, G. L., FISCHER, K., FONT I FURNOLS, M., GISPERT, M., PUNTER, P. & SIRET, F., 1997. EU Research programme on boar taint: preliminary analysis of the results of the consumer surveys. Measurement and prevention of boar taint in entire male pigs. *Proceedings of a meeting of the EAAP working group "Production and Utilization of Meat from Entire Male Pigs".* Royal Swedish Academy of Agriculture and Forestry, Stockholm, Sweden, 1 - 3 October 1997. Wageningen: Wageningen Pers. pp. 29-40.

MATTHEWS, K. R., HOMER, D. B., PUNTER, P., BÉAGUE, M. P., GISPERT, M., KEMPSTER, A. J., AGERHEM, H., CLAUDI-MAGNUSSEN, C., FISCHER, K., SIRET, F., LEASK, H., FONT I FURNOLS, M. & BONNEAU, M., 2000. An international study on the importance of androstenone and skatole for boar taint: III. Consumer survey in seven European countries. *Meat Science* 54 (3) 271-283.

MCPHERSON, A. & MORAN, A., 1994. The significance of fragrance and olfactory acuity for the consumer household product market. *Journal of Consumer Studies and Home Economics* 18, 239-251.

MEAT BOARD, 1987. *Die Suid Afrikaanse Verbruiker: Evaluering en sienswyse van vleis*. Pretoria.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

MEILGAARD, M., CIVILLE, G. V. & CARR, B. T., 1991. *Sensory Evaluation Techniques,* Vol I. Boca Raton: CRC Press.

MOERMAN, P. C., 1982. The 1981 symposium on boar taint in Zeist, The Netherlands. *Livestock Production Science* 8, 573-578.

MORTENSEN, A. B., BEJERHOLM, C. & PEDERSEN, J. K., 1986. Consumer test of meat from entire males in relation to skatole in back fat. *Proceedings of the 32nd European Meeting of Meat Research Workers*, Ghent, p 23-26.

MOSS, B. W., HAWE, S. M. & WALKER, N., 1993. Sensory thresholds for skatole and androstenone. *In.* Bonneau, M. (Ed.) *Measurement and Prevention of Boar Taint in Entire Male Pigs,* 12-14 October Roskilde, Denmark. Paris: Inra Editions. pp. 63-68.

NOLD, R. A., ROMANS, J. R., COSTELLO, W. J., HENSON, J. A. & LIBAL, G. W., 1997. Sensory characteristics and carcass taints of boars, barrows, and gilts fed high- or adequate-protein diets and slaughtered at 100 or 110 kilograms. *Journal of Animal Science* 75, 2641-2651.

O'CONNELL, R. J., 1991. Specific anosmias: Implications for the physiological mechanisms of quality discrimination. *In.* Lawless, H. T. & Klein, B. P. (Eds.) *Sensory Science Theory and Applications in Foods.* New York: Marcel Dekker, Inc. pp.125-150.

PATTERSON, R. L. S., 1968. 5-androst-16-ene-3-one: compound responsible for taint in boar fat. *Journal of the Science of Food and Agriculture* 19, 31-37.

PAUL, P., 1975. Influence of heating methods. *In.* Cole, D. L. A. & Lawrie, R. A. (Eds.) *Meat.* London: Butterworth & Co. Ltd. pp. 403-432.

PEARSON, A. M., NGODDY, S., PRICE, J. F. & LARZELERE, H. E., 1971. Panel acceptability of products containing boar meat. *Journal of Animal Science* 33 (1) 26-29.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

POLLACK, M. S., WYSOCKI, C. J., BEAUCHAMP, G. K., BRAUN JR., D., CALLAWAY, C & DUPONT, B., 1982. Absence of *HLA* association or linkage for variations in sensitivity to the odor of androstenone. *Immunogenetics* 15:579-589.

POTGIETER, C. M., ANDERSON, J., HEINZE, P. H. & MULLER, H., 1998. Final report: Survey to determine the concentrations of skatole and androstenone in the fat of pig carcasses at S.A. pig abattoirs. Agricultural Research Council, Animal Nutrition & Animal Products Institute, Irene, South Africa.

POWERS, J. J. & SCHINHOLSER, K., 1988. Flavour thresholds for vanillin and predictions of higher and lower thresholds. *Journal of Sensory Studies 3, 49-61.*

QUINN, P. J., 1959. *Foods and feeding habits of the Pedi with special reference to identification, classification, preparation and nutritive value of the respective foods.* Johannesburg: Witwatersrand University Press.

RHODES, D. N., 1971. Consumer testing of bacon from boar and gilt pigs. *Journal of the Science of Food and Agriculture* 22, 485-490.

RHODES, D. N., 1972. Consumer testing of pork from boar and gilt pigs. *Journal of the Science of Food and Agriculture* 23,1483-1491.

RHODES, D. N. & KRYLOW, B., 1974. A marketing trial for pork from boars. *Bulletin Institute of Meat* 89, 2-4.

SATHER, A. P., 1995. Consumers and pork: Canadian consumer acceptance of fresh pork from entire male pigs. *Meat Focus International* 4 (9) 365-371.

SATHER, A. P., TONG, A. K. W., JEREMIAH, L. E., SQUIRES, E. J. & JONES, S. D. M., 1995. Factors affecting the development of sex-taint in entire female pigs. *Proceedings of the 41st International Congress of Meat Science and Technology.* San Antonio, USA.

SNYMAN, G. & VAN RENSBURG, F., 1990. *Topline results usage and attitude study: Red Meat.* South African Meat Board. Arcadia, Pretoria.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

SOUTH AFRICAN ADVERTISING RESEARCH FOUNDATION, 1995. *All Media and Products Survey (AMPS)*. Johannesburg: Market Research Africa Ltd.

STAMER, S., NÜRNBERG, K., KANITZ, W. & KALM, E., 1993. Assessment of boar taint by androstenone and skatole levels and organoleptic tests. *In.* Bonneau, M. (Ed.) *Measurement and Prevention of Boar Taint in Entire Male Pigs,* 12-14 October Roskilde, Denmark. Paris: Inra Editions. pp. 87-92.

STATSOFT, INC., (1995) *Statistica for Windows* (Computor program manual). Tulsa, OK, USA.

STEVENS, D. A. & O'CONNELL, R. J., 1995. Enhanced sensitivity to androstenone following regular exposure to pemenone. *Chemical Senses* 20 (4) 413-419.

STEVENS, D. A. & O'CONNELL, R. J., 1996. Semantic–free scaling of odor quality. *Physiology and Behavior* 60 (1) 211-215.

STØIER, S. & OLSEN, E. V., 1998. Classification accuracy for on-line sorting of Danish entire male pigs. In. Jensen, W. K. (Ed.) *Skatole and boar taint*. Roskilde: Danish Meat Research Institute. pp. 179-188.

STONE, H. & SIDEL, J. L., 1993. *Sensory Evaluation Practices*. San Diego: Academic Press, Inc.

SQUIRES E. J., GULLETT, E. A., FISCHER, K. R. S. & PARTLOW, G. D., 1991. Comparison of Androst-16-ene steroid levels determined by a colorimetric assay with boar taint estimated by a trained sensory panel. *Journal of Animal Science* 69, 1092-1100.

SQUIRES, E. J., 1993. Development and detection of boar taint. *Proceedings of the 39th International Congress of Meat Science and Technology,* Calgary, Canada, 1-6 August 1993. pp 165-178.

TAYLOR, A. J. & LINDFORTH, R. S. T., 1996. Flavour release in the mouth. *Trends in Food Science & Technology* 7, 444-448.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

THOMSON, D. M. H., 1985. The sensory characteristics of three compounds which may contribute to boar taint. *In.* Adda, J. (Ed.) *Progress in Flavour Research 1984, Proceedings of the 4th Weurman Flavour Research Symposium*, Dourdan, France, 9-11 May 1984. Amsterdam: Elsevier. pp. 97-101.

VILJOEN, A. T., 1996. *Eetgewoontes en voedselvoorkeure van mans (16-25 jaar) van die Suid-Afrikaanse bevolking.* M. Dietetics-dissertation. University of Pretoria.

WALSTRA, P., 1974. Fattening young boars: Quantification of negative and positive aspects. *Livestock Production Science* 1, 187-196

WALSTRA, P., CLAUDI-MAGNUSSEN, C., CHEVILLON, P., VON SETH, G., DIESTRE, A., MATTHEWS, K. R., HOMER, D. B. & BONNEAU, M., 2000. An international study on the importance of androstenone and skatole for boar taint: Levels of androstenone and skatole by country and season. *Livestock Production Science.* In press.

WALSTRA, P., ENGEL, B. & MATEMAN, G., 1986. The androstenone-skatole dilemma as applied in a consumer test. *Proceedings of the 32th European Meeting of Meat Research Workers*, Belgium. pp 27-29.

WALSTRA, P. & MAARSE, H., 1970. Ondezoek gesclachtsgeur von menneliyke mest varkens. IVO-rapport C-147 en rapport No 2. Researchgroup voor Vlees en Vleeswaren TNO.

WARKUP, C. C., DILWORTH, A. W., KEMPSTER, A. J. & WOOD, J. D., 1990. The effects of sire type, company source, feeding regimen and sex on eating quality of pig meat. *Proceedings of the British Society of Animal Production* (Abstract). Animal Production 50, 550.

WARRISS, P. D., BROWN, S. N. & NUTE, G. R., 1993. Differences in meat quality between boars and gilts. *In.* Wood, J. D & Lawrence, T. L. J. (Eds.) *Safety and Quality of Food from Animals:* Occasional Publication No. 17, British Society of Animal Production.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

WEILER, U., FISCHER, K., KEMMER, H., DOBROWOLSKI, A. & CLAUS, R., 1997. Influence of androstenone sensitivity on consumer reactions to boar meat. *In.* Bonneau et al. (Eds.) *Boar taint in entire male pigs.* EAAP Publication No. 92, 147-151.

WEILER, U., FONT I FURNOLS, M., FISCHER, K., KEMMER, H., OLIVER, M. A., GISPERT, M., DOBROWOLSKI, A. & CLAUS, R., 2000. Influence of difference in sensitivity of Spanish and German consumer to perceive androstenone on the acceptance of boar meat differing in skatole and androstenone concentrations. *Meat Science* 54 (3) 297-304.

WILLIAMS, A. A. & ARNOLD, G. M., 1985. A new approach to the sensory analysis of foods and beverages. *In.* Adda, J. (Ed.) *Progress in Flavour Research 1984, Proceedings of the 4th Weurman Flavour Research Symposium*, Dourdan, France, 9-11 May 1984. Amsterdam: Elsevier. pp. 35 – 49.

WILSON, C. E. & BROWN, W. E., 1997. Influence of food matrix structure and oral breakdown during mastication on temporal perception of flavor. *Journal of Sensory Studies* 21, 69-86.

WINDHOLZ, M., BUDAVARI, S., BLUMETTI, R. F. & OTTERBEIN, E. S., 1983. *The Merck Index. An Encyclopedia of chemicals, drugs and biologicals.* 10th Ed. Rahway, New Jersey: Merck & Co., Inc.

WYSOCKI C. J. & BEAUCHAMP, G. K., 1984 . The ability to smell androstenone is genetically determined. *Proceedings of the National Academy of Science, U.S.* 81, 4899-4902.

WYSOCKI, C. J., PIERCE, J. D. & GILBERT, A. N., 1991. Geographic, cross-cultural, and individual variation in human olfaction. *In*: Getchell, T. V. *et al.* (Ed.) *Smell and Taste in Health and Disease.* New York: Raven Press. pp. 287-313.

XUE, J. L, DIAL, G. D., HOLTON, E. E., VICKERS, Z., SQUIRES E.J., LOU, Y., GODBOUT, D. & MOREL, N., 1996. Breed differences in boar taint: Relationship between tissue levels of boar taint compounds and sensory analysis of taint. *Journal of Animal Science* 74, 2170-2177.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

ZONDAGH, I. B., BRUWER, G. G., ILLSLEY, J. L. L., VAN HEERDEN, S. M., SMITH, M., MÜLLER, H. & NAUDÉ, R. T., 1994. Sensory quality characteristics of belly bacons and pork loin (*M. longissimus lumborum*) chops produced from entire males in South Africa (pig classification/swine sex odour (SSS) project. *Proceedings of the Workshop on Boar Taint and PSE Pork*.. Meat Industry Centre, Irene Animal Production Institute, Irene, South Africa 10 March.

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YUNIBESITHI YA PRETORIA

Appendices

Appendix A

QUESTIONNAIRE/VRAELYS

Respondent Questionnaire/ Respondente Vraelys

Respondent number:/Respondentnommer: 9 1 4

Please answer these questions by marking the appropriate option with an **X**.
Antwoord asseblief die vrae deur die toepaslike opsie met 'n **X** aan te dui.

A. Gender/ Geslag: ☐ Male/ Manlik ☐ Female/ Vroulik

B. Age/ Ouderdom: ☐☐

C. Home language/ Huistaal _____

1. What type of toilet do you have , if any?

- Watter tipe toilet het u, indien enige?

☐ Non-flush toilet / Nie-spoel toilet

☐ Flush toilet - in house/
Spoel - toilet - in huis

☐ Flush toilet - outside house/
Spoel - toilet - buite huis

☐ Communal portable flush toilet/
Gemeenskaplike draagbare spoel-toilet

☐ None / Geen

2. Please read this list and indicate which items, if any, are presently in your household?

- Lees asseblief hierdie lys en dui aan watter items, indien enige, tans in u huishouding is?

☐ Microwave oven/ *Mikrogolfoond*

☐ Refrigerator or combined fridge/freezer
Yskas of yskas/vrieskas gekombineer

☐ Free standing deep freezer
Vrystaande vrieskas

☐ Vacuum cleaner/floor polisher
Stofsuier/vloerpoleerder

☐ Automatic front loading washing mashine
Ten volle automatiese wasmasjien - wat van voor laai

☐ Automatic top loading washing mashine
Ten volle automatiese wasmasjien - wat bo voor laai

☐ Semi-automatic/twin tub washing mashine
Semi-automatiese/dubbelbalie wasmasjien

☐ Television set/ *Televisiestel*

☐ Hi-fi, music centre/ *Hoë-troustel, musieksentrum*

3.1 Here is a list of shops. Please indicate at which shop or shops you usually do your BULK shopping?

- Hier is 'n lys van winkels. Dui asseblief aan by watter winkels u gewoonlik u GROOT INKOPE doen?

STORES/WINKELS

- ☐ Checkers/Shoprite
- ☐ Clicks
- ☐ Diskom
- ☐ Hyperama
- ☐ Multisave
- ☐ OK Supermarket
- ☐ Pick 'n Pay Hypermarket
- ☐ Pick 'n Pay Supermarket
- ☐ Score Supermarket
- ☐ Sentra Stores
- ☐ Spar
- ☐ Woolworths
- ☐ Chemist/Pharmacy
- ☐ Local/ Neighbourhood Supermarket
- ☐ Spaza Shop
- ☐ Township Supermarket
- ☐ Any other outlet
- ☐ NONE

3.2 Where do you usually do your FILL-UP shopping?

- Waar doen u gewoonlik u AANVULLENDE aankope?

STORES/WINKELS

- ☐ Checkers/Shoprite
- ☐ Clicks
- ☐ Diskom
- ☐ Hyperama
- ☐ Multisave
- ☐ OK Supermarket
- ☐ Pick 'n Pay Hypermarket
- ☐ Pick 'n Pay Supermarket
- ☐ Score Supermarket
- ☐ Sentra Stores
- ☐ Spar
- ☐ Woolworths
- ☐ Chemist/Pharmacy
- ☐ Local/ Neighbourhood Supermarket
- ☐ Spaza Shop
- ☐ Township Supermarket
- ☐ Any other outlet
- ☐ NONE

3.3 Here is a list of shops. Please indicate at which shop or shops you usually do your food and grocery shopping?

- Hier is 'n lys van winkels. Dui asseblief aan by watter winkel of winkels u gewoonlik u voedsel en kruideniersware inkope doen?

STORES/WINKELS

- ☐ Checkers/Shoprite
- ☐ Clicks
- ☐ Diskom
- ☐ Hyperama
- ☐ Multisave
- ☐ OK Supermarket
- ☐ Pick 'n Pay Hypermarket
- ☐ Pick 'n Pay Supermarket
- ☐ Score Supermarket
- ☐ Sentra Stores
- ☐ Spar
- ☐ Woolworths
- ☐ Chemist/Pharmacy
- ☐ Local/ Neighbourhood Supermarket
- ☐ Spaza Shop
- ☐ Township Supermarket
- ☐ Any other outlet
- ☐ NONE

3.4 At which ONE food and grocery store do you estimate that you spend MOST money?

- By watter EEN voedsel- en kruidenierswarewinkel skat u dat u die MEESTE geld bestee?

STORES/WINKELS

- ☐ Checkers/Shoprite
- ☐ Clicks
- ☐ Diskom
- ☐ Hyperama
- ☐ Multisave
- ☐ OK Supermarket
- ☐ Pick 'n Pay Hypermarket
- ☐ Pick 'n Pay Supermarket
- ☐ Score Supermarket
- ☐ Sentra Stores
- ☐ Spar
- ☐ Woolworths
- ☐ Chemist/Pharmacy
- ☐ Local/ Neighbourhood Supermarket
- ☐ Spaza Shop
- ☐ Township Supermarket
- ☐ Any other outlet
- ☐ NONE

3.5 Where does the person who is responsible for the day-to-day purchases of your household shop for food and groceries? (We are not talking here of daily purchases, such as bread and milk.)

- Waar doen die persoon wat verantwoordelik is vir die dag-tot-dag aankope van die huishouding die inkopies vir voedsel en kruideniersware? (Ons praat nie hier van DAAGLIKSE aankope soos brood en melk nie.)

STORES/WINKELS

- ☐ Checkers/Shoprite
- ☐ Clicks
- ☐ Diskom

- ☐ Hyperama
- ☐ Multisave
- ☐ OK Supermarket

- ☐ Pick 'n Pay Hypermarket
- ☐ Pick 'n Pay Supermarket
- ☐ Score Supermarket

- ☐ Sentra Stores
- ☐ Spar
- ☐ Woolworths

- ☐ Chemist/Pharmacy
- ☐ Local/ Neighbourhood Supermarket

- ☐ Spaza Shop
- ☐ Township Supermarket
- ☐ Any other outlet

- ☐ NONE

3.6 Here is a list of shops which sells toiletries. Please indicate from which one(s) you usually buy you toiletries?

- Hier is 'n lys van winkels wat toiletware verkoop. Dui asseblief aan by watter winkel(s) u gewoonlik u toiletware koop?

STORES/WINKELS

- ☐ Checkers/Shoprite
- ☐ Clicks
- ☐ Diskom

- ☐ Hyperama
- ☐ Multisave
- ☐ OK Supermarket

- ☐ Pick 'n Pay Hypermarket
- ☐ Pick 'n Pay Supermarket
- ☐ Score Supermarket

- ☐ Sentra Stores
- ☐ Spar
- ☐ Woolworths

- ☐ Chemist/Pharmacy
- ☐ Local/ Neighbourhood Supermarket

- ☐ Spaza Shop
- ☐ Township Supermarket
- ☐ Any other outlet

- ☐ NONE

4. How many motor cars, station wagons, bakkies and mini-buses/kombi's, including company cars, are there in your household? Please exclude motor bikes, scooters or trucks.

- Hoeveel motors, stasiewaens, bakkies en minibusse/kombi's, maatskappy motors ingesluit, is daar in u huishouding? Sluit asseblief motorfietse, bromponies of vragmotors uit.

- ☐ None/ *Geen*
- ☐ One/ *Een*
- ☐ Two/ *Twee*
- ☐ Three or more/ *Drie of meer*

5. Here is a list of different financial services. Which services, if any, do you PERSONALLY have or make use of?

- Hier is 'n lys van verskillende finansiële dienste. Watter van hulle, indien enige, besit u PERSOONLIK of maak u van gebruik.

Financial Services / *Finansiële Dienste*

- ☐ Cheque / *Tjek*
- ☐ Savings / *Spaar*
- ☐ Transmission / *Transmissie*
- ☐ Investments / Sub / Paid-up shares / *Beleggings / Sub /Opbetaalde aandele*
- ☐ Credit card / *Kredietkaart*
- ☐ Petrol/ Garage card/ *Petrol / Garage kaart*
- ☐ ATM Card / *Outo Teller Kaart*
- ☐ Loan / *Lening*

6. a) Do you have electricity at home?

- Het u elektrisiteit by die huis?

☐ Yes/Ja

☐ No/Nee

b) Do you have water laid on to your house?

- Het u water aangelê na u huis toe?

☐ Yes/Ja

☐ No/Nee

7. Here is a list of different types of policies and plans which you can take out with an Insurance Company. Please indicate which, if any, you PERSONALLY have?

- Hier is 'n lys van verskillende soort polisse en planne wat by 'n Versekeringsmaatskappy uitgeneem kan word. Dui asseblief aan watter soort , indien enige, u PERSOONLIK het?

Policies / *Polisse*

☐ Whole life policy / *Hele Lewenspolis*

☐ Endowment / Savings / Investment Policy / *Uitkeer / Spaar / Beleggingspolis*

☐ Retirement annuity / Personal Pension policy or plan/ *Aftree annuïteit / Persoonlike pensioenpolis of -plan.*

☐ FuneralInsurance/*Begrafnisversekering*

☐ Medical insurance / *Mediese versekering*

☐ Short term insurance / *Korttermyninversekering*

☐ Other (STATE) / *Ander (NOEM)*

_____

☐ None of the above / *Geen van die bogemelde nie*

8. Do you have a telephone at home?

- Het u 'n telefoon by die huis?

HOME TELEPHONE/HUIS TELEFOON

☐ Yes/Ja ☐ No/Nee

And at work?

- En by die werk?

WORK TELEPHONE/WERK TELEFOON

☐ Yes/Ja ☐ No/Nee

9. We need to categorise people in heavy, medium, light and never buyers of a product:

- Ons wil persone kategoriseer in swaar, medium, ligte en nooit aankopers van 'n produk:

*** Dishwashing liquid/ *Vloeibare skottelgoedseep.***

Are you a: / Is jy 'n:

☐ Heavy buyer / Swaar aankoper ☐ Light buyer / Ligte aankoper

☐ Medium buyer / Medium aankoper ☐ Never buyer / Nooit aankoper

10. Do you have hot running water from a geyser in your home?

- Het u warm lopende water vanuit 'n geiser in u huis?

☐ Yes/Ja ☐ No/Nee

11. a) Here is a list of different financial services. Which service, if any, do you PERSONALLY have or make use of?

- Hier is 'n lys van verskillende finansiële dienste. Watter van hulle, indien enige, besit u PERSOONLIK of maak u van gebruik?

☐ Credit card/ Kredietkaart ☐ Loan/ Lening

b) Have you bought any durable items on credit during the PAST 12 MONTHS?

- Het u enige duursame goedere op krediet gekoop in die AFGELOPE 12 MAANDE?

☐ Yes/Ja ☐ No/Nee

12. Do you live in a community smaller than 500 persons outside Gauteng and Western Cape.

- Woon u in 'n gemeenskap kleiner as 500 persone buite Gauteng en Wes Kaap.

☐ Yes/Ja ☐ No/Nee

13. Do you live in a:

Bly u in 'n:

- ☐ House/ *Huis*
- ☐ Cluster house/ *Troshuis*
- ☐ Town house/ *Meenthuis*

- ☐ Flat/ *Woonstel*
- ☐ Traditional hut/
- ☐ Hostel

- ☐ Hotel/boarding house
- ☐ Compound
- ☐ Room in backyard

- ☐ Squatter Hut/Shack
- ☐ Caravan/ *Karavaan*
- ☐ Other(STATE)
  Ander(NOEM)

_____

14. How many domestic servants or household helpers are there in your household?

- Hoeveel huisbediendes of huishulpe is daar in u huishouding?

- ☐ None/Geen
- ☐ One/Een
- ☐ Two/Twee
- ☐ Three or more/Drie of meer

15. Do you smoke?/ *Rook u?*

- ☐ Yes/Ja
- ☐ No/Nee

16. Do you like pork meat?/ *Hou jy van varkvleis?*

Mark with an X on the line. / Merk met 'n X op die lyn.

I____1____I____2____I____3____I____4____I____5____I

Strongly dislike	Dislike	Sometimes	Like	Like a lot
Hou glad nie van	Hou nie van	Soms	Hou van	Hou baie van

17. How often do you eat pork in the form of fresh meat(chops, pork roast)?/

- Hoe gereeld eet u varkvleis in die vorm van vars vleis (tjops of varkboud)?

Mark with an X on the line. / Merk met 'n X op die lyn.

I____1____I____2____I____3____I____4____I____5____I

Very often	Often	Now and then	Almost never	Never
Baie gereeld	Gereeld	Nou en dan	Amper nooit	Nooit

18. How often do you eat pork in the form of processed meat (bacon, viennas, polony, pork spare ribs)

- Hoe gereeld eet u varkvleis in die vorm van geprosesseerde vleis (spek, weense worsies, polonie, varkribbetjies)

Mark with an X on the line. / Merk met 'n X op die lyn.

I____1____I____2____I____3____I____4____I____5____I

Very often	Often	Now and then	Almost never	Never
Baie gereeld	Gereeld	Nou en dan	Amper nooit	Nooit

Thank you for your co-operation.

Dankie vir u samewerking.

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Appendix B

Consumer comments on Low Skatole Low Androstenone pork fat samples (translated into English)

Set	Rating	White Men	Rating	White Women	Rating	Black Men	Rating	Black Women
1	6		5	not strong aroma	7	pleasant	5	nice, undesirable fat
2	3	fat and fish	1	bland,fatty	5	acceptable	8	nice
3			3	not very sharp	6	excellent	7	normal fried pork
4	4		4	fatty, oily	6	pleasant	5	grilled pork
5	5		7		2	strong, garbage, unwanted	9	good
6	4	raw fish			2	not attractive, old pig	5	too much
7	5		6	Lard	7	sharp, piquant	2	strong pork, dislike
8	4	fairly odourless	4	bacon fat, salty	9		4	bad smell, neutralised
9	3	slightly chemical	6	soft salty	3	bit rotten	4	mushrooms
10	6	clean, smells good	9	Pleasant	2	burned cow fat	9	delicious
11	5	cooking butter	5		1	not appetising	6	pork
12	2	raw fat, dead	2	Musty	5	average	6	burned bacon fat
13	2	fatty greasy pork	4	Musty	6	fried pork	4	fried pork
14	7	tempting	6	Pleasant	5	fair and simple	7	pleasant
15	5		5	Neutral	5	good	8	well cooked pork
16	2	sharp, chemical	7	fatty chops	4	fat		
17	2	fatty	8		8	want more and more	8	well-prepared pork
18	5	weak	2	no smell	6	pork	1	old fat, not good
19	2	nauseating	6	roasted oil	5	appetising, a bit awful	4	normal meat, old
20	9	fresh crisp	6	Soft	5	chicken	3	nice
21	6	sweetish	3	not strong	2	chicken	8	appetising
22	5	fatty	8	pork fat	9	fried meat, usual taste	5	nice
23	4		3		3	overheated fish oil	7	nice strong pork meat
24	8	natural	8	meaty, wholesome, earthy	9	delicious food	5	nice
25	4		9	mouth-watering	6	appetising	5	not bad
26	4	light smell	4	sharp, wild	5	pork	7	nice
27	7	good , creamy	3	off, bad	4	cooking oil	1	vomiting
28	7	faint	7	braaied fat	3	not aromatic	5	not so bad
29	4	no spices	4	all right	2	not good	5	mutton
30	7		4	musty	9	good	3	not good
31	4		3	fishy	3		3	not nice, rotten meat
32	5	ordinary pork fat	4		9	very good	5	rich, fattening
33	9	well-roasted pork	3	old	4	cooked vegetables	3	old shoes being burned
34	1	smells sterile	7		5	fair	4	good, average
35	4	nothing	6		8	fried bacon	5	pork
36	3	raw pork	7		4	polony pork		
37	7		3	pork	2		4	dung
38	3		3		4	fried in too much oil	2	pork legs
39	4	unpleasant	2	nauseating	3	red meat	3	
40	4		7	clean fat	3	not delicious	5	pork, french polony
41	2		8	pork meat	6	overcooked pork meat	6	polony, vienna
42	3	weak flavour	6		3	light smell	6	fried russian
43	3	putrid	2	too fatty	5	smells good	4	over toasted eggs
44	4	pork fat	3	boar	4		6	bacon, fantastic
45	5	pleasant	5		3	not distinct, not appealing	3	used cooking oil
46	3	sharp	5	cooked meat	5	uncastrated young male	3	old used cooking oil
47	6	fishy smell	3	pungent	6		8	very nice
48	4	light pork	7	sweetish fat	7	extremely good	4	
49	2	sharp pork	4	fatty	2	dirty fats with water	2	fried meat, not very pleasant
50	7		4	rancid	3	rotten eggs	7	nice

Consumer comments on High Skatole Low Androstenone pork fat samples (translated into English)

Set	Rating White Men	Rating White Women	Rating Black Men	Rating Black Women
1	5	4 not very strong	1 not edible	2 quiet smell
2	7 frying pork, almost good	5 pleasant	1 vomiting	6 normal
3	6 smoked	3 not very sharp	2 rotten food	2 oil used many times
4	6 slightly soapy	3 burned fat	2	1 washing detergent
5	3	4	9 fresh, cooked pork	7 nice
6	4 raw, stale		7 small piglet	4 too much, can't eat it
7	6	6 off	6 flat smell	4 don't like it
8	6 pleasant	2 raw pork, butchery	2 not spiced properly	5 soap
9	5 slightly salty	4 sharp salty	1 vomiting, bad smell	8 good
10	4 slightly rancid, off meat, old	2 not special	2 rotten mushroom	1 bad
11	7 fried chop edges	4 sour	5 neutral	8 really good
12	5 cooked fat	1 unpleasant	3 not so good	6 usual pork meat
13	3 edible	2 sour, unpleasant	5 not to bad	1
14	5	1 off, rotten	5 too strong	4 tolerable
15	1 unpleasant, wild	2 rotten	1 bitter	1 dry, no pork
16	3 Suspect	1 rancid pork, moth balls	9 delicious	
17	4 not strong enough, pleasant	4 pleasant	5 hate pork	3 not good
18	3 wet	3 unpleasant	6 pork	1 not good at all
19	2 unpleasant	3 spoiling food	9 good	5 good, lots of fat, old
20	6 nice, rich	9 soft	8 fried steak	4 urine
21	5	1 strange wild	6 sheep fat	2 terrible
22	7 sharp	1 urine	8 strong smell	4 old fat, nearly rotten
23	4	4 oily	used fish oil	8 russian, nice
24	3 wild	1 disgusting, pungent	8 cooked & fried meat	7 very nice
25	3 half cooked	5 fatty not appetising	1 rotten	6 delicious
26	3 unpleasant	6 light, pleasant	2 old refrigerated meat	4 love, not too much
27	4 aromatic, bland	8 salty, rich	4	9 nice
28	7 faint	3 effe vark	2 not appealing	7 not so good, like it
29	7 faint salt	6	1 not good at all	8 strong pork
30	4	6 slightly sweet	2 not good	2 don't like it
31	4	7 aromatics	6	6 strong
32	2 boar taint	5	9 good	1 unpleasant
33	1 old meat	1 rotten pork	8 good	7 great, stewed pork with vegetables
34	4	7	9 beef	5 OK
35	6	5	1 ordinary dough	2
36	3	4	6 good for wors	
37	4	8 flavourful	5 good, slightly appealing	5 not bad
38	3	3 too fresh	2 used cooking oil	6 smoked beef
39	2 faecal, bad	4 weak	2 flower	4
40	5	2 old meat	6 good, no smell like meat	3 polony
41	3	3 bitter	3 underdone pork	4
42	5 weak flavour	1	2 not well	4 cooked spiced chicken
43	8 pleasant	1 strong	4 not strong, not good	5 boiled red meat
44	5 wild	2 boar	8 great smell	1 not nice at all
45	4 unpleasant	4	1 not good	8 fried bacon
46	4 strong	2 rotten	5 aromatic and juicy	6 bacon
47	7 pleasant	5	5 OK	7 like it, appetising
48	7 bacon	6 crackling	4	5
49	6 meaty	5 roasted pork fat	1 cold goat fat	5 OK, ordinary pork
50	2	3 moth balls	3 rotten eggs	2 not nice at all

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Consumer comments on Low Skatole High Androstenone pork fat samples (translated into English)

Set	Rating	White men	Rating	White Women	Rating	Black Men	Rating	Black Women
1	7	braaied meat	5	pleasant, typical pork	3	if stranded	5	not strong
2	5		1	odourless	2	consumable	8	light fat
3	5	off-putting, sour	2		7	fresh, water-like	2	boiled pork, used oil
4	6	slightly salty	4	oily	5	acceptable	8	roasted bacon
5	8		5		9	fresh, cooked pork	9	delicious
6	2	fishy, unpleasant			4	pork at home	5	not smelling at all
7	9		8	fried pork	6	flat smell	1	boring, no pork
8	5	Pleasant	4	bland	3		8	cooked meat
9	3		3	very sharp, musty	9	great	7	good
10	5	clean smell, fresh meat	2	nothing	2	rotten mushroom	9	good
11	8	crackling	2		2	no good	9	delicious pork meat
12	2	raw fat, synthetic	4	braaied pork	5	good	6	side fat of pork meat
13	6	yum,yum	2	hard fat	1	horrible	1	fried pork
14	3	chemical	1	sharp, wild	6	impressive	7	good
15	7	natural pork	5	neutral	8	excellent	1	no pork-like character
16	7	well-cooked meat	4	slightly rancid	8	normal		
17	7	spicy, flavourful	6	fatty	7	good	8	good
18	2	nauseating	4	no smell	4	uncooked meat	7	meaty, tasty
19	6		8	braaied bacon	7	low	5	good, lots of fat
20	8	appealing	4		1	not nice	4	bad smell
21	8	not too fatty	1	strange wild	2	pork	4	not appetising
22	4	bad, sweaty	1		1	unidentifiable	8	pork ribs
23	4		3		4	heated pork leg	5	pork polony, average
24	7	pleasant, light	7	pleasant earthy	7	red meat of pork	6	delicious
25	4		7	light smell	2	impressive	2	too strong
26	7	well-cooked meat	5	raw, artificial product	5	well-prepared pork	5	
27	8	good flavour, creamy	5	ordinary	8	real pork fat	3	not good, inedible
28	5	acceptable	3	strange, braaied pork	8	aromatic	9	very good
29	5	faintly vinegar	1		7	very good	9	bacon
30	2	fishy	2	rancid fat	9	good	3	bad
31	4	neutral	1	turpentine	6		5	not nice
32	3	not so good	8	braaied meat	9	i like	4	
33	4	fatty	6	fresh fat	8	good	6	ham when fried
34	5		5		6	fairly nice	4	just alright
35	2	fishy	7		7		1	castor oil
36	4		4		5	vienna, pork		
37	6		2		8	like very much	4	dung
38	7		5		7	good	1	cod-liver oil
39	3		5		8	pork	8	
40	5			fat	5	little meat odour	7	polony, viennas
41	4		5	fatty, less pork meat	9	delicious pork	6	
42	8	appealing	1		9	most delicious	2	hot mutton
43	6	little odour	3	not desirable	7	like the smell	4	pork
44	3	unpleasant	6	bacon	7	braai meat	2	cod-liver oil
45	7	pleasant	7		8	smell very good	4	not nice
46	2	unpleasant	3	metallic	8	medium aroma	2	pork legs
47	4	not sharp	6		2	too much	5	average
48	3	seafood	4	rancid	3	bad smell	4	
49	7	pleasant	6	potatoes	1	caster oil	5	ordinary
50	1		1	chloroform	5	boiled eggs	4	rich