# MEAT QUALITY OF RAW AND PROCESSED GUINEA FOWL
## *(Numeda meleagris)*

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Thesis presented in partial fulfilment of the requirements for

the Master's degree in Consumer Science at Stellenbosch University

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**Declaration**

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Date: 19 December 2008

## Abstract

The purpose of this study was to investigate the chemical composition mineral and cholesterol content of the different cuts (breast, drumstick and thigh) of raw guinea fowl meat. The study also aimed at establishing the effect of cooking method on guinea fowl quality attributes by investigating the effect of different cooking methods on the chemical composition and sensory attributes of the different cuts. The effect of injecting a brine solution on the chemical composition and sensory attributes were also investigated.

There were no differences in terms of moisture content of the various cuts raw guinea fowl meat The breast had significantly higher protein content when compared to drumstick and thigh ($P \leq 0.05$). The fat content was similar for all the cuts ($P>0.05$). Whilst the drumstick had significantly the lowest value for ash content when compared to the thigh. Saturated fatty acids (SFAs) and total unsaturated fatty acids (TUFAs) were not different ($P>0.05$) in all the cuts. Drumstick had significantly higher monounsaturated fatty acids compared to other cuts ($P \leq 0.05$), and it had the highest polyunsaturated fatty acids ($P \leq 0.05$). The breast had the lowest ($P \leq 0.05$) *n*-6 fatty acid value (44.25) and had relatively the lowest Polyunsaturated:Saturated (P:S) fatty acid ratio of 1.74 when compared to the other cuts. High *n*-6:*n*-3 ratios, ranging from 7.05 to 16.58, were also found in all the cuts. Cholesterol was lowest ($P \leq 0.05$) in the breast. Seventeen amino acids were found, including the eight of the nine essential amino acids. Significant differences were found in amino acid values for the different cuts. Values of iron were significantly higher in the drumstick and thigh cuts ($P \leq 0.05$), whilst drumstick had the highest zinc content of all the cuts ($P \leq 0.05$).

On investigating the effect of three cooking methods (baking-bag, foil-wrap, open-roasting at 140ºC for 65 minutes) on the chemical composition, the open-roasting method produced higher moisture content ($P<0.05$) consistently for all cuts, with the breast having the highest and the drumstick the lowest ($P \leq 0.05$). The moisture content of the baking-bag method on the other hand was consistently the lowest ($P>0.05$). This effect was significant for the breast, which had lost the most moisture ($P \leq 0.05$). The baking-bag method consistently resulted in a higher protein content, which is attributed to the higher moisture loss ($P \leq 0.05$) in comparison with the other methods, resulting in a more concentrated product. With regard to the fat content no effect resulting from the cooking methods could be observed ($P>0.05$), but the cuts' natural fat content was reflected especially in the open–roasting method ($P \leq 0.05$) giving further support to the

understanding that the open-roasting method indeed made the least inroads on the chemical composition of guinea fowl meat under these restraints: controlled for cooking time and temperature, internal temperature not controlled.

All the cuts cooked according to all the methods, had the favourable $>0.4$ Polyunsaturated:Saturated fatty acids (P:S) ratio, ranging from 0.91 to 1.42 between cuts and treatments. The *n*-6:*n*-3 ratio was below the recommended beneficial value, namely $<4:1$, in all the cuts irrespective of all the cooking methods, ranging from 2.47 to 3.08.

The study of the effect of the three cooking methods (baking-bag, foil-wrap and open-roast) on the sensory attributes of the breast meat revealed that aroma-intensity of the three cooking treatments did not differ significantly ($P \geq 0.05$). Foil-wrap produced a more tender and juicier product ($P \leq 0.05$), while, when using the baking-bag method, values for flavour decreased ($P \leq 0.05$). It is proposed that a higher internal temperature (which was not controlled) was attained when using the baking-bag method (temperature and time controlled) resulting in loss of volatile flavour components.

The effect of the three cooking methods (baking-bag, foil-wrap and open-roast) on the proximate composition (moisture, protein, fat and ash) of raw and cooked breast meat was investigated. As anticipated raw breast meat had higher moisture content (74.55%, $P \leq 0.05$) than the cooked cuts, with open-roasting showing the highest (68.55%) value and foil-wrap close second (68.12%). These values differed significantly from the baking-bag method (66.06%, $P \leq 0.05$).

An investigation on the effect of brine infusion on the sensory attributes and chemical composition (proximate and fatty acid composition, and mineral content) of breast meat, baked in foil-wrap, was carried out using descriptive sensory analysis with the injected breast and the control as variable. There were no significant differences ($P > 0.05$) between the injected and the control samples for any of the sensory attributes of aroma, tenderness, initial juiciness, sustained juiciness and flavour. Judge:treatment variations were observed for all the attributes, and samples differed for all attributes except for aroma. It is proposed that the use of the hand injector could not effectively distribute the brine solution, hence the recommendation to repeat the experiment using an electronic multineedle-injector. No effect was observed for the proximate composition ($P > 0.05$). Further research pertaining to cooking methods of meat of free-range guinea fowl is recommended to address certain issues that have been highlighted.

## Opsomming

Die doel van hierdie studie was ’n ondersoek na die chemiese samestelling naamlik proksimale, vetsuur- en aminosuursamestelling, en die mineraal- en cholesterolinhoud van verskillende snitte van tarentaalvleis (*Numeda meleagris)*. Die studie het ook ten doel gehad om die uitwerking van gaarmaakmetodes op tarentaalvleiskwaliteitseienskappe te ondersoek deur die effek van drie gaarmaakmetodes op die chemiese samestelling en sensoriese attribute van die verskillende snitte te ondersoek. Die effek van die inspuiting van ’n pekeloplossing op die sensoriese attribute is ook ondersoek.

In rou tarentaalvleis is bevind dat die bors ooreenstemmende waardes vir voginhoud het as vir die ander snitte, en ’n beduidende hoër proteïeninhoud het wanneer dit met die boudjie en dy vergelyk is ($P\leq0.05$). Die vetinhoud was dieselfde vir al die snitte ($P>0.05$), terwyl die boudjie beduidend die laagste asinhoud in vergelykings met die dy gehad ($P\leq0.05$). Versadigde vetsuur- (SFAs) en totale onversadigde vetsuurinhoud (TUFAs) het nie tussen die drie snitte verskil nie ($P>0.05$). Die boudjie het beduidend hoër monoönversadigde vetsuurinhoud getoon ($P\leq0.05$) in vergelyking met ander snitte en dit het ook die hoogste polionversadigde vetsuurinhoud ($P\leq0.05$) gehad, laasgenoemde was die beduidend meer as in die bors en die dy ($P\leq0.05$). Die bors het die laagste n-6 vetsuurinhoud ($P\leq0.05$) en ‘n relatiewe beter polionversadigde:versadigde verhouding (P:S) van 1.74 gehad in vergelyking met die ander snitte. Hoë n-6:n-3 verhoudings, wat gewissel het van 7.05 tot 16.58 was ook gevind in al die rou snitte. Cholesterol was die laagste ($P\leq0.05$) in die bors. Daar was sewentien aminosure gevind, insluitend agt van die nege essensiële aminosure. Geringe en soms beduidende verskille is in die aminosuurwaardes tussen snitte waargeneem. Ysterinhoud was beduidend hoër in die boudjie en dy, terwyl die boudjie die hoogste sinkinhoud gehad het ($P\leq0.05$).

Ondersoek na die effek van drie gaarmaakmetodes (baksakkie, foelie-omhulsel en ooprooster teen 140°C vir 65 minute) op die chemiese samestelling toon dat ooprooster ‘n hoër voginhoud ($P>0.05$) konsekwent vir al die snitte tot gevolg gehad het, met die bors die hoogste en die boudjie die laagste ($P\leq0.05$). Die voginhoud van die baksakkiemetode, aan die ander kant, het die laagste voginhoud tot gevolg gehad ($P>0.05$). Hierdie verskil vir die baksakkiemetode was beduidend vir resultate op die bors wat meeste vog verloor het ($P\leq0.05$). Die baksakkie metode het konsekwent ‘n hoër proteïeninhoud gehad, wat toegeskryf word aan die hoër vogverlies ($P\leq0.05$) in vergelyking met ander metodes, wat op sy beurt ‘n meer gekonsentreerde produk tot

gevolg gehard het. Wat die vetinhoud betref, het gaarmaakmetode nie ‘n waarneembare effek gehad nie (P >0.05), maar die tendens tov die natuurlike inhoud van die verskillende snitte was weerspieël, veral in die ooproostermetode wat steun gee aan die afleiding wat gemaak word in hierdie studie, naamlik dat die ooproostermetode die minste impak gehad het op die chemiese samestelling van tarentaalvleis, met inagneming van die kondisies van die onderhawige studie: gaarmaaktemperatuur en -tyd was gekontroleer, en nie interne temperatuur nie. Al die snitte het die gunstige (>0.4) polionversadigde:versadigde vetsuurverhouding gehad, naamlik tussen 0.91 en 1.42 vir al die gaarmaakmetodes. Die *n*-6:*n*-3 verhouding was onderkant die voordelige waarde, naamlik C4:1, vir al die snitte ongeag van die gaarmaakmetode, naamlik tussen 2.47 en 3.08.

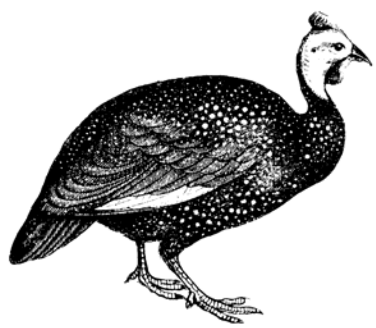
Die ondersoek na die effek van gaarmaakmetodes op die sensoriese attribute op tarentaalvleis het getoon dat die aroma-intensiteit vir die drie gaarmaakbehandelings (baksakkie, foelie-omhulsel en ooprooster) nie beduidend verskil het nie (P>0.05). Foelie-omhulsel het ‘n sagter en ‘n sapswineer produk tot gevolg gehad (P≤0.05), en waardes vir geur het afgeneem (P≤0.05) met die baksakkiemetode. Dit word voorgestel dat ‘n hoër interne temperatuur (waarvoor nie gekontroleer was nie) met die baksakkiemetode (temperatuur en tyd gekontroleer) bereik is, wat vlugtige geursubstanse verlore laat gaan het.

Die effek van drie gaarmaakmetodes (baksakkie, foelie-omhulsel en ooprooster) op die proksimale samestelling (vog, proteïen, vet en as) van rou en gaar borsvleis was ondersoek. Na verwagting het die rou borsvleis die hoogste voginhoud (74.55 %, P≤0.05) gehad, in vergelyking met die gaar snitte, met die ooprooster- wat die hoogste (68.55%) en die foelie-omhulselmetode wat die tweede hoogste waarde (68.12%) gehad het. Hierdie waardes het beduidend verskil van dié van die baksakkiemetode (66.06%, P≤0.05).

‘n Ondersoek na die effek van infusie met pekeloplossing op die sensoriese attribute en chemiese samestelling (proksimale en vetsuursamestellin, en minerale-inhoud) van borsvleis, gebak in foelie-omhulsel, was met behulp van beskrywende sensoriese analise uitgevoer, met die ingespuite en kontrole monsters as veranderlike. Daar was geen beduidende verskille (P>0.05) tussen die ingespuite en kontrole monsters vir enige sensoriese attribute van aroma, sagtheid, aanvanklike sapswineheid, volgehoue sapswineheid en geur. Paneellid: behandelingsvariasie was waargeneem vir al die attribute en monsters het vir al die attribute verskil, behalwe vir aroma. Dit word voorgestel dat die handinspuitingstegniek nie effektief die pekeloplossing versprei het nie, vandaar die aanbeveling om die eksperiment te herhaal met ‘n elektroniese multi-inspuitingsnaald. Geen effek ($P>0.05$) op die proksimale samestelling was waargeneem nie. Verdere navorsing wat verband hou met die gaarmaakmetodes van vleis verkry van vry-loop tarentaal word aanbeveel vir sekere kwessies wat na vore gebring is.

## Dedication

This thesis is dedicated to my two beloved uncles (Mothusiotsile Rancho and Thupayabotlhe Modiakgotla) who passed away during the course of my studies, their affection and strong faith in me saw me through.



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# CHAPTER 1

# INTRODUCTORY PERSPECTIVES

## 1.1 Introduction and problem statement

In the National Development Plan 9 the Botswana's Ministry of Finance and Development Planning (2003:174) indicated that, despite the low contribution of agriculture to the gross domestic product (GDP), this sector remains an important source of food and provides income, employment and investment opportunities for the majority of the population in the rural areas. Agriculture is still regarded as the main source of raw materials for a number of agro-based industries including meat processing, and these have great potential in the creation of jobs. The report indicates that, of all the agricultural sectors, beef processing, steered by the Botswana Meat Commission, remains the major success in the economy of the country, in terms of output and export earnings. Despite this success though, the full potential of the sector in terms of varied and diversified finished product manufacture, has not been exploited adequately.

The Government of Botswana is therefore faced with the challenge of developing the agricultural industry, entrepreneurial skills, as well as employmentment creation. Agriculture represents the principal demand for small-scale enterprises in rural communities (Botswana Ministry of Commerce and Industry, 1997:25). All disciplines in agriculture, as well as food product development, entrepreneurship skills and marketing, need to be integrated in addressing the above-mentioned challenges. The policy further emphasises that new products have the potential of getting into new and growing markets and the commercialisation of these products is a vehicle to developing marketing, sales and service experience in a way that existing products fail to do (Botswana Ministry of Commerce and Industry, 1997:19).

In Botswana, a tremendous growth in poultry production has been observed, with annual per capita consumption of chicken meat increasing from 10.9 kg in 1999 to 16.1 kg in 2000. and a 98% self-sufficiency in eggs and poultry meat production (Botswana Ministry of Finance and Development Planning, 2003:180). The biggest part of this 98% is in broiler production. Badubi, Ravindram and Reid (2004:823-826) however report that, though broiler production has shown to be popular in Botswana, it is still in its infancy. The country is still not able to meet the demand for day-old broiler chicks that are used for rearing purposes, resulting in the need to import these from neighbouring South Africa and Zimbabwe. They further report that there are several constraints that negatively impact on the performance of this sector ranging from policy and operational issues to lack of research on the poultry sector as a whole (Badubi, Ravindram & Reid, 2004:830).

The government of Botswana has made a commitment to diversify into ostrich farming to increase agricultural output (Botswana Ministry of Finance and Development Planning, 2003:174) and this supports the challenge to investigate the potential of other poultry products. Guinea fowl meat is such a product with Hancock and Potts (2002:19) reporting that, though some research still needs to be conducted, there have been indications that there is a need for this species' meat in restaurants and lodges in Botswana.

In Europe, guinea fowl *(Numeda meleagris)* has long been domesticated, raised for food and used for income generation (Mongin, 1991:2). Risse (1991:6) further reports that, in 1965, 15 000 tonnes of guinea fowl was already being exported from France to other European countries. For third-world countries, including Botswana, the bird could become much more valuable than it is now. In Botswana it is presently found in very expensive restaurants in tourist areas and its meat has been eaten and liked by most locals and tourists for a long time (Thamage, Personal communication, 2004). According to Thamage in 2003, the Veld Product Research (VPR) in Botswana, received external aid to start a pearl guinea fowl rearing project with a group of women in Gabane village, west of Gaborone, as an effort to empower rural communities.

Mongin (1991:3) reports that, compared to farming with chickens farming with guinea fowls has low production costs. Guinea fowls have a better resistance to common poultry parasites and diseases, premium quality meat that is dark and delicate with the flavour resembling that of game, though the meat is tough and takes longer to cook. Nutritionally guinea fowl meat is said to be rich in essential fatty acids and is leaner than chicken (Serre, 2002:1). Sales and Hayes (1995:2001-4) report that consumers are presently demanding knowledge and information on the nutritive value of the foods they consume. They demand lean muscle meat with less fat, thus creating a niche for game meat as these are promoted on the basis of their low fat composition, sensory attributes and their organic nature (Hudson, 1999). This is further emphasised by Jiménez-Colmenero, Carballo and Cofrades (2001:5), who report that, as societies become more affluent, great importance is placed on those things that enhance the quality of life, like wellbeing and health and therefore diet. Guinea fowl which is classified as a game bird (Little, Crowe & Barlow, 2000:90), can provide a healthier and lean alternative source of red meat. Badubi *et al.* (2002:832) reports that with the escalating income level in Botswana it can only be anticipated that the demand for poultry products will increase progressively in the following years. There is hence the need to investigate and profile guinea fowl meat quality and the influence of processing on quality characteristics for value enhancement, since very little scientific information on these could be sourced.

Meat is cooked mainly because it is more palatable and appealing when cooked, and some distinct and desirable flavours are developed during the cooking process (Bennion & Scheule, 2004:701). Presently the cooking process of wild guinea fowl is very long, since the meat is generally tough, thus making it expensive for domestic and commercial use (Thamage, personal communication). Scientifically, the effect of cooking on meat has been of research interest over the years and results have shown that cooking has a significant effect on the tenderness of meat (Christensen, Purslow & Larsen, 2000:301). The effect of cooking on the tenderness of meat depends on a variety of factors including temperature, duration of heating and the particular muscle being cooked (Bennion & Scheule, 2004:706). According to Charley and Weaver (1998:420-421), older but still immature birds are suitable for roasting. They further report experiments where chicken were roasted in foil, in an open pan, in ovenproof film and in a baking bag and results were used to determine the best cooking method, temperature and time for cooking. Assessing the proper cooking times and temperatures for the different cooking methods for guinea fowl meat will be highly beneficial in improving the consumption and acceptance of guinea fowl meat by consumers.

Finding ways of making guinea fowl meat more tender and juicy is also important. Archer Daniels Midlands (ADM) (2004:1) report that they have successfully used soy protein and concentrates to further increase the tenderness and juiciness of chicken, attributing this to the role of vegetable protein in the improvement of texture and mouthfeel of meats. Other forms of meat treatments in poultry have been widely used. Numerous research projects have been done over the years mainly investigating the use of sodium chloride and phosphates (Ünal, Erdoğdu, Ekiz & Özdemir, 2004:264), to improve tenderness and juiciness through improved water-holding capacity, as well as protein functionality and yield of meats (Alvarado & Sams, 2003:1332). Fisher, Hoffman and Mellett (2000: 251) have successfully used brine solutions consisting of salts and phosphates on ostrich meat. According to Mehrotra (2004:143), irrespective of whether a product is new, an existing one, enriched or modified, has to meet consumer expectations, be safe and efficacious, retaining good taste and texture, aroma and flavour, while maintaining its originality and authenticity. In addition to meeting consumer expectations, the regulatory environment should be conducive to developing and marketing such foods.

Senauer, Asp and Kinsey (1991:174) report that, consumer decision making process for almost every product that is manufactured and placed in the market, especially food, has been largely influenced by demographic factors, lifestyles, market segmentation, convenience, changing eating patterns, food safety, nutrition, health, food retailing changes, packaging, brands and advertising. These trends have led to consumers being highly critical of what they consume (Asp, 1999), thus compelling the food industry to fully understand the products they sell and equip the consumer with that information. Therefore, full knowledge of the chemical composition of the products, before and after cooking, becomes an important part of food product development. Swartland (1984) reports that, though the meat industry is one of the oldest food industries in the world, there have been established risks associated with beef consumption and consumers are looking for meat alternatives. Determining these facts will be of value to the guinea fowl farmer, the food service industry and the guinea fowl entrepreneur. These individuals need factual information on the product they are breeding and selling. According to Hoffman (2000), knowledge of these factors will not only indicates nutritional potential of game meat, but also the financial output that can be derived from the sales, and the particular markets to target.

## 1.2 Aims

The aim of this research was to investigate the chemical composition — proximate, fatty acid, and amino acid composition, mineral content and cholesterol content – of the different cuts of raw and processed guinea fowl (*Numeda meleagris)* meat, which will inform the consumer and thereby influence the utilisation of guinea fowl meat. The effect of processing (heat and brine injection) on chemical composition and sensory attributes of the different cuts of guinea fowl meat quality for value enhancement was also explored.

Preliminary studies were conducted to establish

1. The correct cooking time and temperature (see Chapter 1, Section 1.5).
2. The effect of the injection of brine solutions on the sensory attributes of the guinea fowl meat cooked according to the three cooking methods (see Chapter 1, Section 1.5).

The main study was done in phases 1, 2, 2, 3A, 3B, 4A and 4B guided by the following specific objectives that have been conceptualised in Figure 1.1.

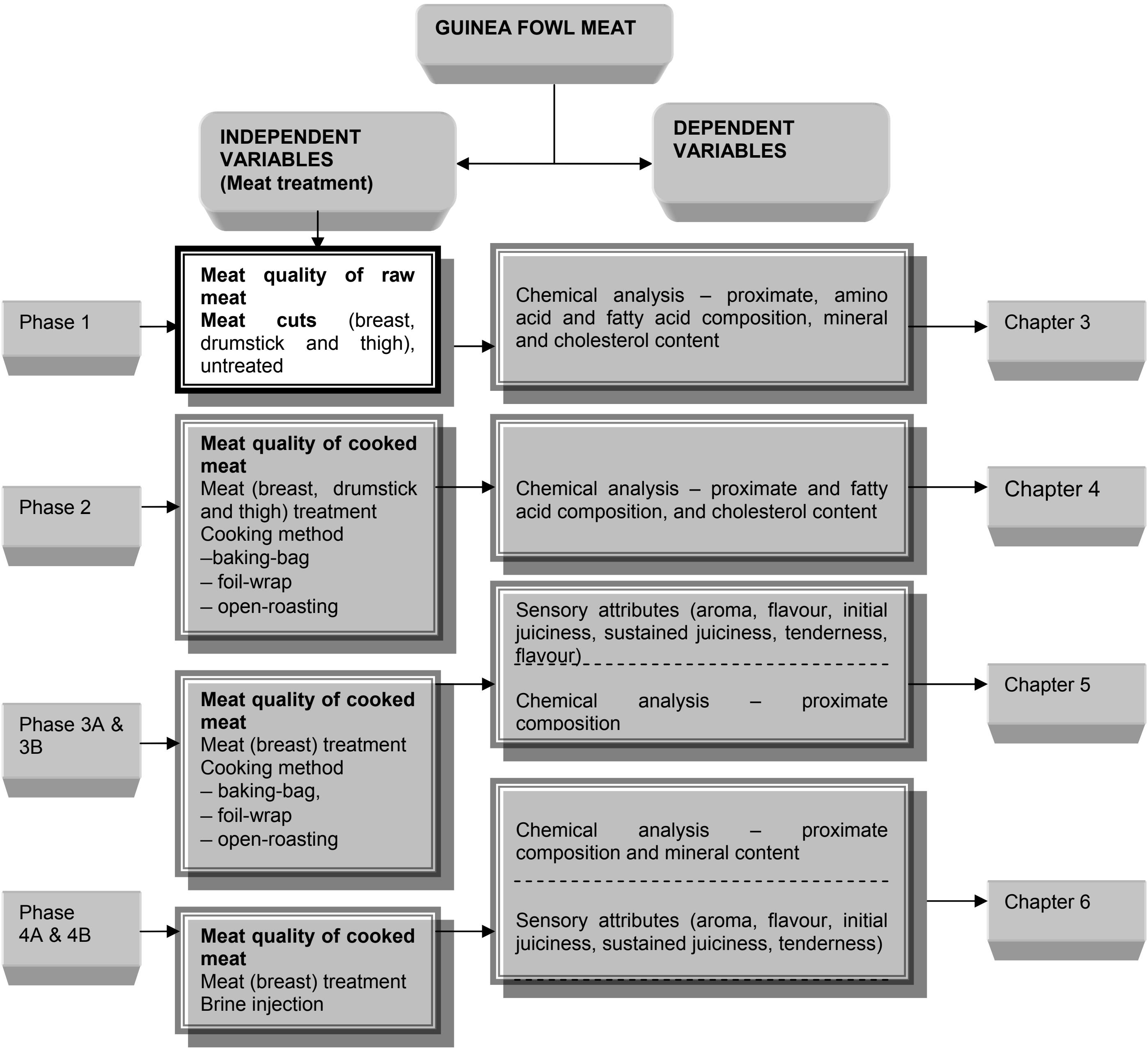


**FIGURE 1.1: Conceptual framework depicting the variables of the study**

The specific objections are listed below:

1. To determine the chemical composition of three different cuts (breast – *pectoralis* muscle; drumstick – *gastrocnemius* and *peronius* muscles; and thigh – *iliotibialis, semitendinosus* and *sartorius* muscles) of raw guinea fowl meat (see Figure 1.1, Phase 1). This is reported in Chapter 3.
2. To determine the effect of cooking methods (baking-bag, foil-wrap and open-roasting) on

the chemical composition of the three different cuts (breast, thigh, drumstick) of guinea fowl meat (see Figure 1.1, Phase 3B). This research is reported in Chapter 4.

3. To determine the effect of three cooking methods (baking-bag, foil-wrap and open-roasting) on the chemical composition of guinea fowl breast meat (see Figure 1.1, Phase 3A). This research is reported in Chapter 5.
4. To determine the effect of three cooking methods (baking-bag, foil-wrap and open-roasting) on the sensory attributes of guinea fowl breast meat (see Figure 1.1, Phase 3B). This research is reported in Chapter 5.
5. To determine, after the application of a pre-selected cooking method, the effect of brine injection vs the untreated guinea fowl meat on the sensory attributes (see Figure 1.1, Phase 4A). This research is reported in Chapter 6.
6. To determine, after the application of a pre-selected cooking method, the effect of brine injection on the proximate composition of guinea fowl meat (see Figure 1.1, Phase 4B). This research is reported in Chapter 6.

## 1.3 Research hypotheses, variables and operational definitions

On the basis of above-mentioned specific aims and variables (see dependent-variables column in Figure 1.1), the following null hypotheses were formulated for the main study.

1. The different cuts of raw guinea fowl meat do not differ in terms of chemical composition (Phase 1).
2. Cooking methods have no effect on the chemical composition of guinea fowl meat (Phase 2).
3. The different cuts of cooked guinea fowl meat show no differences in chemical composition (Phases 3A).
4. The different cuts of cooked guinea fowl meat show no differences in sensory attributes (Phase 3B).
5. Brine injection has no effect on the chemical composition of guinea fowl meat (Phase 4A).
6. Brine injection has no effect on the sensory attributes of guinea fowl meat (Phase 4B).

As indicated in Figure 1.1, the two concepts under investigation in this study are meat treatment and meat quality. Meat treatment is the independent variable and the two aspects that were investigated were cooking methods (heat treatment) and injection of brine solution ("meat treatment"). For meat quality the dependent variables were sensory attributes and chemical composition. Thus these dependent variables, what and how they were measured, tools and processes used for measure are illustrated in Figure 1.2, as well as the meat treatments.

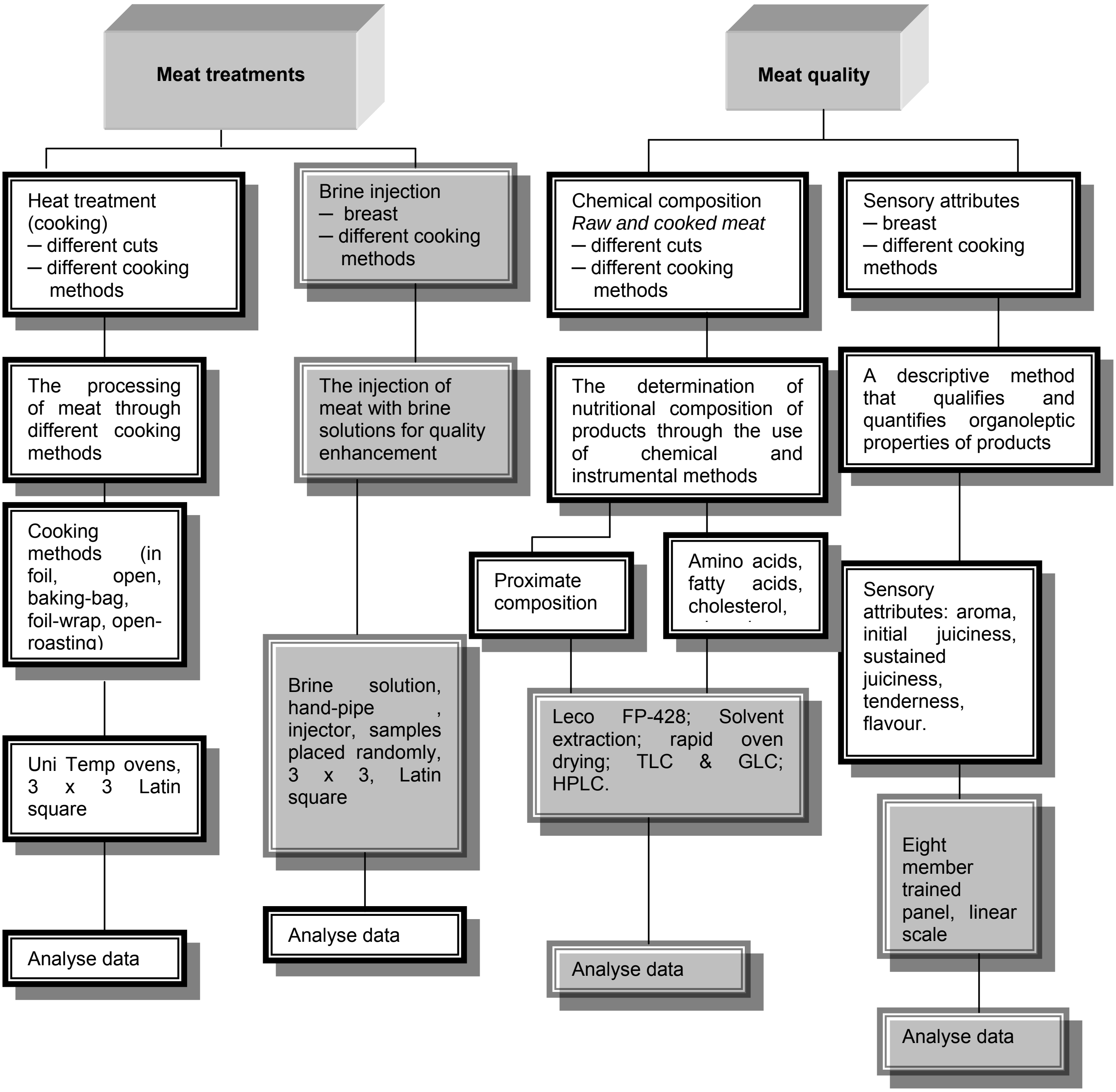


**FIGURE1.2: Summary of the operational definitions pertaining meat quality**

## 1.4 Outline of the study

Chapter 1 gives an introductory perspective of the rationale, aims and specific objectives, and the variables and operational procedures of the study. Chapter 2 is a review of available literature on guinea fowl meat quality and appropriate comparison to poultry meat. Chapter 3 investigates and presents data on the chemical composition of the different cuts of raw guinea fowl meat. Chapter 4 reports the effect of heat treatment on the chemical composition of the different cuts of guinea fowl meat. Chapter 5 focuses on the effect of heat treatment on the sensory and proximate composition of guinea fowl breast meat. Lastly, Chapter 6 reports the injection of a brine solution on the sensory and chemical composition of guinea fowl breast meat.  Chapter 7 is a report of the conclusions and recommendations of the study.

All chapters are written according to the guidelines of the Journal of Family Ecology and Consumer Sciences. The researcher has deviated from these guidelines in one respect, i.e. all authors are listed in the first citing per chapter, irrespective of whether there were two or eight authors.

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## CHAPTER 2

## LITERATURE REVIEW

### 2.1 Introduction

Bennion and Scheule (2004:735) describe poultry as domesticated birds used for human consumption, including chicken, turkeys, ducks, geese, guinea fowl, squab and swineeons. This classification of poultry also includes game birds (Mongin, 1991:1; Priestley, 1979: 195). Little, Crowe and Barlow (2000:90) explain that game birds are wild birds that have been used by humans for food, meat and eggs and one of the attributes common to all game birds is that they are potentially, sufficiently abundant and productive to withstand 'harvesting' year after year. Though guinea fowl is not widely domesticated, it has provided humans with meat and eggs for centuries and can therefore be classified as both poultry and game.

According to Little *et al.* (2000:90), there are no obvious differences between the sexes of guinea fowl, although males are slightly larger and have a small hump at the back when the wings are held close to its body. They further report (2000:90) that the average weight for both males and females is 1,48 kg, whereas Mongin (1991:1) reports that they are larger than chickens with male birds weighing an average of 2,5 kg with the potential to thrive under semi-intensive conditions.

The type of game bird under investigation is the helmeted *Numeda meleagris*. Among the domestic types of these species are the pearl, white, royal purple and lavender. Of these, the pearl species is the one most commonly found in the southern parts of Africa. The common name 'guinea fowl', refers to the Gulf of Guinea, the natural West African home of domesticated guinea fowls.

*Numeda meleagris* generally have dark grey feathers with white spots (Little *et al.*, 2000:90). They are found abundantly in open country terrains, from near desert to the edges of the forests and the bases of mountains, especially in savannas mixed with cultivation. According to Little *et al.* (2000:92) this helmeted guinea fowl has expanded itself enormously in South Western South Africa, and some parts of southern Africa (see Figure 2.1). The areas shown in the map show that this game bird can be found in the Western Cape area of South Africa, spreading around the coast towards the Eastern Cape and inland towards the Northern Cape and in the north western parts. In Botswana guinea fowls can be found around the South central going towards the South Eastern parts. It can also be found around the Western going towards Ngamiland and the Chobe and closer to the Namibian border. It is also abundant along the Eastern band of Namibia as well. Little *et al.* (2000:92) continue to report that the most intense breeding activity for the guinea fowl is during summer in eastern and southern South Africa (October to March) and during late summer (January to March) in the north of South Africa, in Botswana and in Namibia. In the Western Cape and the western half of the Eastern Cape, peak breeding is between September and December to take advantage of the food fostered by the winter rains.

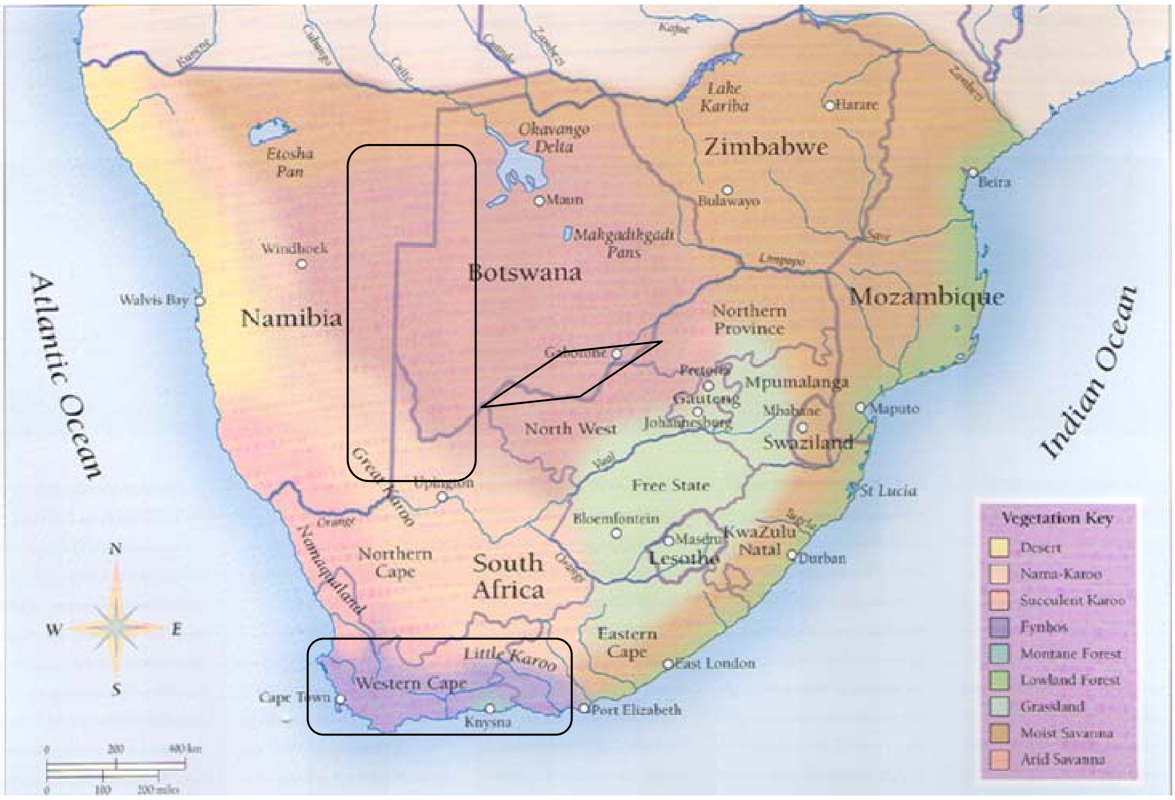


**FIGURE 2.1 Areas where guinea fowls (*Numeda meleagris)* are commonly found in Southern Africa (Little, Crowe & Barlow 2000:92).**

Accumulated knowledge on aspects of guinea fowl as a food product is relatively limited compared to other traditionally farmed poultry species and other game meat species, more especially regarding the meat quality and the manipulation of the meat during processing, such as cooking and brine injection.

Although there is lack of scholarly literature on guinea fowl as a meat product and therefore its chemical composition and suitable cooking methods, it is apparent that understanding these attributes is essential in order to establish how best the meat can be further improved and manipulated to suit the needs of the consumer. Van Heerden, Schönfeldt, Smith and Van Rensburg (2002:47) report that poultry is one of the leading meat products in South

Africa. These authors quote Schönfeldt (1998) who states that data on the nutritional composition of South African foods as compiled in the South African Food Composition Tables, is produced in other countries. They argue that these data cannot be applied to South Africa, prompting a study they undertook on the 'Nutrient Content of South African Chickens'. This study focused on determining the chemical attributes and nutrient content of fresh and frozen, whole South African chicken, raw, and prepared by a dry (oven- roasting) and moist-heat (casserole-stewing) cooking methods, and how they would differ. Baldwin and Cotterill (cited in Priestley, 1979:195) state that edible yield of poultry is influenced, amongst other things, by age, processing techniques, phosphate treatment and cooking method.

Bilgili (1999:3) explains that poultry products are in demand in all parts of the world and are usually preferred where there are no religious and cultural barriers. This preference is usually linked with the perceived safety and health advantages compared to other meat sources. However, recently avian influenza viruses of different strains have attacked and caused different severe diseases and death to poultry and in certain instances to humans (Doyle & Erickson, 2006:98). Hartl and Northoff (2006) in their FAO report on bird flu risk for consumers from poultry and eggs, advise that proper cooking of poultry to a temperature of 70ºC and above, render the meat safe for consumption. It is, however, crucial to investigate the phenomenon more extensively, hereby eliminating any uncertainties. Bilgili (1999:3) also mentions that, introduction of many novel poultry products has been mainly due to the changing needs of the consumers (convenience, nutrition, safety, health, quality and variety) and the development of marination/injection technologies.

Agricultural producers are therefore obliged to be attentive to changes in consumer demands and be able to position their products to respond to the needs and wants of consumers (Senauer, Asp & Kinsey,1991:280-283). They further explain that with the segmentation of the consumer market, opportunities for products aimed at specialised 'niche' markets have increased and consumers are now willing to pay a premium for products such as free-range chickens, natural beef or even game meat that is raised for sale. As in the case of ostrich meat (Sales & Hayes, 1996:167), lack of public knowledge about the nutritive value and limited scientific information about the nutritional composition could be the cause for limited utilisation and consumption and therefore a major justification for chemical analysis of the game bird.

## 2.2 Guinea fowl quality attributes

Issanchou (1996:S7,S10) quotes several authors who report that quality in food products is attributed to animal wellbeing, sensory attributes, safety aspects of foods, nutritional value and convenience of foods. Quality in meats and meat products is crucial since it is a major criteria determining and influencing consumption patterns. Grunert, Bredahl and Brunsø (2004:260) confirmed that the important quality dimensions when evaluating beef are taste, tenderness, juiciness, freshness, leanness, healthiness and nutrition. These authors (2004:260), use a model by Grunert, Larsen, Madsen and Baardsgaard to show how crucial quality dimensions are to the beef consumer, thus illustrating the link between quality and consumer desire (see Figure 2.2).

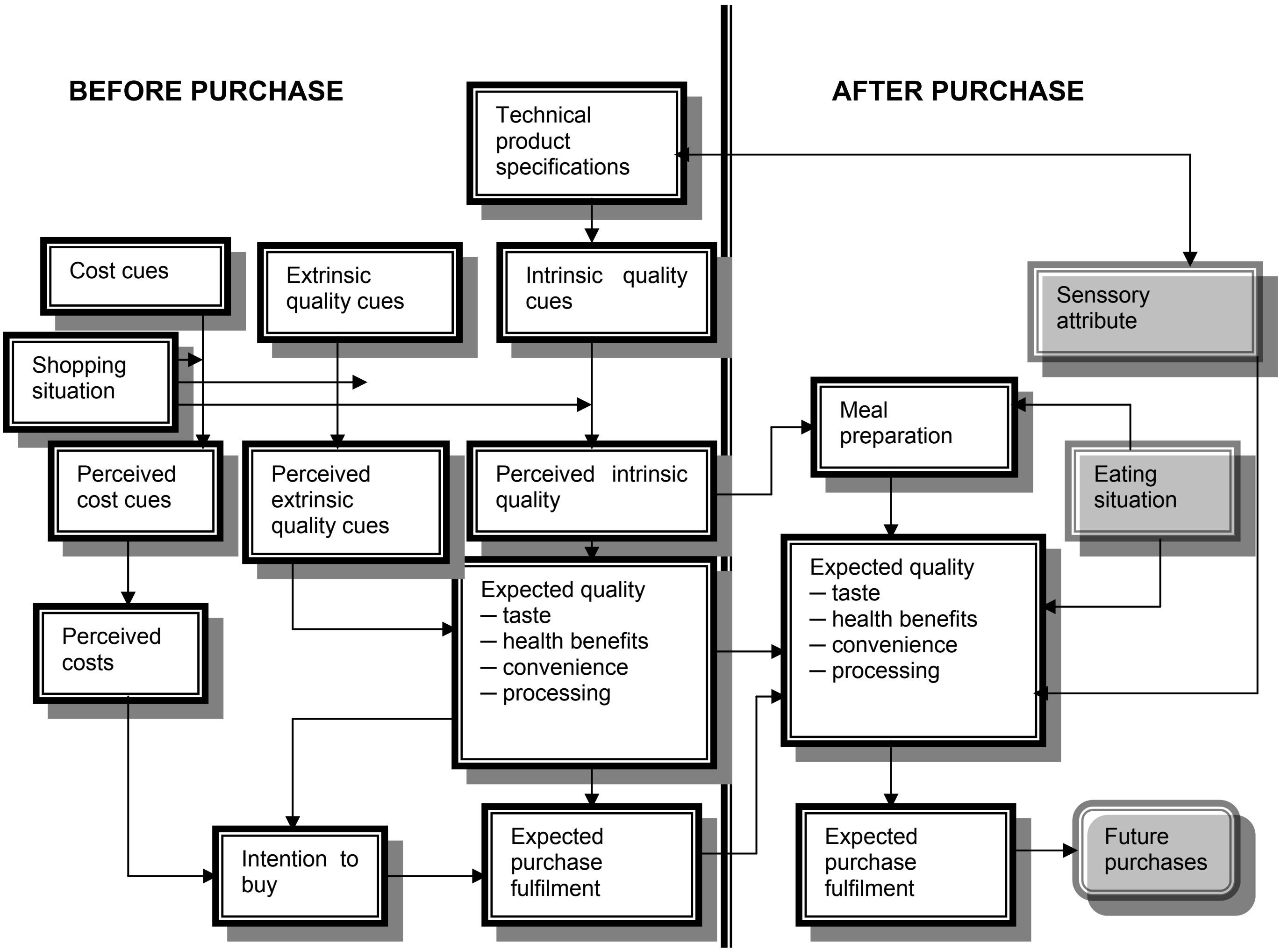


**FIGURE 2.2: The total food quality model (Grunert, Larsen, Madsen & Baardsgaard, cited in Grunert, Bredahl & Brunso 2004:260).**

Though Grunert, Bredahl and Brunsø (2004:260)'s focus is on beef, the concept can be used to evaluate guinea fowl meat since the quality dimensions critical for investigation are the same. According to the model, quality is an important factor in determining the need and the desire for purchasing and for satisfying the set values. These set values by the consumers will impact on which quality dimensions are sought. After purchase, the experienced quality is influenced by many factors among which are the product's sensory, physical, nutritional benefits and ways of preparation. Research by Grunert, Bredahl and Brunsø (2004:260) asserts that consumers have some uncertainties when evaluating fresh meat products, especially the sensory dimensions of quality, thus indicating the imperfect correspondence between quality expectations and quality experience during consumption. It is thus essential to provide the consumer with adequate information in terms of actual nutritional quality benefits.

### 2.2.1 Chemical composition

The most abundant substance in muscle tissue is water followed by protein. The quantity of fat usually varies and carbohydrates are mainly found as glycogen and little amounts of glucose. Vitamins, minerals, trace elements of several organic compounds then complete the chemical composition of the muscle tissue (McWilliams, 1989:321). Bennion and Scheule (2004:736) report that the nutritional composition of poultry is not different from those of other meats, but the breast in particular is lower in fat and cholesterol and higher in niacin compared to other lean meats. The specific composition usually varies from muscle to muscle and sometimes even from within the muscle (Varnam & Sutherland,1995:14). This, as well as the differences that exist between carcasses, makes the testing of meats very challenging.

Biesalski (2005:510) reports that in most instances the consumer has negative health associations with meat due to numerous reasons. These include its fat content, which is seen as high, and red meat especially is seen as a cancer-promoting food. He further explains that, to avoid the risks of cancer, obesity and metabolic syndrome, a low red meat intake is recommended. Even though this is the case, the importance of meat as a source of some micronutrients such as iron, selenium, vitamins A, $B_{12}$ and folic acid should not be overlooked. Baggio and Bragagnolo (2005:611) report that lipids play an important role in improving the organoleptic properties, even though they can be easily affected by molecular oxygen, thereby forming cholesterol oxides and altering fatty acids in the process. Time and temperature control are therefore critical aspects during processing.

### 2.2.2 Nutritional benefits

Scholtz, Vorster, Matshego and Vorster (2001:S39) report that foods from animal origin are essential to the diet as they provide high quality protein, are made up of a number of essential amino acids and essential micronutrients like calcium, iron, zinc, thiamine, riboflavin and fatty acids, and therefore have the potential of preventing undernutrition. Benefits of some nutrients found in meats are discussed below.

#### *2.2.2.1 Proteins and amino acids*

As a concentrated source of protein, meat contributes a sixth of the proteins consumed by humans (Warriss, 2000:4). According to Whitford (2005:9) proteins support every feature of the biological process. Their biological functions include amongst other things, DNA replication, cytoskeletal construction, oxygen transportation throughout the body's multicellular organisms and even the conversion of one molecule to the other (Whitford, 2005:5). Of the total nitrogen content of meat muscles, 95% is protein, the rest being smaller peptides and other compounds (Bennion & Scheule, 2004:664). Proteins provide the body with up to 20 amino acids; of these nine are essential (histidine, isoleucine, leucine, methionine, phenylalanine, threonine, tryptophan, lysine and valine). According to Whitney and Rolfes (2005:182), some non essential amino acids can become conditionally essential. They explain that protein quality is influenced by both protein digestibility and its amino acid composition, with animal protein being highly digestible at 90 to 99 percent and plant protein at 70 to 90 per cent. Animal sources (meat, fish, poultry and their by products) provide the body with high quality protein, whereas most plant proteins are limiting in some essential amino acids (Whitney & Rolfes, 2005:195). Varnam and Sutherland (1995:6) and Bennion and Scheule (2004:664) further support this by stating that meat contains the essential amino acids required for human health. Whitney and Rolfes (2005:194) further report that protein quality determines the proper growth of children and the ability of adults to maintain good health. Whitmire (2004:68) reports that tryptophan is usually low in animal protein. Similarly, it was found to be very low in camel meat (Dawood & Alkanhal, 1995:7), while Varnam and Sutherland (1995:7) reported the low values of tryptophan in beef, chicken, lamb and pork. Amino acids have been reported to be constant in meat protein regardless of the cut (Dawood & Alkanhal, 1995:7; Beach, Munks & Robinson, 1943:435). On the contrary, Lawrie (1998:259) notes significant differences in amino acid composition due to the type of muscle, breed and the type of the animal.

Poultry is a source of protein and is comparable to beef, lamb and pork in composition and nutritional value (Charley & Weaver, 1998:417). In a study by Hamm (1981:1122) on the amino acid composition of breast and thigh meat of broilers, glycine, proline, threonine and serine – amino acids most abundant in cuts with more connective tissue – were found to be higher in the drumstick, whereas the breast and thigh presented similar profiles. In a study by Hoffman, Fisher and Sales (2000) on the Nile crocodile (*Crocodylus niloticus*), all amino acids analysed, with the exception of glycine, histidine and arginine, were more concentrated in cooked meat samples than in raw meat samples.

#### *2.2.2.2 Fat, fatty acids and cholesterol*

Total fat content of the diet, especially the fatty acid composition and cholesterol content, are becoming increasingly critical to the consumer, since it has been discovered that they are a risk factors associated with coronary heart diseases and cancer (Sales, Marais & Kruger, 1996:85). Emphasising this further, Scollan, Choi, Kurt, Fisher, Enser and Wood (2001:115) explain that the consumption of high levels of fat, particularly of saturated fatty acids, expose humans to several diseases particularly to the coronary heart diseases. The need to produce healthier meat has therefore steered interest in meat fatty acid composition (Wood, Richardson, Nute, Fisher, Campo, Kasapidou, Sheard & Enser, 2003:22). Besides being important in the nutritional value of fat for human consumption, fatty acids also play an important role in the differences between the sensory attributes of meat (Santos-Silva, Bessa & Santos-Silva, 2002:187). Valsta, Tapanainen and Männistö (2005:526) report that palmitic acid, oleic acid, linoleic acids and alpha-linolenic acid are the most abundant fatty acids in meat fats. Carbon, hydrogen and oxygen sources like glucose, help the body in the synthesis of most of the fatty acids it needs, but it is not able to synthesise double bonds in the omega-3 and omega-6 position (Smolin and Grosvenor 2000:132), thus making these fatty acids essential. Stopler (2008:855) reports that myristic, palmitic and lauric are the most hypercholesterolemic promoting fatty acids, in that order of potency. The author further reports that palmitic acid is the most prevelant of the three, making up to 60% of the total SFA of the American diet. According to Van Heerden *et al.* (2002:63), palmitic acid was found to be high in frozen chicken saturated fatty acids increase plasma lipids. Their consumption, as well as the oxidation of cholesterol, can potentially lead to accretion of fat in veins, subsequently blocks the normal blood flow (Ettinger, 2004:52).

The longer chain polyunsaturated fatty acids, particularly the ones with the first double bond at the omega-3 position, help to prevent blood clotting (Krummel, 2004:879), whereas some monounsaturated fatty acids, like oleic acid, have protective effects against heart diseases through the lowering of serum cholesterol levels (Smolin & Grosvenor, 2000:132–133).

Baggio and Bragagnolo (2005:611) also stated that chicken products have high quantities of polyunsaturated fatty acids.

Woolsey (2008:1108) reports a beneficial *n*-6:*n*-3 ratio of less than 2:1. A ratio of less than10 has the potential of promoting inflammation and oxidation that can in turn give rise to mental illnesses. The author further explains that even diets low in fat, like vegetables, could have high *n*-6:*n*-3 ratios.

The polyunsaturated:saturated fatty acid (P:S) ratio should be at least 0.45 (Wood *et al.,* 2003:21). Santos-Silva *et al.* (2002:192) argue that, though fats with low P:S ratios are unfavourable due to their potential catalystic attributes pertaining to the increase of cholesterolemia, the chemical structure of the fatty acid may not be the most appropriate characteristic for judging the nutritional value of fats. They contend that all saturated fatty acids induce cholesterol increase and they do not consider the effect of the monounsaturated fatty acids to be as important. According to a study on pork by Wood *et al.* (2003:22, 23), high linoleic acid content tended to cause a rise in the P:S ratio, which could be attributed to the high content of C18:2 fatty acids in the cereal-based diet fed to the animals, consequently producing a high *n*-6:*n*-3 ratio. Wood and Enser (1997:S50) reported that feed manipulation is one of the methods researchers are finding useful in rectifying the imbalance in the *n*-6:*n*-3 ratio in poultry meat. An increase in the consumption of n-3 fatty acids is recommended to overcome the imbalance in the ratio of *n*-6:*n*-3 (Scollan *et al.,* 2001:115).

Stopler (2008:857) reports that linoleic acid is the most predominantly consumed polyunsaturated fatty acid (PUFA) in the American diet. Linoleic acid as well as high levels of the *n*-6 fatty acid, increase the total PUFAs (Wood *et al.,* 2003:22). In particular, linoleic acid is noteworthy due to its isomer, conjugated linoleic acid (CLA), which is important to human health, specifically as a chemo-preventative agent (O'Shea, Lawless, Stanton & Devery, 1998:192).

According to Lawrie (1998:84) variations in fatty acid composition of different muscles have been established. Van Heerden *et al.* (2002:63) report fatty acid differences in cuts of chicken. Ettinger (2004:52) reports that fatty acids with double bonds are easily affected by oxidative damage.

According to Conchillo, Ansorena and Astiasarán (2004:303) changes in fatty acids during cooking can be attributed to oxidation and loss of fatty acids by diffusion as in the case of roasting. They also state that at times unsaturated fatty acids are less affected by cooking.

This is because to a larger extent, unsaturated fatty acids belong to membrane structure than saturated fatty acids, causing a low decrease of PUFAs by diffusion during cooking.

The South African food-based dietary guidelines recommend that, “fats should be eaten sparingly”. To act in accordance with this guideline will therefore imply eating foods low in fat and these will include amongst others, game and ostrich (Scholtz *et al.,* 2001:S45). It is therefore worth investigating the fat content of guinea fowl as it is classified as both game and poultry.

*2.2.2.3 Minerals and vitamins*

Minerals that are generally contained in all meats are iron, copper, zinc and selenium, with iron being of high bioavailability (Warriss, 2000:110). In human health, iron deficiency anaemia is a highly common nutritional deficiency (Stopler, 2004:839) thus making iron a fundamental component of the human diet. Poultry in particular, is a significant source of phosphorus and sulphur (Whitney & Rolfes, 2005:423). According to Whitney and Rolfes (2005:445/449), poultry is one of the main sources of the trace minerals iron and zinc, and most importantly, meat provides the human body with heame iron, which is the highest bioavailable form of iron (Wariss, 2000:5; Lombardi-Boccia, Martinez-Dominquez & Aguzzi 2002:1739). In general, meat is a good source of copper (Lombardi-Boccia *et al.,* 2005:39). The values reported by these authors for iron, zinc and copper for raw chicken are 0.40. 0.65 and 0.05 mg (breast), 0.63, 1.47 and 0.09 mg (drumstick) and 0.70, 1.71 and 0.11 mg (thigh), respectively. Processed meats also contain significant amounts of sodium and chloride (Whitney & Rolfes, 2005:410-411). Meat is also a good source of the B vitamins, in particular thiamin ($B_1$), nicotinic acid (niacin), riboflavin ($B_2$), pyridoxine ($B_6$), cyanocobalamin ($B_{12}$) and retinol (Vitamin A) (Warriss, 2000:110). High sodium intakes are known as a causal factor in arterial hypertension (Alais & Linden, 1991:92). In a study by Sales and Hayes (1996:169) on ostrich, chicken and beef, the darker cuts of the ostrich had a higher sodium content than the poultry meat.

Maintaining balance in the diet is very important. Biesalski (2005:509) reports that micronutrients in meat are either not present in plant foods or have poor bioavalability. It is also important to note that meat lowers the glycaemic index (GI) value of menu items of carbohydrate foods with high GI when used in combination (Biesalski 2005:509). The lowering of the GI is brought about through the lowering of the glycaemic load of the menu items and through nutrient interactions e.g. protein/carbohydrates interactions and lipid/carbohydrate interactions (Mathai, 2004:313). As an essential part of a mixed diet, meat in combination with foods from plant origin, increases the availability of micronutrients in plant-derived foods (Scholtz *et al.,* 2001:S39). They further emphasise that, though possible, it is difficult to achieve an adequate and balanced diet without the inclusion of foods from animals, though it is still very important to pay particular attention to the amounts of saturated fats and the cholesterol content of these foods.

As indicated by Priestley (1979:195) ( Table 2.1), raw chicken and turkey average 65.2% and 64.2% moisture, respectively. Water content may be affected by the absorption of moisture during the chilling process and by any type of phosphate treatment, which favours moisture retention. Other components that influence yield are protein and fat on a raw basis. Protein content averages 18.1% for chicken, and 20.1% for turkey. Fat content averages 15.9% for raw chicken and 14.7% for turkey. This study only gives a comparison of the macronutrient values of turkey and chicken.

**TABLE 2.1: Moisture, protein and fat content of chicken and turkey (adapted from Priestley, 1979: 196**

| | Moisture % | | Protein % | | Fat % | |
|---|---|---|---|---|---|---|
| | Raw | Cooked | Raw | Cooked | Raw | Cooked |
| Chicken | | | | | | |
| Fryers | 75.7 | 53.3 | 18.6 | 30.7 | 4.9 | 11.8 |
| Roasters | 63.0 | 53.5 | 18.2 | 25.2 | 17.9 | 20.2 |
| Hens & Cocks | 56.9 | 45.9 | 17.4 | 24.0 | 24.8 | 29.5 |
| Mean | 65.2 | 50.9 | 18.1 | 26.6 | 15.9 | 20.5 |
| Turkey | | | | | | |
| All classes | 64.2 | 55.4 | 20.1 | 27.0 | 14.7 | 16.4 |

Scholtz *et al.* (2001:S41) provide the nutrient composition of selected foods from animals, and amongst those is the composition of raw chicken reared in South Affrica (see Table 2.2).

**TABLE 2.2: Nutrient composition of chicken (raw white meat) per 100 g adapted from Scholtz, Vorster, Matshego & Vorster (2001:S41)**

| Nutrients | Chicken (white raw meat) |
|---|---|
| Energy (kJ) | 491 |
| Protein (g) | 23.0 |
| Cholesterol (mg) | 41 |
| Fat (g) | 2.7 |
| Saturated fatty acids (g) | 0.75 |
| Monounsaturated fatty acids (g) | 1.05 |
| Polyunsaturated fatty acids (g) | 0.68 |
| Carbohydrates (g) | 0 |
| Calcium (mg) | 14 |
| Iron (mg) | 1.1 |
| Magnesium (mg) | 28 |
| Potassium (mg) | 309 |
| Sodium (mg) | 43 |
| Zinc (mg) | 0.74 |

## 2.3 Cooking methods for application on guinea fowl meat

One of the many reasons why food is cooked is to make it edible and palatable. Proper cooking also destroys most pathogenic microorganisms that may be present in the food when raw (Charley & Weaver, 1998:391).

Cooking can be classified according to the medium through which the heat is transferred, which may be air, water, steam or fat (McWilliams, 1989:359). More than one method of heat transfer is involved during cooking, namely radiation, conduction and convection currents (Charley & Weaver, 1998:53,54). These medium of heat transfer will also determine how fast the food becomes cooked, i.e. what internal temperature is reached during a particular period of time, and usually more than one method is involved. Air as a medium will include methods such as roasting, baking and broiling, and are generally classified as the dry heat cooking methods. The surface of the food comes into contact with dry air, thereafter heat is transferred by the water molecules through the means of convection, which is faster than conduction (Charley & Weaver, 1998:54).

Boiling, stewing, braising and poaching are methods that use water as a medium of heat transfer, and these are classified as the moist-heat cooking methods. Foods cooked using these methods, often cook faster since water is a better conductor of heat than air (Charley & Weaver, 1998:53).

Steaming is a moist heat method as well. Steam is used as the medium of heat transfer in intentional direct and indirect steaming of food. Food may also steam during cooking, e.g. in a baking-bag or foil-wrapping. The water the food contains is trapped when the food product is wrapped in an aluminium or in a baking-bag during cooking. After enough heat had been generated to develop steam from the water molecules in the food, steam develops and it heats the food faster due to its high-energy capacity attributed to change of phase from water to steam.

Heat transfer using fat as medium will be applied during pan frying, deep fat frying as well as sautéing which are other ways of cooking where convection currents are set up in the heated fat to aid in distributing the heat (Bennion & Scheule, 2004:150-151; McWilliams, 1989:359).

Dry heat methods are designed to maximise the quality of muscle proteins, and therefore tender cuts are well suited for roasting and baking because of their relatively high proportion of muscle protein and reduced quantity of collagen (McWilliams, 2001:334). Bennion and

Scheule (2004:746) report that principles of cooking poultry are not in any way different from other kinds of meats. Young and tender poultry can be roasted or baked, though a problem usually arises when roasting whole poultry, since some parts like the breast, are more tender than other, e.g. thigh and drumstick. Somewhat older, but immature birds, are suitable for roasting (Charley & Weaver 1998:419). They also report that the baking bag, aluminium foil and open roasting have long been used for baking and roasting of poultry. When roasting, the oven is used and the meat is uncovered. Any juices from the meat evaporate or are just drained from the draining rack to the bottom of the pan. Oven temperatures for roasting influence the palatability of meats. The higher the oven temperature the less uniform is the heat distribution (McWilliams, 1989:359). On the other hand, preparing poultry meat in a baking bag can be a safe and a delicious alternative to the traditional roasting method. In this technique, a heat-treated polythene bag, especially designed for oven temperatures, is used. When using a baking bag, the oven is preheated and slits are cut in the bag to allow steam to escape. The pan holding the poultry in the bag has to be large enough to prevent the bag from hanging over the sides. Enough space to allow the bag to expand during cooking so that it does not touch the top or sides of the oven is also important to prevent burning. This method produces a moist-heat cooking environment. Another alternative is baking, that can be done with meat wrapped with aluminium foil. This method steams poultry in its own juices, producing a moist product with a light golden, non-crisp skin. The cooking time is reduced due to the higher temperatures caused by the trapped steam inside the foil (http://www.urbanext.uiuc.edu/index.html). Charley and Weaver (1998:419), however, reported that, in the case of turkey, a foil-wrap prolongs roasting time. They report the results of an experiment where in one study, dark muscle cooked in had more moisture than those cooked in an open pan, in an ovenproof film or paper bag, and light meat had more moisture cooked in an open pan or in foil.

In breast and thigh muscles of poultry, temperatures of 70°C–90°C have been reported in various studies as final internal temperatures to indicate degree of doneness. Any oven temperature between 120°C and 204°C can be used to roast poultry provided the internal temperature is monitored to determine the cooking time and degree of doneness. The usual temperature for roasting meat is 163°C and this temperature results in juicier, tender and flavourful meat with less cooking losses, as opposed to temperatures above 218°C (McWilliams, 2001:334).

### 2.3.1 Effect of cooking (heat treatment)

Over the years research has proven that heat processing has a large effect on the toughness of meat (Christensen, Purslow & Larsen, 2000:301). The intensity of cooking is therefore of greater concern since it is the combination of temperature and time that determine the final effect. Temperature, which is critical for the toughening of myofibrillar proteins, and time are important for the softening of collagen, as well as the specific muscle being cooked are some of the factors that have an effect on the decrease or increase in tenderness during cooking (Bennion & Scheule, 2000:548; Lawrie, 1998:241). Cooking meat increases toughness in two phases. The first phase occurs between temperatures of 40°C and 60°C, and results from heat denaturation of myofibrillar proteins, especially myosin. The second rise is above 60°C and could be ascribed to denaturation of intramuscular collagen which is reflected in the measurement of tensile strength (Christensen, Purslow & Larsen, 2000:301; McWilliams, 2001:330). During heating, fats soften and melt, proteins are denatured, and collagen fibres shrink, thereby decreasing the water binding capacity through the narrowing of muscles. In this regard, the actual temperature is very important for the full duration of the conversion of collagen to gelatine. Therefore oven roasting provides more opportunity for the conversion of collagen to gelatine, as cooking times using other dry heat methods are too short to allow for effective conversion (Charley & Weaver, 1998:394,419).

#### *2.3.1.1 Chemical composition*

Cooking generally reduces the moisture content of poultry meat. Different cooking methods also affect poultry meat differently (Stadelman, Olson, Shemwell & Pasch, 1988:109). During the cooking of poultry meat, heat is conducted from the surface of the meat to the interior thereby activating the enzymes responsible for degrading muscle proteins as temperature rises. Protein chains begin to denature, eventually causing the structure of myofribils to shorten, degrading molecules and subsequently decreasing water holding capacity. The muscle is then dehydrated increasing the toughness (Freeland-Graves & Peckham, 1996:515). Proteins and amino acids can be lost in small amounts in the drip of cooked meats, though it is not of serious dietary concern. Protein digestibility on the other hand can be improved (Stadelman *et al.*, 1988:107,109). High temperatures melt fat which may end up in the drippings (Freeland-Graves & Peckham: 1996:515) and when cooked with skin there could be transfer of fats from skin to muscle. Lipids could be increased during cooking due to moisture loss and due to the transfer of fat from skin to muscle (Stadelman *et al.,* 1988:109). Conchillo, Ansorena and Astiasarasia (2004:304) reported that during refrigeration storage of roasted samples, monounsaturated fatty acids (MUFA) decreased, but not during freezing and insignificantly during cooking. Phosphorus and sodium have been noted to decrease significantly in turkey during cooking. Most minerals found in meat will remain stable, calcium on the other hand may increase due to migration from the bone (Stadelman *et al.,* 1988:109).

The level of cholesterol in cooked meat is influenced by the method of cooking. Cholesterol content ranges from 60 mg to 81 mg/100 g for poultry cooked with skin, levels higher than those of red meats. The more dehydrated the meat, the higher the concentration (Stadelman *et al.,* 1988:97,98)

Van Heerden *et al. (*2003:63) report that mineral content for the white and dark meat increased, which could be attributed to moisture loss. None of the cooking methods they used had an effect on copper, zinc and manganese.

*2.2.2.4 Sensory attributes*

Warriss (2000:260) explains that only during cooking do the characteristic flavours associated with meat develop. There is a non-species component common to all meat, and it is this component that determines the differences between beef, lamb, pork and poultry.

A combination of water, fat and volatile losses during cooking reduces the juiciness of meat. Heat is required to develop the aroma and the flavour of meat. Flavour is developed through the interaction of volatile substances, the denaturation and breaking down of proteins, melting and the decomposition of fat. The volatiles that are hence formed, react with other compounds to create flavour. When meat lost some minerals to water such as phosphates and sodium chloride flavour changes (Freeland-Graves & Peckham: 1996:516).

McWilliams (2001:337) explains that use of film wrapping and aluminium foils when cooking meat results in greater cooking losses thereby negatively impacting on the tenderness of meat.

## 2.4 Poultry meat treatment

According to Alvarado and Sams (2003:1332), poultry is marinated in order to improve taste, tenderness, and protein functionality. Most marinades contain sodium chloride and phosphates; specifically sodium tripolyphosphate (STTP), and both have been shown to improve water-holding capacity and yield. In their later research, Alvarado and Sams (2004:

1035) report that, the availability of processed poultry products have increased over the previous 20 years due to consumer demands. Research has therefore focused on methods of improving tenderness. In the Westernised countries, it is a well-established practice to use marinade solutions to enhance the eating quality of meat products (Sheard & Tali, 2004:305). Sodium chloride and phosphates are commonly used to improve the juiciness and tenderness of meats, sometimes independently but often in combination to benefit from their synergistic action. These have also proved to increase the weight of the saleable product because of the retention of the added water (Boles & Swan, 1996: 88; Alvarado & Sams, 2004: 1036).

According to Ünal, Erdoğdu, Ibrahim and Özdemir (2004:264), several studies have proven that phosphates increase the water-binding capacity of meats. This is because they control the loss of natural muscle juices, thereby reducing vulnerability to freeze burn, reducing cook and thaw drip loss, in turn providing the meat with some resistance against oxidation. They also quote several researchers who studied the effect of phosphates on microbial spoilage of food products and polyphosphates. Reduction of bacterial population in meats was shown. Polyphosphates also improve textural properties (i.e. hardness, firmness, chewiness, gumminess, adhesion and tenderness) of meats and also help stabilise the colour, flavour and other sensory attributes. Lawrie (1998:246) states that sodium chloride has a tenderising effect on meat and some of these effects are due to an enhanced water-holding capacity either directly or as in the case of phosphates, through the raising of the pH. The swelling and higher water-holding capacity of the myofibrils result in the increased tenderness and juiciness of the meat (Sheard & Tali, 2004:306). Sheard and Tali (2004:305–311) further report that bicarbonate has been used in meat treatments in order to minimise the problem of a pale and soft product, to mask uncharacteristic aromas and flavours. It is therefore not advisable to use bicarbonate If the flavour and colour are to be maintained, never the less, when used in combination with salt and phosphates it can bring a good product. They advise that marinades that are sufficiently concentrated must be used to improve the tenderness and juiciness without adversely affecting flavour and colour or causing over-tenderisation. The importance of proper concentrations is further emphasised by Shahidi and Synowiecki (1996:296–8) and Ünal *et al*. (2004:263–272) who state that the presence of excessive amounts of phosphates in the diet negatively influence the calcium, iron and magnesium balance in the human body, thereby increasing the risk of bone diseases. Varnam and Sutherland (1995: 173–175) report that concentration of marinade solutions is usually lower in the injection method as opposed to the immersion method. The injection method was preferred for this study (see Chapter 6).

The injection method ensures that marinade ingredients are evenly distributed throughout the interior of the meat. This even distribution is very important because incomplete dispersion of the ions through the meat can possibly affect the water-holding capacity and tenderisation potential of the marinades (Varnam & Sutherland, 1995:173). Injection of the marinade solution can be carried out manually using a process of ‘stitching’ and ‘pumping’, to ensure even distribution of the brine solution. This process is only effective when carried out by a skilled operator, but there are bound to be some variations and the multi-needle injectors are now used in the great majority of large-scale operators. These multi-needle injectors consist of a conveyor that feeds sides of meat pieces to an injection head with two to four rows of needles. The most effective equipment holds the meat sides, simultaneously ensuring a good brine distribution (Varnam & Sutherland, 1995: 173–175).

The immersion method is intended to cure the shallow tissues and exposed meat surfaces (Varnam & Sutherland 1995:175). The brine is distributed evenly between the layers of sides and it is run in a tank with wooden battens used to hold the upper layer below the surface with the immersion process running for three to five days at highly controlled temperatures of 4–5°C.

### 2.5 Sensory attributes of poultry meat

Sensory evaluation is defined by Stone and Sidel in Lawless & Heymann (1999:2) as a scientific discipline that is used to stir up, measure (gauge), analyse (examine) and construe reactions to the attributes of foods as they are perceived by the human senses of smell, sight, touch, hearing and taste. According to Bower (1995:35), using human subjects in sensory evaluation proved to be an irreplaceable method. McWilliams (2000:23) brings in the element of quality and the linkage with the market place into the definition, by highlighting that it will be very costly for food to be tested for quality in the marketplace and hence preliminary scientific research and evaluation by food producers is inevitable. This could be through subjective sensory evaluation (using trained sensory panelists), also known as analytical sensory evaluation, or objective evaluation (use of mechanical devices). To determine acceptability of products in the market, consumer sensory evaluation is used to measure the degree of liking, preferences and reasons for purchase (Lawless & Heymann 1999:430)

There are several sensory evaluation tests available. These could be the paired preference, rating and ranking test, which are known as the consumer or affective techniques, and the discrimination and descriptive tests also known as the analytical or laboratory techniques

(Lawless & Heymann, 1999:6,7). Amongst the discrimination tests are the paired comparison, Duo-Trio, triangle and ranking tests, whereas the descriptive tests include a variety of profiling techniques, e.g. flavour profiling, texture profiling, quantitative descriptive analysis, free choice profiling and time-intensity scaling (Lawless & Heymann, 1999:9; Swinegott, 1995:217). A panelist, also known as a judge, is expected to use words or numbers to indicate the intensity of a specified characteristic on a rating scale (American Meat Science Association,1995:19). Panelists should be well trained to learn the meaning of the key attributes and the evaluation (Lawless & Heymann, 1999:566). There are several attributes that require evaluation through the human senses in foods and these are texture, appearance, aroma and flavour (McWilliams, 2001:37), also the focus of this study.

The quality of meat is highly determined by its sensory and organoleptic attributes. Hence a trained, expert panel is recommended to carry out the evaluation (Labbe, Rytz & Hugi, 2004:341). Consumers view colour, juiciness, texture, water-holding capacity and tenderness as the most important attributes in meat quality and these have been evaluated widely (Varnam & Sutherland, 1995:9; Honikel, 1998: 447). For new food product development, and for maintaining quality control in existing foods, the food industry relies heavily on sensory evaluation. Thus these evaluation techniques are the food industry's basic tools and therefore regarded as a vital source of information (McWilliams, 2001:34).

The present consumer constantly demands healthy and convenient products with desirable quality attributes, thus challenging the researchers to examine the effects of meat treatments on the sensory properties of poultry. The brine injected into meat, and other methods used to tenderise the meat, age and feed of the animal, freezing temperatures and time pertaining to product development, are some of the factors researchers have to investigate as they impact on the sensory properties of meat (Hoffman & Fisher, 2001:335; Mielnik, Herstad, Lea, Nordal, & Nilsson, 2002:29; Anderson, Oksbjerg, Young & Therkildsen, 2005:544).

### 2.5.1 Water-holding capacity (WHC)

Quantitavely water is the most important component of meat comprising up to 75% of the total weight (Warriss, 2000:111). Varnam and Sutherland (1995: 12–28) outline the reasons for this quality as a parameter that influences the perceived juiciness in fresh meat after cooking. This is because meat with low WHC loses a lot of fluid in cooking and may taste dry and lack succulence. Drip loss reflects a decrease in or poor water-holding capacity and leads to weight loss. In processed meats poor WHC has the potential of reducing water retention and hence product yield.

According to Honikel (1998:447), another effect on WHC is cooking. He explains that the moisture loss that occurs during heating is the result of "the different meat proteins [that] denature at varying temperatures, which causes structural changes such as the destruction of cell membranes, transverse and longitudinal shrinkage of muscle fibres, the aggregation of sarcoplasmic proteins and shrinkage of the connective tissue". To measure WHC, the type of muscle and sample location is very important. The chemical composition of lean meat, particularly its protein content, may be important in determining the yield and quality of processed products. They further explain that it is important to minimise drip loss for economic reasons since meat is sold by weight.

To improve WHC, texture, colour and flavour, polyphosphates are used in meat and poultry products. When added to meats, phosphates attach to positively charged groups of proteins, while the rest of the molecule can attract water molecules and therefore increase the WHC by acting as a polyanion (Shahidi & Synowiecki, 1996:296-8). This is because the increased length of phosphate chains is associated with polyelectrolyte properties; thereby enabling the phosphate chains to attach to positive sites on protein molecules and this in turn improves the protein solubility and enhances the WHC. Therefore, the type of phosphate used, determines the water binding mechanism (Ünal *et al.*, 2004:263).

### 2.5.2 Juiciness

As defined by Lawrie (1998:228-9), the two major attributes that express juiciness as a component of palatability are the impression of moisture which is created when fluids are released from the meat during the first few chews, and the sustained juiciness that is a result of the stimulating effect of fat when saliva is produced and fat coats the tongue, teeth and other parts of the mouth. Therefore juiciness and tenderness account for the overall eating quality of meat, whereas juiciness on its own relates to the WHC, as well as high levels of intramuscular marbling fat (Varnam & Sutherland, 1995:10).

### 2.5.3 Flavour

McWilliams (2001:39) defines flavour as a sensory message resulting from the combination of taste and aroma. Lawrie (1998:246) further explains that flavour is a complex sensation involving aroma, taste, texture, temperature and pH with aroma being the most important. This is sometimes complex to the consumer, as it is often not easy to tell it apart from taste. The evaluation of these two parameters depends largely on the sensory taste panel. Flavour though, is a characteristic that consumers use to determine the quality of meat. Water-soluble constituents mainly determine flavour, while aroma is determined by fat-soluble and volatile elements, even though they both contribute to the flavour of foods (Varnam & Sutherland, 1995:9). This would then imply that, as fat content of meat increases, the flavour increases as well.

The temperature at which meat is evaluated is very critical, as it may have an influence on the ability to detect taste and evaluate the flavour. The extremes in temperature can limit the ability of people to judge food accurately, the best temperature range for evaluating the flavour of cooked meat is 20°C to 30°C, depending on how the food being tested is eventually going to be served (McWilliams, 2001:39). Game birds generally have a distinct flavour that needs to be maintained after heating and processing manipulations.

### 2.5.4 Aroma

Aroma is detected by sniffing the food since the response to aroma occurs in the olfactory cells of the nasal surfaces and conveyed to the brain for interpretation (McWilliams, 2001:38, Lawrie, 1998:247). The acceptability of aroma is important to the overall acceptability of food and even more so if the food is ordinarily served hot or cold. A pleasing aroma and sometimes, expected aroma, beckons people to sample the food, whereas a strong irritating aroma discourages diners.

### 2.5.5 Colour/appearance

Appearance is important because it is practically the first criterion the consumer can use to judge acceptability when they purchase meat (Warriss, 2000:111). Colour is the major determinant of appearance, the presence of the muscle swinements myoglobin and haemoglobin are the major determinants of colour in meats. Haemoglobin is the swinement present in the blood, while myoglobin is found in the muscles. The heaem portion of the swinement is specifically interesting and important because the colour of meat is partially dependent on the chemical state of the iron within the haem ring (Varnam & Sutherland,1995:26-29; Lawrie, 1998:11-12). The function of myoglobin in the living animal is oxygen storage, with levels being accordingly higher in muscles with the higher workloads. Thus leg muscles contain more myoglobin and are usually of a darker colour. Similarly myoglobin levels in muscles of animals reared under free-range conditions are likely to be higher than those reared intensively (Varnam & Sutherland, 1995:9-29). Meat of free-range poultry is therefore often darker than that of poultry reared indoors with restricted movement.

They further report that, unlike red meat, poultry meat is retailed with the skin attached. Skin colour is thus a factor influencing perceptions of quality, and therefore the importance of colour should be seen in the context of overall appearance.

### 2.5.6 Texture/tenderness

Bennion and Scheule (2004:18) define texture as a feel or appearance of a surface of the food as detected by the pressure and movement receptors on the skin and muscles of the mouth and tongue. Therefore it includes those qualities that we can feel with the fingers, the tongue, the palate and the teeth. It is also used as a measure of quality. When an animal dies, blood circulation stops and as a result there is no supply of oxygen or nutrients to the muscles resulting in muscles running out of energy and causing them to contract and becoming stiff (Warriss, 2000:110-112). This stiffness is called *rigor mortis*. When the process of *rigor mortis* eventually stops muscles become soft again making them more tender during cooking than what they would have been had they been cooked during the *rigor mortis* stage. Thompson (2000) and Allen (2000) in Nkhabutlane (2003:26) redefined tenderness as a function of production, processing, value-adding and cooking method used to prepare the meat for consumption. Failure of one or more links in the meat supply chain increases the risk of a poor eating experience for the consumer. The textural qualities of a food also have a relationship to the appearance of a product (McWilliams, 2001:40). According to Lawrie (1998:229-230), texture as seen by the eye, is a function of size of the bundles of fibres into which the perimysial septa of connective tissue divide the muscle. If meat is going to be frozen at some stage, the conditions of freezing must be specific and closely monitored for both whole tissue and processed meats as these are going to affect the tenderness measurement. Samples should be packaged, properly sealed and frozen quickly then stored at −18°C or below and the storage period should not exceed three months (Honikel, 1998:448).

## 2.6 Conclusion

Research on guinea fowl meat as a food product is lacking. This implies that information regarding chemical and nutritional value, sensory and physical properties, and storage are basically not known to guide the consumer in making informed decisions during the selection, purchasing, processing and even serving of guinea fowl meat. Literature on chicken, turkey and sometimes ostrich has been used to discuss common attributes, further indicating that there is a lot to be investigated pertaining to guinea fowl. Proven research on guinea fowls in Southern Africa is also lacking and the limited literature on guinea fowl meat elsewhere in the world is scant. Studies on poultry cooking methods are limited and whilst those specific to guinea fowl are lacking. There is also a need to investigate the effect of meat injection on guinea fowl meat in particular. The nutritional composition of guinea fowl meat before and after processing is also critical in characterising guinea fowl as a food product and implication of heat treatment and meat injection are therefore worth investigating.

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## CHAPTER 3

## CHEMICAL COMPOSITION OF RAW GUINEA FOWL (*Numeda meleagris)* MEAT.

**Abstract**

The aim of this study was to quantify the chemical composition of the different cuts (breast, drumstick, thigh) of guinea fowl (*Numeda meleagris).* The breast of raw guinea fowl meat had similar moisture content than the other cuts, and had significantly higher protein content when compared to drumstick and thigh ($P \leq 0.05$). The fat content was similar for all the cuts ($P>0.05$). Ash content did not differ significantly for all cuts ($P>0.05$). The drumstick had significantly different values for ash content when compared to the thigh. Saturated fatty acids (SFAs) and total unsaturated fatty acids (TUFAs) were not different ($P>0.05$) in all the cuts. High concentrations of palmitic acid and stearic acid were detected in all the cuts. The drumstick had significantly higher monounsaturated fatty acids (MUFAs) compared to other cuts ($P \leq 0.05$). Most abundant MUFAs were oleic acid in the thigh and transeladic acid in the breast. The breast had the highest polyunsaturated fatty acids (PUFAs) ($P \leq 0.05$), with the most abundant PUFA detected being linoleic acid. Gamma linoleic acid (C18:3n6), homo-gamma linoleic acid (C20:3n6), alpha-linolenic acid (C18:3n3) and trans-linolelaidic acid (C18:2n6t) were found in very low concentrations.The breast had the lowest ($P \leq 0.05$) *n*-6 fatty acid value, and had the relatively lowest Polyunsaturated:Saturated (P:S) fatty acid ratio of 1.74 when compared to the other cuts. High *n*-6:*n*-3 ratios, ranging from 6.56 to 16.36, were also found in all the cuts. Seventeen amino acids were analysed, including eight of the nine essential amino acids (tryptophan was not detected). Significant differences were found in amino acid values for the different cuts. Values of iron were significantly higher in the drumstick and thigh cuts ($P \leq 0.05$), whilst the drumstick had the highest zinc content of all the cuts ($P \leq 0.05$). Cholesterol content was lowest ($P \leq 0.05$) in the breast.

***Keywords:*** guinea fowl, cuts, chemical composition, proximate composition, minerals, amino acids, fatty acids, cholesterol.

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### 3.1 Introduction

Consumers are increasingly interested in the nutrient content of the food they consume, compelling the food industry to provide information on the chemical composition and nutritive values of food (Ferreira, Morgano, De Queiroz & Mantovani, 2000:259). These include poultry that is one of the leading meat products consumed in South Africa (Van Heerden, Schönfeldt, Smith & Van Rensburg, 2002:47). Bilgili (1999:3) explains that the introduction of many novel poultry products has been mainly due to the changing needs of the consumers (i.e. convenience, nutrition, safety, health, quality and variety) and further reports that poultry products are in demand in all parts of the world. Poultry meat is preferred where there are no religious and cultural barriers, with this preference usually being linked to the perceived safety and health advantages compared to other meat sources.

Scholtz, Vorster, Matshego and Vorster (2001:S39) report that foods from animal origin are essential to the diet as they provide high quality protein, essential micronutrients including calcium, iron, zinc and omega-3 fatty acids, and therefore have the potential of preventing undernourishment. Among other changes in dietary patterns, the intake of animal fat containing saturated fatty acids together with agricultural staple foods, has affected the intake of omega 3:6 fatty acid ratios, decreasing it from 1:4 that man consumed earlier, to 1:25 and even much lower proportions. This has been thought to be the cause of the increase in incidents of dietary induced diseases (DSM Nutritional Products South Africa, 2005). Ferreira *et al.*. (2000:259) report that, as a result, nutritionists advise consumers to cut down extensively on saturated fatty acids intake, and increase their intake of MUFAs and PUFAs so as to lower the production of low density lipoproteins (LDL). Therefore, consumers are increasingly becoming conscious of the effects of fatty acids and cholesterol on health (Pereira, Tarley, Matsushita & de Souza, 2000:916). These trends are further exerting pressure on the food industry and meat researchers to provide the consumer with information on the fatty acid and cholesterol composition of the meat products they consume.

In determining nutritional quality of meat and meat products, it is important to establish protein content and determine the nature of the protein since protein is an essential component of the diet with the primary role of providing the body with sufficient amounts of amino acids (Ismail & Ikram, 2004:54). Thus the quality of the protein is dependent upon its amino acid content. Bender (1992) explains that there are two groups of amino acids, those that should be provided for by the diet (essential), and those that the body can synthesise (non-essential). For the purposes of this study 17 of these amino acids (alanine, arginine, aspartic acid, cystein, glutamic acid, glycine, histidine, isoleucine, leucine, lysine, methionine, phenylalanine, proline, serine, threonine, tyrosine and valine) were investigated.

Minerals and their link with major chronic diseases, as reported by Ferreira *et al.* (2000:259), have also recently attracted a great deal of attention from scientists. The reason for the interest in minerals is partly due to their role in the body's vital processes. According to Lombardi-Boccia, Lanzi and Aguzzi (2005:39), meat is a good source of zinc, copper and bioavailable haem iron. For the purpose of this study some macro minerals and trace elements have been selected (Ca, Cu, Mg, Mn, Fe, P, K, Na and Zn).

Understanding the chemical profile and therefore the quality of the consumed food does not only benefit the consumer but the industry as well. According to Grunert, Larsen, Madsen and Baardsgaard in Grunert, Bredahl and Brunsø (2004:260), product quality is essential as it determines the need and the desire for purchasing and for satisfying the values set by the consumers. These set values have an impact on which quality dimensions are sought. After purchase, the experienced quality is then influenced by many factors among which are the sensory, physical, and nutritional benefits and ways of preparing the product further influencing purchase decisions. For ostrich meat, as reported by Sales and Hayes (1996:167), lack of public knowledge on the nutritive value, and limited scientific information about the nutritional composition, could be the cause for low utilisation and consumption thereof. A similar lack of knowledge exists for guinea fowl meat and thus justifies the determination of the proximate (i.e. moisture, protein, fat, ash) and amino acid composition, mineral content and fatty acids composition, and cholesterol content of guinea fowl meat.

## 3.2 Materials and methods

Fifteen-weeks-old, dressed and frozen guinea fowl were sourced from a Philadelphia farm in the Western Cape, Province, South Africa. The birds were reared according to the standard commercial practices as described by Silverside and Jones (1998). The weights of the carcass weight range from 800g to 1100 g. Thirty sixty of the guinea fowl were ranked by weight and every fourth carcass selected (n=9) for chemical analysis of the raw meat. Of these nine carcasses only seven were used as the other two were used for further training of the panel of the parallel study (see Chapter 6).

### 3.2.1 Meat preparation

For the chemical analysis of the raw meat the *pectoralis* (breast), *iliotibialis*, *semitendinosus* and *sartorius* (thigh) and the *gastrocnemius* and *peronius* (drumstick) muscles were skinned, excess fat trimmed off, packaged and labelled and then stored frozen at –15°C. Samples were then minced, re-packaged, labelled and then further stored at –20°C before analysis.

## 3.3 Chemical analysis

### 3.3.1 Proximate analysis

Proximate analysis of guinea fowl meat was conducted on the breast, the thigh and the drumstick according to AOAC standard techniques (AOAC, 1997). Moisture was determined by drying a 2.5 g sample at 100°C for 24 h, ashing was done at 500°C for 6 h. To determine protein content, dried defatted meat samples were ground with a pestle in a mortar to a fine powder. Samples of 100 mg were inserted into a foil-wrap designed for the Leco protein analyser (Leco FP-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 Lake View Avenue, St. Joseph, HI 49085-2396, USA, part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. Total lipid content was determined by homogenising the samples in a blender followed by the chloroform:methanol (1:2) extraction technique of Lee, Trevino and Chaiyawat (1996).

### 3.3.2 Amino acid analysis

The amino acid composition was determined on a defatted, dried meat sample, according to a modification of the method of Bidlingmeyer, Cohen and Tarvin (1984), using a Waters high performance liquid chromatography system (1525 HPLC with a binary gradient delivery, 717 auto-sampler and Injector, 1500 column heater, 2487 dual wavelength UV detector) and a Breeze data workstation (Waters, Millford, MA, USA). The meat sample was defatted by solvent extraction according to the method of Lee, Trevino and Chaiyawat (1996). The sample was hydrolysed with 6 N HCl in a vacuum-sealed tube for 24 h at 110°C. The samples were then stored at –20ºC. Before use they were thawed at room temperature, then mixed by vortexing for 5 to 10 seconds and then centrifuged (15 000g for 5 min) using a Hermle bench centrifuge. The supernatant was analytically measured with a Hamilton syringe and placed in a glass hydrolysis tube and dried under vacuum for 1 hour and further processed for analysis on HPLC. For samples raw breast (RB), raw drumstick (RD) and raw thigh (RT) and 8μL, 9μL and 10μL were respectively measured. For further processing, the pH was adjusted by adding 20 μL solution of 2:2:1 ethanol:water:triethylamine after which the samples were redried for 1 hour. The resulting sample was derivatised by adding 20 μL derivatising solution of 7:1:1:1 ethanol:water:triethylamine:phenylisothiocyanate (PITC). The mixture was allowed to react at room temperature for 10 min prior to drying under vacuum (minimum of 3 h) to achieve complete dryness. The sample was dissolved in 400 μL of picotag sample diluent (Waters, Millford, MA, USA), filtered through a 0.45 μM filter and an 8 and 16 μL sample was then injected for separation by HPLC (Waters HPLC column, Novapak C18. 60 Å, 4 μM, 3.9 × 150 mm) under gradient conditions, where buffer A was a sodium acetate buffer (pH 6.4) containing 5 000 ppm EDTA, 1:2000 triethylamine and 6%, v/v, acetonitrile and buffer B was 60%, v/v, acetonitrile with 5 000 ppm EDTA. A 1525 HPLC with a binary gradient delivery, 717 auto-sampler and injector, 1500 column heater, 2487 dual wavelength UV detector were also used in the analysis by Breeze software Z (Waters, Milford, MA, USA). Accuracy and repeatability of this analysis is ensured by inclusion of a control sample of known amino acid composition with the samples prior to hydrolysis. For each batch of samples, the standards were dried and treated under the exact conditions as the samples.

### 3.3.3 Mineral content analysis

Elements calcium (Ca), copper (Cu), iron (Fe), magnesium (Mg), manganese (Mn) phosphorus (P), potassium (K), sodium (Na), and zinc (Zn) were determined from the breast, drumstick and thigh. The mineral composition was determined after ashing of the defatted meat samples at 200°C, before being dissolved in 3 N HCl and diluted to appropriate concentrations required for mineral analysis by the AOAC method No. 968.08 (AOAC, 1997). More than 1 g but less that 3 g samples were air dried and ground to pass through a 0.5-1, mm sieve. Thereafter the samples were ashed overnight in a muffle furnace at 550°C. A 6 M hydrochloric acid (HCl) solution was prepared by diluting 500 $cm^3$ of a 36% (m:m) HCl solution to 1 $dm^3$. After ashing, 5 $cm^3$ of a 6 M HCl was added to dissolve the cooled sample. Thereafter the samples were dried in a water bath. After cooling a 5 $cm^3$ 6 M nitric acid ($HNO_3$) solution was added to the samples, then heated in a water bath and removed after the boiling point was reached. The solution was consequently filtered through filter paper into a 100 $cm^3$ volumetric flask and diluted to volume with deionised water according to the method described by Giron (1973). Element concentrations were measured on a Varian (Victoria, Australia) Liberty Series II sequentially inductively coupled plasma atomic emission spectrophotometer.

### 3.3.4 Fatty acid analysis

The fatty acid composition was determined by the method described by Tichelaar, Smuts, Van Stuijnberg, Faber and Benade (1998). The meat was thawed. The lipids were extracted from a 2 g sample with chloroform/methanol at a ratio 2:1, according to a modified method of Folch, Lees and Sloane-Stanley (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (Kinematica, type PT

10–35, Switzerland) was used to homogenise the sample for 30 s within the extraction solvent. A sub-sample of the extracted lipids was transmethylated for 2 h at 70°C using methanol/sulphuric acid (19:1; v/v) as transmethylating agent. After cooling, the resulting fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen.

The fatty acid methyl esthers (FAME) were purified by TLC (silica gel 60 plates) and analysed by GLC (Varian Model 3300 equipped with flame ionisation detection) using 60 m BPX70 capillary columns of 0.25 mm internal diameter (SGE, Australia). Gas flow rate for hydrogen was 25 ml/min and for hydrogen carrier gas it was 2–4 ml/min. Temperature programming was linear at 3°C/min. The initial temperature was 150°C, the final temperature 220°C, the injector temperature 240°C, and the detector temperature 250°C. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500 Sigma–Aldrich Inc. 595 North Harison Road, Bellefonte, PA 16823-0048, USA) to quantify the individual fatty acids. The FAME in the total lipids were identified by comparing the retention times with those of the standard FAME mixture (SuplecoTM 37 component FAME Mix, catalogue number 18919-IAMP, Lot number, LB-16064. Sigma-Aldrich Inc. North Harrison Road, Bellefonte, PA 16823-0048, USA).

#### 3.3.5 Cholesterol analysis

From the same lipid extraction used for the fatty acid determination, a sub-sample was used for cholesterol determination. After drying the sub-sample under nitrogen, Stigmasterol (3-B-hydroxy-24-ethyl-5.22-cholestadiene; Sigma Chemical Co., St. Louis, MO, USA) was added as internal standard and 6% ethanolic KOH was used to saponifise the extraction for 2 h at 70°C in a heating block. After cooling, distilled water and hexane were added and the resultant extraction was analysed by GLC (Varian Model 3700 equipped with flame ionisation detection). A 1.2 m glass column of 2 mm internal diameter packed with 3% SP2401 on 100/120 mesh Supelcoport (Supelco Inc., Bellefonte, PA, USA) was used. Gas flow rates for hydrogen were 20 ml/min, for air 200 ml/min, and for nitrogen (carrier gas) 25 ml/min. The injector temperature was 280°C, that of the column was 255°C and of the detector was 290°C.

### 3.4 Statistical analysis

The data were analysed using ANOVA to test for significant differences between the samples. A one-factor factorial experiment was performed in a linear scale with seven replications. An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Students' t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998).

## 3.5 Results and discussions

### 3.5.1 Proximate composition

Means of the proximate composition of the different cuts (breast, drumstick and thigh) of raw guinea fowl are presented in Table 3.1.

**TABLE 3.1: Proximate composition (%) of different cuts of raw guinea fowl (*Numeda meleagris)* meat**

| | CUT | | | |
|---|---|---|---|---|
| | Breast | Drumstick | Thigh | LSD |
| Moisture | 74.55 ±1.66 | 74.01 ±0.61 | 74.25 ±1.07 | 1.55 |
| Protein | $22.70^{a}$ ±1.78 | $22.35^{ab}$±1.25 | $20.47^{b}$ ±1.64 | 2.08 |
| Fat | 2.26 ±0.49 | 2.83 ±0.89 | 2.99 ±0.99 | 1.12 |
| Ash | $1.01^{ab}$ ±0.09 | $0.95^{b}$ ±0.13 | $1.08^{a}$ ±0.09 | 0.12 |

LSD, Least significant difference, P=0.05

$^{a,b,c}$ Means in rows with different superscript letter are significantly different P=0.05

The breast cut had a slightly higher moisture content than the thigh and the drumstick cuts, though the differences were not significant. The protein content did not differ (P>0.05) between the breast and the drumstick, but was higher ($P\leq0.05$) than the thigh. Though the fat content did not differ significantly in all the cuts, the breast had the lowest value whereas the thigh had the highest. The ash content was higher in the thigh cut ($P\leq0.05$) than in the drumstick, but it did not differ significantly from the breast (P>0.05). The results of the chemical composition of this investigation compares favourably with the research on chicken by Van Heerden *et al.* (2002:52), who noted more moisture and protein in the white meat (breast) than the dark meat, as well as a lower fat content in the white meat. They also recorded higher ash content in the breast though the ash content was not significantly higher than in the thigh. The high protein content in the breast could be due to the larger fibres that imply less cellular membrane, making the protein more concentrated. Guinea fowl meat could therefore be nutritionally favourable because of this low fat content and high protein content, which supports the findings of Ayorinde (1991:23).

### 3.5.2 Amino acid composition

According to Bender (1992), protein quality is measured by its ability to satisfy the human requirements for amino acids. Table 3.2 presents the mean values of different amino acids of the three cuts of guinea fowl meat in g/100 g of the sample (muscle as is).

**TABLE 3.2: Amino acid composition (g/100 g sample) of different cuts of guinea fowl (*Numeda meleagris)* meat.**

| | CUT | | | |
|---|---|---|---|---|
| | Breast | Drumstick | Thigh | LSD |
| Alanine | $2.11^{a} \pm 0.19$ | $2.10^{a} \pm 0.11$ | $1.86^{b} \pm 0.14$ | 0.19 |
| Arginine | 0.94 ±0.09 | 1.01 ±0.06 | 1.90 ±0.09 | 0.11 |
| Aspartic acid | $2.19^{a} \pm 0.23$ | $2.09^{ab} \pm 0.10$ | $1.96^{b} \pm 1.17$ | 0.23 |
| Cystine | $0.16^{a} \pm 0.02$ | $0.15^{b} \pm 0.01$ | $0.14^{b} \pm 0.01$ | 0.02 |
| Glutamic acid | 2.93 ±0.29 | 2.99 ±0.14 | 2.73 ±0.26 | 0.31 |
| Glycine | $1.71^{b} \pm 0.14$ | $2.33^{a} \pm 0.37$ | $1.76^{b} \pm 0.13$ | 0.28 |
| Histidine | $0.59^{a} \pm 0.06$ | $0.44^{b} \pm 0.03$ | $0.41^{b} \pm 0.04$ | 0.06 |
| Isoleucine | 0.55 ±0.08 | 0.58 ±0.05 | 0.52 ±0.08 | 0.08 |
| Leucine | 1.59 ±0.19 | 1.56 ±0.09 | 1.44 ±0.14 | 0.18 |
| Lysine | 1.40 ±0.19 | 1.37 ±0.15 | 1.26 ±0.19 | 0.23 |
| Methionine | $0.55^{a} \pm 0.06$ | $0.52^{ab} \pm 0.03$ | $0.49^{b} \pm 0.04$ | 0.06 |
| Phenylalanine | 0.58 ±0.07 | 0.59 ±0.04 | 0.54 ±0.06 | 0.07 |
| Proline | $0.95^{b} \pm 0.07$ | $1.21^{a} \pm 0.11$ | $1.00^{b} \pm 0.08$ | 0.11 |
| Serine | 1.23 ±0.11 | 1.23 ±0.06 | 1.16 ±0.10 | 0.12 |
| Threonine | 1.02 ±0.11 | 1.03 ±0.06 | 0.97 ±0.10 | 0.12 |
| Tyrosine | 0.48 ±0.06 | 0.48 ±0.04 | 0.44 ±0.04 | 0.06 |
| Valine | 0.70 ±0.10 | 0.71 ±0.05 | 0.66 ±0.09 | 0.09 |

LSD, Least significant difference, P=0.05

$^{a,b}$ Means in rows with different superscript letter are significantly different P=0.05

Seventeen amino acids were analysed, of which eight were essential, namely histidine, isoleucine, leucine, methionine, phenylalanine, threonine, lysine and valine. The missing essential amino acid is tryptophan, which was not detected in guinea fowl meat. According to Whitmire (2004:68), tryptophan is usually low in animal protein. Similarly, it was found to be very low in camel meat (Dawood & Alkanhal, 1995:7), while Varnam and Sutherland (1995:7) reported low values of tryptophan in beef, chicken, lamb and pork. Amino acids have been reported to be constant in meat protein regardless of the cut (Dawood & Alkanhal, 1995:7), whilst Lawrie (1998:259) notes significant differences in amino acid composition due to the type of muscle, breed and the type of the animal. Slight differences and significant differences could be sometimes noted in some amino acids of guinea fowl meat (Table 3.2).

Of the essential amino acids, histidine was higher in the breast ($P \leq 0.05$) than the thigh and the drumstick, which both did not differ ($P>0.05$). Breast also had higher ($P>0.05$) levels of methionine even though it did not differ from the drumstick, and the thigh showed the lowest values ($P \leq 0.05$). The most abundant amino acids identified in guinea fowl meat was glutamic acid, which did not differ ($P>0.05$) between any of the cuts. Aspartic acid was highest in the breast and lowest in the thigh ($P \leq 0.05$). Alanine was lowest in the thigh ($P \leq 0.05$). Glycine was higher ($P \leq 0.05$) in the drumstick than in the breast and thigh, same for proline though with lower values. Values of leucine, lysine, serine, arginine, valine, phenylalanine, threonine, isoleucine and tyrosine differed marginally between the breast, drumstick and thigh, though not significantly ($P>0.05$). The thigh therefore had the lowest values for all the amino acids with the exception of glycine, arginine and proline. Although statistically different, there were no large quantitative differences in amino acid composition between the cuts indicating that, in guinea fowl meat, the amino acid value of the breast, the thigh and the drumstick is similar. These findings are supported by those of Beach, Munks and Robinson (1943:435) who report that amino composition usually do not differ between the cuts of a carcass. In a study by Hamm (1981:1122) on the amino acid composition of breast and thigh meat of broilers, glycine, proline, threonine and serine, amino acids most abundant in cuts with more connective tissue, were found to be higher in the drumstick, whereas the breast and thigh presented similar profiles.

### 3.5.3 Mineral content

The mean values for the mineral content of the different cuts of raw guinea fowl are presented in Table 3.3. Calcium (Ca), magnesium (Mg), manganese (Mn), phosphorus (P), potassium (K), and sodium (Na) did not differ significantly between the cuts ($P>0.05$).

**TABLE 3.3: Mineral content (mg/100 g) of different cuts of guinea fowl (*Numeda meleagris*) meat.**

| | CUT | | | |
|---|---|---|---|---|
| | Breast | Drumstick | Thigh | LSD |
| Calcium | 13.55 ± 2.44 | 15.92 ±4.26 | 15.87 ±2.84 | 3.17 |
| Copper | $0.05^{a}$ ± 0.01 | $0.06^{a}$ ±0.01 | $0.03^{b}$ ±0.01 | 0.01 |
| Iron | $0.70^{b}$ ± 0.08 | $1.46^{a}$ ±0.25 | $1.33^{a}$ ±0.02 | 0.26 |
| Magnesium | 24.81 ± 2.05 | 23.82 ±2.24 | 23.46 ±4.02 | 3.55 |
| Manganese | 0.03 ± 0.00 | 0.03 ±0.00 | 0.03 ±0.01 | 0.01 |
| Phosphorus | 119.50 ±10.73 | 112.72 ±6.12 | 123.10 ±16.01 | 14.05 |
| Potassium | 123.33 ±14.25 | 130.37 ±9.92 | 129.25 ±9.68 | 14.63 |
| Sodium | 16.48 ± 3.75 | 17.50 ±1.84 | 18.32 ±1.26 | 2.34 |
| Zinc | $0.58^{c}$ ± 0.14 | $2.06^{a}$ ±0.17 | $1.50^{b}$ ±0.24 | 0.26 |

LSD, Least significant difference, P=0.05

[a,b,c] Means, in rows with different superscript letter are significantly different P=0.05

However, copper (Cu), iron (Fe) and zinc (Zn) showed significant differences of which copper and zinc cannot be explained from a biological viewpoint at this stage. Copper was lowest

($P \leq 0.05$) in the thigh but did not differ ($P > 0.05$) between the breast and the drumstick. In general, meat is a good source of copper (Lombardi-Boccia *et al.,* 2005:39). The higher iron content of the dark coloured drumstick and thigh as opposed to the breast ($P \leq 0.05$) can partially be ascribed to the higher myoglobin levels of these muscles (Lombardi-Boccia, Lanzi & Aguzzi 2005:39), which in turn can be related to the behaviour of the guinea fowl. It is well known that guinea fowl frequently run (thereby using the red oxidative fibres found in the leg) and only fly (using the predominantly white muscle fibres of the breast) when exposed to extreme danger. However, the higher iron content can also be explained by the fact that in this study the guinea fowl were frozen prior to analysis and resulting in the release of haemoglobin from the red cells of the bone marrow (Charley & Weaver 1998:422). This iron is readily bioavalialbe, being sourced from haem-iron (present in meat, fish and poultry – the MFP factor) and 15% absorbable as opposed to non-haem-iron which is only 3-8 % absorbable (Stopler, 2008:816) and a highly recommended iron food source, especially for the prevention of iron deficiency anaemia (Stopler, 2008:816) It is especially recommended for women of child-bearing age (Stopler, 2008:816). Zinc differed ($P \leq 0.05$) in all the three cuts, with the drumstick showing the highest levels, and the breast the lowest.

The iron values for chicken are lower than those of guinea fowl meat, with the thigh and drumstick having much higher values, especially of iron and zinc, when comparing with values for chicken as recorded by Lombardi-Boccia *et al.* (2005:43) (see Table 3.4). Lombardi-Boccia *et al.* (2005:40–41) do not specifically state that the meat samples used by them were fresh, but there was sufficient evidence to assume the samples to be fresh, thus possibly explaining the lower iron values in their study as opposed to the values found in this study where frozen meat was used. The table below deals with the comparison of minerals copper, iron and zinc in raw chicken meat by Lomardi-Boccia *et al. (*2005:39) in comparison to the findings in this study (Table 3.4).

**TABLE 3.4: Comparison of mineral content (mg/100 g) of different cuts of raw guinea fowl meat (*Numeda meleagris*) taken from this study with those of raw chicken taken from Lombardi-Boccia, Martinez-Dominquez & Aguzzi (2005:42)**

| Mineral | Cut | Chicken | Guinea Fowl |
|---|---|---|---|
| Copper | Breast | 0.05 | 0.05 |
| | Drumstick | 0.09 | 0.06 |
| | Thigh | 0.11 | 0.03 |
| Iron | Breast | 0.40 | 0.70 |
| | Drumstick | 0.63 | 1.46 |
| | Thigh | 0.70 | 1.33 |
| Zinc | Breast | 0.65 | 0.58 |
| | Drumstick | 1.47 | 2.06 |
| | Thigh | 1.71 | 1.50 |

Based on this study, and the comparison with chicken on Table 3.4, guinea fowl meat has higher iron content. This implies that it can assist in meeting the recommended daily allowances (8 mg/day post menopausal women; 8 mg/day for men; 18 mg/day for women of childbearing age; for teenage boys 11 mg/day; and for children 1–14 years of age 7–1mg/day). Guinea fowl meat could thus contribute towards metabolic functions of iron including its role in oxidation and reduction reactions, in the synthesis of amino acids, as well as in the brain functions (Gallagher, 2008:118,119; Whitney & Rolfes, 2005:439).

The lower sodium contents of the three cuts of guinea fowl meat when compared to chicken, is a highly acceptable attribute, since high sodium intakes are known as a causal factor in arterial hypertension (Alais & Linden, 1991:92). It is not clear whether the low sodium content could have been caused by the freezing and thawing process which resulted in drip loss, possibly containing soluble sodium salts that have not been bound in complex molecules, but in the ionic state (Gallagher:2008:103). In a study by Sales and Hayes (1996:169) on ostrich, chicken and beef, the darker cuts of the ostrich had a higher sodium content than chicken meat, as was also found with the guinea fowl with guinea fowl meat in this study. Phosphorus levels are higher in guinea fowl meat compared to ostrich, beef and chicken. Potassium is also high in guinea fowl compared to ostrich and chicken though lower than beef. However, the guinea fowl drumstick is similar to ostrich meat and beef in its magnesium and copper concentrations (Sales & Hayes, 1996:169). Guinea fowl shows higher values of calcium than that of chicken found in the study by Van Heerden *et al.* (2002:53).

**TABLE 3.5: Fatty acid composition* (%) and cholesterol content (mg/100 g) of different cuts of raw guinea fowl (*Numed meleagris*) meat.**

| | Breast | Drumstick | Thigh | LSD |
|---|---|---|---|---|
| **Saturated** | | | | |
| C6:0 (caproic) | $0.35^{a} \pm 0.15$ | $0.37^{a}\pm0.09$ | $0.07^{b}\pm0.02$ | 0.11 |
| C8:0 (caprylic) | $0.00^{b}\pm0.00$ | $0.00^{ab}\pm0.00$ | $0.00^{a}\pm0.00$ | 0.00 |
| C10:0 (capric) | $0.00^{b}\pm0.00$ | $0.05^{a}\pm0.04$ | $0.00^{b}\pm0.00$ | 0.03 |
| C11:0 (undecanoic)* | $0.00^{c}\pm0.00$ | $0.13^{a}\pm0.04$ | $0.08^{b}\pm0.03$ | 0.03 |
| C12:0 (lauric) | $0.03^{b}\pm0.04$ | $0.10^{a}\pm0.02$ | $0.05^{b}\pm0.01$ | 0.03 |
| C13:0 (tridecanoic) | $0.01^{c}\pm0.01$ | $0.10^{a}\pm0.01$ | $0.08^{b}\pm0.02$ | 0.02 |
| C14:0 (myristic) | $0.29^{b}\pm0.04$ | $0.42^{a}\pm0.09$ | $0.31^{b}\pm0.06$ | 0.10 |
| C15:0 (pentadecanoic)* | $0.42^{a}\pm0.12$ | $0.17^{b}\pm0.04$ | $0.21^{b}\pm0.03$ | 0.08 |
| C16:0 (palmitic) | $24.37^{a}\pm2.32$ | $21.61^{b}\pm2.60$ | $23.25^{ab}\pm2.32$ | 2.76 |
| C18:0 (stearic) | $0.31^{a}\pm0.05$ | $0.15^{b}\pm0.04$ | $0.12^{b}\pm0.01$ | 0.05 |
| C20:0 (arachidic) | $0.33^{ab}\pm0.07$ | $0.31^{b}\pm0.06$ | $0.40^{a}\pm0.04$ | 0.07 |
| C21:0 ( lignoceric) | $0.46^{a}\pm0.13$ | $0.20^{c}\pm0.02$ | $0.29^{b}\pm0.03$ | 0.08 |
| C22:0 (behenic) | $0.00^{b}\pm0.00$ | $0.00^{b}\pm0.00$ | $0.08^{a}\pm0.01$ | 0.01 |
| C24:0 (tetracosanoic)* | $0.19^{b}\pm0.01$ | $0.98^{a}\pm0.10$ | $0.19^{b}\pm0.04$ | 0.07 |
| **Monounsaturated** | | | | |
| C14:1 (myristoleic) | $0.00^{c}\pm0.00$ | $0.08^{a}\pm0.04$ | $0.05^{b}\pm0.04$ | 0.03 |
| C15:1 (pentadecanoic)* | $0.29^{a}\pm0.02$ | $0.21^{b}\pm0.03$ | $0.07^{c}\pm0.02$ | 0.03 |
| C16:1n-7 (palmitoleic) | $0.60^{c}\pm0.04$ | $1.81^{a}\pm0.19$ | $0.10^{b}\pm0.04$ | 0.14 |
| C18:1n-9c (oleic) | $22.42^{b}\pm0.88$ | $21.92^{b}\pm1.03$ | $25.81^{a}\pm1.52$ | 1.45 |
| C18:1n-9t (transelaidic) | $1.79^{a}\pm0.12$ | $0.12^{b}\pm0.02$ | $0.09^{b}\pm0.02$ | 0.08 |
| C20:1n-9 (gondoic) | $1.34^{a}\pm0.08$ | $0.12^{b}\pm0.02$ | $0.07^{b}\pm0.02$ | 0.06 |
| C22:1n-9 (erucic) | $0.20^{b}\pm0.04$ | $0.46^{a}\pm0.02$ | $0.08^{c}\pm0.02$ | 0.03 |
| C24:1n-9 (nervonic) | $0.37^{a}\pm0.06$ | $0.40^{a}\pm0.03$ | $0.10^{b}\pm0.02$ | 0.05 |
| **Polyunsaturated** | | | | |
| C18:2n-6c (linoleic) | $28.62^{c}\pm1.47$ | $32.58^{b}\pm1.20$ | $42.57^{a}\pm2.85$ | 2.14 |
| C18:2n-6t (trans-linolelaidic) | $0.00^{c}\pm0.00$ | $1.17^{a}\pm0.03$ | $0.10^{b}\pm0.02$ | 0.03 |
| C18:3n-6 ($\chi$-linolenic) | $0.86^{c}\pm0.09$ | $1.14^{b}\pm0.11$ | $1.38^{a}\pm0.15$ | 0.11 |
| C18:3n-3 ( α-linolenic) | $0.51^{a}\pm0.09$ | $0.11^{c}\pm0.01$ | $0.39^{b}\pm0.05$ | 0.06 |
| C20:2 (eicosadienoic)* | $0.95^{b}\pm0.11$ | $1.89^{a}\pm0.11$ | $0.35^{c}\pm0.05$ | 0.09 |
| C20:3n-3 (eicosatrienoic)* | $0.25^{a}\pm0.02$ | $0.10^{c}\pm0.01$ | $0.20^{b}\pm0.03$ | 0.03 |
| C20:3n-6 (homo-g-linoleic) | $9.87^{a}\pm0.54$ | $6.81^{b}\pm0.29$ | $0.09^{c}\pm0.01$ | 0.43 |
| C20:4n-6 (arachidonic) | $0.95^{a}\pm0.08$ | $0.31^{b}\pm0.02$ | $0.27^{b}\pm0.02$ | 0.05 |
| C20:5n-3 (eicosapentaenoic)* | $0.18^{c}\pm0.03$ | $0.63^{a}\pm0.05$ | $0.47^{b}\pm0.05$ | 0.04 |
| C22:2 (docosadienoic)* | $0.43^{a}\pm0.03$ | $0.17^{b}\pm0.02$ | $1.10^{c}\pm0.02$ | 0.03 |
| C22:5n-3 (docosapentaenoic)* | $0.60^{b}\pm0.05$ | $2.36^{a}\pm0.08$ | $0.14^{c}\pm0.02$ | 0.07 |
| C22:6n-3 (docosahexaenoic)* | $3.01^{a}\pm1.32$ | $3.01^{a}\pm0.12$ | $1.51^{b}\pm0.15$ | 0.89 |
| **Total** | | | | |
| SFA | $26.77 \pm2.20$ | $24.60\pm2.50$ | $25.12\pm2.19$ | 2.66 |
| MUFA | $26.99^{a}\pm0.78$ | $25.11^{b}\pm1.05$ | $27.28^{a}\pm1.47$ | 1.44 |
| PUFA | $46.24^{b}\pm2.25$ | $50.29^{a}\pm1.86$ | $47.59^{b}\pm3.30$ | 2.63 |
| TUFA | $73.23 \pm2.20$ | $75.40\pm2.50$ | $74.88\pm2.19$ | 2.66 |
| P:S | $1.74^{b}\pm0.23$ | $2.07^{a}\pm0.31$ | $1.92^{ab}\pm0.30$ | 0.30 |
| n-6 | $40.30^{b}\pm2.13$ | $40.83^{b}\pm1.57$ | $44.32^{a}\pm2.98$ | 2.47 |
| n-3 | $4.56^{b}\pm1.28$ | $6.23^{a}\pm0.19$ | $2.72^{c}\pm0.29$ | 0.85 |
| n-6:n-3 | $8.83^{b}\pm6.25$ | $6.56^{b}\pm0.13$ | $16.36^{a}\pm0.71$ | 4.23 |
| Cholesterol (mg/100 g) | $56.84^{b}\pm17.63$ | $126.18^{a}\pm65.81$ | $131.75^{a}\pm40.37$ | 54.97 |

LSD, Least significant difference, P=0.05, [a,b,c] Means in rows within groups with different superscript significantly differ P=0.05 **.**

* Common names have mainly been used in brackets in the first column. However, common names were not available for all the fatty acids, in which case the systemic names were used, marked with an *.

### 3.5.4 Fatty acid composition

Valsta, Tapanainen and Männistö (2005:526) reported that palmitic acid, oleic acid, linoleic acids and alpha-linolenic acid were the most abundant fatty acids in meat fats. According to Lawrie (1998:84) variations in fatty acid composition of different muscles have been established, which supports Van Heerden *et al.* (2002:63)'s report on fatty acid differences in chicken cuts. Table 3.5 presents the different fatty acids, total solurated fatty acids (SFAs), monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs) and total unsaturated fatty acids (TUFAs), *n*-3 (Omega 3) and *n*-6 values, P:S and *n*-6:*n*-3 ratios, and cholesterol content of the different cuts for guinea fowl.

The number of fatty acids detected in raw guinea fowl in this study were 12 PUFAs, 8 MUFAs and 14 SFAs. The total unsaturated fatty acids (TUFAs) did not show any significant differences between the cuts ($P>0.05$), nor did the total SFAs ($P>0.05$). The TUFAs were made up of 46.24%, 50.29% and 47.59%, PUFAs for breast, drumstick and thigh respectively. The MUFAs contributed the rest of the TUFAs, namely 26.99%, 25.11% and 27.28% for the breast, the dumsick and the thigh respectively. The drumstick had significantly lower values than the other cuts ($P\leq0.05$). On the other hand the SFAs were 27.8%, 24.6% and 25.12% for the breast, drumstick and the thigh respectively with no significant difference within the cuts.

The drumstick showed the highest PUFAs ($P\leq0.05$, 50.29%), with the breast having a slightly lower value than the thigh 46.24% and 47.59% ($P\geq0.05$) respectively. The highest concentrations of the essential fatty acid linoleic acid were found in the thigh (42.57%, $P\leq0.05$), and was lowest in the breast (28.62%, $P\leq0.05$). The breast value is relatively high. Stopler (2008:857) reports that it is the most predominantly consumed PUFA in the American diet refers to population studies that have demonstrated a negative correlation between linoleic acid intake and cardiovascular hart disease. The linoleic acid content largely influenced the high PUFA value. Linoleic acid and the high levels of the *n*-6 fatty acids increase the total PUFAs (Wood *et al.,* 2003:22), which increase the overall TUFAs of guinea fowl meat in the dark cuts as opposed to the breast. Significant differences between all the cuts were found for gamma-linoleic acid with the breast lowest (0.86%), drumstick at 1.14%, and the thigh the highest (1.38%, $P\leq0.05$). Homo-gamma linoleic acid also had significant differences between all the cuts, with the breast highest at 9.87%, drumstick at 8.81% and the thigh lowest at 0.09% ($P\leq0.05$). Alpha-linolenic acid was significantly different for all cuts as well, the breast having the highest value, namely 0.51%, the drumstick lowest at 0.11%, and the thigh at 0.39% ($P\leq0.05$). *Trans*-linolelaidic acid also differed significantly for all cuts drumstick highest at 1.17%, thigh at 0.10%, and the breast lowest at 0.00% (P≤0.05). The breast was also high in eicosatrienoic (EPA) and docosahexaenoic acid (DHA), which are needed by the body for cognitive and behavioural functions (Mostert & Hoffman, 2007:568).

Wood *et al.* (2003:22) further report that fatty acid composition can be used to evaluate the differences between muscles, and as found in this study, the thigh and the drumstick, which are the cuts with the dark muscles, contain higher proportions of phospholipids than the white muscles (breast) and therefore have a higher PUFA content. In total, the drumstick had the lowest (P≤0.05) amount of the total MUFAs (25.11%), and the breast 26.99% and thigh 27.28% not showing any differences (P≥0.05). For the monounsaturated fatty acids, oleic acid was the most abundant fatty acid and was highest in the thigh (25.81%,P≤0.05) than the breast and drumstick, whereas transelaidic acid was more concentrated in the breast (1.79%,P≤0.05). The abundance of oleic acid in guinea fowl is beneficial in the diet because it has anti-inflammatory effects. Wood and Enser (1997:S51) report that in swine oleic acid increases and stearic acid decreases as the fat content increases, a relationship that leads to the rise in the level of unsaturation and softness of the lipids. They further explain that the high oleic acid content and low stearic acid content indicate a softer fat in a leaner carcass. This trend was found for the thigh in the present study, whereby the thigh, that had more fat, had more oleic acid and less stearic acid. Wood *et al.* (2003:23) confirm that fatty acids studies on poultry meat and pork have shown similarities.

The breast had the highest value (26.77) of total saturated fatty acid (SFA), though not different (P>0.05) from the other cuts, of which 24.37% was palmitic acid. The drumstick on the other had the highest values for both myristic and lauric acid, 0.42% and 0.10% respectively. These high values differed significantly (P≤0.05) from the thigh and breast. Stopler (2008:855) reports that myristic, palmitic and lauric, are the most hypercholesterolemic promoting fatty acids, in that order of potency. The author further reports that palmitic acid is the most prevelant of the three, making up to 60% of the total SFA in the American diet. According to Van Heerden *et al.* (2002:63), palmitic acid was found to be high in frozen chicken, which could explain the high palmitic acid values found in this study where the meat was kept frozen.

The omega-6 (n-6) fatty acids were significantly highest in the thigh (44.32%, P≤0.05) than the other cuts, the lowest value being found in the breast (40.30%). The drumstick had the highest omega-3 (n-3) value (6.23, P≤0.05) and the thigh had the lowest (2.72).

The *n*-6:*n*-3 ratio is used to assess the nutritional value of fat. It was found that the n-6:n-3 ratios were unfavourably high for all the cuts. The *n*-6:n-3 ratio was highest in the thigh (16.36, P≤0.05) than the other cuts. For nutritional benefits it is important to find out how this ratio stands after cooking since it is known that cooking affects the *n*-6:*n*-3 ratio. Woolsey (2008:1108) reports a beneficial *n*-6:*n*-3 ratio of <2:1, and the dangers of an >10 ratio that has the potential of promoting inflammation and oxidation that can in turn give rise to mental illnesses. The author further explains that even diets low in fat, like vegetables could have high *n*-6:*n*-3 ratio. The high *n*-6:*n*-3 ratios are attributed to the feed of animals (Wood & Enser, 1997:S50/S51). The guinea fowls were commercially raised on a farm in the Philadelphia (Western Cape Province) and in view of these research by Woosley, Wood and Enser, it is construed it will be crucial to reconsider the composition and nutritional content of their feed.

The polyunsaturated fatty acids:saturated fatty acids (P:S) ratio can also be used to assess the nutritional value of fat. According to Mostert and Hoffman (2007:569) the British Department of Health recommends a P:S ratio of above 0.4. The P:S ratio was found to be well above the value for all the cuts. The drumstick had the highest value (2.07, P≥0.05) for the polyunsaturated:saturated (P:S) fatty acid ratio, the breast the lowest value (1.74) and the thigh at 1.92 did not differ (P≥0.05) from the breast from or from the drumstick. According to a study on pork by Wood *et al.* (2003:22, 23), high linoleic acid content tended to raise the P:S ratio, which could be attributed to the high content of C18:2 fatty acids in the cereal-based diet fed to the animals, consequently producing a high *n*-6:*n*-3 ratio. This could explain the similar results for guinea fowl meat, which have similarly high C18:2n-6c values. Wood and Enser (1997:S50/S51) report that feed manipulation is one of the methods researchers are finding useful in rectifying the imbalance in the *n*-6:*n*-3 ratio of poultry meat.

3.5.5 Cholesterol content

Low cholesterol intake is important for the control in obesity, hypercholesterolemia, cardiovascular diseases and some cancers, and intake per day should not exceed 300 mg (Gallagher, 2008:595). Chizzolini *et al.* (1999:119) report that significant differences in cholesterol content have been noted between muscles of chicken. The more the fibres within a muscle, the more the total sarcolemma perimeter to fibre per volume ratio, and hence the more cholesterol. This phenomenon could be used to explain the high cholesterol levels in the thigh and drumstick cuts, the breast have larger fibres and therefore less cellular membrane resulting in less cholesterol.

Chizzolini *et al.* (1999:121) report cholesterol content of broiler *pectoralis* as 47.41 mg/100g and that of duckling 99.11 mg/100g, while Van Heerden *et al.,* 2002:59 recorded 61.21 mg/100 g for white chicken meat and 89.27 mg/100 g in dark meat. In the present study, cholesterol was lower ($P \leq 0.05$) in the breast (56.84 mg/100 g), with no differences ($P \geq 0.05$) between the drumstick (126.18 mg/100 g) and the thigh (131.75 mg/100 g) (Table 3.6).

### 3.6 Conclusions

The aim of this study was to develop a profile of the proximate and amino acid composition, mineral content and fatty acid and cholesterol content, of the three cuts (breast, drumstick and thigh) of raw guinea fowl meat. With the exception of protein and ash, the different cuts did not differ significantly in terms of proximate composition. Higher levels of protein and moisture were found in the breast whereas the thigh was higher in fat and ash. Guinea fowl meat can be classified as lean, high protein meat.

The three cuts were found to contain a wide range of amino acids, with eight essential amino acids being present and with very slight differences observed within cuts of all amino acids.

Guinea fowl meat can also be considered a very good source of minerals with relatively high values for calcium, iron and zinc compared to chicken, ostrich and beef, especially in the darker muscles. A significantly higher amount of iron in guinea fowl meat, which was also has low sodium content (lower than chicken) with the darker muscles having values similar to those of ostrich meat. However these analyses were performed on frozen guinea fowl meat with the concomitant mineral content implications.

Polyunsaturated fatty acids were highest in the breast, with the highest values of linoleic acid found in the thigh and lowest in the breast. The breast was also high in alpha-linolenic acid, eicosatrienoic acid (EPA) and docosahexaenoic acid (DHA). This study shows P:S ratios higher than recommended minimum of 0.4. The high *n*-6 fatty acids increased the *n*-6:*n*-3 ratio to above 2.1 as recommended and below 10 for all the cuts. The high *n*-6 is a problem with poultry as opposed to ruminants and more research could be undertaken to manipulate the feed to increase the *n*-3 fatty acids and reduce the *n*-6 fatty acids in order to achieve a healthier and more favourable *n*-6:*n*-3 ratio. Differences in the fatty acid composition between muscles were observed with the drumstick having the lowest MUFAs and the highest PUFAs. The different cuts did not show any significant differences in the SFAs, with high values of palmitic acid, especially in the breast, and high values of myristic acid in the drumstick.

A comparative study on the fatty acid composition of wild guinea fowl vs those reared commercially could be undertaken to assess the effect of feed and activity on the chemical composition of the meat.

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## CHAPTER 4

## PROXIMATE AND FATTY ACID COMPOSITION, AND CHOLESTEROL CONTENT OF DIFFERENT CUTS OF GUINEA FOWL MEAT COOKED ACCORDING TO THREE COOKING METHODS

**Abstract**

This study aimed at investigating the effect of cuts (i.e. breast, drumstick and thigh) and cooking method (i.e. baking-bag, foil-wrap, open-roasting at 140ºC for 65 minutes) on the proximate, and fatty acid composition, and cholesterol content of guinea fowl (*Numeda meleagris).* The open-roasting method produced a higher moisture content (P>0.05) consistently for all cuts, with the breast having the highest and the drumstick the lowest ($P \leq 0.05$). The moisture content of the baking-bag method on the other hand was consistently the lowest (P<0.05). This effect was significant for the breast, which had lost the most moisture ($P \leq 0.05$). The baking-bag method consistently resulted in a higher protein content, which can be attributed to the higher moisture loss ($P \leq 0.05$) in comparison with the other methods, resulting in a more concentrated product. No effect resulting from the cooking methods could be observed in terms of the fat content (P<0.05), but the natural fat content was reflected especially in the open–roasting method ($P \leq 0.05$) lending support to the understanding that the open-roasting method indeed made the least inroads on the chemical composition of guinea fowl meat under these restraints: controlled for cooking time and temperature, internal temperature not controlled. Ash content was higher (P>0.05) in the open-roasted drumstick. All the cuts cooked according to all the methods, had a favourable polyunsaturated:saturated fatty acids (P:S) ratio (>0.4), ranging from 0.91 to 1.42 between cuts and treatments. The *n*-6:*n*-3 ratio was within the recommended beneficial range (<4:1) in all the cuts irrespective of all the cooking methods, ranging from 2.47 to 3.08.

***Keywords:*** guinea fowl, cooking methods, heat treatments, cuts, proximate composition, fatty acids content, cholesterol content.

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### 4.1 Introduction

According to Van Heerden, Schönfeldt, Smith and Van Rensburg (2002:47), poultry is one of the leading meat products in South Africa. Schönfeldt (1998 cite in Van Heerden *et al.*. 2002), reported that information used in the compilation of the South African food composition tables, is generated in other countries and argued that these data cannot be readily applied to the South African scenario, thereby challenging food researchers to generate data on the foods consumed locally, also serving as justification for this study.

Meat supplies the body with lipids, which the human body uses for energy, particularly important for people whose overall dietary intake is limited (Varnam & Sutherland 1995:11). Total fat content of the diet, especially the fatty acid composition and cholesterol content, are becoming increasingly important to the consumer, as these have been reported to be risk factors associated with coronary heart diseases and cancer (Sales, Marais & Kruger, 1996:85). Carbon, hydrogen and oxygen sources like glucose, help the body in the synthesis of most of the fatty acids it needs, but it is not able to synthesise double bonds in the omega-3 and omega-6 position (Smolin & Grosvenor 2000:132), thus making these essential nutrients. These fatty acids are not commonly found in beef, and as a matter of fact, in most animal products, due to their high SFAs and MUFAs. They are more abundant in fish and some poultry (McWilliams, 2001:323; Whitney & Rolfes, 2005:159).

Joseph, Awosanya, Adeniran and Otagba (1996:57) report that cooking makes raw meat edible and generally more acceptable. They add that there are some chemical changes that take place during cooking which differ, amongst other things, according to the muscle, the cooking time and the temperature. The proximate (moisture, protein, fat, ash) composition, fatty acid composition and cholesterol content of the different muscles (breast, drumstick and thigh) of the guinea fowl meat, cooked according to three different methods (baking-bag, foil-wrap, open-roasting) were investigated. Literature on the quality of guinea fowl meat in general is scant, even more so the research reporting on the impact of cooking methods on the proximate and fatty acids composition and cholesterol content.

## 4.2 Materials and methods

### 4.2.1 Main study

Twenty-seven, 15-weeks-old, dressed and frozen guinea fowl were sourced from a farm in Philadelphia in the Western Cape Province. The birds were reared according to standard commercial practices as described by Silverside and Jones (1998). The weights of the birds ranged from 800–1100g. They were frozen at –15°C for later chemical analysis.

4.2.2 Defrosting and cooking

The 27 frozen birds were defrosted for eight hours in the refrigerator at 4°C to 6°C, cut into halves, assigned random numbers identifying the carcasses and re-frozen at –15°C. The samples were later defrosted in the refrigerator at a temperature of 4°C to 6°C for 12 hours before cooking. They were then put at room temperature to prepare them for cooking. Before being put into the ovens, internal temperatures of between 15°C and 18°C were recorded to ensure that the samples were adequately defrosted. The carcasses were cooked with their skin according to the three selected methods, namely in a baking bag, in foil-wrap and open-roasting for 65 minutes at 140°C in *Defy 835* electric ovens connected to a computerized temperature control system (Viljoen, Muller, De Swart, Sadie & Vosloo, 2001:30), using the 3 x 3 Latin square design for arranging the samples in the oven (see Table 4.1). This was meant to give each sample an equal chance of being anywhere in the oven (Ott, 1998).

**TABLE 4.1: 3 x 3 Latin square design used to place the bird halves in the oven**

| | | | |
|---|---|---|---|
| **Row** | FOIL | BAG | OPEN |
| **Row** | BAG | OPEN | FOIL |
| **Row** | OPEN | FOIL | BAG |

Each row represents a tray and two trays could be used in each of the two ovens at a time, and each column represents the position in the oven (Table 4.1). Nine carcasses were used for each cooking method, and the two halves of the same carcass used per cooking method. Prior to placing the samples in the oven specific preparations for the different cooking methods were applied.

**Baking-bag method** Heat resistant clear and light polythene bags specially designed for oven-roasting (*Glad*) were used**.** The bags were perforated with a fork after the samples were put in a bag. The number of perforations was not controlled and was just enough to let out air. A wire tie was used to close the bags.

**Foil-wrap method** 0.01–0.018 mm thick silver-coloured domestic aluminium foil was used to wrap the samples fully before baking. The samples were given one single wrap in the foil, ensuring that all sides were fully covered.

**Open-roasting method** There was no specific instructions prior treatment.

After cooling, the breast *pectoralis*, the drumstick *gastrocnemius* and *peronius,* and the thigh *iliotibialis, semitendinosus* and *sartorius* muscles were removed and thereafter skinned and stored at –15°C, minced and thereafter vacuum-packed and stored frozen at –15°C before being tested for chemical composition.

## 4.3 Chemical analysis

### 4.3.1 Proximate analysis

Proximate analysis of guinea fowl meat was conducted on the breast, the drumstick and the thigh cooked in three different methods, namely baking-bag, foil-wrap and open roasting, according to AOAC standard techniques (AOAC, 1997). Moisture was determined by drying a 2.5 g sample at 100°C for 24 h, ashing was done at 500°C for 6 h. To determine protein content, dried defatted meat samples were ground with a pestle and mortar to a fine powder. Samples of 100 mg were inserted into a foil-wrap designed for the Leco protein analyser (Leco FP-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 Lake View Avenue, St. Joseph, HI 49085-2396, USA, part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. Total lipid content was determined by homogenising the samples in a blender followed by the chloroform:methanol (1:2) extraction technique of Lee, Trevino and Chaiyawat (1996).

### 4.3.2 Fatty acid analysis

The fatty acid composition was determined by the method described by Tichelaar, Smuts, Van Stuiivenberg, Faber and Benade (1998). The meat was thawed; the lipids in a 2 g sample were extracted with chloroform/methanol at a ratio 2:1, according to a modified method of Folch, Lees and Sloane-Sloane-Stanley (1957). All the extraction solvents contained 0.01% butylated hydroxytoluene (BHT) as an antioxidant. A polytron mixer (Kinematica, type PT 10-35, Switzerland) was used to homogenise the sample for 30 s within the extraction solvent. A sub-sample of the extracted lipids was transmethylated for 2 h at 70°C using methanol/sulphuric acid (19:1; v/v) as transmethylating agent. After cooling, the resulting fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane phase was transferred to a spotting tube and dried under nitrogen.

The fatty acid methyl esthers (FAME) were purified by TLC (silica gel 60 plates) and analysed by GLC (Varian Model 3300 equipped with flame ionisation detection) using 60 m BPX70 capillary columns of 0.25 mm internal diameter (SGE, Australia). The hydrogen gas flow rate was 25 ml/min and for hydrogen carrier gas 2–4 ml/min. Temperature programming was linear at 3°C/min, with an initial temperature of 150°C, a final temperature of 220°C, an injector temperature of 240°C and a detector temperature of 250°C. Heptadecanoic acid (C17:0) was used as an internal standard (catalogue number H3500. Sigma–Aldrich Inc. 595 North Harison Road, Bellefonte, PA 16823-0048, USA) to quantify the individual fatty acids. The FAME in the total lipids was identified by comparison of the retention times with those of standard FAME mixture (SuplecoTM 37 component FAME Mix, catalogue number 18919-IAMP, Lot number, LB-16064. Sigma-Aldrich Inc. North Harrison Road, Bellefonte, PA 16823-0048, USA).

### 4.3.3 Cholesterol analysis

From the same lipid extraction used for the fatty acid determination, a sub-sample was used for cholesterol determination. After drying the sub-sample under nitrogen, Stigmasterol (3-B-hydroxy-24-ethyl-5.22-cholestadiene; Sigma Chemical Co., St. Louis, MO, USA) was added as internal standard and 6% ethanolic KOH was used to saponifise the extraction for 2 h at 70°C in a heating block. After cooling, distilled water and hexane were added and the resultant extraction was analysed by GLC (Varian Model 3700. equipped with flame ionisation detection). A 1.2 m glass column of 2 mm internal diameter packed with 3% SP2401 on 100/120 mesh Supelcoport (Supelco Inc., Bellefonte, PA, USA) was used. Gas flow rates for hydrogen were 20 ml/min, for air 200 ml/min and for nitrogen (carrier gas), 25 ml/min. The injector temperature was 280°C, that of column was 255°C and of the detector was 290°C.

## 4.4 Statistical analysis

The data were analysed using ANOVA to test for significant differences between the samples. The cooking methods experiment consisted of a 3 x 3 Latin square combination. The treatment combinations involved a 1 x 3 factorial array where one guinea fowl species was cooked using three cooking methods (baking-bag, foil-wrap open-roasting). A one-factor factorial experiment was performed in a linear scale with seven replications. An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Students' t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998). A probability smaller than 0.05 was considered significant.

## 4.5 Results and discussions

According to Rodriquez-Estrada, Penazzi, Caboni, Bertacco and Lercker (1997:365) cooking makes meat edible and easily digestible, but it can also affect some properties like the nutritional value. Literature on the effect of cooking methods on the chemical composition of guinea fowl meat was scant. Therefore, in the discussion of the results certain arguments will be drawn from the results of a parallel study in Chapter 3 of raw meat, to make certain comparisons especially for fatty acids and cholesterol. It should be noted that, even though the samples used for the study in Chapter 3 and those of this study were reared at the same farm, under the same conditions, they were not from the same batch.

### 4.5.1 Proximate composition

The mean values for the proximate chemical composition of the different cuts (breast, drumstick, thigh) using three cooking methods (baking-bag, foil-wrap, open-roasting) are presented in Table 4.2.

**TABLE 4.2: The effect of cooking methods on the proximate composition of the different cuts of guinea fowl *(Numeda meleagris)* meat**

| | CUT | TREATMENT | | | |
|---|---|---|---|---|---|
| | | Baking bag | Foil wrap | Open roasting | LSD |
| Moisture | Breast | $66.06^{b}$ | $66.59^{ab}$ | $68.08^{a}$ | 1.52 |
| | Drumstick | $62.80^{c}$ | $63.78^{c}$ | $63.82^{c}$ | |
| | Thigh | $66.75^{ab}$ | $67.11^{ab}$ | $67.12^{ab}$ | |
| Protein | Breast | $31.40^{a}$ | $31.13^{ab}$ | $29.50^{b}$ | 1.65 |
| | Drumstick | $32.23^{a}$ | $31.43^{a}$ | $31.16^{a}$ | |
| | Thigh | $27.57^{c}$ | $27.17^{c}$ | $26.67^{c}$ | |
| Fat | Breast | $2.82^{c}$ | $2.67^{c}$ | $2.52^{c}$ | 0.75 |
| | Drumstick | $4.24^{b}$ | $4.25^{b}$ | $4.30^{b}$ | |
| | Thigh | $4.88^{ab}$ | $4.71^{ab}$ | $5.05^{a}$ | |
| Ash | Breast | $1.27^{bc}$ | $1.36^{bc}$ | $1.43^{b}$ | 0.18 |
| | Drumstick | $1.35^{bc}$ | $1.28^{bc}$ | $1.60^{a}$ | |
| | Thigh | $1.21^{c}$ | $1.38^{bc}$ | $1.35^{bc}$ | |

LSD, Least significant difference, *P*=0.05

[a,b,c] Means, in rows within groups with the same superscript letter are significantly the same

Moisture content of the open-roasted cuts were the highest for the respective cuts, in comparison with other treatments, with the breast significantly ($P \leq 0.05$) the highest. The effect of conduction in the open-roasted method vs convection currents in the other two treatments is borne in mind (Charley & Weaver, 1998:54) (see Chapter 2, section 2.3). The moisture content of the open-roasted treatment is not suprising as air is a poor conductor of heat. Therefore it is suggested that the open-roasted cuts were not cooked to the same internal temperature as the baking-bag and the foil-wrap methods, where wrapping trapped the steam, resulting in higher internal temperatures. The end point (internal) temperature was not controlled. For the baking-bag and the foil-wrap methods, the food was also cooked by water, which had seeped from the fibres and collected in the bag and the foil (personal observation), indicating that perforation of the bag was not sufficient, bearing in mind that slitting of the bag is sometimes recommended (http://www.urbanext.uiuc.edu/index.html) but was unfortunately not applied. After enough heat had been generated by the voluminous steam and due to its higher heat capacity the other treatments had greater moisture loss (contained less moisture) as a result of the lower water-holding capacity. It is also suggested that the foil with its more porous nature, did not generate as much steam as the baking bag which was more water tight, more effective wrapping.

Cooking methods had a significant effect on the protein content of the drumstick across treatments ($P \leq 0.05$) resulting from a significant high moisture loss (lower moisture content) ($P \leq 0.05$). The thigh had the lowest ($P \leq 0.05$) protein content due to its high moisture content ($P > 0.05$) across two of the three treatments. The high protein content ($P \leq 0.05$) in the drumstick supports findings by Hamm (1981:1122) who reports that muscles with more connective tissues concentrate the protein more. The baking-bag method had a relatively high protein content compared to other treatments ($P > 0.05$), with the open-roasting having the lowest values that were significantly different in all the cuts ($P \leq 0.05$). These high protein values are explained by the concentration of protein due to high moisture loss. According to Honikel (1998:447) the moisture loss that occurs during heating, is the result of "the different meat proteins [that] denature at varying temperatures, which cause structural changes such as the destruction of cell membranes, transverse and longitudinal shrinkage of muscle fibres, the aggregation of sarcoplasmic proteins and shrinkage of the connective tissue". The drumstick had a significantly higher protein content (baking-bag 32.23%, foil-wrap 31.43%, open-roasting 31.16%) when compared to the thigh ($P \leq 0.05$) when using the baking-bag method ($P > 0.05$). These findings do not support findings of research by Van Heerden *et al.* (2002:48) on breawst cut of chicken where the open-roasting method recorded the highest (66.01%) values, followed by the foil-wrap method (64.71%) and the baking-bag method (63.83%). The research of Van Heerden *et al.* was controlled for internal temperature – 85 °C (Van Heerden *et al.*, 2002:48).

The fat content in the breast was significantly the lowest ($P \leq 0.05$), and the thigh was the highest ($P > 0.05$) with cooking methods having no effect on any of the cuts ($P > 0.05$). The fat content of the drumstick was not as high as that of the thigh, but nevertheless higher

(P≤0.05). Throughout, open-roasting resulted in the retention of more fat content, while the baking-bag and the foil-wrap showed lower values (P>0.05). As in the case of moisture content, this can be explained by the lower internal temperature of the open-roasting method, resulting in less melted fat (internal temperature was not controlled).

The ash content differed significantly for the three cuts (P≤0.05) the drumstick being the highest (1.60%, P≤0.05) between heat treatment and the cuts. The foil-wrap method did not result in different value for ash (P>0.05) between the cuts, nor did the baking-bag method. The baking-bag resulted in the lowest (P>0.05) ash content for the thigh in comparison with the other cuts and other heat treatments.

### 4.5.2 Fatty acid composition

The qualitative mean values of the fatty acids (%) and quantitative (mg/100 g) cholesterol content of three portions (breast, drumstick, thigh) of guinea fowl meat cooked in three different cooking method (baking-bag, foil-wrap, open-roasting) are presented in Table 4.3.

The number of fatty acids detected in raw guinea fowl in this study were 12 for PUFAs, 8 for MUFAs and 14 for SFAs respectively. The total unsaturated fatty acids (TUFAs) were highest in the breast (70.61%, P≤0.05) and for the foil-wrap method (67.58%, P≤0.05). Of these PUFAs were significantly the highest in the breast (39.24%, P≤0.05) and did not differ (P>0.05) in the cooking methods. Linoleic acid (C18:2n6c) generally had high values and was highest in the breast (28.30%, P≤0.05) with the open-roasting method having the lowest values (24.75%). Homo-gamma linoleic acid had the highest values in the drumstick (4.81%, P>0.05) and the open-roasting method (4.99%, P≤0.05). Docosahexaenoic was highest in the breast (4.01%, P≤0.05) and lowest for the foil-wrap method (3.82%, P≤0.05).

**TABLE 4.3: Fatty acids composition* (%) and cholesterol content (mg/100 g) of different cuts of guinea fowl meat (*Numeda meleagris)* cooked according to three cooking methods**

| | CUTS | | | | TREATMENTS | | | |
|---|---|---|---|---|---|---|---|---|
| | Breast | Drum stick | Thigh | LSD | Baking bag | Foil wrap | Open roast | LSD |
| **Saturated** | | | | | | | | |
| C6:0 (caproic) | 0.07$^{a}$ | 0.04$^{b}$ | 0.03$^{b}$ | 0.02 | 0.04 | 0.04 | 0.05 | 0.02 |
| C8:0 (caprylic) | 0.08$^{a}$ | 0.05$^{b}$ | 0.05$^{b}$ | 0.02 | 0.05 | 0.07 | 0.07 | 0.03 |
| C10:0 (capric) | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 | 0.02 |
| C11:0 (undecanoic) | 0.41$^{a}$ | 0.32$^{b}$ | 0.20$^{c}$ | 0.06 | 0.35$^{a}$ | 0.23$^{b}$ | 0.35$^{a}$ | 0.06 |
| C12:0 (lauric) | 0.09$^{a}$ | 0.06$^{b}$ | 0.06$^{b}$ | 0.02 | 0.07 | 0.07 | 0.07 | 0.02 |
| C13:0 (tridecanoic) | 0.48$^{a}$ | 0.34$^{b}$ | 0.43$^{a}$ | 0.05 | 0.41$^{ab}$ | 0.45$^{a}$ | 0.39$^{b}$ | 0.04 |
| C14:0 (myristic) | 0.25$^{c}$ | 0.38$^{b}$ | 0.58$^{a}$ | 0.08 | 0.45 | 0.39 | 0.37 | 0.09 |
| C15:0 (pentadecanoic) | 0.13$^{c}$ | 0.16$^{b}$ | 0.19$^{a}$ | 0.02 | 0.16 | 0.17 | 016 | 0.03 |
| C16:0 (palmitic) | 14.64$^{b}$ | 16.56$^{a}$ | 16.98$^{a}$ | 1.19 | 15.86$^{b}$ | 15.03$^{b}$ | 17.29$^{a}$ | 1.15 |
| C18:0 (stearic) | 12.34$^{b}$ | 16.45$^{a}$ | 16.55$^{a}$ | 1.06 | 15.23 | 15.04 | 15.07 | 0.86 |
| C20:0 (arachidic) | 0.35$^{c}$ | 0.45$^{b}$ | 0.56$^{a}$ | 0.04 | 0.46$^{ab}$ | 0.43$^{b}$ | 0.48$^{a}$ | 0.05 |
| C21:0 ( lignoceric) | 0.09 $^{a}$ | 0.04$^{ab}$ | 0.23$^{b}$ | 0.05 | 0.03$^{b}$ | 0.09$^{a}$ | 0.04$^{b}$ | 0.03 |
| C22:0 (behenic) | 0.27$^{b}$ | 0.34$^{a}$ | 0.32$^{a}$ | 0.03 | 0.32 | 0.29 | 0.32 | 0.04 |
| C24:0 (tetracosanoic) | 0.15$^{b}$ | 0.21$^{a}$ | 0.23$^{a}$ | 0.03 | 0.23$^{b}$ | 0.08$^{c}$ | 0.26$^{a}$ | 0.03 |
| **Monounsaturated** | | | | | | | | |
| C14:1 (myristoleic) | 0.05 | 0.04 | 0.05 | 0.01 | 0.05 | 0.05 | 0.04 | 0.01 |
| C15:1 (pentadecanoic)* | 0.05$^{a}$ | 0.04$^{b}$ | 0.03$^{b}$ | 0.01 | 0.04 | 0.04 | 0.04 | 0.01 |
| C16:1n-7 (palmitoleic) | 0.43$^{b}$ | 0.81$^{a}$ | 0.83$^{a}$ | 0.07 | 0.65$^{b}$ | 0.64$^{b}$ | 0.77$^{a}$ | 0.04 |
| C18:1n-9c (oleic) | 29.60$^{a}$ | 25.90$^{b}$ | 24.99$^{b}$ | 1.05 | 26.37 | 27.91 | 26.21 | 1.94 |
| C18:1n-9t (selaidic) | 0.68$^{a}$ | 0.68$^{a}$ | 0.59$^{b}$ | 0.07 | 0.66 | 0.64 | 0.64 | 0.06 |
| C20:1n-9 (gondoic) | 0.36$^{b}$ | 0.58$^{a}$ | 0.62$^{a}$ | 0.04 | 0.52$^{ab}$ | 0.48$^{b}$ | 0.56$^{a}$ | 0.06 |
| C22:1n-9 (erucic) | 0.04$^{b}$ | 0.05$^{b}$ | 0.06$^{a}$ | 0.01 | 0.05 | 0.05 | 0.05 | 0.01 |
| C24:1n-9 (nervonic) | 0.16$^{b}$ | 0.21$^{a}$ | 0.23$^{a}$ | 0.02 | 0.23$^{a}$ | 0.18$^{b}$ | 0.17$^{b}$ | 0.04 |
| **Polyunsaturated** | | | | | | | | |
| C18:2n-6c (linoleic) | 28.30$^{a}$ | 24.61$^{b}$ | 25.30$^{b}$ | 1.62 | 26.63$^{ab}$ | 26.84$^{a}$ | 24.75$^{b}$ | 1.94 |
| C18:2n-6t (linolelaidic) | 0.11$^{a}$ | 0.09$^{b}$ | 0.09$^{b}$ | 0.01 | 0.10$^{a}$ | 0.09$^{a}$ | 0.10$^{a}$ | 0.02 |
| C18:3n-6 ($\chi$-linolenic) | 0.59$^{c}$ | 0.79$^{b}$ | 0.85$^{a}$ | 0.06 | 0.72$^{b}$ | 0.73$^{ab}$ | 0.0.79$^{a}$ | 0.07 |
| C18:3n-3 ( α-linolenic) | 0.08$^{b}$ | 0.12$^{a}$ | 0.11$^{a}$ | 0.01 | 0.12$^{a}$ | 0.09$^{b}$ | 0.10$^{b}$ | 0.02 |
| C20:2 (eicosadienoic)* | 0.54 | 0.55 | 0.50 | 0.05 | 0.53$^{a}$ | 0.50$^{a}$ | 0.56$^{a}$ | 0.07 |
| C20:3n-3 (eicosatrienoic)* | 0.34 | 0.37 | 0.34 | 0.04 | 0.37$^{a}$ | 0.33$^{a}$ | 0.36$^{a}$ | 0.05 |
| C20:3n-6 (homo-g-linoleic) | 4.57$^{ab}$ | 4.81$^{a}$ | 4.32$^{b}$ | 0.28 | 4.28$^{b}$ | 4.42$^{b}$ | 4.99$^{a}$ | 0.32 |
| C20:4n-6 (arachidonic) | 0.05 | 0.04 | 0.05 | 0.01 | 0.05 | 0.04 | 0.05 | 0.02 |
| C20:5n-3 (eicosapentaenoic)* | 0.99$^{a}$ | 0.81$^{b}$ | 1.02$^{a}$ | 0.07 | 0.95 | 0.96 | 0.91 | 0.09 |
| C22:2 (docosadienoic)* | 0.12$^{a}$ | 0.03$^{b}$ | 0.03$^{b}$ | 0.02 | 0.04$^{b}$ | 0.06$^{b}$ | 0.09$^{a}$ | 0.02 |
| C22:5n-3 (docosapentaenoic)* | 0.05$^{a}$ | 0.04$^{b}$ | 0.04$^{ab}$ | 0.01 | 0.04 | 0.04 | 0.05 | 0.01 |
| C22:6n-3 (docosahexaenoic)* | 3.50$^{b}$ | 4.01$^{a}$ | 3.72$^{b}$ | 0.24 | 3.93$^{a}$ | 3.48$^{b}$ | 3.82$^{a}$ | 0.24 |
| **Total** | | | | | | | | |
| SFA | 29.39$^{b}$ | 35.43$^{a}$ | 36.23$^{a}$ | 1.62 | 33.68$^{ab}$ | 32.42$^{b}$ | 34.94$^{a}$ | 1.49 |
| MUFA | 31.37$^{a}$ | 28.30$^{b}$ | 27.39$^{b}$ | 1.06 | 28.58 | 29.99 | 28.58 | 1.90 |
| PUFA | 39.24$^{a}$ | 36.27$^{b}$ | 36.38$^{b}$ | 1.68 | 37.74 | 37.59 | 36.56 | 1.99 |
| TUFA | 70.61$^{a}$ | 64.57$^{b}$ | 63.77$^{b}$ | 1.62 | 66.32$^{ab}$ | 67.58$^{a}$ | 65.06$^{b}$ | 1.49 |
| P:S | 1.36$^{a}$ | 1.04$^{b}$ | 1.01$^{b}$ | 0.10 | 1.15$^{ab}$ | 1.18$^{a}$ | 1.07$^{b}$ | 0.09 |
| *n*-6 | 29.42$^{a}$ | 25.78$^{b}$ | 26.40$^{ab}$ | 1.64 | 27.79$^{a}$ | 27.90$^{a}$ | 25.91$^{b}$ | 1.64 |
| *n*-3 | 9.70$^{b}$ | 10.46$^{a}$ | 9.95$^{b}$ | 0.47 | 9.91$^{b}$ | 9.63$^{b}$ | 10.56$^{a}$ | 0.48 |
| *n*-6:*n*-3 | 3.08 $^{a}$ | 2.49 $^{b}$ | 2.67 $^{b}$ | 0.22 | 2.93$^{a}$ | 2.84$^{a}$ | 2.47$^{b}$ | 0.22 |
| **Cholesterol (mg/100 g)** | **125.85$^{b}$** | **245.05$^{a}$** | **239.79$^{a}$** | **12.40** | **201.31$^{ab}$** | **189.60$^{b}$** | **214.78$^{a}$** | **22.31** |

LSD, Least significant difference, *P*=0.05, $^{a,b,c}$ Means, in rows within groups with different superscript letter are significantly different *P*=0.05 .

* Common names have mainly been used in brackets in the first column. However, common names were not available for all the fatty acids, in which case the systemic names were used, marked with an *.

From the results of this study it appears that cooking resulted in a decrease in PUFAs, when compared with the results of a parallel study (see Chapter 3). The high content of linoleic acid in particular in this study is noteworthy due to its isomer conjugated linoleic acid (CLA), which is revealed of great importance to human health, most essentially as a chemopreventative agent (O'Shea, Lawless, Stanton & Devery, 1998:192). The monounsaturated fatty acids (MUFAs) were highest in the breast (31.37%, $P \leq 0.05$) but not affected by any of the cooking methods. Oleic acid (C18:1n9c) had high values across all cuts and cooking methods but was higher in the breast (29.60%, $P \leq 0.05$) and not affected by any of the cooking methods. Cooking increased the MUFAs, especially the breast which resulted in the highest values, including those of oleic acid, as opposed to the raw meat (see Chapter 3), where the highest concentrations of oleic acid were found in the thigh. Oleic acid was increased in the breast (raw – 22.42% and cooked – 29.60%) but reduced in the drumstick and thigh cuts, and the opposite was noted for the transelaidic acid, where lower values were found in the breast, whilst the drumstick and thigh cuts increased their concentration. Stadelman, Olson, Shemwell and Pasch (1988:109) report that lipids could be increased during cooking due to moisture loss and due to the transfer of fat from skin to muscle, and samples in this study were cooked with skin. Freeland-Graves and Peckham (1996:515) further explain that high temperatures melt fat, which may end up in the drippings, and when cooked with skin there could be transfer of fats from skin to muscle.

Saturated fatty acids (SFAs) were lowest in the breast (29.39%, $P \leq 0.05$) and the open-roasting method had the highest values. This could imply that the foil-wrap method and the baking-bag method have a similar effect on the fatty acids. Stopler (2008:855) reports that the saturated fatty acids, namely myristic acid (C14:0), palmitic acid (16:0) and lauric acid (12:0), respectively, are the most hypercholesterolemic, whereas stearic acid (C18:0) is neutral and has no effect on blood lipoproteins. Myristic acid differed significantly for all cuts and was highest in the thigh (0.58%), then the drumstick (0.38%), and ($P \leq 0.05$) lowest in the breast (0.25%) but not affected by any of the cooking methods ($P > 0.05$). Palmitic acid was the most abundant saturated fatty acid with the breast having lowest values (14.64, $P \leq 0.05$) as opposed to the drumstick and thigh (16.56% and 16.98% respectively) and the open-roasting method (17.29%, $P \leq 0.05$) showing the highest values. Lauric acid was highest in the breast (0.09%, $P \leq 0.05$) and not ($P > 0.05$) affected by the cooking methods. These cooking methods therefore have no effect on these fatty acids, except for the open-roasting method that seemed to raise palmitic acid, when compared with the values of raw meat (see Chapter 3). It was found that cooking increased the SFA content, though it reduced palmitic acid that was even further reduced in the breast. Lauric acid was reduced in the drumstick and thigh cuts, but slightly increased in the breast, whereas myristic acid was slightly lower in the breast but increased in the thigh.

There was a significant difference ($P \leq 0.05$) noted in the omega-6 (*n*-6) fatty acids, with the breast having the highest value (29.42%, $P \leq 0.05$) and drumstick the lowest (25.78%, $P \leq 0.05$). The open-roasting method resulted in the lowest *n*-6 value (25.91%, $P \leq 0.05$) than the baking-bag (27.79%) and the foil-wrap method (27.90%). The omega-3 (*n*-3) fatty acids on the other hand were higher in the drumstick (10.46%, $P \leq 0.05$). The breast (9.70%) and the thigh (9.95%) did not differ ($P > 0.05$). The open-roasting method resulted in higher (10.56%, $P \leq 0.05$) than both the baking-bag (9.91%) and the foil-wrap (9.63%) methods. The *n*-6:*n*-3 ratio was higher in the breast (3.08, $P \leq 0.05$) and did not differ between the drumstick and the thigh at 2.49% and 2.67% respectively. The open-roasting method had a lower *n*-6:*n*-3 ratio (2.47%, $P \leq 0.05$) than the baking-bag method (2.93%) and (2.84%), which di not differ.

The high *n*-6 values in this study are disturbing and an indication that processing alters the fatty acid composition. Baggio and Bragagnolo (2006:613) report that lipid components are susceptible to attack by molecular oxygen, resulting in lipid oxidation with the generation of cholesterol oxides and alteration of fatty acids. The fatty acid composition of foods can also be altered by auto-oxidation, especially affecting foods containing unsaturated fatty acids. Wood *et al.* (2003:22) report that omega-3 (*n*-3) fatty acids are mostly abundant in leafy plants, the fat of roaming and grazing animals will hence contain more *n*-3 fatty acids than animals or species that does not graze like poultry. This could explain the low *n*-3 fatty acids recorded in this study since the guinea fowls were commercially raised in a confined area and do not naturally graze. The Japan Society for Lipid Nutrition recommends that the *n*-6:*n*-3 ratio should be less than 4:1 for healthy adults and less than 2:1 for the prevention of the chronic diseases of the elderly. On the other hand, the Department of Health (UK) also recommends a maximum 4:1 for the *n*-6:*n*-3 ratio (Milinsk, Padre, Hayashi, De Souza & Matsushita, 2003:554). According to these recommendations, the *n*-6:*n*-3 ratio found in cooked guinea fowl meat, fall within the acceptable range of less than 4:1, though the ratios would need to be altered to suit the elderly. This could be achieved by increasing the *n*-3 content of guinea fowl meat through feed manipulation.

The polyunsaturated:saturated (P:S) ratio was highest (1.36, $P \leq 0.05$) in the breast. The P:S ratio for the foil-wrap method (1.18) differed ($P \leq 0.05$) with that of the open-roast method (1.07) but was not significantly different from that of the baking-bag method (1.15, $P > 0.05$).

According to Mostert and Hoffman (2007:569) the British Department of Health recommends a P:S ratio of above 0.4. The P:S ratio was found to be acceptable for all the cuts and treatments. According to a study on pork by Wood *et al.* (2003:22, 23), high linoleic acid content tended to raise the P:S ratio, which could be attributed to the high content of C18:2 fatty acids, consequently producing a high *n*-6:*n*-3 ratio. This could explain the similar results for guinea fowl meat, which have similarly high C18:2n-6c values.

The relationship between cooking methods and cuts on the polyunsaturated fatty acids (PUFAs) are shown in Table 4.4.

The breast cooked using all the methods, as well as the thigh cooked in a baking-bag had highest content of PUFAs ($P \leq 0.05$), the drumstick on the other hand had the lowest ($P>0.05$) values. The open-roasted thigh was lowest ($P \leq 0.05$) in the thigh. The PUFAs were best preserved in the baking-bag vs open-roasting ($P \leq 0.05$) for the thigh, so that generalisation can not be made. The breast had the ($P \leq 0.05$) highest TUFAs across all treatments. The thigh cooked in foil-wrap had the lowest TUFA value (61.56%), though not ($P>0.05$) different from the drumstick and thigh cooked in baking bag.

**TABLE 4.4: The effect of the cooking method on fatty acid composition (%) of guinea fowl (*Numeda meleagris)* meat**

| | | TREATMENT | | | |
|---|---|---|---|---|---|
| | CUT | Baking Bag | Foil Wrap | Open roast | LSD |
| C18:2n6t | Breast | $0.10^{ab}$ | $0.11^{ab}$ | $0.12^{a}$ | 0.02 |
| Trans-inolelaidic | Drumstick | $0.10^{ab}$ | $0.09^{b}$ | $0.09^{b}$ | |
| | Thigh | $0.09^{ab}$ | $0.09^{b}$ | $0.10^{ab}$ | |
| C18:2n6c | Breast | $29.74^{a}$ | $29.28^{a}$ | $26.89^{abc}$ | 2.81 |
| Linoleic | Drumstick | $24.13^{cd}$ | $25.48^{bcd}$ | $24.22^{bcd}$ | |
| | Thigh | $27.01^{ab}$ | $25.76^{bcd}$ | $23.13^{d}$ | |
| C18:3n3 | Breast | $0.59^{e}$ | $0.61^{de}$ | $0.59^{e}$ | 0.10 |
| α-linolenic | Drumstick | $0.79^{b}$ | $0.69^{cd}$ | $0.89^{a}$ | |
| | Thigh | $0.77^{bc}$ | $0.89^{a}$ | $0.89^{a}$ | |
| C18:3n6 | Breast | $0.08^{d}$ | $0.08^{d}$ | $0.09^{cd}$ | 0.02 |
| χ-linolenic | Drumstick | $0.16^{a}$ | $0.09^{cd}$ | $0.10^{bcd}$ | |
| | Thigh | $0.12^{b}$ | $0.11^{bc}$ | $0.10^{bc}$ | |
| C20:2 | Breast | $0.53^{ab}$ | $0.53^{ab}$ | $0.56^{ab}$ | 0.09 |
| Eicosedienoic | Drumstick | $0.57^{a}$ | $0.51^{ab}$ | $0.56^{ab}$ | |
| | Thigh | $0.48^{b}$ | $0.47^{b}$ | $0.56^{ab}$ | |
| C20:3n-3 | Breast | $0.33^{bc}$ | $0.34^{bc}$ | $0.34^{bc}$ | 0.08 |
| Eicosatrienoic | Drumstick | $0.42^{a}$ | $0.30^{c}$ | $0.39^{ab}$ | |
| | Thigh | $0.35^{bc}$ | $0.35^{bc}$ | $0.31^{c}$ | |
| C20:3n-6 Homo- | Breast | $4.27^{cd}$ | $4.44^{cd}$ | $4.99^{ab}$ | 0.49 |
| gamma- linoleic | Drumstick | $4.46^{cd}$ | $4.68^{bc}$ | $5.28^{a}$ | |
| | Thigh | $4.11^{d}$ | $4.13^{d}$ | $4.71^{bc}$ | |
| C20:4n-6 | Breast | $0.04^{b}$ | $0.04^{b}$ | $0.06^{a}$ | 0.02 |
| Arachidonic | Drumstick | $0.05^{ab}$ | $0.04^{b}$ | $0.04^{b}$ | |
| | Thigh | $0.05^{ab}$ | $0.04^{ab}$ | $0.05^{ab}$ | |
| C20:5n-3 | Breast | $1.08^{a}$ | $0.86^{b}$ | $1.02^{a}$ | 0.13 |
| EicosaPentaenoic | Drumstick | $0.73^{bc}$ | $1.01^{a}$ | $0.71^{c}$ | |
| | Thigh | $1.04^{a}$ | $1.02^{a}$ | $1.00^{a}$ | |
| C22:2 | Breast | $0.06^{c}$ | $0.11^{b}$ | $0.19^{a}$ | 0.02 |
| Docosadienoic | Drumstick | $0.03^{d}$ | $0.03^{d}$ | $0.03^{cd}$ | |
| | Thigh | $0.03^{d}$ | $0.03^{cd}$ | $0.04^{d}$ | |
| C22:5n-3 | Breast | $0.04^{bc}$ | $0.05^{ab}$ | $0.06^{a}$ | 0.02 |
| DocosaPentaenoic | Drumstick | $0.03^{c}$ | $0.04^{bc}$ | $0.04^{abc}$ | |
| | Thigh | $0.04^{bc}$ | $0.04^{abc}$ | $0.04^{bc}$ | |
| C22:6n-3 | Breast | $3.47^{de}$ | $3.36^{de}$ | $3.67^{cde}$ | 0.42 |
| Docosahexaenoic | Drumstick | $4.19^{a}$ | $3.77^{abcd}$ | $4.07^{abc}$ | |
| | Thigh | $4.13^{ab}$ | $3.30^{e}$ | $3.73^{bcde}$ | |
| PUFA | Breast | $39.33^{ab}$ | $39.81^{a}$ | $38.59^{abc}$ | 2.91 |
| | Drumstick | $35.67^{de}$ | $36.71^{bcde}$ | $36.43^{bcde}$ | |
| | Thigh | $38.22^{abcd}$ | $36.26^{cde}$ | $34.66^{e}$ | |
| TUFA | Breast | $71.83^{a}$ | $70.84^{a}$ | $69.18^{a}$ | 2.81 |
| | Drumstick | $63.29^{bc}$ | $65.99^{b}$ | $64.44^{b}$ | |
| | Thigh | $63.84^{bc}$ | $65.91^{b}$ | $61.56^{c}$ | |

LSD, Least significant difference, P=0.05, Means, in rows within groups with different superscript letter are significantly different P=0.05.

For the purpose of the discussion of Table 4.4, only linoleic acid will be discussed, as this polyunsaturated fatty acid is the most abundant. Linoleic (C18:2n-6c) was highest in the breast ($P\leq0.05$) for all the cooking method as well as in the thigh cooked in a baking-bag, whereas the lowest ($P>0.05$) values were found in the open-roasted thigh. Foil-wrapped thigh and drumstick, open-roasted drumstick and drumstick in baking-bag, were also lower in linoleic acid. High linoleic acid in the breast therefore was not affected by any of the cooking methods.

The effect of the relationship between the cuts and cooking methods on the *n*-3 and *n*-6 composition, the P:S and the *n*-6:*n*-3 ratios are shown in Table 4.5.

**TABLE 4.5: The effect of cooking method on the *n*-3 and *n*-6 composition (%) the P:S and the *n*-6:*n*-3 ratios of guinea fowl (*Numeda meleagris)* meat**

| | | TREATMENT | | | |
|---|---|---|---|---|---|
| | CUT | Baking Bag | Foil Wrap | Open roast | LSD |
| P:S | Breast | $1.42^{a}$ | $1.39^{a}$ | $1.27^{ab}$ | 0.18 |
| | Drumstick | $0.98^{cd}$ | $1.09^{bc}$ | $1.04^{cd}$ | |
| | Thigh | $1.07^{cd}$ | $1.07^{cd}$ | $0.91^{d}$ | |
| *n*-6 | Breast | $28.61^{bc}$ | $28.66^{bc}$ | $27.67^{b}$ | 0.08 |
| | Drumstick | $26.79^{a}$ | $26.84^{c}$ | $26.79^{b}$ | |
| | Thigh | $27.10^{b}$ | $27.15^{bc}$ | $26.16^{bc}$ | |
| *n*-3 | Breast | $9.44^{cd}$ | $9.32^{d}$ | $10.33^{ab}$ | 0.80 |
| | Drumstick | $10.19^{bc}$ | $10.18^{bc}$ | $10.99^{a}$ | |
| | Thigh | $10.08^{bcd}$ | $9.40^{cd}$ | $10.37^{ab}$ | |
| *n*-6:*n*-3 | Breast | $3.01^{a}$ | $2.96^{a}$ | $2.78^{b}$ | 0.01 |
| | Drumstick | $2.71^{bc}$ | $2.67^{c}$ | $2.71^{bc}$ | |
| | Thigh | $2.80^{b}$ | $2.76^{b\ c}$ | $2.57^{c}$ | |

LSD, Least significant difference, P=0.05. Means in rows within groups with different superscript letter are significantly different P=0.05.

All the cuts cooked in all the methods had the favourable polyunsaturated:saturated fatty acids (P:S) ratio of above 0.4. The breast had the highest ($P \leq 0.05$) values across all treatments. The omega-6:omega-3 (*n*-6:*n*-3) ratio was also within the acceptable range of the recommended below 4:1 in all the cuts and across all treatments. Woolsey (2008:1108) report a beneficial *n*-6:*n*-3 ratio of <2:1, and the dangers of an >10 ratio that has the potential of promoting inflammation and oxidation which have the potential of giving rise to mental illnesses. It was not possible to make adequate inferences and comparisons due to scarcity of literature on the relationship of the cuts and the cooking methods of either guinea fowl or poultry in general. Ettinger (2004:52) reports that fatty acids with double bonds are easily affected by oxidative damage, which could have caused the observed decreased unsaturated fatty acids in this study compared to the raw meat.

Table 4.6 shows relationships between cooking methods and cuts on the monounsaturated fatty acids.

**TABLE 4.6: The effect of cooking method on monounsaturated fatty acid composition (%) and total (MUFA) of guinea fowl (*Numeda meleagris)* meat**

| | CUT | TREATMENT | | | LSD |
|---|---|---|---|---|---|
| | | Baking Bag | Foil Wrap | Open roast | |
| C14:01 Myristoleic | Breast | $0.05^{a}$ | $0.05^{a}$ | $0.05^{a}$ | 0.02 |
| | Drumstick | $0.04^{a}$ | $0.04^{a}$ | $0.04^{a}$ | |
| | Thigh | $0.05^{a}$ | $0.05^{a}$ | $0.04^{a}$ | |
| C15:01 Pentadecenoic | Breast | $0.04^{abc}$ | $0.05^{abc}$ | $0.06^{a}$ | 0.02 |
| | Drumstick | $0.03^{bc}$ | $0.04^{abc}$ | $0.04^{bc}$ | |
| | Thigh | $0.03^{c}$ | $0.03^{c}$ | $0.03^{c}$ | |
| C16:1n7 Palmitoleic | Breast | $0.38^{c}$ | $0.42^{c}$ | $0.50^{c}$ | 0.12 |
| | Drumstick | $0.70^{b}$ | $0.81^{ab}$ | $0.91^{a}$ | |
| | Thigh | $0.88^{a}$ | $0.69^{b}$ | $0.91^{a}$ | |
| C18:1n9t Transeladic | Breast | $0.62^{bcd}$ | $0.76^{a}$ | $0.66^{abcd}$ | 0.12 |
| | Drumstick | $0.74^{ab}$ | $0.64^{abcd}$ | $0.67^{abc}$ | |
| | Thigh | $0.63^{bcd}$ | $0.53^{d}$ | $0.60^{cd}$ | |
| C18:1n9c Oleic | Breast | $30.88^{a}$ | $29.21^{ab}$ | $28.71^{bc}$ | 1.81 |
| | Drumstick | $25.16^{e}$ | $27.00^{dc}$ | $25.55^{de}$ | |
| | Thigh | $23.08^{f}$ | $27.53^{bc}$ | $24.37^{ef}$ | |
| C20:1n9 Gondoic | Breast | $0.34^{d}$ | $0.36^{d}$ | $0.40^{d}$ | 0.08 |
| | Drumstick | $0.60^{ab}$ | $0.52^{c}$ | $0.62^{ab}$ | |
| | Thigh | $0.63^{ab}$ | $0.56^{bc}$ | $0.66^{a}$ | |
| C22:1n9 Erucic | Breast | $0.04^{b}$ | $0.05^{ab}$ | $0.05^{b}$ | 0.02 |
| | Drumstick | $0.05^{ab}$ | $0.05^{ab}$ | $0.05^{ab}$ | |
| | Thigh | $0.06^{a}$ | $0.06^{a}$ | $0.06^{a}$ | |
| C24:1n9 Nervonic | Breast | $0.15^{c}$ | $0.15^{c}$ | $0.18^{bc}$ | 0.04 |
| | Drumstick | $0.29^{a}$ | $0.19^{b}$ | $0.14^{c}$ | |
| | Thigh | $0.26^{a}$ | $0.20^{b}$ | $0.21^{b}$ | |
| MUFA | Breast | $32.50^{a}$ | $31.03^{ab}$ | $30.59^{b}$ | 1.83 |
| | Drumstick | $27.62^{de}$ | $29.28^{bcd}$ | $28.01^{cde}$ | |
| | Thigh | $25.62^{f}$ | $29.65^{bc}$ | $26.90^{ef}$ | |
| TUFA | Breast | $71.83^{a}$ | $70.84^{a}$ | $69.18^{a}$ | 2.81 |
| | Drumstick | $63.29^{bc}$ | $65.99^{b}$ | $64.44^{b}$ | |
| | Thigh | $63.84^{bc}$ | $65.91^{b}$ | $61.56^{c}$ | |

LSD, Least significant difference, P=0.05. Means in rows within groups with different superscript letter are significantly different P=0.05.

The breast cooked by the baking-bag and foil-wrap methods had the (P>0.05) high values of MUFAs and the thigh cooked in baking-bag and open-roasting methods had the lowest ($P\leq0.05$) MUFAs content. The most abundant MUFA is oleic acid. The breast cooked in a baking-bag and in foil-wrap had higher ($P\leq0.05$) values of oleic acid (C18:1n-9c), though the breast cooked in foil-wrap was not signicantly different (P>0.05) from the thigh cooked in foil-wrap and the open-roasted breast. The baking-bag and open-roasting in the lowest oleic values ($P\leq0.05$) for the thigh. These relationships showed that oleic acid is most abundant in the breast regardless of the cooking method.

Table 4.7 shows the effect of relationship between cooking methods and cuts on the saturated fatty acids.

**TABLE 4.7: The effect of cooking methods on the fatty acid composition (%) of guinea fowl (*Numeda meleagris)* meat**

| | CUT | Treatment | | | LSD |
|---|---|---|---|---|---|
| | | Baking bag | Foil wrap | Open roast | |
| C6:0 Caproic | Breast | 0.04$^{bc}$ | 0.09$^{ab}$ | 0.10$^{a}$ | 0.04 |
| | Drumstick | 0.05$^{bc}$ | 0.03$^{bc}$ | 0.04$^{bc}$ | |
| | Thigh | 0.03$^{c}$ | 0.03$^{bc}$ | 0.03$^{c}$ | |
| C8:0 Caprylic | Breast | 0.07$^{ab}$ | 0.09$^{ab}$ | 0.09$^{a}$ | 0.05 |
| | Drumstick | 0.04$^{b}$ | 0.06$^{ab}$ | 0.06$^{ab}$ | |
| | Thigh | 0.05$^{ab}$ | 0.05$^{ab}$ | 0.05$^{ab}$ | |
| C10:0 Capric | Breast | 0.02$^{ab}$ | 0.02$^{ab}$ | 0.04$^{a}$ | 0.02 |
| | Drumstick | 0.02$^{ab}$ | 0.03$^{ab}$ | 0.02$^{ab}$ | |
| | Thigh | 0.03$^{ab}$ | 0.03$^{ab}$ | 0.01$^{b}$ | |
| C11:0 Hendecanoic | Breast | 0.41$^{ab}$ | 0.39$^{abc}$ | 0.45$^{a}$ | 0.11 |
| | Drumstick | 0.32$^{bcd}$ | 0.29$^{cd}$ | 0.34$^{abcd}$ | |
| | Thigh | 0.31$^{cde}$ | 0.30$^{cd}$ | 0.26$^{d}$ | |
| C12:0 Lauric | Breast | 0.10$^{a}$ | 0.08$^{abc}$ | 0.09$^{ab}$ | 0.03 |
| | Drumstick | 0.06$^{bc}$ | 0.06$^{bc}$ | 0.06$^{abc}$ | |
| | Thigh | 0.07$^{abc}$ | 0.06$^{bc}$ | 0.05$^{c}$ | |
| C13:0 Tridecanoic | Breast | 0.49$^{a}$ | 0.48$^{a}$ | 0.47$^{ab}$ | 0.08 |
| | Drumstick | 0.35$^{c}$ | 0.33$^{c}$ | 0.35$^{c}$ | |
| | Thigh | 0.39$^{bc}$ | 0.54$^{a}$ | 0.37$^{c}$ | |
| C14:0 Myristic | Breast | 0.24$^{ef}$ | 0.22$^{f}$ | 0.29$^{def}$ | 0.15 |
| | Drumstick | 0.37$^{cd}$ | 0.40$^{cd}$ | 0.39$^{cd}$ | |
| | Thigh | 0.74$^{a}$ | 0.56$^{b}$ | 0.44$^{bc}$ | |
| C15:0 Pentadecanoic | Breast | 0.13$^{cd}$ | 0.11$^{d}$ | 0.16$^{bc}$ | 0.04 |
| | Drumstick | 0.16$^{bc}$ | 0.18$^{b}$ | 0.15$^{bcd}$ | |
| | Thigh | 0.18$^{b}$ | 0.23$^{a}$ | 0.16$^{bc}$ | |
| C16:0 Palmitic | Breast | 13.52$^{c}$ | 14.06$^{c}$ | 16.35$^{b}$ | 2.07 |
| | Drumstick | 17.52$^{ab}$ | 15.46$^{bc}$ | 16.71$^{b}$ | |
| | Thigh | 16.56$^{b}$ | 15.57$^{bc}$ | 18.82$^{a}$ | |
| C18:0 Stearic | Breast | 12.39$^{b}$ | 12.75$^{b}$ | 11.90$^{b}$ | 1.83 |
| | Drumstick | 16.71$^{a}$ | 16.35$^{a}$ | 16.28$^{a}$ | |
| | Thigh | 16.60$^{a}$ | 16.02$^{a}$ | 17.03$^{a}$ | |
| C20:0 Arachidic | Breast | 0.35$^{ef}$ | 0.33$^{f}$ | 0.38$^{ef}$ | 0.07 |
| | Drumstick | 0.45$^{cd}$ | 0.41$^{de}$ | 0.50$^{bc}$ | |
| | Thigh | 0.58$^{a}$ | 0.55$^{ab}$ | 0.56$^{ab}$ | |
| C21:0 Lignoceric | Breast | 0.04$^{b}$ | 0.19$^{a}$ | 0.05$^{b}$ | 0.09 |
| | Drumstick | 0.03$^{b}$ | 0.05$^{b}$ | 0.05$^{b}$ | |
| | Thigh | 0.03$^{b}$ | 0.03$^{b}$ | 0.03$^{b}$ | |
| C22:0 Behemic | Breast | 0.26$^{e}$ | 0.27$^{de}$ | 0.27$^{de}$ | 0.04 |
| | Drumstick | 0.37$^{a}$ | 0.30$^{cde}$ | 0.35$^{ab}$ | |
| | Thigh | 0.31$^{bcd}$ | 0.31$^{bcd}$ | 0.33$^{abc}$ | |
| C24:0 Tetracasanoic | Breast | 0.13$^{c}$ | 0.10$^{cd}$ | 0.21$^{b}$ | 0.05 |
| | Drumstick | 0.26$^{a}$ | 0.08$^{d}$ | 0.28$^{a}$ | |
| | Thigh | 0.30$^{a}$ | 0.08$^{d}$ | 0.31$^{a}$ | |
| SFA | Breast | 28.17$^{c}$ | 29.16$^{c}$ | 30.82$^{c}$ | 2.81 |
| | Drumstick | 36.71$^{ab}$ | 34.01$^{b}$ | 35.56$^{b}$ | |
| | Thigh | 36.16$^{ab}$ | 34.09$^{b}$ | 38.44$^{a}$ | |

LSD, Least significant difference, P=0.05. Means in rows within groups with different superscript letter are significantly different P=0.05

For the totale saturated fatty acids, the breast had the lowest ($P \leq 0.05$) content in all the cooking methods, the thigh cooked in baking bag and open-roasted as well as the drumstick cooked in a baking-bag, had the highest SFA values, though not significant ($P>0.05$). Thus the breast had the lowest SFAs ($P \leq 0.05$) regardless of the cooking method used (see Table

4.4). The most abundant SFAs were palmitic acid and stearic acid. Lower, though insignificant (P>0.05) values of palmitic acid were found in the breast cooked in a baking-bag than in foil-wrapped breast, thigh and drumstick, and insignificant (P>0.05) higher values were found in open-roasted thigh, as well as in the drumstick cooked in a baking-bag, hereby implying that foil-wrap method results in lower palmitic acid values.

The breast had the lowest (P≤0.05) stearic acid content throughout all the cooking methods, and the drumstick and thigh had signicantly the highest stearic content (P≤0.05) in all the cooking methods.

According to Conchillo, Ansorena and Astiasarán (2004:303) change in fatty acids during cooking can be attributed to oxidation and loss of fatty acids by diffusion as in the case of roasting. They also state that sometimes unsaturated fatty acids are less affected by cooking because they to a larger extent, belong to membrane structure than saturated fatty acids causing a low decrease of PUFAs by diffusion during cooking. These findings are as observed on PUFAS in this study. In their study on the effect of cooking and storage on the fatty acid profile of chicken breast, the roasted samples did not show the decrease in either the MUFAs or the PUFAs. Baggio and Bragagnolo (2006:611) explain that lipids are generally vulnerable to attack by molecular oxygen, which results in lipid oxidation that alters fatty acids and aids the generation of cholesterol oxides. As explained by Charley and Weaver (1998:391), heat brings about changes in fat, and this could explain the altered fatty acids after cooking. Stadelman, Olson, Shemwell & Pasch (1988:109) also report that when poultry is cooked with skin there could be transfer of fat from skin to muscle.

### 4.5.3 Cholesterol content

**TABLE 4.8: The effect of cooking methods on the cholesterol content (mg/100 g) of guinea fowl (*Numeda meleagris)* meat**

| | | TREATMENT | | | |
|---|---|---|---|---|---|
| | CUT | Baking Bag | Foil Wrap | Open roast | LSD |
| Cholesterol | Breast | $127.51^{d}$ | $124.07^{d}$ | $125.96^{d}$ | 21.47 |
| | Drumstick | $245.92^{ab}$ | $227.27^{bc}$ | $261.95^{a}$ | |
| | Thigh | $230.51^{c}$ | $217.45^{c}$ | $256.42^{a}$ | |

LSD, Least significant difference, P=0.05. Means in rows within groups with different superscript letter are significantly different P=0.05

According to Table 4.8, cholesterol content was lowest (P≤0.05) in the breast for all the cooking methods, and the highest values (P≤0.05) found in the open-roasted drumstick (261.95 mg/100g) and thigh (256.42 mg/100g). Cholesterol values were higher after cooking in comparison to the results of Sales, Marais and Kruger (1996:86) ostrich meat. This could be attributed to the loss of moisture and hence a concentration of nonvolatile compounds in the meat. Kasava-Rao, Kowale, Babu & Bisht (1996:181) in their study on water buffalo meat, remarked that oxidative rancidity is a problem in storage of meat and meat products, and reported an increase on oxidative rancidity values due to the high content of total lipids in the presence of non-heame iron that acts as a catalyst in lipid oxidation. In Chapter 3 high values for total lipids and iron were observed. Lower values of the total lipids in raw guinea fowl in comparison with the cooked samples were found in this study.

### 4.6 Conclusion

The aim of this study was to investigate the effect of three different methods on the proximate composition, fatty acid composition and cholesterol content of different cuts of guinea fowl (*Numeda meleagris*) meat. The open-roasting method resulted in a higher protein content in the breast than the other cooking methods and cuts. The thigh had a higher fat content which was lower in the breast, with no effect from the cooking methods. Open-roasted drumstick had a higher ash content. As in the drumstick, the moisture content of the thigh did not differ between the three cooking methods and the open-roasted breast retained moisture the most.

Cooking decreased the PUFAs of all the cuts. Linoleic acid was consistent in the breast and decreased in the thigh that had high values in raw meat. Alpha-linoleic acid was also consistent in the breast and became more concentrated in the drumstick after cooking. Oleic acid was found to be more abundant in the breast, regardless of the cooking method. High linoleic acid in the breast was not affected by any of the cooking methods. Foil-wrapped and open-roasted red cuts were found to be better sources of alpha-linolenic acid. The breast cooked in all the methods, as well as the thigh cooked in a baking-bag had the highest content of PUFAs, thus the baking-bag method retains the PUFAs better.

All the cuts cooked in all the methods had the favourably above 0.4 P:S ratio, with the breast having the highest values across all treatments.

The omega-6:omega-3 (*n*-6:*n*-3) ratio was found to be within the acceptable limits of the recommended below 4:1 in all the cuts and across all treatments. The breast cooked according to baking-bag and in foil-wrap methods had the highest content of MUFAs.

In comparison with raw meat, cooking was found to generally increase the SFA content, though it reduced palmitic acid. Lauric acid was decreased in the dark cuts but slightly increased in the breast, an effect that all cooking methods had on lauric acid, whereas the thigh and drumstick had lower values especially when open-roasted. Cooking the breast in foil-wrap attained lower myristic acid values, and the highest values were found in the thigh when cooked in a baking-bag. Cooking increased the MUFAs, especially the breast which ended up with the highest values as opposed to the raw meat. Oleic acid was increased in the breast but reduced in the dark cuts.

Cooking the breast in foil-wrap is better for the attainment of low cholesterol.

More research is recommended to investigate the cooking methods, fibers and muscle differences of free-range guinea fowl. Studying the same effects taking into cognisense the internal temperatures, to see the effect on the fat and the fatty acids is also recommended for future studies. The effect of cold storage on the unsaturated fatty acid could be studied further in comparison with raw meat. Using the same batch of birds to compare the raw and cooked meat could be beneficial for future work.

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# CHAPTER 5

## EFFECT OF THE THREE COOKING METHODS ON THE SENSORY ATTRIBUTES AND PROXIMATE COMPOSITION OF GUINEA FOWL *(NUMEDA MELEAGRIS)* BREAST MEAT

**Abstract**

This study investigated the effect of the three cooking methods on the sensory attributes and proximate composition of guinea fowl breast meat. Twenty-seven, 15-weeks-old guinea fowl weighing 800 ─1100 g were sourced and used to evaluate the cooking methods and sensory attributes as well as the proximate composition. The sensory attributes of the breast meat revealed that cooking methods had no impact on guinea fowl aroma intensity ($P \geq 0.05$). Foil-wrap produced a more tender and juicier product ($P \leq 0.05$), while, when using the baking-bag method, flavour decreased significantly ($P \leq 0.05$). It is proposed that a higher internal temperature was attained when using the baking-bag method (temperature and time controlled) resulting in loss of volatile flavour components. The effect of the three cooking methods on the proximate composition of raw and cooked breast meat was also investigated. As anticipated raw breast meat had a higher moisture content (74.55%, $P \leq 0.05$) than the cooked cuts, with open-roasting showing the highest (68.55%) value compared to other cooking methods. These values differed significantly from the baking-bag method (66.06%, $P \leq 0.05$) which was lowest. Low moisture resulted in the concentration of protein, fat and ash, thus the higher the moisture content the lower the protein, fat and ash.

***Keywords:*** guinea fowl meat, proximate composition, sensory attributes, cooking methods

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### 5.1 Introduction

The nutritional composition of poultry is not different from those of other meats, but the breast is lower in fat and cholesterol compared to other lean meats (Bennion and Scheule, 2004:736). Nutritionally guinea fowl meat is said to be rich in essential fatty acids and is leaner than chicken (Serre, 2002:1). Biesalski (2005:510) reports that consumers usually have negative health associations with meat for various reasons. These include its fat content, which is seen as high, and red meat especially, is seen as a cancer-promoting food. He further explains that, to avoid the risks of cancer, obesity and metabolic syndrome, a low red meat intake is recommended. In agreement, Hudson (1999) recounts that consumers demand lean muscle meat with less fat, therefore creating a niche for game meat as these are promoted on the basis of their low fat composition, sensory attributes and their organic nature. Due to all these reasons there has been a generally observed reduction in the consumption of red meat, which could be a reflection of a trend towards industrialised farming, and new perspectives on nutrition. These trends have made cheaper and more efficient production of other animal proteins, such as poultry, available on a much larger scale (Kennedy, Steward-Knox, Mitchell & Thurnham, 2004:123). Quality of meat and meat products can be considered as an important phenomenon that can influence consumption, animal welfare, sensory attributes, safety aspects, nutritional value and convenience (Issanchou, 1996:S7,S10). Joseph, Awosanya, Adeniran and Otagba (1996:57) explain that raw meat is cooked so that it can be acceptable for consumption, since it has an unacceptable odour, with a weak flavour and is often has a lot of blood. They further quote different authors who attest that cooking determines meat quality and attributes such as flavour, juiciness, tenderness, colour and overall acceptability.

Clearly after purchase, the experienced quality of the product is influenced by many factors among which are its sensory and physical attributes, possible cooking methods, situational factors as the time of day and type of meal, presentation and even the previous experience (Grunert, Larsen, Madsen & Baardsgaard cited in Grunert, Bredahl & Brunso 2004:260). Open roast and use of a baking bag and foil wrap have been used in cooking young and tender poultry meat (Charley & Weaver 1998:419). In this study, three adapted cooking methods, namely baking-bag, aluminium foil-wrap and open-roasting were applied, and were evaluated for their effect on sensory and chemical properties of guinea fowl breast meat.

## 5.2 Materials and methods

Prior to the main study, a pilot study was conducted with the objective of establishing the best cooking time and temperature combination for oven roasting guinea fowl meat. The outcome of the pilot study was then used in conducting the main study.

### 5.2.1 Pilot study

Two guinea fowl carcasses from Philadelphia farm, each weighing ±900 g and 15 weeks old, were sourced. The carcasses were defrosted at a temperature of 4–6°C for 26 h before being split into halves. Two different temperatures (140ºC, 160ºC) and time (40 min, 65 min) combinations were used, the left sides (L) were wrapped in aluminum foil then cooked, whilst the right sides (R) were open roasted (see Table 5.1).

**TABLE 5.1: Cooking times (min) and temperature (ºC) used for guinea fowl (*Numeda meleagris)* meat cooked by means of the foil-wrap and open-roasting methods**

| Guinea fowl halves | 1 left | 1 right | 2 left | 2 right |
|---|---|---|---|---|
| Oven (ºC) | 160 | 140 | 140 | 160 |
| Time (min) | 40 | 65 | 65 | 40 |
| Treatment | Foil | Open | Foil | Open |

The pilot study was conducted to develop a procedure for the foil-wrap and open-roasting methods. Samples were cooked in two *Defy* 835 electric ovens connected to a computerised temperature control system (Viljoen, Muller, De Swart, Sadie & Vosloo, 2001:30). The *pectoralis* (breast), without the skin, was used for the sensory tests by a five-member focus group. The focus group collectively preferred the product cooked at 140°C for 65 minutes, which was wrapped in foil-wrap. The focus group also suggested the use of a baking-bag as a third cooking method. The three cooking methods (baking-bag, foil-wrap and open-roasting) were then used in the main study.

### 5.2.2 Main study method

Sixty-three, 15 weeks-old commercially reared guinea fowl from a farm in Philadelphia (Western Cape Province, South Africa) were sourced. The birds were reared according to the standard commercial practices described by Silverside and Jones (1998). The weights of the carcasses ranged from 800–1100g. Nine carcasses were randomly selected to be used to train the sensory panel, whilst 18 carcasses were frozen at –15°C for later treatment with salts and phosphates using injection method (see Chapter 6). The 36 remaining guinea fowl carcasses were ranked by weight and every fourth carcass selected (n=9) for chemical analysis of the raw meat, whilst the remaining 27 were frozen at –15°C to be used for evaluation of the cooking methods.

#### *5.2.2.1 Defrosting and cooking*

The 27 frozen carcasses were defrosted for eight hours at 4–6°C, cut into halves, assigned random numbers to identify the carcasses, and re-frozen at –15°C. On their assigned sensory analysis dates the samples were defrosted at a temperature of 4–6°C for 24 h before cooking. The cooking methods selected were the baking-bag method, where a heat-resistant, clear and light polythene bag – specifically designed for oven roasting (*Glad*) – was used; for the foil-wrap method, 0.01–0.018 mm thick silver-coloured domestic aluminium foil was used to wrap and roast in the oven; the open-roasting method, the samples were baked in the oven uncovered.

The carcasses were cooked according to the selected methods for 65 minutes at 140°C in two *Defy* 835 electric ovens connected to a computerised temperature control system (Viljoen, Muller, De Swart, Sadie & Vosloo, 2001:30). Samples were cooked with skin, and skinned before sensory evaluation.  Nine replications were used to cook halves of 27 carcasses. Three carcases were cooked per replication (six halves) and the two halves of the same carcass used per cooking method. A 3 x 3 Latin square plot was used to control the position of the sample in the oven. Columns indicating position of sample in the oven with 1=left, 2=middle and 3=right. Each row represents a tray and two trays could be used in each of the two ovens at a time (See Chapter 4, Table 4.1). This 3 x 3 Latin square design was meant to give each sample an equal chance of being anywhere in the oven (Ott, 1998).

## 5.3 Raw meat

### 5.3.1 Meat preparation

Samples of the *Pectoralis* (breast) muscle from seven carcasses were stored at –15°C before being analysed for proximate composition, the other two carcasses were used for further training of the panel for a parallel study in Chapter 6.

## 5.4 Sensory evaluation

Eight experienced panel members were used to evaluate the samples. Panelists were trained according to the guidelines for sensory evaluation of meat of the American Meat Science Association (1995:16–28) using the descriptive analysis technique (Lawless & Heymann, 1998:566). To further affirm some common ground, a consensus method was used to train the panel, as described by Lawless and Heymann (1998:566), and attributes decided on were aroma, juiciness (initial and sustained), tenderness and flavour. Two replications were used during training, after which the panelists felt they needed to ascertain the aroma and flavour differences between the reared guinea fowl and wild guinea fowl in comparison to poultry meat, which has familiar attributes in terms of taste and aroma, and the intensity of these attributes. Chicken was therefore used as a reference standard.

A guinea fowl reared on the Philadelphia farm, a chicken from the local supermarket and a wild guinea fowl were sourced, prepared and cooked, each in an individual baking-bag at 140ºC for 65 minutes in a *Defy* 835 electric oven connected to a computerised temperature control system (Viljoen, Muller, De Swart, Sadie & Vosloo, 2001:30). The panel, in a focus group discussion, that the aroma and flavour of the wild guinea fowl was more intense than that of the reared guinea fowl. Though the reared guinea fowl had a typical guinea fowl aroma and flavour, the intensity of its attributes were judged to be much closer to that of chicken meat. This was expected as the birds were reared on the same commercial diet. The panelists collectively agreed that the most appropriate attributes to use would be "intense guinea fowl aroma" for aroma and "flavour" remained flavour. A third training session was then conducted before running a re-test. The final definitions and attributes arrived at by the panellists and in the study used are indicated in Table 5.2.

**TABLE 5.2: Definition of attributes used in the sensory analysis of guinea fowl meat**

| Attributes | Methodology and verbal definition | Score |
|---|---|---|
| Aroma (intense guinea fowl) | The intensity of guinea fowl aroma after taking a few short sniffs as soon as the foil has been removed | 100 High<br><br>0 Low |
| Flavour | The intensity of the guinea fowl flavour (combination of taste and swallowing) | 100 High<br><br>0 Low |
| Initial juiciness | The amount of fluid exuded in the cut surface when pressed between forefinger and thumb | 100 Juicy<br><br>0 Dry |
| Sustained juiciness | The impression formed after the first two to three chews between the molar teeth. | 100 High<br><br>0 Low |
| Tenderness | The impression of tenderness after two to three chews between the molar teeth | 100 Tender<br><br>0 Tough |

## 5.5 Product evaluation

The breasts from the halves of 27 carcasses, prepared and cooked, were evaluated using the attributes decided on by the panel during training. Nine replications were used to evaluate the samples. Samples were coded with three-digit random codes. A questionnaire was used and an unstructured line scale of 100 mm was used to indicate the intensity of each attribute. Immediately after cooking and cooling at room temperature for 10 minutes, the skin was removed and excess fat trimmed off the breast, which was then cut into

1-cm-square cubes from the outer meat of the *pectoralis* muscle. Three sample cubes of each bird from each cooking method were wrapped in a square aluminium foil, placed in pre-heated glass ramekins marked with the three-digit codes and warmed in an oven (100°C) five minutes before being served for evaluation by the panel. Panelists cleansed their palates in between each sample with distilled water, *Carr's* Table Water Biscuits and with slices of apples.

### 5.6 Proximate analysis

Proximate analysis of the guinea fowl breasts prepared by the different cooking methods and the raw meat was determined according to AOAC standard techniques (AOAC, 1997). Moisture was determined by drying a 2.5 g sample at 100°C for 24 h, ashing was done at 500°C for 6 h. To determine protein content, dried defatted meat samples were ground with a pestle in a mortar to a fine powder. Samples of 100 mg were inserted into a foil-wrap designed for the Leco protein analyser (Leco FP-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 Lake View Avenue, St. Joseph, HI 49085-2396, USA, part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. Total lipid content was determined by homogenising the samples in a blender followed by the chloroform:methanol (1:2) extraction technique of Lee, Trevino and Chaiyawat (1996).

### 5.7 Statistical analysis

The data was analysed using ANOVA to test for significant differences between the samples. Non-normality was tested by performing the Shapiro-Wilk test (Shapiro & Wilk, 1965). The Students' t-Least Significant Difference (LSD) was used to compare treatment means (Ott, 1998) and a probability smaller than 0.05 was considered significant.

For the chemical analysis, a one-factor factorial experiment was performed in a linear scale with two replications. A single carcass was considered as an experimental unit. The variables were recorded as interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Students' t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998).

## 5.8 Results and discussions

### 5.8.1 Sensory evaluation

Table 5.3 shows the results of the analysis of variance (ANOVA) for the sensory attributes analysed. The judge and treatment interactions did not show any significant differences ($P \geq 0.05$) in the samples for all the attributes except for aroma ($P \leq 0.05$). Though outliers were removed from the data to get a normal distribution in order to remove interactions between judges and the treatment, it was unsuccessful for aroma. This was encountered with the sessions (rows) effect, where aroma, initial juiciness and flavour differed significantly ($P \leq 0.05$), with the exception of sustained juiciness and tenderness ($P>0.05$). The judge effect was also different ($P \leq 0.05$) for all the sensory attributes, indicating that judges used different parts of the scale over the nine sessions. In the judge and session interactions all the sensory attributes evaluated differed ($P \leq 0.05$), indicating that the judges rated different cooking methods differently over the nine sessions for all the sensory attributes. These variations could have been due to the unfamiliarity of the guinea fowl meat to the panel, despite the training, as well as the short cooking time at low temperatures that could not make the sensory attributes more prominent.

Table 5.4 depicts the means of the sensory attributes of the baking-bag, foil-wrap and open roasting cooking methods. The panel did not find any significant differences ($P>0.05$) when comparing aroma with the three cooking methods. The birds studied were only 15-weeks-old, and this young age may have been responsible for the low aroma intensity.

**TABLE 5.3: Analysis of variance (ANOVA) for different attributes of the three cooking methods**

| ANOVA | Aroma | | | Initial juiciness | | Tenderness | | Sustained Juiciness | | Flavour | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Source | DF | MS | P | MS | P | MS | P | MS | P | MS | P |
| Judge | 7 | 1867.58 | <0.01 | 2055.81 | <0.01 | 691.50 | <0.01 | 1626.76 | <0.01 | 1692.43 | <0.01 |
| Session * Judge | 55 | 72.81 | <0.01 | 99.34 | <0.01 | 130.82 | <0.01 | 101.96 | 0.0233 | 67.08 | <0.01 |
| Judge ** Treatment | 14 | 86.96 | 0.0094 | 57.46 | 0.0610 | 35.52 | 0.8984 | 69.21 | 0.3961 | 8.28 | 0.9105 |
| Sampling Error | 109 | 38.35 | - | 33.37 | - | 64.75 | - | 64.92 | - | 15.62 | - |
| Corrected Total | | 211 | | 212 | | 212 | | 211 | | 207 | |
| Shapiro-Wilk's test | | Pr < W | 0.1228 | Pr < W | 0.6697 | Pr < W | 0.2223 | Pr < W | 0.1762 | Pr < W | 0.5736 |

DF= degree of freedom

MS= mean square

P= Probability value of F-ratio test

<u>Interaction between main effects</u>

* Interaction between judge number and the session

**Interaction between judge number and the treatment

**TABLE 5.4: Sensory attributes means of guinea fowl (*Numeda meleagris*) meat cooked according to the baking-bag, foil-wrap and open-roasted cooking methods**

| | Bag | Foil | Open | LSD |
|---|---|---|---|---|
| Aroma | 75.5 | 74.3 | 74.1 | 2.01 |
| Initial juiciness | $71.8^{b}$ | $75.7^{a}$ | $74.5^{a}$ | 2.14 |
| Sustained Juiciness | $66.9^{b}$ | $72.6^{a}$ | $69.4^{b}$ | 3.07 |
| Tenderness | $76.8^{ab}$ | $80.2^{a}$ | $75.3^{b}$ | 3.41 |
| Flavour | $73.0^{b}$ | $75.1^{a}$ | $75.0^{a}$ | 1.42 |

LSD, Least significant difference, P=0.05

$^{a,b}$ Means, in rows, within treatments, with different superscript letters differ (P≤0.05).

When comparing initial juiciness, the foil-wrap method was significantly higher (P≤0.05) than the baking-bag method (75.7 vs. 71.8) but not significantly different from the open-roasting method (74.5). The foil-wrap method showed slightly higher values in initial juiciness, thus indicating that there was more fluid exuded on the meat surface when pressed between the forefingers. The foil-wrap method sustained juiciness better (72.6; P≤0.05) than meat cooked in a baking bag or roasted open. The baking-bag method retained (P≤0.05) the least flavour (73.0) in guinea fowl meat when comparing three cooking methods. It is suggested that a higher internal temperature obtained with the baking-bag method could have resulted in the loss the volatile carboryl components in the meat (Charley & Weaver, 1998:422). The panel found meat cooked in foil-wrap to be significantly more tender than open-roasted meat (80.2 vs.75.3; P≤0.05), with meat cooked in a baking-bag not significantly different in tenderness from the other two cooking methods used (P>0.05). Similarities can be drawn from these and the results reported by Heine, Bowers and Johnson (1973) as quoted by Charley and Weaver (1998:421) that cooking dark poultry muscles in foil, a juicies end product results in comparison to cooking in an open pan and film an ovenproof-film. The cooking period of their turkey samples was internal temperature dependent. Though their study was with dark meat, this study showed the same trend with white meat where the sustained juiciness in the guinea fowl breast was significantly higher in the foil. Contrary to our results, these authors also noted that none of the treatments they used (i.e. foil, open, ovenproof film, paper bag) showed any differences in tenderness. Apart from cooking methods, lipids among other things also contribute largely to the flavour of meat (Wood *et al.*, 1999:364). Guinea fowl, and particularly the breast meat is lean, thus explaining the marginal differences in flavour (Table 5.4).

5.8.2 Proximate analysis

The proximate chemical composition of cooked and raw guinea fowl breast meat are presented in Table 5.5.

**TABLE 5.5: Proximate composition raw guinea fowl (*numeda meleagris)* breast meat and guinea fowl breast meat cooked by baking-bag, foil-wrap and open-roasted**

| | Baking Bag | Foil Wrap | Open Roast | Raw | LSD |
|---|---|---|---|---|---|
| Moisture (%) | $66.06^{c}$±1.33 | $68.12^{b}$ ± 2.68 | $68.55^{b}$ ± 1.31 | $74.55^{a}$ ± 1.66 | 1.51 |
| Protein (%) | $29.6^{a}$ ±1.27 | $28.21^{b}$ ± 2.58 | $28.18^{b}$ ± 1.21 | $22.70^{c}$ ± 1.78 | 1.46 |
| Fat (%) | $2.91^{a}$ ± 0.38 | $2.75^{ab}$ ± 0.52 | $2.84^{a}$ ± 0.62 | $2.26^{b}$ ± 0.49 | 0.46 |
| Ash (%) | $1.44^{a}$ ± 0.51 | $1.47^{a}$ ± 0.23 | $1.12^{ab}$ ± 0.44 | $1.01^{b}$ ± 0.09 | 0.36 |

LSD, Least significant difference, P=0.05

$^{a,b}$ Means, in rows within groups with different superscript letter are significantly different P=0.05

As expected, the raw meat had a higher (P≤0.05) moisture content (74.55 %) than the cooked meat. Moisture content of the open-roasted breast followed that of raw meat, with the baking-bag having the lowest values (66.06%, P≤0.05). For the baking-bag and the foil-wrap methods, the food was also cooked by water and thus steam, which collected in the bag and the foil (personal observation), resulting in greater moisture loss due to lower water-holding capacity resulting from a higher internal temperature. This could possibly be due to the collected steam in the bag which may have led to an increase in cooling temperature, and a decrease in water-holding capacity. The effect of conduction in the open-roasting method vs convection currents in the other two treatments is borne in mind (Charley & Weaver, 1998:54) (see Chapter 2, section 2.3). This higher moisture loss of the cooked breast resulted in all the other chemical compounds becoming more concentrated. Hence the lower protein content of the raw meat (22.70 %, P≤0.05) than that of the different cooking methods, with the baking-bag method showing the highest values (P≤0.05, 29.61%). Similarly, the raw meat had a lower (P≤0.05) fat content (2.26 %) than the cooked meat, an effect of the concentration of compounds due to loss of moisture. Stadelman, Olson, Shemwell and Pasch (1998:109) report that fats are increased during cooking due to moisture loss and due to the transfer of fat from skin to muscle when samples are cooked in skin as was the case in this study. Freeland-Graves and Peckham (1996:515) further explain that high temperature melt fat, which may end up in the drippings, and when cooked with skin there could be transfer of fats from skin to muscle. The raw meat also had a lower ash content (P≤0.05, 1.01 %) though it did not differ significantly from that derived from the open-roasting cooking method.

Ayorinde (1991:23) acknowledges that guinea fowl meat has a higher protein and lower fat content than chicken meat, though 32.2% to 35.8% protein was recorded in his study as opposed to the 22.70–29.61% in Table 5.5. These moisture and protein results classify guinea fowl as a good protein source and lean meat since it contains less than 5% fat (Santos-Silva, Bessa & Santos-Silva, 2002:191).

## 5.9 Conclusions

The aim of this study was to assess the effect of heat treatment on the sensory and proximate composition of *Numeda meleagris pectoralis* muscle. With regard to sensory properties cooking method did not affect the intensity of the aroma, whereas the foil-wrap method appeared to be the best method for the retention of juiciness and tenderness. The baking-bag method caused a low flavour intensity in comparison to the other methods. It can also be noted that over the sessions, aroma was rated differently by the panel which could be an indication that aroma is a difficult phenomenon to study in sensory science especially where the samples were kept warm for sensory evaluation. Furthermore, aroma-intensity evaluation may also require more time for training than was allocated. The fact that the birds were 15 weeks old, and reared similar to chicken, could also have contributed to a low aroma and flavour. Aroma compounds are volatile, great care should therefore be taken when preparing samples for the sensory panel.

The raw meat samples had the highest moisture content with the lowest values for protein, fat and ash. The samples cooked by the open-roasting method had the higher moisture content and therefore the lowest protein, fat and ash.

Further study on the cooking methods on guinea fowl meat is advised adapting the existing methodology to address the issues. It would be interesting to repeat this study comparing wild guinea fowl (free range conditions) with domesticated birds receiving a commercial diet. Evaluating consumer acceptance towards this fowl may also be of value.

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## CHAPTER 6

## INFLUENCE OF BRINE INFUSION ON THE SENSORY ATTRIBUTES AND PROXIMATE COMPOSITION OF GUINEA FOWL (*NUMEDA MELEAGRIS*) BREAST MEAT


### Abstract

The study investigated the influence of brine infusion on the sensory attributes and proximate composition of guinea fowl breast muscle, baked in aluminium foil. Eighteen 15 week old guinea fowl weighing 800–1100 g were used in the study. Descriptive sensory analysis was conducted with the injected breast and the control as the main effects. There were no differences (P>0.05) between the injected and the control samples for any of the sensory attributes of aroma, tenderness, initial juiciness, sustained juiciness and flavour. Moisture increased and protein of the injected guinea fowl meat decreased (P≤0.05) while the fat and ash content did not differ between non-injected and injected guinea fowl meat. No significant differences in the sensory qualities of injected versus non-injected meat were found. This could be due to the fact that application of brine solution during the main study was not effective (hand-pipe injection) and could have resulted in low binding of the solution to the meat protein. Thus the advantages of higher water holding capacity of injected meat was lost, therefore the injected meat was not found to be higher in juiciness, tenderness and flavour as would be expected.



***Keywords:*** guinea fowl meat, breast muscle, brine solution injection, proximate composition, sensory attributes


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### 6.1 Introduction

Alvarado and Sams (2004:1035) report that, the availability of processed poultry products have increased over the past 20 years due to consumer demands. Colour, texture, water-holding capacity and tenderness has been ssen by consumers as the most important attributes in the quality of meat and meat products. Sensory evaluation is thus regarded as a vital instrument in food product development (Varnam & Sutherland, 1995:97; Honikel, 1998:447). For the improvement of tenderness and juiciness, some strategies have been employed (Kolle, McKenna & Savell, 2004:145-146). Injecting meat with salts and phosphates has been widely used to increase the tenderness, juiciness and weight of the end product through the enhancement of the water-holding capacity of the meat (Sheard & Tali, 2004:305; Shahidi & Synowiecki, 1997:29). In agreement, Alvarado and Sams (2003:1332) report that, marination of broiler breasts with brine solution has been used to enhance taste and improve tenderness, water-holding capacity and yield. According to Ünal, Erdoğdu, Ibrahim and Özdemir (2004:264), phosphates increase the water-binding capacity of meats by controling the loss of natural muscle juices, thereby reducing vulnerability to freeze burn, reducing cook and thaw drip loss, in turn providing the meat with some resistance against oxidation. Lawrie (1998:246) also states that sodium chloride has a tenderising effect on meat and some of these effects are due to an enhanced water-holding capacity either directly or as in the case of phosphates, through the raising of the pH. The swelling and higher water-holding capacity of the myofibrils result in the increased tenderness and juiciness of the meat (Sheard & Tali, 2004:306). Varnam and Sutherland (1995: 173–175) report that concentration of marinade solutions is usually lower in the injection method as opposed to the immersion method. In the injection method, which was chose for this study, even distribution of the marinade is very important because incomplete dispersion of the ions through the meat can possibly affect the water-holding capacity and tenderisation potential of the marinades (Varnam & Sutherland, 1995:173). The effect of injected brine solution on guinea fowl breast muscle, baked in aluminum foil, compared to non-injected muscle, on the sensory attributes and proximate composition was investigated.

## 6.2 Materials and methods

Sixty-three 15-weeks-old commercially reared guinea fowl carcasses were sourced from a commercial farm (Philadelphia, Western Cape Province, South Africa). The birds were reared according to the standard commercial practices described by Silverside and Jones (1998). The weights of the carcasses ranged from 800 –1100 g. Nine carcasses were randomly selected to be used to train the sensory panel, whilst 18 carcasses were frozen at –15°C until infused, whilst the rest of the carcasses were used for parallel studies reported in Chapters 4 and 5.

### 6.2.1 Defrosting, infusion and cooking

For the pilot study samples were cooked for 2 h and 30 minutes at 120°C to determine the effect of the brine solution. Reduction of the cooking time was recommended by an informal focus group panel. In determining cooking time and temperature, 160ºC for 40 minutes and 140ºC for 65 minutes were tried and evaluated by an informal taste panel. All the samples in the main study were cooked for 65 minutes at 140ºC. A phosphate, sodium chloride and starch brine solution was injected into the breast cut prior to refrigeration and cooking. Two different injection procedures were carried out respectively for the pilot study and the main study.

**Pilot study** The left sides were injected, using an electronic multi-needle injector, with a commercially available brin preblend, consisting of a blend of salt (50%), pre-gelatinised starch (20%), phosphates (20%) and sugars (10%). This blend was dissolved in water at a ratio of 1 to 20. injected to gain 20% addition. One part solution and 20 parts water was injected by weight – 220 ppm, at 3 bars.

**Main study** The 18 carcasses, of which two were used for further training of the panel, were defrosted at 4°C for 24 h, halved, and weighed. The treatment combinations involved a 1 x 2 factorial array where one guinea fowl species was injected with salts on the left side, with the right side used as the control. Since the product was too salty, and to reduce the drip loss from the injected portions, the salt content was reduced and hydrocolloids were added. A brine solution consisting of 0.275 kg hydrocolloids, 0.375 kg pregelatinised starch, 0.5 kg salt (NaCl), 0.5 kg sugar, 0.25 kg phosphates and 50 litres of water, was injected into the guinea fowl with a hand-pipe injector. The weights of the injected sides were recorded before and after injection. The injected samples were then placed under atmospheric pressure in a net enclosed in an inflated plastic bag so that the exudates were collected in the bag without coming into contact with the sample. The samples were hung for 48 h in a 4°C walk-in refrigerator for equilibration. After 48 h the samples were weighed to determine drip loss. The samples were subsequently frozen at 20°C until required for the sensory analyses. Additional drip loss was recorded.

For sensory analyses the frozen samples were defrosted at 7°C for 12 h prior to cooking. Weights of the samples were recorded before and after cooking to determine cooking loss. During the cooking process, the carcass halves were wrapped in aluminium foil (0.01–0.018 mm thick domestic aluminium foil), labelled and randomly placed in baking trays and baked at 140°C for 65 minutes in two *Defy* 835 electric ovens connected to a computerised temperature control system (Viljoen, Muller, De Swart, Sadie & Vosloo, 2001:30). The non-injected sides were weighted before and after cooking to determine the cooking loss.

The following calculations were made:

| | |
|---|---|
| % Injection gain | $= [(m_2\ m_1) / m_1] \times 100$ |
| % Drip loss after equilibration | $= [(m_2 \_ m_3) / m_2] \times 100$ |
| % Cooking loss | $= [(m_3 \_ m_4) / m_3] \times 100$ |
| % Yield | $= (m_4 / m_1) \times 100$ |

Where Mass before injection was ($m_1$); mass after injection ($m_2$); mass before cooking ($m_3$) and mass after cooking ($m_4$).

### 6.3 Sensory evaluation

#### 6.3.1 Training of the panel

Eight experienced sensory panel members were used to evaluate the samples. Panelists were trained according to the guidelines for sensory evaluation of meat of the American Meat Science Association (1995:16–28), using the descriptive analysis technique (Lawless & Heymann, 1998:566). To further establish some common ground, a consensus method was used to train the panel as explained by Lawless and Heymann (1998:566). Attributes decided on were aroma, juiciness (i.e. initial and sustained), tenderness and flavour. Two replications were used during the training, mainly to train the panel on the attributes of the injected meat versus the control. The final definition and attributes used in this study are summarised in Table 6.1.

**TABLE 6.1: Attributes and definition of attributes used in the sensory analysis of guinea fowl meat**

| Attributes | Methodology and verbal definition | Score |
|---|---|---|
| Aroma (intense guinea fowl) | The intensity of guinea fowl aroma after taking a few short sniffs as soon as the foil had been removed. | 100 High<br>0 Low |
| Flavour | The intensity of the guinea fowl flavour (combination of taste and swallowing). | 100 High<br>0 Low |
| Initial juiciness | The amount of fluid exuded in the cut surface when pressed between forefinger and thumb. | 100 Juicy<br>0 Dry |
| Sustained juiciness | The impression formed after the first two to three chews between the molar teeth. | 100 High<br>0 Low |
| Tenderness | The impression of tenderness after two to three chews between the molar teeth. | 100 Tender<br>0 Tough |

#### 6.3.2 Product evaluation

Breast muscles were removed from the cooked birds and evaluated using an unstructured line scale of 100 mm to indicate the intensity of each attribute (Table 6.1). The samples were coded with three-digit random codes. Immediately after cooking and cooling at room temperature for 10 minutes, the skin was removed and excess fat trimmed off the breast, which was then cut into 1 cm x 1 cm square cubes from the outer meat of the breast muscle. Three sample cubes of each bird were wrapped in aluminium foil, placed in pre-heated glass ramekins marked with the respectve three-digit codes and warmed in an oven (100°C) for 5 minutes before being served to the panel for evaluation. Panelists cleansed their palates in between each sample with distilled water, *Carr's* Table Wafer Biscuits and with slices of apple. Sixteen replications (carcasses) were used to evaluate the meat samples.

## 6.4 Proximate analysis

The chemical composition of cooked guinea fowl (*Numeda meleagris)* breast meat was determined for the injected and the non-injected samples. Proximate analysis was determined according to the AOAC standard techniques (AOAC, 1997). Moisture was determined by drying a 2.5 g sample at 100°C for 24 h, ashing was done at 500°C for 6 h. To determine protein content, dried defatted meat samples were ground with a pestle and mortar to a fine powder. Samples of 100 mg were inserted into a foil wrap designed for the Leco protein analyser (Leco FP-528). The nitrogen content was multiplied by 6.25 to calculate the protein concentration in the sample. An EDTA calibration sample (LECO Corporation, 3000 Lake View Avenue, St. Joseph, HI 49085-2396, USA, part number 502-092, lot number 1038) was analysed with each batch of samples to ensure accuracy and recovery rate. Total lipid content was determined by homogenising the samples in a blender followed by the chloroform:methanol (1:2) extraction technique of Lee, Trevino and Chaiyawat (1996).

## 6.5 Statistical analysis

The data was analysed using ANOVA to test for significant differences between the samples. Sensory analyses on aroma, flavour, initial juiciness, sustained juiciness and tenderness of the cooked guinea fowl meat were done by placing the meat randomly in the oven, 16 replications (times by eight panel members) using a completely randomised block design. An experimental unit was a single carcass. Non-normality was tested by performing the Shapiro-Wilk test (Shapiro & Wilk, 1965). The Students' t-Least Significant Difference (LSD) was calculated to compare treatment means (Ott, 1998), where a probability smaller than 0.05 was considered significant. For the chemical analysis, a one-factor factorial experiment was performed in a linear scale with two replications. An experimental unit was a single carcass. The variables were recorded as interval data and subjected to an analysis of variance using SAS version 8.2 (SAS, 2002) statistical software. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Students' t-Least Significant Difference (LSD) was calculated at the 95% confidence level to compare treatment means (Ott, 1998).

## 6.6 Results and discussions

### 6.6.1 Drip loss, cooking loss and yield

Wariss (2000:240) states that more drip is formed when there is poor waterholding capacity. However, drip loss of the control sample was unfortunately not measured, thereby making comparisons with those of the injected sample difficult. No significant difference in cooking loss (injected 36.94% and control 33.44%; P>0.05) were found when comparing injected versus non-injected guinea fowl meat. The absence of a difference in cooking losses could indicated a low water holding capacity, also of the injected sample, however a tendency towards significance could be seen in the injected sample that was expected to be more tender.

The use of a hand-pipe injector could have directly affected the waterholding capacity in that the brine solution could not be fully and efficiently distributed through the sample affecting the anticipated tenderisation process and anticipated low drip loss. Thus high water holding capacity results in less moisture being lost during cooking the meat, hence a good impression of juiciness when chewing. Cooking at varying temperatures denatures different meat proteins (Honikel, 1998:449). This denaturation causes structural changes, which results in cooking loss. The loss of water during cooking is usually due to the shrinking of myofibrils caused by expansion of the filament lattice.

Table 6.2 presents the injected gain, drip loss, cooking loss and the yield of the injected samples; as well as the cooking loss and the yield of the non-injected samples.

**TABLE 6.2: The effect of brine injection on gain, drip loss, cooking loss and final product yield of (*Numeda meleagris*) of breast meat**

| | Injected gain | Drip loss | Cooking loss | Yield |
|---|---|---|---|---|
| Control | - | - | $33.44^{a}$ | $63.49^{a}$ |
| Injected | 7.72 | 4.68 | $36.94^{a}$ | $64.75^{a}$ |

Although drip loss was not assessed for the control, the relatively high value (4.68%) for drip loss of the injected sample in this study suggested that the samples were not able to sufficiently retain the added water. The value for the cooking loss in the injected sample, though insignificant, was greater than the control, indicating that the added water was not bound strongly enough. Though the yield did not differ significantly, greater yield translates to higher moisture retention and possibly, higher juiciness.

According to Anderson, Oksbjerg, Young and Therkildsen (2005:544) meat quality, including sensory attributes of flavour, texture and water-holding capacity, depend on several factors and numerous interactions, including the conditions of production which include management systems, genotype, feeding, pre-slaughter handling and slaughter method, chilling and storage conditions. However, the guinea fowls used in this experiment had all received the same *ante* and *post mortem* treatments and any differences could therefore be attributed to bird variation and/or the main treatment (brine infusion).

6.6.2 Sensory analyses

Means of the effect of the treatment on the sensory attributes of the injected breast guinea fowl meat compared to the non-injected meat are presented in Tables 6.3 and 6.4.

**TABLE 6.3: The ffect of treatment on the sensory attributes of guinea fowl *(Numeda meleagris)* breast meat**

| | Aroma | Initial juiciness | Tenderness | Sustained juiciness | Flavour |
|---|---|---|---|---|---|
| Injected | 77.0 | 78.4 | 80.5 | 72.4 | 76.1 |
| Control | 78.7 | 79.1 | 80.3 | 74.1 | 77.1 |
| t-LSD (P=0.05) | Ns | ns | ns | Ns | ns |

Mean values for the different sensory attributes measured, are given in Table 6.3. These results indicated that there were no (P>0.05) differences in any of the attributes observed. The marinade solution and the injection procedure used in the pilot study differed from that used in the main study. In the former, an electronic multi-needle injector was used, that improved the probability of the solution been evenly distributed in the sample, unlike the hand pipe injector which was used in the main study. This could have caused variations in the samples and the quantity of the brine solution injected. The mean values for both injected and non-injected guinea fowl meat for all the attributes measured are above 70. This indicates that that the meat had a relavely high guinea fowl aroma and flavour. The meat was percieved as juicy as both initial juiciness and sustained juiciness had mean values of above 70 when evaluating these attributes on a 100 mm line scale. The meat was perceived as being tender, with a mean value for tenderness of 80 for both injected and non-injected meat.

According to the results of the analysis of variance (Table 6.4), the main treatment of injection had no significant (P>0.05) effect on the sensory attributes of guinea fowl breast muscle. The carcasses also differed in terms of most attributes, with aroma and sustained juiciness being the exceptions. This could have been due to the naturally occurring variations in the carcasses in the main study, as well as the variations caused by the poor distribution of the marinade due to the use of the hand pipe. The judge and carcass effects were also observed in all attributes except for in the aroma and in sustained juiciness.

**TABLE 6.4: ANOVA of sensory attributes of guinea fowl (*Numeda meleagris)* breast meat**

| Source | Aroma | | | Initial Juiciness | | | Tender | | | Sustained Juiciness | | | Flavour | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DF | MS | Pr>F | DF | MS | Pr>F | DF | MS | Pr>F | DF | MS | Pr>F | DF | MS | Pr>F |
| Experimental error | 14 | 65.21 | 0.0866 | 14 | 77.49 | 0.0256 | 14 | 66.48 | 0.4504 | 14 | 110.12 | 0.0935 | 14 | 25.40 | 0.3579 |
| Judge*carcass | 93 | 54.99 | 0.0650 | 93 | 78. 69 | 0.0004 | 93 | 100.02 | 0.0225 | 93 | 68.25 | 0.5156 | 93 | 66.77 | <.0001 |
| Judge*treatment | 7 | 10.97 | 0.9628 | 7 | 27.43 | 0.6642 | 7 | 56.42 | 0.5434 | 7 | 62.35 | 0.5053 | 7 | 9.45 | 0.8906 |
| **Sampling error** | 93 | 40.11 | | 93 | 38.67 | | 93 | 65.82 | | 93 | 68.81 | | 93 | 22.84 | |
| Corrected Total | 229 | | | 229 | | | 229 | | | 229 | | | 229 | | |
| Shapiro-Wilk's test | | Pr<W | 0.0221 | | Pr<W | 0.7509 | | Pr<W | 0.0601 | | Pr<W | 0.4116 | | Pr<W | 0.1408 |

A study on sensory attributes of broilers treated with tri-sodium phosphates (TSP) after chilling, revealed that the baked samples showed no significant differences between the treated and the control breast samples flavour (Hollender, Bender, Jenkins & Black, 1993:758). According to Charley and Weaver (1998:422) freshly cooked poultry has a more meaty taste with a more distinct aroma than when re-heated after storage. Therefore the methodology used in this study, that involved cooking the sample, cooling for 10 minutes and then wrapping in foil could have affected the aroma, preventing it from being pronounced for easy detection. Hathcox, Hwang, Resurreccion and Beuchat (1995: 605) also investigated the effect of TSP and lactic acid/sodium benzoate solution treatments on fried chicken breasts and thighs as pertaining to sensory quality and reported no significant differences for texture, flavour and moistness. Another study by Sheard and Tali (2004:308) investigating different types of marinade solutions showed that all marinating solutions using phosphate, bicarbonate, salt and phosphate, salt and bicarbonate, phosphate and bicarbonate, as well as salt, phosphate and bicarbonate had a significantly higher yield except when salt was used alone, in which case no differences were observed.

Baeza, Juin, Rebours, Constantin, Marche and Leterrier (2001:471) quote the findings by other authors who reported that rearing conditions have an influence on the quality of guinea fowl meat, and as the fat content in the carcasses of birds increases it results in more tender and more flavoursome meat, than with lean guinea fowl meat. Although the fat content of the guinea fowl meat investigated in this study was low (2.79% to 2.86%), the sensory panel scored the flavour of the meat relatively high with mean values of 76.1 for injected guinea fowl and 77.1 for non-injected guinea fowl. Capita, Alonso-Calleja, Sierra, Moreno and Garcia-Fernandez (2000:473) evaluated the influence of TSP solutions on the sensory quality of raw and cooked chicken thighs, and noted that, in the cooked samples, the differences detected in colour, smell, texture and flavour depended on the TSP percentage solution. They detected significant differences at a 12% TSP solution whereas none were detected at an 8% TSP solution. Lack of an effect of the TSP in the present study, could probably indicate a too low TSP percentage in the marinade solution.

### 6.6.3 Proximate composition

The proximate composition of the cooked injected and non-injected guinea fowl breast (control samples) is shown in Table 6.5.

**TABLE: 6.5 The effect of brine injection on the proximate composition of guinea fowl (*Numeda meleagris)* breast meat**

| | TREATMENT | | LSD |
|---|---|---|---|
| | Injected | Control | |
| Moisture | $68.62^{a}\pm 2.34$ | $68.57^{b}\pm 2.34$ | 0.02 |
| Protein | $27.66^{b}\pm 1.91$ | $28.82^{a}\pm 2.27$ | 0.70 |
| Fat | 2.79± 0.97 | 2.86± 0.57 | 0.58 |
| Ash | 1.20± 0.19 | 1.10± 0.05 | 0.11 |

LSD, Least significant difference, P=0.05

[a,b] Means, in rows, within treatments, with different superscript letters differ (P≤0.05).

**TABLE 6.6. ANOVA for proximate chemical analysis of guinea fowl (*Numeda meleagris)* breast meat**

| Source | | Moisture | | Protein | | Fat | | Ash | |
|---|---|---|---|---|---|---|---|---|---|
| | **DF** | **MS** | **Pr>F** | **MS** | **Pr>F** | **MS** | **Pr>F** | **MS** | **Pr>F** |
| Carcass | 14 | 5.58 | 0.19 | 10.54 | 0.22 | 0.74 | 0.28 | 0.06 | 0.17 |
| Treatment | 1 | 23.96 | 0.02 | 5.94 | 0.37 | 0.04 | 0.79 | 0.05 | 0.24 |
| Sampling error | **14** | **3.45** | | **6.96** | | **0.54** | | **0.03** | |
| Corrected Total | 29 | | | | | | | | |
| Shapiro-Wilk's test | | Pr<W | 0.38 | Pr<W | 0.99 | Pr<W | 1.00 | Pr<W | 0.42 |

The result indicate that the injection had a significant effect (P≤0.05) on the moisture content of guinea fowl meat, which support the findings of Demby and Cunningham (1980:48), who reported that marinades bind moisture, resulting in meat with a higher moisture content. A higher water-holding capacity of myofibrils result in increased tenderness and juiciness of meat (Sheard & Tali, 2004:306). However, differences in the tenderness and juiciness of guinea fowl meat could not be detected by the sensory panel, possibly due to this study could be due to low water-holding capacity. Protein content of the injected meat was significantly decreased ($P \leq 0.05$). There was no difference in fat content. The slightly higher ash content could be an indication that some of the salts were bound in ionic state (Gallagher, 2008:118) in the raw meat, reflected in higher, though insignificant ash values in the injected samples.

## 6.7 Conclusions

The aim of this study was to assess the influence of meat treatment, through the injection with salts and phosphates, on the sensory attributes and on the proximate composition of the breast muscle baked in aluminum foil. The injection had no effect on any of the sensory attributes of aroma, tenderness, initial juiciness, sustained juiciness, and flavour of the meat, suggesting that in terms of sensory properties, the injection marinade and/or technique used did not improve the sensory properties of guinea fowl meat. There was also no major effect on the proximate composition of guinea fowl meat when comparing injected with non-injected meat, although the moisture content of the injected meat was significantly higher ($P \leq 0.05$) than non-injected meat and the protein content significantly lower ($P \leq 0.05$) than the non-injected sample.

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# CHAPTER 7

## CONCLUSIONS AND RECOMMENDATIONS

### 7.1 Introduction

This study was undertaken because comprehensive data on the quality of raw and processed guinea fowl *(Numeda meleagris)* meat was found lacking, regardless of the consumer trends towards more leaner and healthier meat. The hypothesis that the different cuts of raw guinea fowl meat differ in chemical composition and processing by heat treatment and brine injection, have no effect on the chemical composition and sensory attributes of the different cuts of guinea fowl meat, could only be affirmed after a thorough investigation of the properties that have an influence on the chemical and sensory parameters associated with the meat qualities have been studied.

From the findings of the study the following conclusions can be drawn.

### 7.2 Conclusions

#### 7.2.1 Cuts of raw guinea fowl meat and chemical composition (Chapter 3)

From the findings of the proximate analysis (moisture, protein, fat and ash) of guinea fowl meat it is concluded that the breast, drumstick and thigh did not differ in moisture nor in fat content ($P>0.05$). The highest protein content was found in the breast and the lowest in the thigh ($P\leq0.05$). Regarding ash content the thigh had the highest and the drumstick the lowest ($P\leq0.05$).

The three cuts were found to be good sources of amino acids, with eight of the essential amino acids being present and with very slight differences observed within cuts. The essential amino acid not being present was tryptophane. The amino acids alanine, aspartic acid, threonine, serine, lysine, leucine, glycine and serine were found in higher amounts, with significant differences within cuts only found for alanine and aspartic acid.

There were no significant differences observed for the most minerals. Guinea fowl meat had high values for iron, calcium and zinc compared to chicken, ostrich and beef, especially in the darker muscles which could possibly be ascribed to the higher myoglobin content of the darker muscles, as well as to the fact that this investigation was conducted on frozen and thawed guinea fowl. These processes release haemoglobin from the red cells in the bone marrow, contributing to the higher bio-available iron values with its concomitant nutritional benefits. Lower sodium values, than found for chicken in other studies, was reported. Sodium, which is in its ionic state in meat muscle, becomes part of drip loss, which can possibly be ascribed to the processes of feezing and thawing.

Differences in the fatty acid composition between muscles were observed, with the drumstick having the lowest monounsaturated fatty acids (MUFA) content when compared to the thigh and breast ($P \leq 0.05$). The MUFA most abundant was oleic acid. Drumstick had the highest polyunsaturated fatty acid (PUFA) ($P \leq 0.05$); the most abundant PUFA being linoleic acid. The polyunsaturated fatty acids:saturated fatty acids (P:S) ratio for all cuts met the nutritional recommendation, whilst the *n*-6:*n*-3 ratio was very high in all the cuts and much higher than the recommended range of <2. It should be noted that the poor *n*-6:*n*-3 ratios were found in raw meat, which were dramatically altered when cooked.

Cholesterol was generally very high, but lower in the breast, and very high in the drumstick and thigh. These results were verified by repeating the analysis.

### 7.2.2 Different cooking methods on the chemical composition of different cuts of cooked guinea fowl meat (Chapter 4)

Under the conditions of this study cooking methods had an impact on the proximate composition of the different cuts of guinea fowl meat. Results on cooked breast meat using the baking-bag and open-roasting method showed significant differences ($P \leq 0.05$), with the baking-bag method resulting in lower values for moisture than the open-roasting method. For the other cuts (drumstick and thigh) the baking-bag method also resulted in lower moisture values than the foil-wrap and the open-roasting methods, with. It is suggested that the cooking time and oven-temperature control that was necessitated in this experimental design, resulted in a higher internal temperature for cuts cooked in the baking-bag method, hence loss of moisture from within the cuts.

For the baking-bag method the drumstick had the lowest moisture content ($P \leq 0.05$) in comparison to the thigh and breast. Such differences were not found in the raw cuts. The open-roasting method had the least impact on moisture content. It is suggested that when the cuts were cooked using the open-roasting method, a lower internal temperature was achieved. The drumstick had a higher protein content regardless of cooking method and the thigh the lowest ($P \leq 0.05$) across all cooking methods, which is attributed to the higher concentration of the drumstick, having had the lowest moisture content ($P \leq 0.05$) when compared to the other cuts.

The fat content in the thigh was higher, and in the breast lower, with no effect from any of the cooking methods (P>0.05). However, these quantities are relative as cooked guinea fowl meat under the conditions of this study can be regarded as a lean food product, i.e. containing <5% fat.

The baking-bag method preserved the PUFAs better than all the other treatments. From the results of the previous study on raw meat, it appears that cooking reduced the MUFAs and PUFAs whilst it increased the SFAs. All cooked cuts regardless of the cooking method were within the recommended value (<4:1) for the *n*-6:*n*-3 ratio and ranging between 2.47 and 3.08. The beneficial P:S ratio is >0.4. Regardless of cooking method the P:S ratio for the cooked cuts ranged between 0.91 and 1.42. Under the conditions of this study, cooking affected the fatty acid parameters used to assess the nutritional benefits of fat-containing food sources very advantageously. Cholesterol was generally very high in all the samples, especially on the roasted thigh and lower in the breast.

During cooking, the internal temperature was not controlled, rather the oven temperature and cooking time were standard for all the different methods, which used different medium of heat to cook. Inferences were drawn from raw meat results in Chapter 3, though the samples used in the two chapters were not from the same batch. Future research could therefore look into the comparison and correlation of these results on cooking methods with the values for raw meat. Collagen could also be assessed especially when looking at wild guinea fowl to assess the phenomenon regarding the of tenderisation of the meat during cooking.

### 7.2.3 Cooking methods and sensory attributes (Chapter 4).

The sensory attributes of the breast meat revealed that cooking methods had no impact on guinea fowl aroma, although differences in initial and sustained juiciness, flavour and tenderness were detected. The foil-wrap cooking method produced a more tender and juicier product when compared to either the baking-bag or open-roasting method. The use of the baking-bag lowered the flavour. It is suggested that the open-roasting method resulted in cooked products with the lowest internal temperature, which resulted in the insufficient breakdown of collagen, while it is suggested that the foil-wrap method had an ideal internal temperature, while it is suggested that the baking-bag method resulted in too high an internal temperature, with concomitant flavour and moisture loss.

### 7.2.4 Proximate composition: raw guinea fowl breast meat meathods and cooked guinea fowl breast applying three cooking (Chapter 5)

As anticipated raw breast meat had a higher moisture content than the other cooked cuts, with open-roasting showin the highest value ($P \leq 0.05$) when compared to the baking-bag method. This can be ascribed to differences in the internal temperatures of the cuts when cooked by means of the baking-bag, foil-wrap and open-roasted methods. Raw meat had low protein, fat and ash content and the baking-bag method had the highest protein content.

### 7.2.5 Cooking methods and sensory attributes of cooked guinea fowl meat

Cooking methods significantly affected the sensory attributes of guinea fowl breast meat with the exception of aroma. Aroma did not differ for all the cooking methods. The baking-bag method was low in initial juiciness, flavour, sustained juiciness, and was in between for tenderness. The foil-wrap method on the other hand produced a more tender, juicier and more flavourful product. It is suggested once more that these differences could also be ascribed to differences in internal temperature.

### 7.2.6 Injection with brine solution

None of the sensory attributes was affected by the brine injection. Therefore injection of brine solution used in this tudy (hand-pipe, no pressure) could not improve the sensory attributes.

### 7.2.7 Brine injection and chemical composition of guinea fowl breast meat

There was a higher moisture content in the injected sample, which had low protein and no differences in either the fat nor the ash. The use of a hand injector directly affected the water-holding capacity. The marinade could not be fully and efficiently distributed to the sample in order to effect the anticipated tenderation process.

## 7.3 Recommendations

Various recommendations can be made from this study with a view to further research, for the agricultural industry involved in the raising and marketing of guinea fowl, and for nutrition education purposes.

### 7.3.1 Further research

#### *7.3.1.1 Experimental design of research based on this research*

The experimental design used in this study resulted in the situation that control of the internal temperature of cooked samples were not possible. It is advised that, using the same procedure, internal temperature of the cuts cooked at 140°C for 65 min be monitored as a pilot study. Researchers recommend an internal temperature of 85°C. It is suggested that the cooking-bag method may have resulted in too a high internal temperature, and the oven-roasting method in too a low internal temperature. A different experimental design, may however require three identical ovens using a computerised electronic control system. For this study only two of these ovens were available which influenced the experimental design of this research.

Controlling the internal temperature could have been benefical to ensure that these three methods cooked the meat to same internal temperature but the experimental design of this research did not make internal temperature control possible. This would affect cooking time (minutes) and further research is recommended. Sensory attributes could have been affected by the freezing process, period of frozen storage and the thawing process. These processes could be used in an experimental design in which raw guinea fowl is also included. The effects of freezing on sensory properties could also be researched on further. For future research the multi-needle electronic injector should be used as was done in the pilot study.

#### *7.3.1.2 Sourcing of guinea fowl*

Frozen guinea fowls were sourced from a farm in Philadephia. Comparative studies (especially with regards to the mineral content) of raw fresh and raw frozen, all other conditons equal, would be able to validate the findings of this study. It is suggested that the freeze-thaw-freeze cycles necessitated for the treatments in this study may have equalised differences, as also the commercial feed of the guinea fowl. Sourcing of commercially – raised and wild guinea fowl for comparative studies is recommended.

#### *7.3.1.3 Further research*

It was unfortunate that the multi-needle injector was not available during the main study, obviously the availability of this effective injection method when conducting infusion studies is essential. Comparative studies on reared and wild guinea fowl is recommended as feeding has an impact on the nutritional profile and sensory attributes of meat. This research found high *n*-6:*n*-3 ratio in raw samples, with an advantageous effect found in cooking. These and other research results can be validated as it is clear that evidence is required to market guinea fowl using validated evidence from research, on the positive nutritional profile or fresh and frozen guinea fowl, cooked according to tested and validated procedures.

### 7.3.2 Raising and marketing of guinea fowl

This research has brought interesting marketing potential for guinea fowl to the fore. The low fat profile of guinea fowl meat has been sufficiently validated in this study – also the high protein content, ash and minerals, especially iron so that immediate benefit can be derived from this study for marketing purposes.

### 7.3.3 Nutrition education

The most common deficiency disease in the world is iron deficiency anaemia. Results have shown that guinea fowl meat is a good source of iron and protein. Iron is especially absorbable when in the presence or meat, fish or poultry – called the MFP factor. In a third world country where this nutritional disease is especially prevalent this attribute of guinea fowl meat in an agricultural product so readily available, should receive focus. Dietary requirements for increased iron uptake, such as the intake of a Vitamin C source at the same time, should be borne in mind. The advantage of marketing guinea fowl with this additional nutritional properties, also bearing positive *n*6:*n*3 ratio of cooked guinea fowl meat in mind should benefit the consumer, the commercial guinea fowl industry, as well as the wild game bird market.

## ADDENDUM A

# JOURNAL OF FAMILY ECOLOGY AND CONSUMER SCIENCES

**TYDSKRIF VIR GESINSEKOLOGIE EN VERBRUIKERSWETENSKAPPE**

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## Editorial and Typographical Guidelines for Authors

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- The Journal for Family Ecology and Consumer Sciences (JFECS) is an official publication of the South African Association of Family Ecology and Consumer Sciences (SAAFECS) with the following objectives:

  - To provide a medium for reporting scientific research and knowledge pertaining to family ecology and consumer sciences
  - To stimulate research and knowledge pertaining to family ecology and consumer sciences through publications of a high scientific standard and in doing so to promote these fields of study
  - To benefit the family and the community by means of publications on family ecology, consumer science and related disciplines.

- Manuscripts in the fields of family ecology and consumer sciences and related disciplines are welcomed:

  - Articles on original research or other material dealing with research or education
  - Critical reviews promoting the theory of or stimulating research in the above fields
  - General articles containing new information.

- Review and research articles are published in English or Afrikaans. Contributions are welcomed from both members and nonmembers of the SAAFECS. Manuscripts may preferably be submitted electronically to the Editor at hebos@intekom.co.za
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3. Have all relevant studies and not only those that agree with the author's viewpoint been considered? Are the conclusions logical and objective?
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Each separate part of the manuscript begins on a new page. Arrange the different parts as follows:

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**Books, government publications, proceedings and theses:**

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**7. Tables**

Well-planned tables contribute to the value of an article. Only essential information should be included in support of the text:

- Each table has to be typed on a separate page and in single spacing.
- Tables have to be numbered and given headings that reflect the content:

**TABLE 1: RANKING OF THE FIVE MOST IMPORTANT ACTIVITIES AND RESPONSIBILITIES OF HOME ECONOMISTS**

- Each column should have a heading and should contain measurements of the same unit.
- No full stops are used after headings.
- Note the use of a decimal comma.
- Abbreviations (explained in a footnote under the table) may be used as space is limited.
- In the text a table is referred to by its number: Table 1 or (Table 1).
- Indicate placement of the table in the text as follows:

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Place Table 1 here

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**8. Figures and other graphical material**

Carefully selected graphs, sketches or other graphic material could facilitate understanding of the text. Bear in mind that figures have to fit into one or two columns of the Journal. Detail may be lost in the process of scaling down graphic material to fit into one or two columns:

- ♦ Design the graphics with the width of a column (75 mm) or page (170 mm) in mind. The largest size graphics is 225 mm x 170 mm.
- ♦ Text-based figures should be constructed in Microsoft Office PowerPoint XP/2003 and saved as a PowerPoint Presentation (.ppt format).
- ♦ Use Arial type-face as the base font for all text-based figures.
- ♦ Charts should be constructed in Microsoft Office Excel XP/2003 and saved an Excel spreadsheet (.xls format).
- ♦ Use Arial type-face as the base font for all text in charts.
- ♦ Graphical material accompanying the text should be in a format that is ready for typographical processing. Additional fees will be charged for editing of incorrect graphical material.
- ♦ Photographs or maps should be clear, with sufficient contrast, but keep the pixel size of the photograph as low as possible for easy downloading from the Internet.
- ♦ Submit photographs electronically in a .jpg format.
- ♦ All photographs and graphic material are referred to as figures.
- ♦ Most of the conventions for tables apply to figures as well, except that figures have subscripts:

**FIGURE 1: FACTORS THAT INFLUENCE THE FORMATION OF HABITUAL EATING HABITS OF UNIVERSITY STUDENTS**

♦ In the text figures are referred to by their numbers: Figure 1 or (Figure 1).

♦ Indicate placement of the figure in the text as follows:

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Place Figure 1 here

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