DEVELOPMENT OF VALUE ADDED OSTRICH (*STRUTHIO CAMELUS)* MEAT PRODUCTS

SUMARI SCHUTTE

Thesis presented in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN FOOD SCIENCE

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DECLARATION

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

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SUMMARY

The objectives of this study were threefold: (i) to investigate the effect of the replacement of pork fat with olive oil on the physico-chemical and sensory characteristics of ostrich polony; (ii) to investigate the effect of replacement of sodium tri-polyphosphate (STPP) with iota-carrageenan (CGN) on the physico-chemical and sensory characteristics of restructured cooked ostrich ham; and (iii) to investigate the effect of salt (NaCl) reduction on the physico-chemical and sensory characteristics of ostrich bacon.

Five levels of olive oil were added to a polony formulation in 5% increments from 0 to 20%. Hardness, gumminess and shear force values decreased ($P \leq 0.05$) with increased levels of olive oil. The L* and b* values decreased ($P \leq 0.05$) with increased levels of olive oil producing lighter and more yellow products. Ostrich polony proved to have a favourable fatty acid profile in line with international recommended standards. A trained sensory panel found that the effect of increased levels of olive oil on had an effect ($P \leq 0.05$) on the sensory characteristics of colour; processed meat aroma and flavour; ostrich aroma; olive oil aroma; firmness and juiciness. A consumer panel found all the olive oil treatments to be acceptable. It can be concluded that olive oil can be used successfully for the production of low fat ostrich meat polony.

In a restructured ostrich ham five decreasing levels of phosphate (0.7, 0.53, 0.35, 0.18 and 0%) were substituted with five increasing levels of carrageenan (0, 0.1, 0.2, 0.3 and 0.4%). The cooked yield of the restructured ostrich ham decreased significantly ($P \leq 0.05$) with decreased levels of phosphate. No tendencies in instrumental colour measurements with relation to decreased levels of phosphate were revealed. Hardness, cohesiveness and gumminess increased with decreased levels of phosphate. Ostrich ham had a favourable fatty acid profile and the latter is in line with international recommended standards. The trained sensory panel found that decreased levels of phosphate had a significant effect on the ham sensory characteristics of meat aroma and flavour; ostrich meat aroma and flavour and mealiness, but no significant effect on the spicy aroma and flavour. Three ham treatments with different levels of phosphate (0.7, 0.35 and 0%) were presented to a consumer panel. The consumer panel found the ham treatments with levels of 0.7 and 0.35% most acceptable. Carrageenan can be used to substitute phosphate at a level of 0.35% phosphate and 0.2% carrageenan in ostrich ham.

Ostrich bacon was produces with five targeted salt (NaCl) levels of 3.5, 2.75, 2.0, 1.25, and 0.5%. Decreased salt levels had no significant effect on the L*, a* and b* values of the five treatments. Ostrich bacon had a favourible fatty acid profile. A trained sensory panel found that the effect of increased levels of salt had a significant effect on bacon sensory characteristics of ostrich aroma and flavour smoky bacon aroma and flavour and saltiness. A consumer panel found all the bacon treatments acceptable, with 2.75 and 2.0% being most likable. It can be concluded that, from a technical point of view, the salt content in ostrich bacon can be reduced successfully to produce ostrich bacon with low salt levels, although consumer preference for salt remains high.

OPSOMMING

Die doelstellings van hierdie studie was drievoudig: (i) om die effek van die vervanging van varkvet met olyfolie op die fisiko-chemiese en sensoriese eienskappe van volstruispolonie te bestudeer; (ii) om die effek van die vervanging van natriumtripolifosfaat met iotakarrageenan op die fisiko-chemiese en sonsoriese eienskappe op die van hergestruktureerde volstruisham te bestudeer; en (iii) om die effek van sout (NaCl) vermindering op die fisiko-chemiese en sensoriese eienskappe van volstruisspek te bestudeer.

Die polonie behandelings het uit vyf vlakke olyfolie bestaan wat by die polonie formulasie in 5% inkremente 0% tot 20% gevoeg is. Hardheid, taaiheid en skeurkrag het afgeneem ($P \leq 0.05$) met verhoogde vlakke van olyfolie. Die L*- en b*-waardes het afgeneem ($P \leq 0.05$) met verhoogde vlakke van olyfolie en uiteibdelik ‘n ligter en geler produk geproduseer. Die betrokke volstruispolonie behandelings het ‘n gunstige vetsuurprofiel wat in lyn is met internasionale aanbevole standaarde. ‘n Opgeleide sensoriese paneel het gevind dat die verhoogde vlakke van olyfolie ‘n betekenisvolle ($P \leq 0.05$) effek het op die kleur, geprossesseerde vleisgeur en -aroma, volstruis aroma, olyfolie aroma, fermheid en sappigheid. ‘n Verbruikerspaneel het gevind dat al vyf polonie behandelings aanvaarbaar is. Olyfolie kan dus suksesvol gebruik word in die produksie van laevet volstruispolonie.

Hergestruktureerde volstruisham het bestaan uit vyf afnemende fosfaat vlakke (0.7, 0.53, 0.35, 0.18 and 0%) en vyf toenemende vlakke van karrageenan (0, 0.1, 0.2, 0.3 and 0.4%). Die opbrengs van gaar hergestruktureerde volstruisham het afgeneem ($P \leq 0.05$) met verlaagde vlakke van fosfaat. Geen betekenisvolle patroon is in instrumentele kleurmeting gevind nie. Hardheid, binding en taaiheid het toegeneem met afnemende fosfaat vlakke. Daar is bewys dat volstruisham ‘n gunstige vetsuurprofiel het wat in lyn is met internasionale aanbevole standaarde het. ‘n Opgeleide sensoriese paneel het gevind dat afnemende fosfaatvlakke ‘n betekenisvolle effek op die sensoriese eienskappe van volstruisvleis geur en aroma asook melerigheid, maar geen betekenisvolle effek op die speserygeur en -aroma gehad nie. Drie behandelings met verskillende fosfaat vlakke (0.7, 0.35 and 0%) is deur ‘n verbruikerspaneel vir aanvaaraarheid getoets. Die verbruikerspaneel het gevind dat die behandelings met 0.7 en 0.35% fosfaat aanvaarbaar was. Karrageenan kan dus gebruik word om fosfaat te vervang by ‘n vlak van 0.35% fosfaat en 0.2% karrageenan in volstruisham.

Volstruisspek is geproduseet met vyf soutvlakke (NaCl), nl 3.5, 2.75, 2.0, 1.25 en 0.5%. Verlaagde soutvlakke het geen beteknisvolle effek op die L*-, a*- en b*-waardes van die vyf behandelings gehad nie. Volstruisspek het ook ‘n besonder gunstige vetsuurprofiel. ‘n Opgeleide sensoriese paneel het gevind dat die effek van verhoogde soutvlakke ‘n betekenisvolle effek het op die volgende sensoriese eienskappe: geur en aroma van volstruisvleis; geur en aroma van gerookte spek; en southeid. ‘n Verbruikerspaneel het gevind dat al die behandelings aanvaarbaar was, met die monsters met 2.75 and 2.0% sout as mees aanvaarbaar. In opsomming, die

soutinhoud van volstruisspek kan uit ‘n tegniese oogpunt suksesvol verlaag word om ‘n produk met ‘n laer soutinhoud te produseer, alhoewel verbruikersvoorkeur vir sout hoog bly.

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TABLE OF CONTENTS

NOTES

The language and style used in this thesis are in accordance with the requirements of the scientific journal, *International Journal of Food Science and Technology.* This thesis represents a compilation of manuscripts where each chapter is an individual entity and some repetition between the chapters has therefore been unavoidable.

Chapter 1

Introduction

Over time, economic and social changes have led to the transformation and modification of nutritional demands in many societies. The South African and international meat markets presently experience a substantial increase in the demand for game and other exotic meat types as healthier alternatives to traditional red meat species. Nowadays, consumers favour meat that is authentic, tasty, rich in protein and low in lipids and cholesterol. Therefore, the purchase of alternative sources of red meat, as opposed to products from the traditional species of red-meat-producing animals, is becoming more acceptable. One such example is the meat from ratites, i.e. ostrich, emu, rhea, cassowary and kiwi. The latter are perceived and marketed as a healthy alternative to other red meats due to its leanness, low cholesterol content and favourable fatty acid profile (Sales & Horbanczuk, 1998). Growing consumer concerns about the relationship between diet and health underlies the purpose of this study.

South Africa is regarded as a pioneer and world leader in the ostrich industry - about 90% of the ostrich meat produced in South Africa is exported to the European Union (EU) as chilled meat (-2 to -4°C). The first recorded trade of ostrich's dates back to 1838 when South Africa exported feathers (plumes) to Europe. Between 1838 and 1913, the ostrich industry was exclusively based on feathers and during 1913, ostrich plumage ranked fourth on the list of South African exports following gold, diamonds and wool. However, in 1914 the ostrich feather industry collapsed. Factors contributing to this sudden collapse include the worldwide economic impact of World War I, poorly co-ordinated marketing, changing fashions and an over supply of feathers. Economic instability plagued the industry until 1945, when the Klein Karoo Cooperative was established by farmers in the Little Karoo Region, South Africa in an effort to bring stability in the ostrich industry. One of the results of the establishment of the Klein Karoo Cooperative was that the world's first ostrich abattoir was built in Oudtshoorn in 1964 for the production of biltong and fresh meat for local consumption. The market for ostrich leather was developed after a tannery was erected during 1970. Ostrich leather was the main source of income during this period (NAMC, 2003; Gillespie & Schupp, 2000).

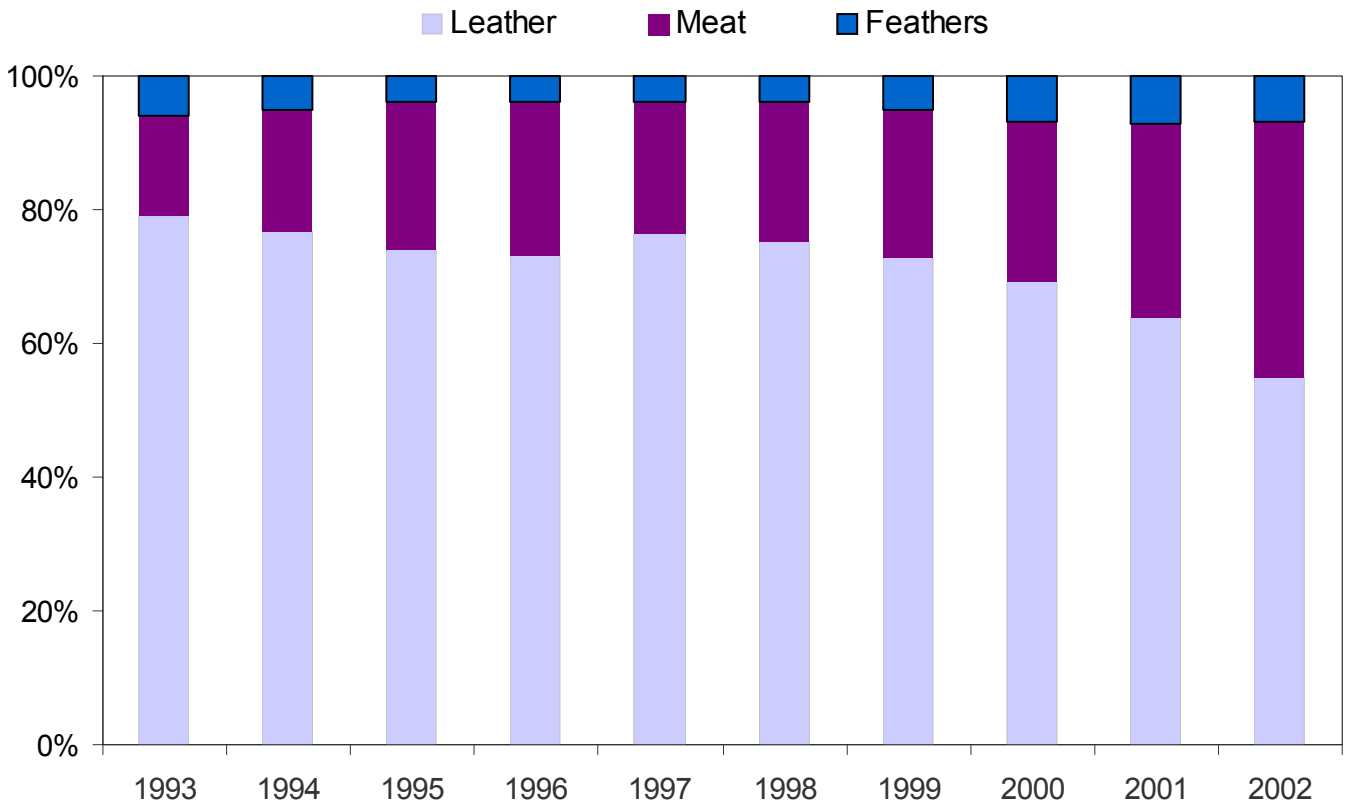

Figure 1 Relationship between the value of leather, meat and feathers (NAMC, 2003).

Since the mid nineties the value of ostrich meat steadily increased relative to the value of the skin and feathers as illustrated in Figure 1 (NAMC, 2003). One of the major factors that led to an increase in demand of ostrich meat was the outbreak of *Bovine Spongiform Encephalopathy* (BSE) and Foot and Mouth Disease (FMD) in Europe during 2001. However, this increase in demand lasted only three years (August 2004 and September 2005) whereafter the export of ostrich meat was banned due to the outbreak of the pathogenic flu, *Avian influenza*. *Avian influenza* is a contagious viral infection and is found naturally in waterfowl, shorebirds and gulls. It is mutagenic and is able to spread rapidly between avian species (Cooper *et al*., 2004). The *Avian influenza* strain was confirmed to be the H5N2 type, but according to reports by the World Health Organisation (WHO), the World Organisation for Animal Health (OIE) and the South African Institute for Communicable Diseases, the H5N2-virus poses no risk to humans, as humans do not have receptors for the virus in their respiratory tract (Cooper *et al*., 2004). The advent of the *Avian influenza* virus and the cessation of the export of chilled ostrich meat out of South Africa had a serious negative impact in the economy of the ostrich industry and led to an over supply of unprocessed ostrich meat in the South African market. Since August 2004, ostrich meat products that have undergone heat treatment to a core temperature of 70°C, is allowed by the European Union (EU) commission to be imported. Therefore, the ostrich meat industry is compelled to conduct more scientific research on the development of heat-treated ostrich meat products. The

relative high ultimate pH value (6.0) of ostrich meat makes it an ideal processing meat since the natural water binding capacity is high (Fisher *et al.*, 2000; Sales & Mellett, 1996). However, it is generally accepted that processed meat products contain constituents, added during processing for technological, microbiological or sensory reasons, i.e. saturated animal fats, salt, phosphate and nitrite that may have a negative effect on human health.

There are a number of commercially available value added ostrich meat products of which most have been derived from transferring traditional technologies applied to the traditional red meat species to ostrich meat. However, in order to maintain the ostrich meat's healthy characteristics, ostrich meat products should be developed by reformulation of meat derivatives so as to decrease or eliminate those elements that are negative to human health.

As identified in literature, the main elements that are harmful to human health and which are added during processing of meat products for technological, microbiological, or sensory reasons, are saturated animal fat, salt (NaCl) and phosphate. A high intake of saturated fat is linked to the development of major chronic diseases such as cardiovascular heart diseases, obesity and cancer (Kuller, 1997; Weisburger, 1997), high sodium intake correlated positively with mortality and risk of coronary heart disease, independent of other cardiovascular risk factors, including blood pressure (Tuomilehto *et al*., 2001) and the presence of excessive amounts of phosphates in the diet may influence the calcium, iron and magnesium balance in the human body, and can increase the risk of bone diseases (Calvo & Park, 1996; Sandberg *et al.,* 1999).

In line with current published research designs, this research project will investigate the possibility to develop three viable value added ostrich meat products, namely polony, bacon and ham, in which the above mentioned elements (saturated fat, sodium chloride, and phosphate, respectively) are key ingredients. Therefore, with the beneficial effect of unsaturated fat, decreased salt (NaCl) and phosphate reduction, together with the health and processing characteristics of ostrich meat, this study was designed to develop a healthier and acceptable alternative to traditional value added meat products. Hence, the objectives of this study were:

- to investigate the effect of the replacement of pork fat with olive oil on the physical, chemical, and sensory characteristics of ostrich polony;
- to investigate the effect of replacement of sodium tri-polyphosphate (STPP) with iota-carrageenan (CGN) on the physical, chemical and sensory characteristics of restructured cooked ostrich ham and
- to investigate the effect of salt (NaCl) reduction on the chemical, textural and sensory characteristics of ostrich bacon.

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Chapter 2

Literature review

1. Introduction

Ostrich meat is gaining more attention in the marketplace and is increasingly marketed as a healthy alternative to other red meats due to its leanness, low cholesterol content and favourable fatty acid profile (Sales & Horbanczuk, 1998). This is the result of increased consumer awareness for the relationship between health and diet. Considering the fact that there is an over supply of ostrich meat on the export-orientated South African ostrich meat market, mainly due to *Avian influenza*, the option arises to explore the viability of producing value added meat products derived from ostrich meat for the export market. Therefore, this study will focus on the development of healthy value added ostrich meat products that would maintain the health characteristics that is generally associated with ostrich meat.

2. Product development driven by the consumer

New product development is often used as a suitable strategy to build a competitive advantage and long-term financial success in today's global food market. It is generally argued that new products help maintain economic growth, spread the risk in the food production market, enhance the company's stock market value and increase competitiveness (Costa & Jongen, 2006). According to Rudolph (1995) between 80% and 90% of new food products that are put on the market fail within one year of production. One of the reasons for this phenomenon could be the lack of product developers tapping into the consumers' food related needs and wishes prior to production; the latter approach is often referred to as consumer driven product development.

This study can be described as consumer driven, as international trends and consumer preferences and demands regarding meat consumption form the underlying motivation for the arguments regarding the development of value added ostrich meat products.

3. International trends and consumer preference and demand regarding meat consumption

Though meat was once thought to be a vital daily component of a healthy diet, nutritionists nowadays advice consumers to seek protein from alternative sources. This trend reflects a swing in attitude away from red meat as a central part of a healthy diet in industrialised countries. The

change in meat consumption, changes in the way meat consumption is distributed across different kinds of meat, and purported changes in attitude to meat as a source of protein (often linked to meat-related food scares), are topics widely discussed in literature (Becker *et al*., 2000; Grunert *et al*., 2004; Hughes, 1995; Resurreccion, 2003; Tarrant, 1998; Verbeke, 2000, 2004). The following discussion will focus on the factors identified in the literature that influenced changes in meat consumption.

3.1 Factors changing the demand for meat

Among the most important factors influencing the changes in consumer demand for meat and meat products are increased health concerns; demographic and social change; change in socio-economic profiles; the need for convenience; and increased eating away from the home and growing food safety, environmental and ethical concerns. The influence of each of these factors will be addressed briefly in the following paragraphs.

3.1.1. Increased health concerns

During the last half of the twentieth century, diseases connected to lifestyles have increased in the Western world. Various researchers established some relationships between constituents in the diet and general health, especially between saturated fat in animal products and illnesses such as cardiovascular diseases, high blood pressure, hypertension, obesity and cancer (Alothaimeen *et al.,* 2004; Appel *et al.,* 2006; Campbell *et al.,* 1998; He *et al*., 2000; Kuller, 1997; Law, 1997; Nkondjock *et al.,* 2003; Parpia & Chen*,* 1998; Svetkey *et al*., 1999; Vaskonen, 2003; Weisburger, 1997). This relationship and the health problems related to modern lifestyle (the so-called "disease of affluence") have had a considerable effect in the decline of meat consumption over the last decade. The aforementioned relationship between constituents in the diet and increased health concerns has resulted in a shift away from high-fat, high-protein diets to a trend of more fresh vegetables and fruits in the diet (Pollard *et al*, 2002).

3.1.2. Demographic influences

Long-term demographic changes have a significant effect on the food market, which is reflected in changes in size and make-up of the population, the way consumers live their lives and the wealth of the consumers – all of which will influence the demand for different kinds of products. These factors are gender, ethnicity and religion, and socio-economic status (income, education and occupational status). Regarding gender, females, in contrast to males, tend to avoid the consumption of red meat and replace it with chicken (Kubberød *et al*., 2002a). Dislike with meat and sensory factors, disgust with blood and raw meat, difficulties with divorcing the meat concepts from the living animal (Kenyon & Barker, 1998; Santos & Booth, 1996) and body weight concerns (Ryan, 1997; Worsley & Skrzypiec, 1997) have frequently appeared as females' main reasons for

adapting to a meatless diet. A qualitative study among young females found that sensory drivers of dislike and disgust with meat were especially the appearance of blood and raw meat, but also chewy texture and fattiness (Kubberød *et al*., 2002b). This study further revealed that females tended to associate meat with "heavy" food weighing in their stomach. It is also known that ethnicity and religion play a significant role in the consumer's demand for meat. Communities with ethnically diverse consumers are likely to have a more diverse demand for meat products, especially when catering for their cultural food preference (i.e. halaal, kosher, spices, etc.). The influential effect of ethnicity is carried further via the phenomena of globalisation and regionalisation. The international integration of markets has the effect that food products are increasingly traded across national borders and this exposes consumers to other international cultures (cultural diffusion) and its cuisine. This trend will strengthen as increasingly open markets are coupled with growing consumer demand for variety and year-round availability of fresh produce (Blackman, 2005). It is also accepted that socio-economic status has a determining effect on meat consumption. Socio-economic status is a measure of class standing, typically indicated by income, occupational prestige and educational attainment (Anderson & Taylor, 2004). Consumers from the higher socio-economic group are generally, due to associated higher educational levels and exposure to diversity, more sensitive towards a healthy lifestyle. Mainland (1998) found that increases in income over time support beef demand and depress the demand for other foods. This might suggest that across all income groups, red meat is increasingly becoming a luxury food for the affluent (Mainland, 1998). Furthermore Berry and Hasty (1982) found that households with larger incomes tend to purchase leaner and larger quantities of ground beef compared to lower income households. The influence of income on the meat consumption was also reflected in a USDA/ERS (2002) report that associated an estimated 10% increase in income with a 0.7% increase in demand for convenience meals. Furthermore, humans often use food to differentiate themselves from others and to convey their membership of a particular social group, i.e. ordering a vegetarian meal, dining at a trendy restaurant, or eating exotic cuisine. The latter may be used and interpreted as social 'markers' of the individual's social status and group membership (Pollard *et al.*, 2002). Radder and Le Roux (2005) found that the consumption of venison could be regarded as a social marker, since 40% of the respondents perceived venison as a "luxurious meat", "a meat associated with the high social class" (40%) and "a meat for the high income groups" (35%). In the latter study meat was regarded as an essential part of a meal as 28% of the respondents would never serve a meal to guests without red meat, while 43% would not serve a meal to guests without some type of meat.

3.1.3. Need for convenience

Demographic changes in lifestyle have led to a shift towards more convenience in food preparation. Given the reports of the fast tempo of industrial lifestyles, the increasing time-pressure brought about by job and leisure related activities into meal preparation, an increase in

woman entering the labour force and the extraordinary reduction of time for cooking (Bowers, 2000; Sloan, 1997), industry and service sectors have readily reacted to the convenience trend by stepping up the development of products that considerably expand their offer of convenience products and services. Convenience foods are orientated towards comfort savings such as labour and time, as the instruments of modern convenience reduce the amount of toil required in the accomplishment of routine domestic tasks (Warde, 1999). Furthermore, the proportion of single households has increased, which seems to be the result of a general increase in the divorce rate, increase in life expectancy with more surviving singles and more dependant young people moving out of traditional households (Annette *et al.* Cited in Shiu *et al.*, 2004). Households of smaller size are generally less likely to spend time on preparing food and therefore, are more likely to consume convenience-orientated food products (Hutchins & Dawson Cited in Shiu *et al.*, 2004).

3.1.4. Food safety and growing environmental and ethical concerns

Food safety concerns have increased significantly over the past decade with consumers becoming more aware of the possible health hazards associated with processed food and the impact of environmental factors on food. Various researchers (Becker, 2000; Fearne *et al*., 2000; Hornibrook & Dedman, 2001; Richardson *et al*., 1993; Richardson *et al.*, 1994; Roosen *et al.*, 2003; Smith *et al.*, 1999; Verbeke, 2001) found that the main risks related to meat consumption perceived by consumers are chemical residues of growth hormones and antibiotics; high fat content and the related hazard of increased cholesterol; microbial infections (*Salmonella*, *Escherichia coli*), and the resulting danger of food poisoning; use of genetic modification in the production of animal feeds; as well as food scares, i.e. Belgian dioxin and *Bovine Spongiform Encephalopathy* (BSE). The BSE crisis during the 1990s set off European Union (EU) consumers' intense concern regarding the safety of mainly beef, leading to substantial effects on the overall patterns of meat consumption. The annual per capita beef consumption in the EU dropped from 21.5 kg in 1990 to 18.6 kg in 1996, when the British Government first admitted there might be a connection between BSE and the appearance of the new variant of Creutzfeld Jacob Disease in humans, to recover to 19.7 kg in 1998. The next BSE outbreak in 2000 resulted in a further drop of the EU annual per capita beef consumption by 27% or 5.3 kg relative to the 1990 level (Roosen *et al.*, 2003). Furthermore, consumers are turning to organic meat, not only out of concern about food safety, but also because of animal welfare and production issues (McIntyre, as cited in O'Donovan & McCarthy, 2002). In a study by Radder and Le Roux (2005) almost half the respondents (47%) expressed a concern for the treatment of animals and preferred to buy meat from animals they believed had been treated well during slaughtering.

3.2 Consumers' perception of meat quality

The decrease in meat consumption is accompanied by a large mistrust among consumers in the quality of meat produced (Becker, 2000). However, food quality is a rather complex issue as

consumers' quality judgements of food depend on the perceptions, needs and goals they have (Steenkamp, 1990) and are therefore not easy to measure. With reference to this complexity of food quality, Grunert (1997) stated that quality is a multi-dimensional phenomenon, described by a set of characteristics that are subjectively perceived by the consumer. For the consumer to be able to evaluate quality, he or she needs to have information on the quality characteristics associated with the product. This information reaches the consumer in the form of quality cues which are defined by Steenkamp (1990) as informational stimuli that, according to the consumer, say something about the product. It is further argued that cues can be intrinsic and extrinsic (Olsen & Jacoby cited in Bernués *et al.*, 2003). Intrinsic cues relate to physical aspects of the product (e.g. colour, shape, appearance, etc.) whereas extrinsic cues relate to the product but are not physically part of it (brand, quality, stamp, origin, store, packaging, production information, etc.). It is also essential for this discussion to note that some authors make a distinction between product characteristics and product features (Becker, 2000; Bernués *et al.,* 2003). Features of the product that are used as technical indicators for quality and are in principle measurable by analytical methods are called product characteristics, whilst features of the product that meet consumer needs are called product attributes. The term characteristics is mainly used in the food science literature, whilst the term attributes is more prominent in consumer behaviour literature, though sometimes both terms are used interchangeable in literature.

Table 1 Categories of product characteristics measurements on meat quality (Ernst cited by Becker, 2000)

Category	**Characteristic**
Nutritional value	• Protein • Fat • Carbohydrate content
Processing quality	• Shear force • pH-value • Water-binding capacity
Hygienic-toxicological quality	• Contaminants • Microbacterial status • Additives
Sensory quality	• Texture (tenderness, juiciness) • Flavour/odour • Colour appearance (marbling)

In the product characteristic approach, technical indicators (intrinsic product features) are used to measure product quality. Food science literature on meat quality (Ernst cited by Becker, 2000) refers to four categories of product characteristics (Table 1).

From a marketing perspective, these product quality characteristics can be used to differentiate a product to favour a competitive edge towards similar products on the market. On the other hand, in the product attribute approach, cues are used by the consumers to evaluate the performance of the product with respect to those needs. Becker (2000) distinguished between three categories of quality attribute cues (Table 2).

In general, quality perception of meat has largely been based on intrinsic cues like the colour of the meat, the visible fat content and the cut. However, Bernués *et al*. (2003) argue that the use of extrinsic cues for quality inference will increase, due to the general food and health debate (pros and cons of eating red meat) and various meat scandals, as consumers seem to attach more importance to issues related to health and safety in their meat purchase. As health and safety are credence characteristics and not easily inferred from intrinsic cues, it is expected that the focus will mainly be on the use of extrinsic cues in the future.

Table 2 Categories of quality attribute cues (Becker, 2000)

Quality attribute cues	Intrinsic cues	Extrinsic cues
Search quality: (quality attribute cues, which become available at the time of shopping)	• Colour • Leanness • Marbling	• Brand/label • Place • Price • Origin
Experience quality: (quality attribute cues which are available in use or with consumption)	• Colour • Texture • Tenderness • Smell and flavour • Juiciness	
Credence quality: (quality attributes which are of concern for the consumer but where no cues are accessible in the process of buying and consuming e.g. food safety, concerns)	• Freshness	• Origin • Producer • Organic • Feed • Hormones • Fat/cholesterol • Antibiotics • Salmonella

The product characteristic approach, as reflected in Table 1, were used to measure the quality of the products development in this study by means of objective instrumental measurements and a trained sensory panel. Since the focus of this study was to develop value added meat products whilst maintaining the nutritional quality characteristic of ostrich meat, it is important to know what the existing perceptions of consumers are regarding health-relating issues with respect to value added meat products.

4. Consumer perception towards value added meat products regarding health

Although processed meat has enjoyed sustained popularity as a foodstuff, consumers have in recent years expressed growing health concerns over some consequences of processed meat consumption. As discussed previously, people are becoming increasingly concerned about the quality and safety of the food they are consuming. According to Colmenero *et al.* (2001), like any other food, processed meat products contain elements, which in certain circumstances and in inappropriate proportions may have a negative effect on human health (Table 3).

Table 3 Potential harmful elements in meat and meat products

I	Constituents (natural or otherwise) present in live animals	• Fat • Cholesterol • Residues from environmental pollution
II	Elements added to the product during processing for technological, microbiological or sensory reasons	• Salt • Nitrite • Phosphate
III	Elements produced by technological treatment	• Contaminants from disinfectants or detergents • Toxic compounds formed during cooking
IV	Elements developed - particularly in the storage/commercialisation phase	• Pathogenic bacteria • Formation of certain lipid oxidation products • Migration of compounds from the packing material to the product

Several of the most important aspects of the potential health problems associated with processed meat consumption, relevant to this study, will be discussed in more detail.

4.1 Fat, fatty acids, cholesterol and kJ value

The apparent relationship between dietary fat and the development of major chronic diseases such as obesity (Riccardi *et al*., 2003), cancer (Alothaimeen *et al*., 2004; Nkondjock *et al.,* 2003), and cardiovascular diseases (Campbell *et al*., 1998; Kuller, 1997; Vaskonen, 2003; Weisburger, 1997) have prompted consumers to be more aware of and concerned about the amount of fat in their diet. For these reasons, the World Health Organisation (WHO, 1990) has drawn up the following nutritional recommendations: Fat should provide between 15 and 30% of the kilojoules in the diet, saturated fatty acids (SFA) should provide not more than 10% of these kilojoules and cholesterol intake should be limited to 300 mg/day. These limitations refer not only to the amount of fat, but also to the fatty acid composition and the cholesterol levels in foods, of which processed meat products constitute a major part (Table 4). Plasma cholesterol levels are correlated to the fatty acid composition of the diet (Flynn *et al*., 1985). In general, monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) do not result in increased cholesterol levels, but high levels of long-chain saturated fatty acids (SFA) do (Grundy & Denke, 1990). From data derived from meat consumption and cholesterol intake Chizzolini *et al.* (1999) estimated that from 30-50% of the daily recommended cholesterol intake is provided by processed meat products.

Table 4 Normal fat content of meat products (Colmenero, 2000)

Meat product	Fat content (%)
Frankfurters	20-30
Bologna	20-30
Fresh pork sausage	30-50
Nugget	20-25
Liver sausage	30-45
Salami	30-50
Beef patty	20-30
Ham	<10

The above-mentioned dietary health concern has led to a consumer demand for low or reduced fat products, prompting the meat industry to modify the composition of many processed meats and to develop a variety of low fat meat products which are reflected in reviews by Colmenero (2000; 2001) and Keeton (1994). According to Colmenero (2001), the manufacture of low-fat products generally follows two basic approaches: the use of leaner raw materials (which raises the cost) and/or the reduction of fat and kilojoule content by adding water and other ingredients that contribute few or no kilojoules. Most of the ingredients and/or additives used in research studies to reduce fat levels can be classified as added water (Claus, 1990; Park *et al.*, 1990); non-meat proteins (soy, dairy proteins, gluten, albumin) (Gujral *et al.,* 2002; Homco-Ryan *et al.,* 2004;

Muguerza *et al.*, 2003; Pietrasik *et al.*, 2006); carbohydrates (gums or hydrocolloids, starches and maltodextrins and cellulose derivatives) (Hughes *et al.,* 1997; Osburn & Keeton, 2004; Pietrasik, 2003; Sampaio *et al.,* 2004;) or other products (functional mixtures, vegetable oils and synthetic products) (Bloukas & Paneras, 1993; Lurueña-Martínez *et al.*, 2004; Vural *et al.*, 2004).

4.2 Sodium chloride (Salt)

The positive association between excessive intake of sodium, blood pressure and prevalence of hypertension and cardiovascular heart disease (Appel *et al.,* 2006; He *et al*., 2000; Svetkey *et al.,* 1999) has prompted public health authorities to recommend reducing dietary intake of salt (NaCl). Meat products are one of the main contributors to the high dietary sodium intake in the form of sodium chloride (NaCl) added during processing (Engstron *et al.*, 1997) (Table 5). Estimations taking eating habits into account suggest that approximately 20-30% of common salt intake comes from processed meat products (Wirth, 1991).

As a result of the ongoing campaign by public health authorities, meat technologists responded to the international trend of producing food products with low NaCl. This is reflected in various studies on reducing the salt content of processed meat products (Barbut *et al.,* 1988; Barbut & Mittal, 1989; Brandsma, 2006; Collins, 1997; Colmenero *et al.*, 2005; Gelabert *et al.,* 2003; Guàrdia *et al.,* 2006; Ruusunen *et al.,* 2003; Ruusunen & Puolanne, 2005). Apart from lowering the level of salt added to products, Desmond (2006) exemplifies three major approaches to reduce the salt content in processed foods, namely the use of salt substitutes, in particular potassium chloride (KCl), the use of flavour enhancers, and optimising the physical form of salt so that it becomes more taste bioavaliable (therefore less salt is needed). There is a number of flavour enhancing and masking agents commercially available and the number of products coming to the market is increasing. These include yeast extracts, lactates, monosodium glutamate and nucleotides. Flavour enhancers work by activating receptors in the mouth and throat, which helps compensate for the salt reduction (Brandsma, 2006).

4.3 Phosphate

There is an increase in the demand for phosphate free meat products (Ruusunen *et al*., 2003). The presence of excessive amounts of phosphates in the diet may influence the calcium, iron and magnesium balance in the human body, and can increase the risk of bone diseases (Calvo & Park, 1996; Cerklewski, 2005; Moretti *et al.,* 2006; Sandberg *et al.,* 1999; Shahidi & Synowiecki, 1997). Furthermore, consumers and retailers generally associate polyphosphates with cost reduction and lower quality products. Consumers also seem to associate the name “polyphosphates” with non-food applications, viewing them as “chemical products”. The aforementioned factors indicate an

interest in the use of alternatives to phosphates in restructured cooked meat products (Dimitrikopoulou *et al.,* 2005; Flores *et al.,* 2007; Shahidi & Synowiecki, 1997).

Table 5 Sodium and salt equivalent content (per 100 g) of typical meat products (Desmond, 2006)

Product	Sodium (mg)	Salt equivalent (g)
Irish and United Kingdom products		
Beef burgers	290 – 590	0.7 – 1.5
Sausages	433 – 1080	1.1 – 2.7
Frankfurters	720 – 920	1.8 – 2.3
Cooked ham	900 – 1200	2.3 – 3.0
Bacon/rashers	1000 – 1540	2.5 – 3.9
Salami	1800	4.6
Reduces fat sausages	800 – 1180	2.0 – 3.0
Breaded chicken	200 – 420	0.5 – 1.1
Chicken nuggets	510 – 600	1.3 – 1.5
Crispy chicken	300	0.8
United States products		
Beef patties	68	0.17
Pork sausage	636	1.6
Frankfurters	1120	2.8
Oscar Myer Weiners	1025	2.6
Cured ham	1500	3.8
Corned beef	1217	3.1
Hormel Canadian bacon	1016	2.6
Beef bologna	1080	2.7
Salami	1890	4.8

4.4 Toxic compounds produced during meat processing and storage

Meat and meat products undergo chemical changes during processing and commercialisation (grinding, curing, cooking, smoking, storage, exposure to light, etc.). These changes include the formation of numerous compounds, many of which impart desirable characteristics to food. Others can possess potentially harmful biological properties. The compounds that can cause disease include polycyclic aromatic hydrocarbons (PAHs), nitrosamines and lipid oxidation products (Hotchkiss & Parker, 1990).

PAHs result from the combustion of organic matter in the cooking and smoking of meat and meat products, as in many other foods. Their presence is determined by a number of factors, among which the composition of the product and the heat treatment applied features prominently. It is

also important to detect variable amounts of these PAHs in certain meat derivatives, as some of them are carcinogenic (Hotchkiss & Parker, 1990).

Sodium nitrite used in cured meat products interacts with various constituents in the meat's complex biological systems. Thus, at the end of the manufacturing process, only about 10–20% of the nitrite originally added can be detected with analysis. Residual nitrite levels can drop even further during storage and distribution, and again during preparation and consumption (Cassens, 1997). Despite the technological, microbiological and sensory advantages of nitrite, its use was brought seriously into question in the 1970s because of its interaction with secondary amines to form N-nitrosamines, chemical agents with carcinogenic properties. These compounds, which are detected in a number of different foods, including heat-treated cured meat products, can form both in the product itself (depending on the heating conditions, salt and nitrite concentration, and pH or ascorbate content) and/or in the consumer's stomach after ingestion (Pegg & Shahidi, 1997). Cassens (1997) highlighted the need to review the effect on health of residual nitrite and ascorbate in meat derivatives (the latter inhibit the formation of N-nitrosamines).

Polyunsaturated fatty acids and cholesterol may undergo oxidation during the processing and storage of meat and meat products. This oxidation produces numerous compounds (hydroperoxides, aldehydes, ketones, cholesterol oxides such as oxysterols), some of which are believed to have mutagenic and carcinogenic effects, and cytotoxic properties. Oxidation products are usually not abundant in foods and are well below the threshold of toxicity. The threshold of sensory detection of these compounds is also very low, which together with their unpleasant smell and taste, means that they are easily detected and the food is rejected. This is a mechanism to protect against exposure to high concentrations of these substances, though the long-term impact on health of continually consuming small amounts is not known (Hotchkiss & Parker, 1990).

5. Potential production of "healthy" value added ostrich meat products

According to Colmenero (2001), "healthy" meat products must possess one of the following characteristics: modified composition and/or processing conditions to prevent or limit the presence of certain potentially harmful compounds, and/or the possibility of including certain desirable substances, either natural or by addition, with the subsequent added benefits to health. The concept of "healthier" products includes what are known as "functional foods". The latter is defined as foods that are used to prevent and treat certain disorders and diseases, in addition to their nutrition value *per se*. According to Goldberg (cited in Colmenero, 2001), the three basic requirements for a food to be regarded as functional are that it is a food (not capsules, tablets or powder) derived from natural occurring ingredients; it can and should be consumed as part of the daily diet and once ingested; and it must regulate specific processes such as enhancing biological defence mechanisms, preventing and treating specific diseases, controlling physical and mental

conditions, and delaying the ageing process. The remainder of this discussion will look into the potential of producing "healthy" value added ostrich meat products.

5.1 Characteristics of ostrich meat

Ostrich meat is perceived and marketed as a healthy alternative to other red meats (Fisher *et al*, 2000). Moisture content, fat content, kJ value, cholesterol content and fatty acid composition of ostrich meat compared to that of beef and chicken are shown in Table 6 (Sales *et al*, 1996). The low fat content of ostrich meat could be a promising tool in marketing strategies of this meat type to the developed western market. The low fat content is the reason for the lower kJ value of ostrich meat. Furthermore, ostrich meat is lower in MUFA and higher in PUFA than either beef or chicken. The cholesterol content of ostrich meat is similar to other meat producing species.

Table 6 Fat content, kJ value, cholesterol content and fatty acid composition of ostrich meat compared to beef and chicken (Sales *et al*, 1996)

Chemical component	**Species**		
	Ostrich	**Beef**	**Chicken**
Moisture (g/100 g)	76.1	74.0	74.4
Ether-extractable fat (g/100 g)	0.9	4.6	4.3
Kilojoule volume (kJ/100 g)	391	517	508
Cholesterol (mg/100 g)	57	59	57
Fatty acids (% of total fatty acids)			
Saturated			
16:0	18.7	26.9	26.7
18:0	14.1	13.0	7.1
Monounsaturated			
16:1	4.1	6.3	7.2
18:1	30.8	42.0	39.8
Polyunsaturated			
18:2*w*6	17.9	2.0	13.5
18:3*w*3	6.3	1.3	0.7
20:4*w*6	5.6	1.0	2.79
20:5*w*3	1.5	<0.1	1.63

In South Africa, ostrich meat is classified into four main classes: (i) class fillet (demembraned); (ii) class steak (de-membraned); (iii) class A (very lean off-cuts); and (iv) class B (off-cuts containing visual connective tissue and some fat) (Fisher *et al.*, 2000). Meat quality is to a large extent influenced by the rate of pH decline in the muscles after slaughter and by the ultimate pH. A rapid fall in pH causes a decrease in water holding capacity (WHC), changes in colour and texture and sometimes increased toughness. A slow decrease in pH to a final value of above 6.0, results in a dark, firm, dry (DFD) meat with reduced bacteriological keeping quality (Tarrant & Mothershill, 1977). Ostrich muscles can be classified as DFD meat (pH > 6.2) (Sales & Mellett, 1996) of which the final pH is reached between 2 to 6 h after exsanguination (Botha *et al.*, 2006). The relative high ultimate pH value (6.0) of ostrich meat makes it an ideal processing meat since the natural water binding capacity is high; a good characteristic in the elaboration of cooked meat products (Fisher *et al.*, 2000; Sales & Mellett, 1996).

The colour of the meat is one of the major contributing components of appearance and is known to be the foremost selection criteria for fresh meat and meat products (Fletcher, 2002; Risvik, 1994). Consumers use colour as an indicator for meat freshness and favour red meat types with bright red colour above meat with a purple or brown colour (Carpenter *et al.*, 2001). The colour appearance of ostrich meat resembles that of raw liver because of its inherent dark colour, which may create a marketing problem. This dark colour may be anticipated, because of the high ultimate pH value and high pigment content of ostrich meat (30μg Fe/g meat) (Berge *et al.,* 1997; Paleari *et al.,* 1998).

Tenderness is the most important quality characteristic sought by the average meat consumer. Tenderness refers to the ease of shearing or softness and structural fineness of the meat before and after mastication (Sales & Horbanczuk, 1998). Warner-Bratzler shear force is the most commonly used instrument to determine the tenderness of meat (Voisey, 1976). Sales (1994) indicated that Warner-Bratzler shear force values of ostrich meat compare well with that of tender beef cuts, although the muscle type has a marked effect on tenderness (Cooper & Horbanczuk, 2002). Instrumental measurements and sensory analysis ranked *M. iliofibularis* as the most tender ($P<0.001$), *M. gastrocnemius* as the least tender ($P<0.001$), whereas *M. iliutibialis* showed an intermediate tenderness (Girolami *et al.,* 2003). Ostrich meat shear values were therefore indicative of a moderately tender meat. The report of Girolami *et al.* (2003) supported the work of earlier researchers (Mellett & Sales, 1996; Sales, 1994) that ostrich age (8, 10, 12, 14-months) has no effect on Warner-Bratzler shear force. However, Hoffman & Fisher (2001) compared 14-month old and 8-year old birds (*Struthio camelus* var*. domesticus)* and found that age did have an effect on Warner Bratzler shear force.

5.2 Current value added ostrich meat products on the market

Limited research has been conducted on the manufacturing of value added products made from ostrich meat. Though South Africa mainly export ostrich meat as fresh, it does produce a number of commercially available value added products of which most of these have been derived from transferring traditional technologies applied to the traditional red meat species to ostriches (Table 7).

Table 7 Processed ostrich products commercially available in South Africa (Klein Karoo, 2007)

Fresh Products	Value added products
Skinpack fillet	Bacon
Skinpack steak	Ham
Skinpack kebab	Wieners
Skinpack goulash	Russians
Skinpack sausage	Smoked fillet
Skinpack burger	French polony
Skinpack mince	

Ground ostrich meat (mince) is most probably the first and easiest value adding that can be performed and Walter *et al.* (2000) compared the use of ground ostrich meat to ground beef in stew and stir-fry and found that ground ostrich was an acceptable alternative to ground beef with the judges rating the former as moderately desirable. Although ostrich sausage is sold in South Africa, no sensory analysis of the product has yet been conducted, nor any comparisons made to sausage produced from the traditional red meat. Hoffman and Mellett (2003) evaluated the quality characteristics of low fat ostrich meat patties formulated with either pork lard or modified corn starch, soya isolate and water as a means to try and maintain as much of the “healthy” nutritional composition (Cooper & Horbaňczuk, 2002) of ostrich meat as possible. It was found that a trained sensory panel could not distinguish between the patties made with pork fat (with saturated fat) or the fat replacer (with favourable polyunsaturated fatty acid profile). The sensory panel could distinguish between the types of ostrich muscle/meat cuts, however, a significant number of judges indicated that patties made from the meat containing a higher collagen content (3% *ca* vs <1%) were more acceptable from a quality point of view. Fernández-López *et al.* (2006) investigated the quality characteristics and storage stability of three types of burgers prepared with ostrich meat (alone or mixed with pork or beef meat). The results from their study indicated that the manufacture of burgers from ostrich meat is a viable option, with burgers formulated with 100% ostrich meat or mixed beef and ostrich meat were most preferred. However, changes in fat and meat pigments occurred during storage that reduced the acceptability of the burgers. It was also found that the shelf life of the burgers was unacceptable and they recommend further investigation on the use of preservatives and antioxidants in order to enhance burger presentation.

Italian type salami was one of the first value added products made from ostrich meat that was reported in the scientific literature (Böhme *et al.,* 1996) and Dicks *et al* (2004), evaluated the use of bacteriocin producing starter culture *Lactobaillus plantarum* and *Lactobacillus curvatus* in ostrich meat salami and found that these inhibited *Listeria monocytogenes.*

In a study completed by Fisher *et al*, (2000), chopped hams and wieners were also produced from ostriches and found to be highly acceptable. Fernández-López *et al.* (2003) compared the production of Bologna sausage made from two ostrich muscles (*M. iliofibularis* and *M, femoraotibialis medius)* with that made from beef meat (*M. subscapularis)*. The authors found that although the final products made from ostrich meat had a darker appearance, they were comparable in terms of chemical composition and other sensory characteristics. Fernández-López *et al.* (2004) also developed ostrich liver pâté and results from this study indicated that the manufacture of pâtés from ostrich liver is a viable option as the product was acceptable based on its chemical composition and sensory scores. It is interesting to note that the authors recommend further studies on the use of antioxidants to control colour changes of the product.

The chemical composition of processed ostrich products (Table 8) suggests that these products can be formulated to compete successfully with similar types of products derived from other meat species. If the additional fat added to the ostrich products is selected for an advantageous fatty acid profile, ostrich products will also be able to compete with other healthy meat products.

CONCLUSIONS

With the low fat content of ostrich meat (Sales & Hayes, 1996) it can clearly perceived and marketed as an alternative to other red meats such as beef and lamb. The health characteristics of ostrich meat, presents itself as a healthy alternative in response to growing consumer demand for healthy meat. Before entering this market, it is of great value for the ostrich meat industry to investigate the viability of developing healthy value added ostrich meat products, with reformulation that reduces the harmful elements for human health, and to evaluate the physical chemical and sensory effect thereof.

Table 8 The chemical composition of various processed ostrich meat products sold in retail outlets in South Africa (Hoffman, 2005)

Chemical component	French Polony	Ham	Bacon	Smoked Russian	Smoked Vienna	Smoked Fillet
Dry mass (%)	29.31	32.32	26.60	33.91	36.41	26.90
Protein (%)	12.36	17.87	20.45	17.73	13.35	20.85
Fat (%)	6.93	1.75	1.92	10.78	14.85	2.28
Ash (%)	7.66	11.54	11.55	6.60	5.77	8.87
Cholesterol (mg/100 g)	36.60	32.90	50.70	39.50	43.70	51.00
Fatty acids (% of total fatty acids)						
C14:0	0.60	1.38	1.30	1.69	0.67	0.86
C16:0	25.79	21.97	27.65	27.30	24.31	19.84
C18:0	7.94	12.65	10.20	12.53	8.36	13.38
C20:0	0.11	0.12	0.20	0.22	0.21	0.15
C22:0	0.01	0.00	0.08	0.00	0.02	0.11
C24:0	0.01	0.00	0.35	0.00	0.02	0.11
SFA	34.46	36.11	39.78	41.74	33.59	34.44
C16:ln7	5.61	2.97	5.03	2.96	5.50	3.80
C18:ln9	37.60	46.65	28.95	44.61	43.04	32.22
C20:ln9	0.33	0.09	0.00	0.16	0.28	0.21
C24:ln9	0.04	0.00	0.00	0.00	0.27	0.19
MUFA	43.58	49.70	33.97	47.73	49.09	36.41
C18:2n6	15.91	8.20	14.78	7.94	12.92	17.99
C18:3n6	0.06	0.25	0.72	0.06	0.04	0.06
C18:3n3	4.47	1.98	2.90	1.63	3.36	2.28
C20:2n6	0.17	0.00	1.13	0.00	0.19	0.22
C20:3n6	0.08	0.19	0.20	0.00	0.11	0.55
C20:4n6	0.84	2.23	5.64	0.43	0.53	5.63
C20:3n3	0.06	0.12	0.20	0.00	0.00	0.00
C20:5n3	0.11	0.56	0.90	0.00	0.06	1.08
C22:2n6	0.00	0.00	0.00	0.00	0.00	0.00
C22:4n6	0.10	0.00	0.46	0.48	0.05	0.46
C22:5n3	0.14	0.37	0.42	0.00	0.06	0.43
C22:6n3	0.06	0.30	0.10	0.00	0.00	0.43
PUFA	22.00	14.18	26.25	10.53	17.32	29.15

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Chapter 3

Physical, chemical and sensory characteristics of ostrich polony manufactured with increasing levels of olive oil

ABSTRACT

The effect of increased olive oil levels in ostrich meat polony was investigated with regard to physical, chemical and sensory attributes, as well as consumer's acceptability. Treatments consisted of five levels of olive oil added to polony in 5% increments from 0% to 20%. The lean meat content was reduced accordingly to yield products with a constant total meat content of 75% (lean meat plus fat). Hardness, gumminess and shear force values decreased ($P \leq 0.05$) with increased levels of olive oil, whereas springiness and cohesiveness did not differ ($P > 0.05$). The L* and b* values decreased ($P \leq 0.05$) with increased levels of olive oil producing lighter and more yellow products. The P:S ratio of all the polony were above the recommended value of 0.45, whereas only the polony formulated with 0% and 5% olive oil were close to the recommended n-6:n-3 ratio value of <4.0. The effect of increased levels of olive oil on polony sensory characteristics including colour; processed meat aroma and flavour; ostrich aroma; olive oil aroma; firmness and juiciness, were also investigated. Colour scores decreased ($P \leq 0.05$) with increased levels of olive oil, implicating that increased olive oil produced a lighter (more yellow) product. A decrease ($P \leq 0.05$) in processed meat aroma flavour was found by the panel with increased levels of olive oil. The panel experienced a decrease ($P \leq 0.05$) in the ostrich meat aroma between polony formulated with 0.5 and 10% olive oil, whereas no ostrich meat aroma was detected in the polony formulated with 15 and 20% olive oil. The panel also found that olive oil had a significant effect ($P \leq 0.05$) on the texture of the product where increased levels of olive oil produced a softer (less firm) polony. Olive oil aroma and oily mouth feel was highly correlated with the percentage total fat ($r = 0.919$; $P = 0.027$ and $r = 0.921$; $P = 0.026$, respectively) in the product. Firmness, scored by the taste panel, was highly correlated with the instrumental values for hardness ($r = 0.962$; $P = 0.009$) and gumminess ($r = 0.969$; $P = 0.007$), as well as with instrumental shear force ($r = 0.976$; $P = 0.004$). A consumer panel found all the polony treatments acceptable, with a tendency for the samples with 10% olive oil to be the most likable. It is concluded that olive oil can be used successfully for the production of low fat ostrich meat polony.

Keywords: Ostrich meat, Polony, Reduced fat, Olive oil

INTRODUCTION

Polony, a type of bologna sausage, is a large smooth textured cooked sausage that usually contains beef, veal and pork. Polony is a meat emulsion formed from a coarse and viscous dispersion of water, fat and protein, which, during heating, is transformed into a protein gel filled with fat particles (Giese, 1992). Polony generally contains a high fat content of 20 to 30% (Colmenero, 2000). Fat plays an important role in the formation of a stable meat emulsion and influences the texture, juiciness and flavour of comminuted meat products (Crehan *et al.,* 2000). Although there have been suggestions that dietary fatty acids influence tenderness (texture) and juiciness of meat products, Wood *et al*. (2003) found that the total amount of fat, rather than specific fatty acids, is related to tenderness.

Pork back fat is commonly used for polony production and is rich in saturated fatty acids (SFA) and cholesterol (German & Dillard, 2004; Muguerza *et al.,* 2003). High SFA (>10% of total energy intake) and cholesterol (>300 mg per day) consumption (WHO, 2003) is linked to the development of major chronic diseases such as obesity (Lairon, 1997; Riccardi *et al.,* 2003; Vaskonen, 2003), cancer (Alothaimeen *et al.,* 2004; Menendez, *et al.,* 2005; Navarro *et al.,* 2003; Nkondjock *et al.,* 2003), and cardiovascular heart diseases (Campbell *et al.,* 1998; Kuller, 1997; Vaskonen, 2003; Weisburger, 1997). Therefore, health organisations all over the world promote the strategy that the intake of SFA and cholesterol should be limited in order to reduce the risk of major chronic diseases (WHO, 2003). This dietary health concern has led to a consumer demand for low or reduced fat products, prompting meat companies to develop a variety of low fat meat products using fat replacements. However, the use of fat replacements presents a number of difficulties in that fat has a considerable influence on the texture (Crehan *et al.,* 2000; Hughes *et al.,* 1998; Kähkönen & Tuorila, 1998; Lurueña-Martínez *et al.,* 2004; Muguerza *et al.,* 2002; Resurreccion, 2003; Severini *et al.,* 2003; Teye *et al.,* 2006; Yang *et al.,* 2007) of the product. There are numerous techniques to reduce the SFA and cholesterol content of meat products. The use of vegetable oils such as olive oil containing unsaturated fatty acids (UFA) to replace animal fats is one of these strategies (Akoh, 1998; Arihara, 2006; Colmenero, 2000; Colmenero *et al.,* 2001; Keeton, 1994; Muguerza *et al.,* 2002; Stark & Mader, 2002). Comminuted meat products containing olive oil can be beneficial to human health as olive oil is considered to have a high biological value, attributed to its high content of vitamin E and polyunsaturated fatty acids (PUFA), as well as its lower ratio of SFA to monounsaturated fatty acids (MUFA) (Viola, 1970). Furthermore, olive oil consumption has also been linked to reduced risk of heart disease and breast cancer (Trichopoulou *et al.,* 1995).

An increase in PUFA intake has become increasingly popular due to their health benefits. Plasma cholesterol levels are correlated to the fatty acid composition of the diet (Flynn *et al.,* 1985). In general, MUFA and PUFA do not result in increased cholesterol levels, but high levels of long-chain SFA do (Grundy & Denke, 1990). It has been reported that palmitic acid (C16:0) increases cholesterol levels, but stearic acid (C18:0) does not (Rowe *et al.,* 1999). The n-3 fatty

acids have been found to decrease serum triacylglycerol and cholesterol levels (Kim & Edsall, 1999). Guidelines for consumers suggest the reduction in intake of n-6 PUFA to n-3 PUFA, as well as the intake of short- and medium-chain SFA. As meat and meat products are a source of dietary fat, the lipid profile can be modified by enhancing the n-3 PUFA content. This will improve the nutritional quality of the occidental diet (Ansorena & Astiasaran, 2004).

The two main parameters currently used to assess nutritional quality of the lipid fraction of foods are the ratios between PUFA and SFA (P:S ratio) and between n-6 and n-3 fatty acids (n-6:n-3 PUFA ratio). Accordingly, to improve the health status of the population, nutritional authorities have recommended on regulating the consumption of foods rich in n-3 PUFA. A n-6:n-3 PUFA ratio of less than 4 is recommended, as well as a P:S ratio of more than 0.45 (Wood *et al.,* 2004).

Research has been done on the effect of olive oil replacement on the physical, chemical and sensory properties of emulsified meat products (Ansorena & Astiasaran, 2004; Bloukas *et al.,* 1997a,b; Kayaardi & Gök, 2003; Lurueña-Martinez *et al.,* 2004; Muguerza *et al.,* 2001, 2002; Pappa *et al.,* 2000; Severini *et al.,* 2003). However, no research was found that focused on the development of an emulsified ostrich meat product (polony), in which saturated animal fat was replaced with olive oil.

Ostrich meat is frequently marketed as a healthy alternative to other red meats as it has a favourable fatty acid profile and a low intramuscular fat content (Sales, 1994). The high ultimate pH of ostrich meat (< 6.2) (Botha *et al.,* 2007) makes it an ideal processing meat, since the natural water holding capacity is high (Fisher *et al.,* 2000).

In order to maintain the health characteristics of ostrich meat, it is suggested that saturated animal fat be replaced with plant oil in emulsified ostrich meat products. Therefore, the objective of this study was to investigate the effect of olive oil (five levels of olive oil in 5% increments from 0% to 20%) on the physical, chemical, and sensory properties of ostrich polony.

MATERIALS AND METHODS

Emulsified sausage manufacture

This experiment was preceded by a development phase of which the details are in Annexure 1. Five different polony treatments were produced (Table 1). Each treatment was formulated to contain 75% Total Meat Equivalent (TME) on chemical analysis (lean meat and fat; N x 30). The following ingredients were added per kilogram of meat mixture; 16 g sodium chloride, 3 g sodium tri-polyphosphate, 1 g ascorbic acid, 1 g monosodium glutamate, 2 g ground white pepper, 2 g garlic powder, 2 g paprika powder, 0.5 g nutmeg powder, 0.5 g coriander powder, 0.3 g ginger powder and 2 g nitrite salt (NaCl + 0.6% nitrite).

Class A (very lean off-cuts - Fisher *et al.,* 2000) ostrich meat (*Struthio camelus* var. *domesticus*), was obtained from a local European Union approved abattoir, Mosstrich (2 Mkuzi

Street Mossdustria, Mossel Bay, South Africa). All five treatments were produced from the same meat batch. The meat was vacuum packed and frozen before being transported to Stellenbosch, were it was stored at -20°C until used. A single batch of cold-pressed extra-virgin olive oil (Frontoia variety) from Tokara Olive Farm (Tokara Olive Shed, Helshoogte Pass, Stellenbosch, South Africa) was used. All the remaining ingredients were provided by a single provider, Deli Spices (25 Bertie Avenue, Epping 2, Cape Town, South Africa).

Thawed (24 h at 4°C) lean meat was chopped for three rounds in a bowl cutter (Sharfen, South Africa) at low speed. Curing ingredients, together with one third of the water in the form of ice, were added and the meat was chopped for 30 s at high speed ensuring that the temperature remained at 2-4°C. The seasoning and another third of the ice were added to the meat mixture, which was chopped at high speed until a temperature of 7-9°C was reached. Olive oil and the remaining ice were then added and mixed at a high speed until the batter reached a temperature of 12-14°C and a stable emulsion formed. Immediately after chopping, samples of approximately 125 g per treatment were taken from the raw batter for subsequent emulsion stability analysis. The remaining emulsion was vacuum stuffed (Multivac C200, Germany) into 12 cm diameter impermeable plastic casings to produce four replications of emulsified sausages per treatment of approximately 2 to 2.5 kg in weight, 30 cm in length and 12 cm in diameter. Products were cooked at 80°C in a water bath until an internal temperature of 72°C was reached. The internal temperature of the polony was measured using a thermocouple probe inserted into the centre of the product. After cooking, the sausages were immediately cooled on ice for 15 min before refrigerating at 4°C prior to subsequent analyses.

Table 1 Formulation of five ostrich polony treatments.

Ingredients (%)	**Treatments**				
	Low fat……..High fat				
	A	B	C	D	E
Olive oil	0	5	10	15	20
Lean meat	75	70	65	60	55
Water[a]	21.7	21.7	21.7	21.7	21.7
Additives	3.3	3.3	3.3	3.3	3.3
Total	100	100	100	100	100
TME *(lean + oil)	75	75	75	75	75

[a]Water was added in the form of ice

*Calculated (Total Meat Equivalent (TME) = % Lean Meat + % Total Fat)

Chemical analyses

Homogenised samples of the five polony treatments (of a randomly selected polony within each treatment) were analysed in duplicate for total percentage of moisture, protein and ash (AOAC, 2005). For protein content, dried and defatted samples were ground with a pestle in a mortar until a fine powder was obtained. Subsequently 0.1 mg of the powder was used per sample and inserted into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The protein concentration in the sample was determined as nitrogen x 6.25. The moisture content was analysed by drying 2.5 g sample at 100ºC for a period of 24 h and ashing was done at 500ºC for a period of 6 h. The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform:methanol (Lee *et al.,* 1996). The pH of refrigerated (4ºC) cooked polony treatments were measured with the use of a calibrated (standard buffers pH 4.0 and 7.0) portable Testo 502 pH-meter. According to South African legislation (Foodstuffs, Cosmetics and Disinfectant Act and Regulations, 1974), manufactured meat products are required to contain 75% TME on chemical analysis. TME is calculated as follows:

TME = % Lean Meat + % Total Fat *where* % Lean Meat = % N x 30 *and* % Total Fat = Solvent extractable fat

Physical analyses

Emulsion stability, cooking loss, colour (CIE L*, a* and b* colour coordinates), Warner-Bratzler (WB) shear force and Texture Profile Analysis (TPA) measurements were recorded on each of the four replicates within each polony treatment. Emulsion stability was determined according to the method described by Hughes *et al* (1997). Approximately 25 g (exact weight recorded) of raw emulsion was placed in a centrifuge tube with a 2 cm diameter (five replications per treatment) and centrifuged at 3600 *g* for 1 min. The samples were then heated in a water bath for 30 min at a temperature of 70ºC and then centrifuged for 3 min at 3600 *g*. The pelleted samples were removed and weighed and the supernatants poured in pre-weighed crucibles, dried overnight at 100ºC, and re-weighed. The volumes of total expressible fluid (TEF) and the percentage fat therein were calculated as follows:

TEF = (weight of centrifuge tube and sample) – (weight of centrifuge tube and pellet) *where* % TEF = TEF/sample weight x 100 *and* % Fat in TEF = [(weight of crucible + dried supernatant) – (weight of empty crucible)]/TEF x 100

Cooking loss percentages were determined by calculating the weight difference of a polony before and after cooking, using the following equation:

% Cooking loss = (W1 – W2)/W1 x 100 *where* W1 = polony weight before cooking *and* W2 = polony weight after cooking.

Instrumental colour measurements of cooked polony were recorded on three slices obtained from each of the four replicates per treatment, according to the method described by Honikel (1998). A colour-guide 45º/Oº colorimeter (Cat no: 6805; BYK-Gardner, USA) was used. The three polony slices (1.5 to 2.0 cm thick) of each treatment were allowed to "bloom" for 30 min at room temperature (18 to19ºC) prior to colour measurements. Four colour measurements were recorded for each slice at randomly selected positions and expressed by the coordinated L*, a* and b* of the CIELab colorimetric space (MINOLTA, 1998). In the colour space L* indicates lightness and a* and b* are the chromaticity coordinates, where a* is the red-green range, and b* the yellow-blue range of the colour spectrum.

Textural properties were analysed using the Instron Universal Testing Machine (UTM) (Instron 3344) (Bourne, 1978). Texture Profile Analysis (TPA) was performed on five cores (2.5 cm height and 2 cm diameter) per slice (two slices of each of the four replicates within the five treatments = 40 measurements per treatment). The cores were placed on the platform of the UTM. A circular plate of 2.5 cm diameter was attached to a 500 N load cell and the sample was compressed to 50% of its original height at a cross head speed of 200 mm/min twice in two cycles as described by Desmond and Troy (2001). Hardness (N), springiness (mm), cohesiveness (ratio) and gumminess (N) (Bourne, 1978) were calculated for each sample.

Shear force was also measured using a V-shaped Warner-Bratzler blade attached to the same UTM machine. The same sample numbers were used as described in TPA analysis. Each core (1.27 cm diameter) was radially sheared at a crosshead speed of 200 mm/min. Shear force (N) was determined as the maximum force required to move the blade through the sample.

Fatty acid composition analysis

Fatty acid methyl esters (FAME) were prepared from the extracted total lipids (Lee *et al.,* 1996) according to the procedures published by Morrison and Smith (1964). The FAME were analysed with a gas-liquid chromatograph (Varian Model 3300), equipped with flame ionisation detection and two 30 mm fused silica megabore DB-225 columns of 0.53 mm internal diameter (J&E Scientific, Folsom, CA). Gas flow rates were: hydrogen 25 ml/min and nitrogen (carrier gas) 5-8 ml/min. The temperature program was linear at 4ºC/min with initial and final temperatures of 160°C and 220°C (held for 10 min), respectively. The injector temperature was 240°C and the detector temperature 250°C. FAME were identified by comparison of the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

Sensory analysis

The purpose of the sensory analysis was to determine the effect of fat reduction on the sensory quality characteristics and to ascertain the overall degree of liking of the ostrich polony treatments. All encased polony (stored at 4ºC) were opened, sliced into 3.5 mm thick slices and vacuum packed (Multivac C200, Germany) 2 h prior to their pre-assigned sensory analysis dates. Five slices were placed next to each other and the slices did not overlap when vacuum packed.

Descriptive sensory analysis was performed to ascertain the sensory quality characteristics. The panel was chosen based on their experience in sensory analysis and on their availability. Panellists were trained in accordance with the generic descriptive analysis techniques as described by Lawless and Heymann (1998). An eight member panel was trained in two interactive sessions to familiarise the panellists with the treatments and to identify the sensory characteristics to be evaluated. A questionnaire was compiled during the first training session. The questionnaire was refined and tested during the second training session. An unstructured line scale ranging from 0-100 mm was used to analyse the sensory characteristics (Annexure 2). Table 2 depicts the characteristics and definitions used. The sensory tests were performed in individual booths in a temperature (21ºC) and light controlled (equivalent to daylight) room. One sample of each of the five treatments was served to the panellists in a randomised order in five sessions. Distilled water, apple and crackers were given to the panellists in between treatments. Each sample was coded with randomly selected three digit numbers and served at a refrigeration temperature of 6-10ºC.

For the determination of degree of liking, a hundred consumers (59 female, 41 male) were recruited among staff and students at the University of Stellenbosch, South Africa. The consumers tested the polony, without any knowledge as to the formulation of the products. Each panellist received one sample of each treatment, coded with three-digit codes, in a random order. Testing was done individually in a temperature (21ºC) and light controlled (equivalent to daylight) room. The traditional nine-point hedonic scale ranging from 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; to 9, like extremely, was used. The latter instrument is used to test preference and acceptability. Panellists were asked to assign an order to the samples in accordance to overall preferences and acceptability and in this study, treatments were considered acceptable if 50% or more of the responses were between 6 to 9 on the hedonic scale (Annexure 3).

Statistical analysis

A complete randomised design with five treatments and different numbers of replicates for different measurements, were performed. A one-way analysis of variance (ANOVA) was performed on all the data using SAS version 9.1 statistical software (SAS, 1999). The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). In some cases deviations from normality were the cause of one or two outliners, which were removed before the final analysis (Glass *et al.,* 1972). Student's t-Least Significant Difference (LSD) was calculated at a 5%

significant level to compare treatment means. Pearson correlation coefficients were calculated between objective and descriptive sensory variables. For the consumer data, scores were subjected to one-way (Treatments) and two-way (Treatments x Gender) ANOVA. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at a 5% significant level to compare treatment means. Also, a RxC contingency table (Rows = Treatments; Columns = Degree of liking) of frequency was set up and tested for association using Chi square.

Table 2 Verbal definitions of sensory characteristics used in the descriptive sensory analysis of ostrich polony.

Characteristic	Definition	Scale
Colour	Presence of yellow/pink colour	0 = Light 100 = Dark
Processed meat aroma	The intensity of a processed meat aroma, perceived by sniffing	0 = None 100 = Strong
Ostrich meat aroma	The intensity of an ostrich meat aroma, perceived by sniffing	0 = None 100 = Strong
Olive oil aroma	The presence of an olive oil aroma perceived by sniffing	0 = None 100 = Strong
Processed meat flavour	The intensity of a processed meat flavour, perceived by tasting	0 = None 100 = Strong
Oily mouth feel	The presence of an oily layer on the palate	0 = None 100 = Prominent
Firmness	The degree of force required to bite the sample	0 = Soft 100 = Firm
Juiciness	The degree of juice released while chewing the sample	0 = Dry 100 = Juicy

RESULTS AND DISCUSSION

Descriptive characteristics

The chemical composition, total meat equivalent (TME), product pH, cooking loss, emulsion stability, instrumental texture properties and colour measurements of the five polony treatments with increased levels of olive oil are presented in Table 3.

Table 3 Means (± SD) of the physical characteristics of polony treatments*.

	Olive oil level					LSD
	0%	5%	10%	15%	20%	
Chemical Composition						
Moisture (%)	76.3^{a} ± 0.0	73.2^{b} ± 0.1	69.7^{c} ± 0.1	66.2^{d} ± 0.0	62.5^{e} ± 0.1	0.29
Fat (%)	3.9^{e} ± 0.0	9.1^{d} ± 1.2	12.7^{c} ± 0.7	17.6^{b} ± 0.6	23.5^{a} ± 1.5	2.51
Protein (%)	18.2^{a} ± 0.0	15.3^{b} ± 0.0	15.1^{b} ± 0.1	13.3^{bc} ± 0.5	11.2^{c} ± 0.8	2.20
Ash (%)	3.1^{ab} ± 0.0	3.1^{a} ± 0.2	3.0^{ab} ± 0.3	2.8^{ab} ± 0.0	2.6^{b} ± 0.2	0.53
TME (calculated)¤	91.5	82.9	85.2	81.8	77.2	n/a
Product pH	5.9	6.0	6.1	6.0	6.1	n/a
Cooking loss (%)	0.9	0.9	0.9	0.9	0.8	n/a
Emulsion stability						
TEF (%)	n/a	15.0^{a} ± 1.3	13.1^{b} ± 1.3	15.3^{a} ± 1.6	16.0^{a} ± 1.2	1.89
Fat in TEF (%)	n/a	7.0^{c} ± 0.9	7.4^{cb} ± 0.1	8.3^{b} ± 0.3	13.4^{a} ± 1.2	1.10
Textural properties						
Hardness (N)	31.8^{a} ± 5.2	24.8^{b} ± 2.6	20.3^{c} ± 3.0	14.0^{d} ± 2.5	11.5^{d} ± 1.8	2.94
Cohesiveness (ratio)	0.6^{a} ± 0.2	0.6^{a} ± 0.0	0.6^{a} ± 0.0	0.6^{a} ± 0.0	0.6^{a} ± 0.0	0.03
Gumminess (N)	21.2^{a} ± 4.1	16.8^{b} ± 1.6	14.0^{c} ± 3.1	9.3^{d} ± 1.8	7.7^{d} ± 1.3	2.38
Springiness (mm)	6.9^{b} ± 0.5	6.9^{b} ± 0.5	7.5^{a} ± 0.6	6.9^{b} ± 0.3	6.7^{b} ± 0.3	0.45
Shear force value (N)	11.9^{a} ± 0.5	10.8^{b} ± 0.7	9.8^{c} ± 0.2	8.9^{d} ± 0.2	7.9^{e} ± 0.1	0.41
Instrumental colour						
Lightness (L*)	52.1^{e} ± 1.3	53.2^{d} ± 0.9	56.9^{c} ± 0.8	59.3^{b} ± 0.8	61.8^{a} ± 0.8	0.81
Redness (a*)	9.9^{a} ± 0.5	9.6^{b} ± 0.3	9.5^{c} ± 0.2	9.4^{d} ± 0.2	9.1^{e} ± 0.2	0.29
Yellowness (b*)	18.8^{e} ± 0.6	19.9^{d} ± 0.3	20.7^{c} ± 0.7	21.5^{b} ± 0.4	22.8^{a} ± 0.3	0.45

*Statistical analyses were performed on all data with the exception of TME, cooking loss and pH, as these were only calculated or measured once per treatment

SD - Standard Deviation

LSD = Least Significant Difference (P=0.05)

¤TME = % Lean Meat + % Total Fat

$^{a-e}$Means within the same row with different superscripts differ significantly (P≤0.05)

Chemical composition

The moisture content of the polony decreased significantly (*P*≤0.05*)* as the levels of lean meat decreased (Table 3). This is due to the high moisture content of lean meat versus the low moisture content of olive oil used to replace the lean meat in the formulations. As expected, the fat content of the polony increased (*P*≤0.05*)* with increasing olive oil levels. Polony formulated with 20% olive oil had the highest fat content of 23.5% and the lowest moisture content of 62.5%. This is a high total fat content compared to similar emulsion products. The fat content of bolognas, formulated with pork meat and back fat, ranged between 10-22% (Carballo *et al.,* 1995; Colmenero, 1995) whilst low fat bolognas formulated with fat replacers, i.e. konjac flour, carrageenan and starch, had a total fat content of 1.0-1.5% (Chin *et al.,* 1999). The protein content in the present investigation was proportionally inverse to the total fat content. A maximum water to protein ratio of 3.9 (N x 6.25) is generally acceptable in emulsion meat products (Lawrie, 1991). The polony in this study presented a water:protein ratio ranging between 4.1 and 5.5. This higher water:protein ratio can be ascribed to the loss of moisture during thawing of the meat before processing commenced (24 h, 4ºC). The result of this moisture loss resulted in a higher concentration of protein (N x 6.25) in the meat. Unfortunately this moisture loss was not measured. The ash content decreased with increasing olive oil, most probably due to the decreasing lean meat content.

Total Meat Equivalent (TME)

In this study, the TME values of the five polony treatments are higher than 75% (ranging between 77.2 to 91.5%), and therefore exceed the legal requirements (Table 3). This phenomenon is not in line with the expected results and warrants further explanation. A graphical illustration of the change in the composition of the polony is presented in Figure 1. Moisture and protein content decreased proportionally with the increased fat (olive oil) content. The decrease in moisture may have been due to either a loss of water from the emulsion during the cooking or less total moisture being present. As noted in Table 3, there was very little weight loss during the cooking of the polony and when the casing was removed, all the water was bound into the emulsion. This leads to the speculation that the second explanation may be the cause. Moisture in the product was composed of (i) moisture in the meat and (ii) water added at a constant volume to the emulsion mixture. Taking this into account, it seems that the decrease in moisture content of the polony was attributed to a decrease of the moisture in the meat, possibly caused by the high level of drip noted during the thawing of the samples. The high TME values may therefore be attributed to the increased protein concentration (N x 6.25) in the lean meat (Table 1). As expected, the TME values decreased with the addition of olive oil.

Cooking loss

Increased olive oil levels had no effect (*P*≤0.05) on the cooking loss of polony since impermeable casings were used. However, these results contradict that of Kayaardi and Gök (2003) who noted

that incorporating olive oil in the meat mixture of Turkish soudjouk had an effect ($P \leq 0.05$) on cooking loss. Bloukas *et al.* (1997a) reported that an increase in cooking loss is dependant on the amount of water used to emulsify the protein – in the present investigation the amount of water used was sufficient to cause all the water to be bound within the emulsion.

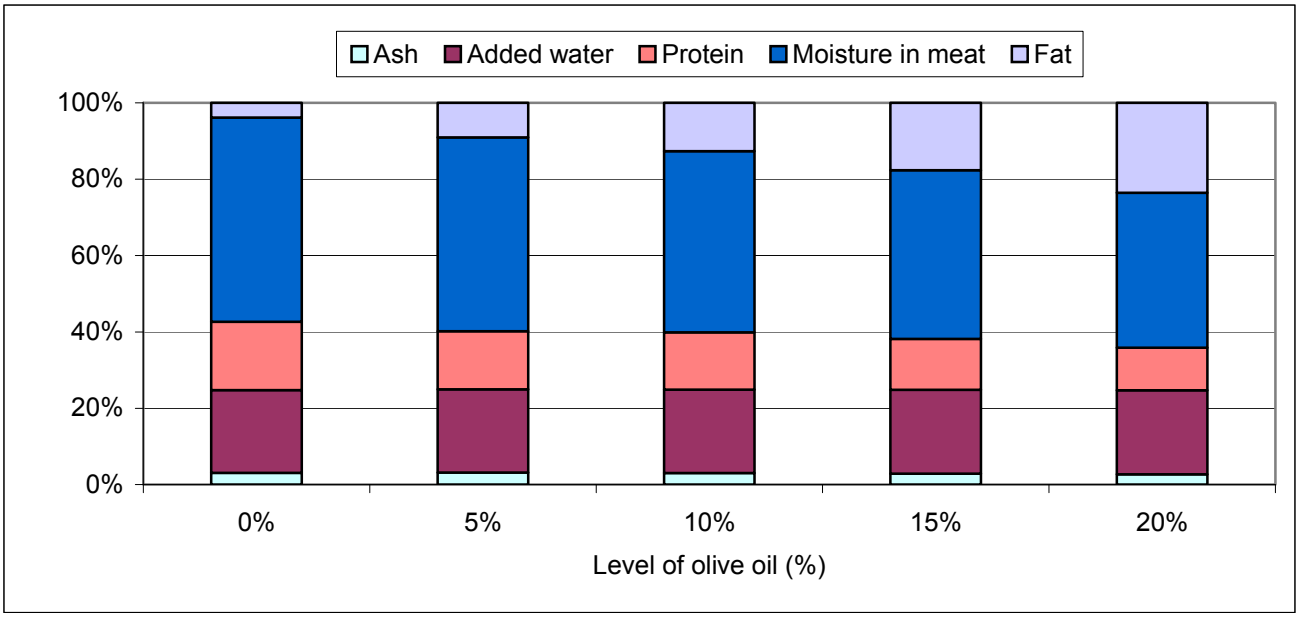

Figure 1 Proportional changes in ash, lean meat (water and protein) and fat of polony manufactured with increasing olive oil.

Emulsion stability

The polony formulated with 10% olive oil had the lowest ($P \leq 0.05$) percentage of expressible fluid (% TEF). This may be due to an optimum fat, moisture and protein relation for the formulation of a stable emulsion. The percentage of fat in the TEF increased with the addition of olive oil indicating that these high levels of fat were not emulsified sufficiently by the protein to form a stable emulsion. Though Hughes *et al.* (1998) and Crehan *et al.* (2000) found a correlation between % TEF and cooking loss, the results of the present investigation seems to agree with Lurueuña-Martinez *et al.* (2004) who found no relationship between % TEF and cooking loss. In the present investigation, the difference between cooking loss and emulsion stability (% TEF) may be the result of the slow and extended heat treatment during the cooking process of the polony. In both cases the temperature used was similar (72ºC versus 70ºC) but for the polony, the target temperature was attained after 2 h (cooked in a waterbath to an internal temperature of 72ºC) before cooling. In the second case (determination of % TEF), a small quantity (5 g) of batter was heated at 70ºC for 30 min, reaching the temperature very quickly and thus improving the formation and strength of the gel. An alternative strategy, applied by Hughes *et al* (1997) in order to reduce cooking loss and to increase emulsion stability, was to introduce fat replacers such as carrageenan and oat bran in the

formulation. In the current study cooking losses were insignificantly small and it was therefore not necessary to manipulate the emulsion stability.

Instrumental textural properties

The addition of olive oil caused a decrease ($P \leq 0.05$) in hardness, gumminess and shear force of the polony, which may be due to the lipid composition of the polony as monounsaturated fat has a lower hardness at room temperature. These results are in agreement with that of Lurueuña-Martinez *et al.* (2004), Muguerza *et al.* (2001) and Bloukas *et al.* (1997a), who studied the effect of olive oil on the textural properties of sausages. No changes ($P > 0.05$) were observed in cohesiveness and springiness of the polony. As pertaining to the handling of the product during display in a supermarket, these results indicate that even though more "oil" is added, the product will retain its shape.

Instrumental colour

The lightness in meat and meat products depend on several factors such as water holding capacity, fat and collagen content, free water and the degree of mincing (Fernández-Lopez *et al.,* 2003). The lightness (L* value) of the samples was in the range of 52.1 to 61.8, the redness (a* value*)* was between 9.1 and 9.9 and yellowness (b* values) ranged between 18.8 and 22.8. The level of olive oil in polony had an influence ($P \leq 0.05$) on the L*, a* and b* values of the product. Olive oil has a yellow appearance and thus induced an increase in the paleness and level of yellow in the polony. Similarly, Bloukas *et al.* (1997b) determined that the colour of a product in which animal fat was replaced with olive oil, was lighter and more yellow. Ostrich meat is known to have a darker colour than other red meat types (Hoffman & Fisher, 2001; Morriss *et al.,* 1995). Though not measured, it was observed that storage of the polony under lighting conditions (exposure of polony to light) between manufacture and consumption led to browning (decrease in redness) of the product. In this respect, Fernández-Ginéz (2003) reported that the light has a pro-oxidant effect that provokes a decrease in a* value due to oxidation and degradation of the nitroso-pigment. Furthermore, the degree of ingredient homogenisation may be responsible for the rapid decrease in redness, since more fat was exposed to oxidation conditions (oxygen and/or light). The same phenomenon was found by Fernández-Lopez *et al.* (2004) in the production of ostrich liver paté. In trying to inhibit these reactions, the latter authors included ascorbic acid at a high level, but this had no effect. This rapid oxidation warrants further investigation.

Fatty acid composition

The fatty acid profiles (% of total fatty acids) of five ostrich polony treatments with 0, 5, 10, 15 and 20% olive oil levels are depicted in Table 4. Olive oil has an unique fatty acid profile compared to other vegetable oils, containing mainly oleic (C18:1n-9), linoleic (C18:2n-6), palmitic (C16:0) and

stearic (C18:0) acids (Ryan *et al.,* 1998). In this investigation the most abundant fatty acids in the olive oil (Table 4) were oleic (52%), palmitic (18.59%), linoleic (17.6%) and stearic (5.26%) acid.

Ostrich meat is also known for its favourable fatty acid profile (intramuscular ostrich fat contains 16.50% polyunsaturated n-3 fatty acids) as well as for its low intramuscular fat content (Sales, 1998; Sales *et al.,* 1996). The fatty acid profile of the polony formulated with 0% olive oil (75% ostrich meat) is similar to that reported previously for ostrich meat (Horbanczuk *et al*., 1998; Sales, 1998; Sales *et al.,* 1996; Hoffman & Fisher, 2001), with oleic acid being present in the highest concentration (28.44%), followed by palmitic acid (28.44%) and then linoleic acid (12.74%) (Table 4). As expected, due to the high contribution of olive oil to the total lipid content in the sample with 20% olive oil, the fatty acid profile of the polony is similar to that of olive oil. The oleic and linolenic acid content increased (28.44 to 55.62 and 12.74 to 16.74, respectively), whereas palmitic and stearic acids, decreased with increased levels of olive oil (22.14 to 15.84 and 10.90 to 4.25, respectively).

To assess the possible nutritional impact of the polony, the P:S ratio, the PUFA n-6:n-3 ratio and the desirable fatty acids (DFA), were determined (Table 4). To improve the health status of a population, a n-6:n-3 PUFA ratio of less than 4 and a P:S ratio of more than 0.45 is recommended (Wood *et al.,* 2004; Simopoulos, 2004). In the present study the polony showed an increase in both the P:S (0.58 to 0.91) and n-6:n-3 (1.71 to 6.47) ratio with an increase in olive oil levels. The P:S ratio of all the treatments are above the recommended value of more than 0.45. The polony formulated with 0 and 5% olive oil are close to the recommended n-6:n-3 value of less than 4.0 (1.71 and 4.50, respectively), whereas the polony with 10, 15 and 20% olive oil had a ratio higher than what is recommended. Therefore, the ostrich polony formulated with 5% olive oil proves to be the most desirable in terms of fatty acid composition since it complies to the recommended values of both P:S and n-6:n-3 ratios.

Table 4 Fatty acid composition (%) of polony manufactured with increasing olive oil levels.

Fatty acids (%)	Olive oil	Olive oil level				
		0%	5%	10%	15%	20%
Saturated Fatty Acids						
6:0	0.02	0.18	0.28	0.02	0.01	0.03
8:0	0.08	0.06	0.05	0.05	0.06	0.04
10:0	0.02	0.05	0.06	0.03	0.05	0.02
11:0	0.12	0.46	n/d	0.13	0.16	0.14
12:0	0.06	0.20	0.10	0.07	0.07	0.07
13:0	0.07	0.31	0.13	0.09	0.10	0.09
14:0	0.26	0.86	0.36	0.24	0.23	0.21
15:0	0.05	0.43	0.19	0.14	0.16	0.14
16:0	18.59	22.14	17.15	19.13	17.51	15.84
18:0	5.26	10.90	5.55	5.21	4.64	4.25
20:0	0.71	0.14	0.41	0.52	0.47	0.51
22:0	0.08	0.60	0.30	0.02	0.04	0.25
24:0	0.19	0.11	0.15	0.14	0.17	0.14
24:0	0.20	4.89	0.52	0.01	0.20	0.51
Mono-unsaturated Fatty Acids						
14:1	0.01	n/d	0.02	0.02	0.01	0.01
15:1	0.01	0.32	0.01	0.01	0.01	n/d
16:1	1.87	4.68	1.95	1.73	1.49	1.23
18:1 n-9	52.00	28.44	54.94	52.30	54.56	55.62
20:1	0.10	0.26	0.37	0.44	0.44	0.48
22:1 n-9	0.02	0.77	0.03	0.07	0.15	0.04
24:1	0.05	0.20	0.05	0.05	0.03	0.04
Poly-unsaturated Fatty Acids						
18:2 n-6	17.60	12.74	13.00	15.63	15.95	16.74
18:3 n-6	0.02	0.07	0.03	0.01	0.01	0.02
18:3 n-3	2.37	6.78	2.40	2.48	2.09	2.23
20:2	0.04	0.32	0.12	0.12	0.17	0.08
20:3 n-6	0.06	0.08	0.04	0.04	0.03	0.02
20:3 n-3	0.03	0.23	0.10	0.10	0.09	0.06
20:4 n-6	0.03	2.02	1.00	0.73	0.74	0.75
20:5 n-3	0.03	0.49	0.18	0.21	0.17	0.17
22:2	0.01	0.05	0.03	0.04	0.03	0.03
22:5 n-3	0.01	0.45	0.22	0.21	0.14	0.18
22:6 n-3	0.03	0.75	0.22	0.04	0.05	0.07
Total	100.00	100.00	100.00	100.00	100.00	100.00
Total Fatty Acid profile						
∑SFA	32.51	9.62	14.24	17.39	17.79	17.79
∑MUFA	62.33	8.03	32.11	36.35	41.73	45.46
∑PUFA	25.59	5.57	9.77	13.20	14.48	16.25
∑TUFA	87.91	13.61	41.88	49.56	56.21	61.71
DFA	94.56	16.15	45.02	53.07	59.67	65.11
P:S	0.79	0.58	0.69	0.76	0.81	0.91
n-6	22.39	3.46	7.92	11.05	12.44	14.01
n-3	3.12	2.03	1.76	2.05	1.89	2.16
n-6:n-3	7.17	1.71	4.50	5.38	6.59	6.47

SFA = Saturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids; TUFA = Total Unsaturated Fatty Acids; DFA = Desirable fatty acids (C18:0 + TUFA); n/d = not detected

Sensory characteristics

The sensory profiling results for colour, aroma, flavour and mouth feel are presented in Table 5 and Figure 2. Correlations between objective and sensory measurements relevant to this study are depicted in Table 6.

Differences ($P \leq 0.05$) in the colour of the samples were found with increased levels of olive oil (Table 5). Colour scores decreased ($P \leq 0.05$) with increased levels of olive oil, implicating that increased olive oil produced a lighter (more yellow) product. Colour, scored by the taste panel, correlated with the L* (r = -0.994; P = 0.001) and b* (r = -0.986; P = 0.002) values of the instrumental colour measurements. A lower correlation (r = 0.856; P = 0.064) was found between the instrumental *a** values and the scores of the taste panel (Table 6). These findings illustrate a relationship with the negative correlation (r = -0.990; P = 0.001) that exists between colour as scored by the taste panel and the total percentage fat content of the product (Table 6).

A decrease ($P \leq 0.05$) in processed meat aroma and processed meat flavour, ranging from 76.7 to 28.2 and 72.0 to 30.0 respectively, was found by the panel with increased levels of olive oil. This suggests that increasing levels of olive oil produced a less artificial aroma and flavour in the polony. These findings were validated in that the processed meat aroma and processed meat flavour were negatively correlated (r = -0.981; P = 0.003 and r = -0.977; P = 0.004, respectively) with the percentage total fat, and positively correlated (r = 0.946; P = 0.014 and r = 0.938; P = 0.019, respectively) with the percentage protein in the product (Table 6).

The panel experienced a decrease ($P \leq 0.05$) in the ostrich meat aroma between polony formulated with 0.5 and 10% olive oil, whereas no ostrich meat aroma was detected in the polony formulated with 15 and 20% olive oil (Table 5). From this it seems that the inclusion of 15 and 20% olive oil concealed the ostrich meat aroma. These findings were endorsed in that the ostrich meat aroma was negatively correlated (r = -0.908, P = 0.033) with the percentage total fat, and positively correlated (r = 0.870; P = 0.054) with the percentage protein in the product (Table 6).

Olive oil aroma and an oily mouth feel for the polony formulated with 0, 5 and 10% olive oil was very low and did not differ, though the polony formulated with 15 and 20% olive oil showed higher ($P \leq 0.05$) values. It is to be noted that the panel used the lower part of the scale (lower than 50), indicating that the inclusion of 15 and 20% olive oil in ostrich polony did not produce an overwhelming olive oil aroma or a prominent oily mouth feel. As expected, olive oil aroma and oily mouth feel was highly correlated with the percentage total fat (r = 0.919; P = 0.027 and r = 0.921; P = 0.026, respectively) in the product (Table 6).

Firmness differed ($P \leq 0.05$) between the five polony samples (Table 5). Olive oil had a significant effect ($P \leq 0.05$) on the texture of the product where increased levels of olive oil produced a softer (less firm) polony. These findings were verified by the results obtained from the instrumental analyses, i.e. TPA and Warner-Bratzler shear force analyses (Table 3). Firmness, scored by the taste panel, was highly correlated with the instrumental values for hardness (r = 0.962; P = 0.009) and gumminess (r = 0.969; P = 0.007), as measured by TPA with the Instron

UTM (Instron 3344) (Table 6). Firmness was also highly correlated (r = 0.976; *P* = 0.004) with the instrumental shear force values (Table 6).

The five treatments differed (*P*≤0.05*)* with regard to juiciness, as perceived during mastication. It seems that this may be due to the increased levels of olive oil as there is a high correlation (r = 0.987; *P* = 002*)* between juiciness scored by the trained panel and the percentage total fat in the product. However, juiciness showed a highly negative correlation (r = -0.995; *P* = 0.001) with the total percentage of moisture in the product. Therefore, it would seem as if the olive oil, and not the moisture contributed towards the juiciness perceived by the trained panel.

The other observed correlations in Table 6 can all be ascribed to the fat content of the product, i.e. the L* value showing a highly significant positive correlation with juiciness. This is due to the phenomenon that increased fat contents increase L* values and juiciness (Table 3 and 6).

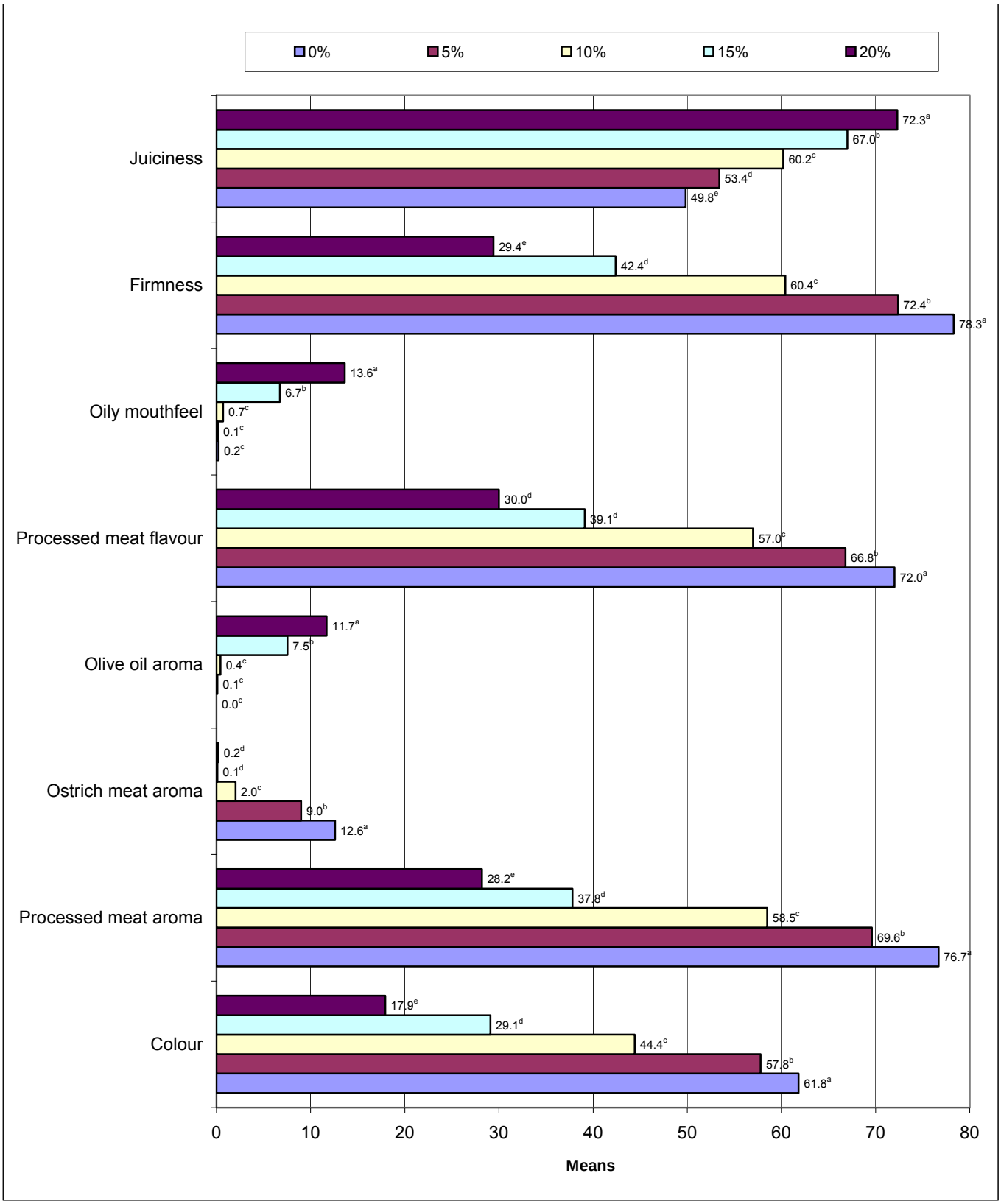

Figure 2 Means for the sensory analysis of ostrich polony manufactured with increasing levels of olive oil.

Table 5 Means (± SD) for the sensory analysis of ostrich polony manufactured with increasing levels of olive oil.

Characteristic	Scale	Olive oil level					LSD
		0%	5%	10%	15%	20%	
Colour	0 = Light 100 = Dark	61.8^{a} ± 13.8	57.8^{b} ± 15.2	44.4^{c} ± 14.3	29.1^{d} ± 14.5	17.9^{e} ± 7.8	3.67
Processed meat aroma	0 = None 100 = Strong	76.7^{a} ± 11.8	69.6^{b} ± 10.1	58.5^{c} ± 11.0	37.8^{d} ± 8.8	28.2^{e} ± 11.7	2.67
Ostrich meat aroma	0 = None 100 = Strong	12.6^{a} ± 6.8	9.0^{b} ± 6.1	2.0^{c} ± 4.7	0.1^{d} ± 0.4	0.2^{d} ± 0.6	2.33
Olive oil aroma	0 = None 100 = Strong	0.0^{c} ± 0.2	0.1^{c} ± 0.2	0.4^{c} ± 1.3	7.5^{b} ± 5.1	11.7^{a} ± 5.4	1.54
Processed meat flavour	0 = None 100 = Strong	72.0^{a} ± 15.7	66.8^{b} ± 10.6	57.0^{c} ± 13.0	39.1^{d} ± 11.2	30.0^{d} ± 10.3	3.15
Oily mouth feel	0 = None 100 = Prominent	0.2^{c} ± 0.6	0.1^{c} ± 0.4	0.7^{c} ± 2.9	6.7^{b} ± 4.4	13.6^{a} ± 5.2	1.24
Firmness	0 = Soft 100 = Firm	78.3^{a} ± 12.8	72.4^{b} ± 8.1	60.4^{c} ± 11.1	42.4^{d} ± 9.3	29.4^{e} ± 10.8	2.95
Juiciness	0 = Dry 100 = Juicy	49.8^{e} ± 14.8	53.4^{d} ± 15.1	60.2^{c} ± 14.1	67.0^{b} ± 15.6	72.3^{a} ± 17.7	3.17

$^{a-e}$Means within the same row with different superscripts differ significantly ($P \leq 0.05$)

SD - Standard Deviation

LSD - Least Significant Difference ($P=0.05$)

Table 6 Correlations between sensory and objective measurements of ostrich polony manufactured with increasing levels of olive oil.

	Colour		Processed meat aroma		Metal aroma		Olive oil aroma		Processed meat flavour		Oily mouth feel		Firmness		Juiciness	
	r	***P***	**r**	***P***	**r**	***P***	**r**	***P***	**r**	***P***	**r**	***P***	**r**	***P***	**r**	***P***
L*	-0.994	0.001	-0.987	0.002	-0.938	0.018	0.909	0.032	-0.984	0.003	0.907	0.034	-0.990	0.001	0.998	0.000
a*	0.856	0.064	0.843	0.072	0.805	0.100	-0.782	0.118	0.853	0.066	-0.795	0.108	0.860	0.062	-0.869	0.056
b*	-0.986	0.002	-0.972	0.005	-0.910	0.032	0.904	0.035	-0.967	0.007	0.913	0.030	-0.975	0.005	0.982	0.003
Total fat (%)	-0.990	0.001	-0.981	0.003	-0.908	0.033	0.919	0.027	-0.977	0.004	0.921	0.026	-0.982	0.003	0.987	0.002
Protein (%)	0.956	0.011	0.946	0.014	0.870	0.054	-0.887	0.045	0.938	0.019	-0.891	0.043	0.944	0.016	-0.947	0.015
Moisture (%)	0.995	0.000	0.988	0.002	0.928	0.023	-0.915	0.029	0.983	0.003	-0.913	0.030	0.988	0.002	-0.995	0.001
Hardness (N)	0.969	0.006	0.970	0.006	0.955	0.011	-0.867	0.057	0.957	0.011	-0.846	0.071	0.962	0.009	-0.974	0.005
Gumminess (N)	0.975	0.005	0.977	0.004	0.947	0.014	-0.884	0.047	0.966	0.008	-0.860	0.061	0.969	0.007	-0.978	0.004
Cohesiveness	0.286	0.640	0.332	0.585	-0.005	0.994	-0.531	0.357	0.370	0.540	-0.467	0.428	0.340	0.576	-0.276	0.653
Springiness (mm)	0.262	0.670	0.289	0.637	-0.140	0.822	-0.550	0.337	0.322	0.597	-0.524	0.365	0.296	0.629	-0.219	0.723
Shear Force (N)	0.986	0.002	0.977	0.004	0.938	0.019	-0.891	0.042	0.969	0.007	-0.892	0.042	0.976	0.004	-0.986	0.002

r – Correlation value

P – Probability value ($P \leq 0.05$)

Consumer sensory analysis

Table 7 and Figure 3 illustrate the degree of liking of the five treatments of polony according to the gender of a group of 100 consumers.

Table 7 Mean values (±SE) for degree of liking of ostrich polony manufactured with increasing levels of olive oil.

Olive oil inclusion level	Means of overall acceptability for		
	Total group (n = 100)	Female consumers (n = 59)	Male consumers (n = 41)
0%	6.4^{ab} ± 0.1	6.3^{a} ± 0.2	6.6^{a} ± 0.2
5%	6.3^{b} ± 0.1	6.3^{a} ± 0.2	6.4^{a} ± 0.2
10%	6.7^{a} ± 0.1	6.8^{a} ± 0.2	6.7^{a} ± 0.2
15%	6.7^{ab}± 0.1	6.8^{a} ± 0.2	6.6^{a} ± 0.2
20%	6.4^{ab}± 0.1	6.6^{a} ± 0.2	6.3^{a} ± 0.2
LSD	0.38	0.49	0.59

SE - Standard Error

LSD - Least Significant Difference (P=0.05)

$^{a-e}$Means within the same column with different superscripts differ significantly (P≤0.05)

Consumers were unable to distinguish between the overall acceptability of polony prepared with different levels of olive oil. Although the polony formulated with 5 and 10% olive oil differed significantly (P≤0.05), the males and females indicated that all the treatments were liked equally (P>0.05). These findings correspond with that of Lurueña-Martínez *et al.* (2004) who studied the acceptability of the replacement of pork fat with 5% olive oil in frankfurters and found that the inclusion of 5% olive oil had no (P≤0.05) effect on the acceptability of the product. However, Pappa *et al*. (2000) found a negative correlation between the level of olive oil and the overall acceptability of frankfurters produced by pork back fat. Bloukas and Paneras (1993) also noted that low fat frankfurters (<10% fat) produced by total replacement of pork backfat with olive oil had lower overall acceptability ratings than high fat frankfurters produced with pork back fat. But, it is to be noted that in the present study, the inclusion of olive oil was investigated, rather than the replacement of pork back fat. Comparatively the results of this study agree with the findings of Lurueña-Martínez *et al.* (2004).

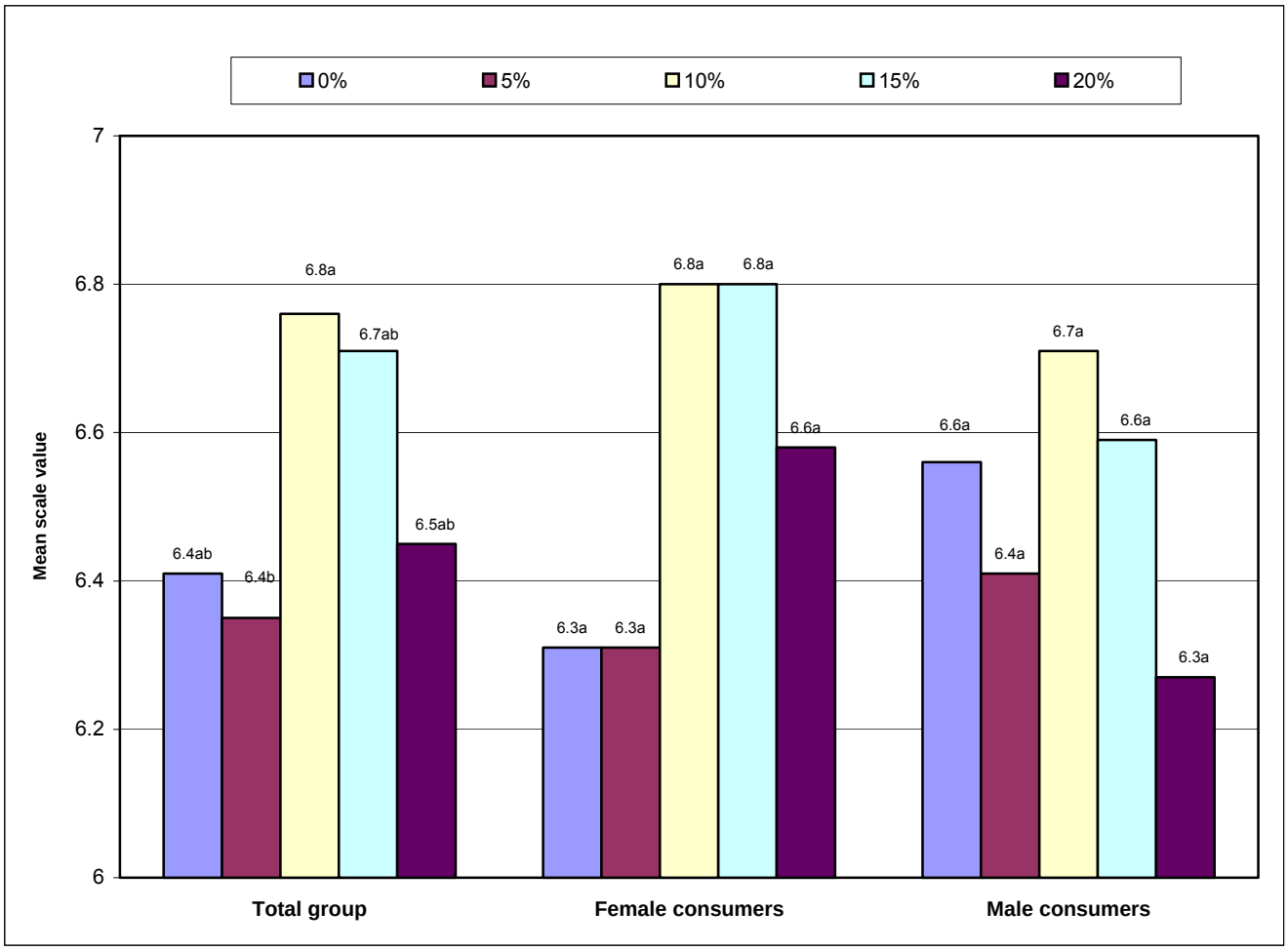

Figure 3 Mean values for degree of liking of ostrich polony manufactured with increasing levels of olive oil.

The frequency scores in Table 8 and Figure 4 give an indication of the distribution of the preference of the consumers over the nine classes of the hedonic scale.

The chi-square value (x^2 =31.8; *P* = 0.28) indicates that there was insufficient evidence for any pattern in the responses between olive oil level and degree of liking of the product. More than 50% of the respondents scored between 6 and 9 on the nine-point hedonic scale. Therefore, all the treatments can be considered as acceptable. Polony formulated with 10 and 15% olive oil had the highest ranking score (added values of responses 6-9) of 83 and 82%, respectively, followed by the polony formulated with 5% olive oil at 77%. The polony formulated with 0 and 20% had the lowest score of 76% and may be considered as the least acceptable of the five polony formulations.

Table 8 Distribution of frequency (%) for preference of ostrich polony manufactured with increasing levels of olive oil (n=100).

Hedonic classes	Olive oil level				
	0%	5%	10%	15%	20%
Dislike extremely (1)	0	0	0	0	0
Dislike very much (2)	2	3	0	0	1
Dislike moderately (3)	4	5	2	2	6
Dislike slightly (4)	9	6	4	9	9
Neither like nor dislike (5)	9	9	11	7	8
Like slightly (6)	27	24	15	18	20
Like moderately (7)	20	29	38	36	27
Like very much (8)	19	18	27	18	21
Like extremely (9)	10	6	3	10	8

Chi-square $x^2_{(DF = 28)} = 31.8$, $P = 0.28$

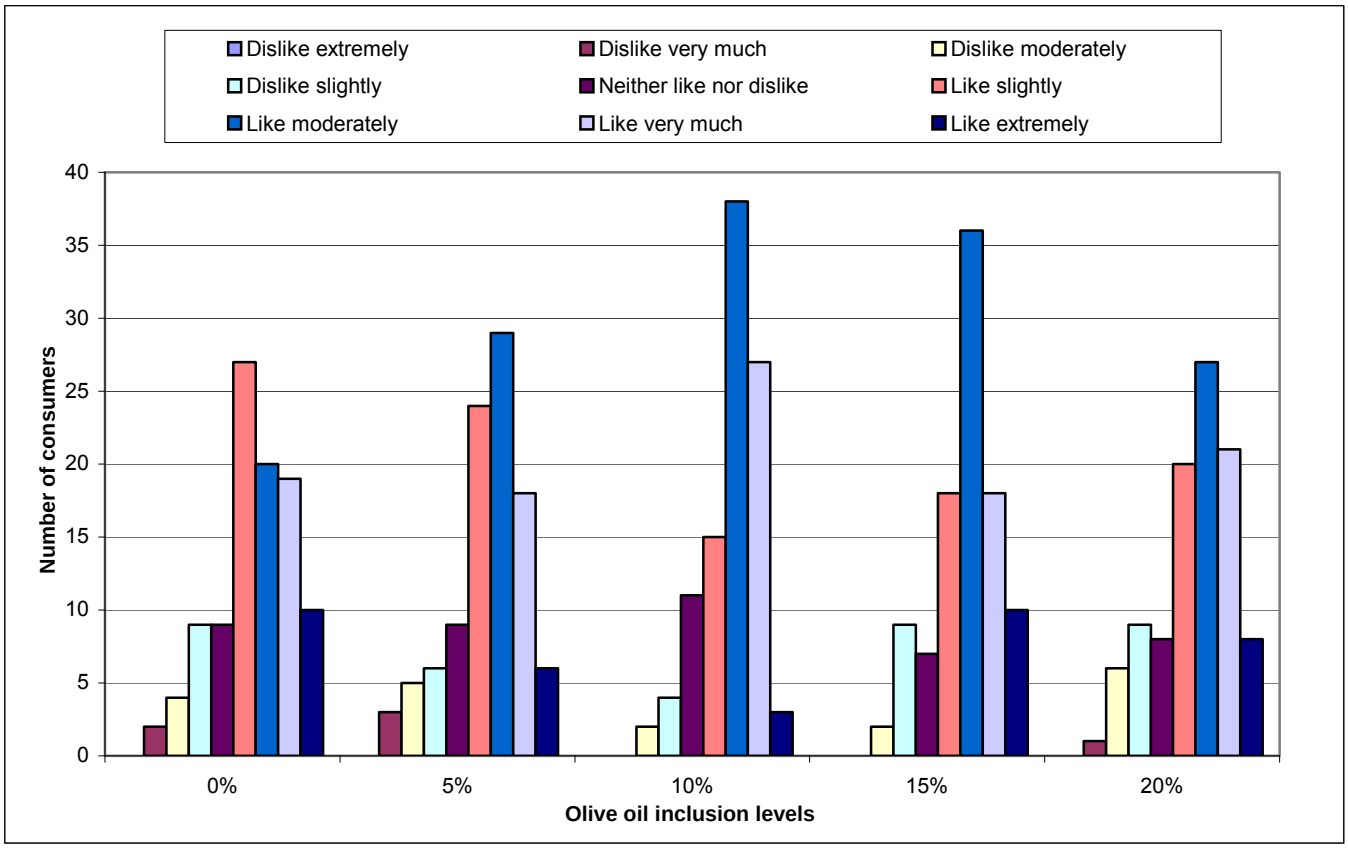

Figure 4 Distribution of frequency (%) for preference of ostrich polony manufactured with increasing levels of olive oil (n=100).

CONCLUSIONS

The results from this study indicate that the manufacture of ostrich polony with olive oil is a viable option for the industry. The polony formulated with 5, 10 or 15% olive oil had good physical characteristics and resulted in acceptable products based on their chemical composition and sensory scores. The low fat content and favourable fatty acid profile of ostrich polony formulated with 5 and 10% olive oil, proved to maintain and enhance the health characteristics of ostrich meat. Since the sensory panel could not distinguish between the polonies within the 5 to 15 % olive oil range, the final decision on acceptable level may be financially driven. Further research should include the use of antioxidants to control colour changes and shelf life studies of the product.

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Chapter 4

Replacement of sodium tri-polyphosphate with carrageenan in the formulation of restructured ostrich ham

ABSTRACT

The use of carageenan to minimise the use of phosphate in ostrich ham with a constant total meat content of 95% (lean meat plus fat) was investigated with regard to physical, chemical and sensory acceptability. Treatments consisted of five decreasing levels of phosphate (0.7%, 0.53%, 0.35%, 0.18% and 0%) that was simultaneously substituted with five increasing levels of carrageenan (0%, 0.1%, 0.2%, 0.3% and 0.4%). The cooked yield of restructured ostrich ham decreased ($P \leq 0.05$) with decreasing levels of phosphate (together with increased levels of carrageenan). No trends in instrumental colour measurements with relation to decreased levels of phosphate in ostrich ham was revealed. Hardness, cohesiveness and gumminess increased with decreased levels of phosphate, whereas springiness showed no fixed trend. The P:S ratio of all the ham treatments were above the recommended value of 0.45, whereas only the ham formulated with 0.53 and 0.35% phosphate were below the recommended n-6:n-3 ratio value of <4.0. The effects of decreased levels of phosphate on ham sensory characteristics including meat aroma and flavour; ostrich meat aroma and flavour; spicy aroma and flavour and mealiness were also investigated. A meaty aroma and flavour was found by the panel members to be the highest ($P \leq 0.05$) in the ham formulated with 0.35%. An ostrich meat aroma and flavour for the ham formulated with 0.18 and 0% phosphate was found to be stronger ($P \leq 0.05$) than the rest of the ham treatments. No significant patterns in a spicy aroma and flavour were associated with the decrease in phosphate levels. No pattern in the analysis of mealiness in relation to the various phosphate treatments was observed. No correlation ($P > 0.05$) was found between the percentage fat, protein, moisture, phosphate and L*, a* and b* colour values, and the sensory characteristics. Correlations ($P \leq 0.05$) were found between the total ash content as well as cooked yield with the same set of sensory characteristics (spicy flavour, spice aroma and mealiness), though inversely so (ash was positively correlated, and cooked yield was negatively correlated with these characteristics). Mealiness, scored by the panel, correlated with the instrumental values for hardness (r = -0.900; P = 0.037), gumminess (r = -0.885; P = 0.046), cohesiveness (r = -0.952; P = 0.012) and springiness (r = -0.967; P = 0.007). Three of the ham treatments with different levels of phosphate (0.7, 0.35 and 0%) were presented to a consumer panel. The consumer panel found the ham treatments with 0.7 and 0.35% phosphate acceptable, whereas the ham formulated with 0% phosphate was much less acceptable. It is concluded that carrageenan can be substituted for phosphate (to a level of 0.35% phosphate and 02% carrageenan) for the production of reduced phosphate ham.

Keywords: Ostrich meat, Ham, phosphate, carrageenan

INTRODUCTION

Restructured ham is usually prepared from large pieces of meat that are moulded together to resemble a whole muscle meat product after cooking. The actual binding of adjacent meat pieces relies on extraction of myofibrillar proteins by salt (NaCl), phosphate and mechanical action (massaging or tumbling). During subsequent heating, these proteins, of which myosin is the major protein, coagulate and act as a bonding agent holding the meat pieces together (Gillett *et al.,* 1981; Macfarlane *et al.,* 1977; Raharjo *et al.,* 1995; Siegel *et al.,* 1978; Theno *et al.,* 1978). The binding properties of restructured ham are essential in order to produce a uniformly attractive product with desirable slicing characteristics. According to Schnell *et al.* (1970) the most desirable properties of high quality cooked ham are cohesiveness, textural firmness and juiciness.

Polyphosphates are used extensively in restructured meat products due to their functional properties of increasing the binding strength, water holding capacity and yield (Dobson *et al.,* 1993; Lee *et al.,* 1998; Moiseev & Cornforth, 1997; Moore *et al.,* 1976; Nielsen *et al.,* 1995; Pepper & Schmidt, 1975; Pexara, 2006; Sheared *et al.,* 1999; Theno *et al.,* 1978; Schultz & Wierbicki, 1973). Polyphosphate action is ascribed to the increase of the pH and ionic strength in meat products (Dziezak, 1990; Young *et al.,* 2005). Tri-polyphosphates (TPP) are the most widely used of all the phosphates utilised in meat processing (Pearson & Tauber, 1984) and are permitted up to 3.5% of final product weight in South Africa (Foodstuffs, Cosmetics and Disinfectant Act and Regulations, 1974).

However, there is an increase in the demand for meat products with reduced phosphate (Ruusunen *et al.,* 2003). The presence of excessive amounts of phosphates in the diet may influence the calcium, iron and magnesium balance in the human body, and can increase the risk of bone diseases (Calvo & Park, 1996; Cerklewski, 2005; Moretti *et al.,* 2006; Sandberg *et al.,* 1999; Shahidi & Synowiecki, 1997; Steinhardt *et al.,* 1984). Furthermore, consumers and retailers generally associate polyphosphates with cost reduction and lower quality products. Consumers also seem to associate the term “polyphosphates” with non-food applications, viewing them as “chemical products”. The aforementioned factors indicate an interest in the use of alternatives to phosphates in restructured cooked meat products (Dimitrikopoulou *et al.,* 2005; Flores *et al.,* 2007; Ruusunen, 2003; Shahidi *et al.,* 1997). Numerous non-meat functional ingredients, mainly proteins and polysaccharides, have been applied as binders, fillers and extenders to improve the quality of restructured meat products (Mittal & Usborne, 1985; Pearson & Tauber, 1984; Ramírez *et al.,* 2002). These ingredients are primarily used for their water binding ability and texture modification functionality (Comer, 1979; Comer & Dempster, 1981).

Hydrocolloids with their unique characteristics in building texture, stability and emulsification are of great interest in the low-fat processed meat area due to their ability to bind water and form gels (Candogan & Kolsarici, 2003). Carrageen (CGN), a sulphated polysaccharide extracted from seaweed, is a hydrocolloid used extensively in the food industry in a broad range of applications because of its water binding, thickening and gelling properties (DeFreitas *et al.,* 1997). There are

three major types: kappa (κ, gelling), iota (ι, gelling), and lambda-CGN (λ, non-gelling). They differ in degree and manner of sulfation, the position of the 3-6 anhydrogalactose residues, their pyranose ring conformations, and the cations associated with the sulfate groups (Towle, 1973).

CGNs, alone or combined with other ingredients, have been used extensively in restructured meat products (Bater *et al.,* 1993; Berry & Bigner, 1996; Motzer *et al.,* 1998; Pietrasik, 2003; Shand *et al.,* 1994; Tsai *et al.,* 1998) for their ability to form gels, retain water and to provide a desirable texture (Trudso, 1985; Verbeken *et al.,* 2005). An in-depth study of the influence of CGN on the thermal gelation of salt-soluble meat proteins was done by Verbeken *et al*. (2005). Berry and Binger (1996) found that the use of 1.5% salt with iota-CGN improved the cooking yield, juiciness and tenderness of restructured pork nuggets. Kappa-CGN favourably affected hydration properties and thermal stability, yielding lower cooking loss, purge and expressible moisture of beef gels (Pietrasik, 2003). Bater *et al.* (1993) also found that kappa-CGN increased the sliceabillity and rigidity in roasted turkey breasts, and Motzer *et al.* (1998) found that it improved adhesion in pork hams.

Ostrich meat is frequently marketed as a healthy alternative to other red meats as it has a favourable fatty acid profile and a low intramuscular fat content (Sales 1998; Sales *et al.,* 1996). Ostrich meat has a high ultimate pH of *ca.* 6.0, and should by implication have a high water binding capacity (Lawrie, 1991) and thus be able to retain high levels of moisture. Therefore, moisture-retaining agents, such as phosphates, in restructured meat products could be reduced.

In order to maintain the health characteristics of ostrich meat, it is suggested that an alternative ingredient, that mimics the textural, functional and flavour characteristics of phosphate, be introduced in the formulation of restructured meat products. Therefore, the objective of this study was to investigate the effect of replacement of sodium tri-polyphosphate (STPP) with iota-CGN on the physico-chemical and sensory characteristics of restructured cooked ostrich ham.

MATERIALS AND METHODS

Ham manufacture

This experiment was preceded by a development phase of which the details are in Annexure 1. Five different ham formulations with decreased levels of STPP replaced with increased levels of iota-CGN were produced (Table 1). Each treatment was formulated to contain a 95% Total Meat Equivalent (TME) on chemical analysis (lean meat and fat). Brine ingredients, expressed as percentage in the brine, consisted of 9% NaCl, 0.25% sodium erythorbate, 1% curing salt (NaCl + 0.6% nitrite), 20% starch (corn flour), 1% ground garlic, 1% ground ginger, STPP (3.5%, 2.63%, 1.75%, 0.88% and 0% respectively), iota-CGN (0%, 0.5%, 1.0%, 1.5% and 2.0% respectively), water (64.25%, 64.62%, 65%, 65.37% and 65.75% respectively). The corn flour was added to the brine and the meat after the first tumble cycle.

Ostrich (*Struthio camelus* var. *domesticus*) fan fillet (Fisher *et al.,* 2000) was obtained from a local European Union approved abattoir, Mosstrich (2 Mkuzi Street Mossdustria, Mossel Bay, South Africa) with all five treatments being produced from the same meat batch. The meat was vacuum packed and frozen before being transported to Stellenbosch, were it was stored at -20°C until used. Iota-CGN (GENU® texturizer type MB-150F) from Tranarc (Tranarc Holdings Pty Ltd., Benmore, South Africa) was used. All the remaining ingredients were provided by a single provider, Deli Spices (25 Bertie Avenue, Epping 2, Cape Town, South Africa).

Thawed (24 h at 4°C) ostrich fan fillet was cut into fist sized pieces. The meat structure was subsequently further disrupted by the mild shearing action of passing through a meat mincing machine without any cutting blades or plates. This opened the meat structure to facilitate brine penetration and protein extraction, without reducing the particle size. The brine mixture for each treatment was then added to the meat and the latter mixture was tumbled (Biro VTS-41) under vacuum (25 kPa) for 6 h (4°C) with a cycle of 20 min tumble and 10 min rest. After tumbling, the ham mixtures were vacuum stuffed (Talsa Model T0101, Germany) into impermeable plastic casings to produce four ham replicates per treatment of approximately 1.5 kg in weight, 30 cm in length and 12 cm in diameter. Each stuffed casing within each treatment was weighed and cooked in a water bath until a core temperature of 72°C was reached. The internal temperature of the ham was measured using a thermocouple probe inserted into the centre of the product. After cooking, the hams were immediately immersed in cold water containing ice for 15 min before refrigeration at 4°C prior to subsequent analyses.

Table 1 Formulation of five ham treatments.

	Treatments				
Ingredients (%)	**A**	**B**	**C**	**D**	**E**
STPP[a]	0.70	0.53	0.35	0.18	0.00
Carrageenan	0.00	0.10	0.20	0.30	0.40
Additives[#]	6.45	6.45	6.45	6.45	6.45
Water	12.85	12.92	13.00	13.07	13.15
Brine	20.00	20.00	20.00	20.00	20.00
Meat	80.00	80.00	80.00	80.00	80.00
TOTAL	100.00	100.00	100.00	100.00	100.00

[a]STPP, Sodium tri-polyphosphate

[#]Salt (1.8%), curing salt (0.2%), sodium erythorbate (0.05%), ginger (0.2%), garlic (0.2%), starch (4%)

Chemical analyses

Homogenised samples of the five ham treatments (of a randomly selected ham within each treatment) were analysed in duplicate for total percentages of moisture, protein, ash and

phosphorus (AOAC, 2005). For protein content determinations, dried and defatted samples were ground with a pestle in a mortar until a fine powder was obtained. Subsequently 0.1 mg of the powder was used per sample and inserted into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The protein concentration in the sample was determined as Nitrogen x 6.25. The moisture content was analysed by drying 2.5 g sample at 100ºC for a period of 24 h and ashing was done at 500ºC for a period of 6 h. The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform:methanol (Lee *et al.,* 1996). The phosphorus content of the cooked ham samples were analysed by Elsenburg Production Technology Laboratory (Department Agriculture, Elsenburg, Western Cape, South Africa) using the AOAC (AOAC, 2005) techniques. The pH of the refrigerated (4ºC) cooked hams was measured with the use of a calibrated (standard buffers pH 4.0 and 7.0) portable Testo 502 pH-meter.

Physical analyses

Cooked yield, colour (CIE lightness L*, a* and b* colour coordinates) and Texture Profile Analysis (TPA) measurements were recorded on each of the four ham replicates per treatment. Cooking yield was expressed as follows:

Cooked yield (%) = (W1-W2) x 100 *where* W1 = ham weight after cooking *and* W2 = ham weight before cooking

The weight of the cooked product was recorded after 24 h chilling (4ºC), when the products were removed from the casings, touch dried with absorbent paper, and casing weight recorded, separate from product weight. Product weight losses occurred primarily during thermal processing; weight loss due to the exudate remaining in the tumbler was small (about 1%) as the tumbler surfaces had been scraped with a spatula to reclaim as much exudate as possible.

Instrumental colour measurements of cooked ham were recorded on three slices obtained from each of the four ham replicates per treatment, according to the method describe by Honikel (1998). A colour-guide 45º/Oº colorimeter (Cat no: 6805; BYK-Gardner, USA) was used. Three ham slices (1.5 to 2.0 cm thick) of each treatment were allowed to “bloom” for 30 min at room temperature (18 to19ºC) prior to colour measurements. Four colour measurements were recorded for each slice at randomly selected positions and expressed by the coordinated L*, a* and b* of the CIELab colorimetric space (MINOLTA, 1998). In the colour space L* indicates lightness and a* and b* are the chromaticity coordinates, where a* is the red-green range, and b* the yellow-blue range of the colour spectrum.

Instrumental textural properties were analysed using the Instron Universal Testing Machine (UTM) (Instron 3344) (Bourne, 1978). Texture Profile Analysis (TPA) was performed on five cores (2.5 cm height and 2 cm diameter) per slice (two slices of each of the four replicates within the five treatments = 40 measurements per treatment). The cores were placed on the platform of the

UTM. A circular plate of 2.5 cm diameter was attached to a 500 N load cell and the sample was compressed to 50% of its original height at a cross head speed of 200 mm/min twice in two cycles as described by Desmond and Troy (2001). Hardness (N), springiness (mm), cohesiveness (ratio) and gumminess (N) were calculated for each sample (Bourne, 1978).

Fatty acids composition analysis

Fatty acid methyl esters (FAME) were prepared from the extracted total lipids (Lee *et al.,* 1996) according to the procedures published by Morrison and Smith (1964). The FAME were analysed with a gas-liquid chromatograph (Varian Model 3300), equipped with flame ionisation detection and two 30 mm fused silica megabore DB-225 columns of 0.53 mm internal diameter (J&E Scientific, Folsom, CA). Gas flow rates were: hydrogen 25 ml/min and nitrogen (carrier gas) 5-8 ml/min. The temperature program was linear at 4ºC/min with initial and final temperatures of 160°C and 220°C (held for 10 min), respectively. The injector temperature was 240°C and the detector temperature 250°C. FAME were identified by comparison of the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

Sensory analyses

The purpose of the sensory analysis was to determine the effect of phosphate reduction on the sensory quality characteristics and to ascertain the overall degree of liking of the treatments of ostrich ham. Two hours prior to sensory analysis, all the encased hams (stored at 4ºC) were opened, sliced into 3.5 mm thick slices and vacuum packed (Multivac C200, Germany). Five slices were placed next to each other and the slices did not overlap when vacuum packed.

Descriptive sensory analysis was performed to ascertain the sensory quality characteristics. The panel was chosen based on their experience in sensory analysis and on their availability. Panellists were trained in accordance with the generic descriptive analysis techniques as described by Lawless and Heymann (1998). An eight member panel was trained in two interactive sessions to familiarise the panellists with the treatments and to identify the sensory characteristics to be evaluated. A questionnaire was compiled during the first training session. The questionnaire was refined and tested during the second training session. An unstructured line scale ranging from 0-100 mm was used to analyse the sensory characteristics (Annexure 4). Table 2 depicts the characteristics and definitions used. The sensory tests were performed in individual booths in a temperature (21ºC) and light controlled (equivalent to daylight) room. One sample of each of the five treatments was served to the panellists in a randomised order in five sessions. Distilled water, apple and crackers were given to the panellists in between treatments. Each sample was coded with randomly selected three digit numbers and served at a refrigeration temperature of 6-10ºC.

For the determination of degree of liking, a hundred consumers (79 females, 21 males) were recruited among staff and students at the University of Stellenbosch, South Africa. The

consumers tested the ham, without any knowledge as to the formulation of the products. Each panellist received one sample of each treatment, coded with three-digit codes, in a random order. Testing was done individually in a temperature (21ºC) and light controlled (equivalent to daylight) room. The traditional nine-point hedonic scale ranging from 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, liked slightly; 7, liked moderately; 8, liked very much; to 9, like extremely, was used. The latter instrument is used to test preference and acceptability. Panellists were asked to assign an order to the samples in accordance to overall preferences and acceptability and in this study, treatments were considered acceptable if 50% or more of the responses were between 6 to 9 on the hedonic scale (Annexure 5).

Table 2 Verbal definitions of sensory characteristics for the descriptive sensory analysis of ham.

Characteristics	Definition	Scale
Meaty aroma	The intensity of a meaty aroma, perceived by sniffing	0 = None 100 = Strong
Ostrich meat aroma	The intensity of an ostrich meat aroma, perceived by sniffing	0 = None 100 = Strong
Spicy aroma	The intensity of a spicy aroma, produced by ginger and garlic, perceived by sniffing	0 = None 100 = Strong
Meaty flavour	The intensity of a meat flavour, perceived by tasting	0 = None 100 = Strong
Ostrich meat flavour	The intensity of an ostrich meat flavour, perceived by tasting	0 = None 100 = Strong
Spicy flavour	The intensity of a spicy flavour, derived from the ginger and garlic content, perceived by tasting	0 = None 100 = Strong
Mealiness	The degree of mealiness in the mouth, indicative of cohesiveness of sample, perceived by tasting.	0 = None 100 = Prominent

Statistical analysis

A complete randomised design with five treatments and different numbers of replicates for different measurements, were performed. A one-way analysis of variance (ANOVA) was performed on all the data using SAS version 9.1 statistical software (SAS, 1999). The Shapiro-Wilk test was

performed to test for non-normality (Shapiro & Wilk, 1965). In some cases deviations from normality were the cause of one or two outliners, which were removed before the final analysis (Glass *et al.,* 1972). Student's t-Least Significant Difference (LSD) was calculated at a 5% significant level to compare treatment means. Pearson correlation coefficients were calculated between objective and descriptive sensory variables. For the consumer data, scores were subjected to one-way (Treatments) and two-way (Treatments x Gender) ANOVA. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at a 5% significant level to compare treatment means. Also, a RxC contingency table (Rows = Treatments; Columns = Degree of liking) of frequency was set up and tested for association using Chi-square.

RESULTS AND DISCUSSION

Descriptive chemical and physical characteristics

The chemical composition, total meat equivalent (TME), product pH, cooking yield, textural properties and results for instrumental colour of the five ham treatments with decreasing levels of phosphate are presented in Table 3.

Chemical composition

The ham formulated with 0.18% phosphate presented the highest moisture content of 74.35% that differed ($P \leq 0.05$) from the hams formulated with 0.7, 0.53 and 0% phosphate (Table 3). As expected, since no fat was added during the manufacturing process, there were no differences ($P > 0.05$) in the lipid and protein content between the five ham treatments. In a study by Dimitrakopoulou (2005), the lipid content of restructured pork shoulder was found to be in a range of 23% to 25%. This is much higher than the lipid content (2.5 to 2.9%) in this study, which could be attributed to the low intramuscular fat content of ostrich meat (Sales, 1998). The ash content decreased ($P \leq 0.05$) with decreased levels of phosphate; the ham formulated with 0.70% phosphate had the highest ash content (4.01%) whilst the ham formulated with 0% phosphate had the lowest (3.16%). As the spice content was kept constant, the decrease in ash content may be attributed to the decreasing phosphate levels. As expected the phosphorus content in the hams also decreased with decreasing levels of phosphate. However, the phosphorus content measured in the end product proved to be much higher than the expected calculated phosphate content. These elevated values could be due to the natural phosphorus content (0.51%) of the meat as reflected in the ham formulated with no phosphate added to the brine. Since a constant amount of phosphate was incrementally decreased in the formulation, it must then be assumed that the discrepancies in the elevated phosphorus values were due to either sampling error or increased phosphorus content for the specific batch. Decreasing levels of phosphate were found to have no effect on the pH of the cooked product.

Table 3 Means (± SD) of the descriptive characteristics of ham treatments*.

	Phosphate / Carrageenan level					LSD
	0.70/0.0%	**0.53/0.1%**	**0.35/0.2%**	**0.18/0.3%**	**0.00/0.4%**	
Chemical Composition						
Moisture (%)	$73.2^{b} \pm 0.0$	$73.4^{b} \pm 0.1$	$73.8^{ab} \pm 0.1$	$74.3^{a} \pm 0.6$	$73.4^{b} \pm 0.0$	0.78
Fat (%)	$2.9^{a} \pm 0.1$	$2.8^{a} \pm 0.3$	$2.5^{a} \pm 0.2$	$2.8^{a} \pm 0.3$	$2.7^{a} \pm 0.2$	0.61
Protein (%)	$19.4^{a} \pm 0.3$	$19.6^{a} \pm 0.4$	$19.4^{a} \pm 0.0$	$18.9^{a} \pm 0.8$	$19.6^{a} \pm 0.1$	1.07
Ash (%)	$4.0^{a} \pm 0.0$	$3.7^{ab} \pm 0.0$	$3.4^{bc} \pm 0.3$	$3.3^{bc} \pm 0.1$	$3.2^{c} \pm 0.1$	0.42
Phosphorus (%)	1.42	1.03	0.78	0.76	0.51	n/a
TME (calculated)¤	97.00	96.79	95.87	93.28	96.78	n/a
Product pH	6.24	6.23	6.26	6.21	6.20	n/a
Cooked yield (%)	$86.0^{d} \pm 0.9$	$88.1^{c} \pm 0.2$	$91.9^{b} \pm 2.4$	$94.1^{a} \pm 1.5$	$92.5^{ab} \pm 1.2$	2.0
Instrumental colour						
Lightness (L*)	$48.1^{c} \pm 1.9$	$49.4^{bc} \pm 2.3$	$51.7^{a} \pm 1.2$	$48.6^{c} \pm 1.5$	$50.8^{ab} \pm 2.2$	1.53
Redness (a*)	$9.8^{a} \pm 0.6$	$9.1^{b} \pm 0.7$	$8.3^{c} \pm 0.5$	$9.5^{ab} \pm 0.8$	$9.5^{ab} \pm 0.9$	0.59
Yellowness (b*)	$11.4^{b} \pm 0.5$	$12.4^{a} \pm 1.2$	$12.7^{a} \pm 1.2$	$12.6^{a} \pm 0.9$	$13.0^{a} \pm 0.7$	0.77
Instrumental textural properties						
Hardness (N)	$18.9^{c} \pm 4.2$	$21.2^{c} \pm 2.3$	$29.5^{b} \pm 5.1$	$30.8^{b} \pm 4.2$	$35.1^{a} \pm 3.3$	3.55
Cohesiveness (ratio)	$0.42^{c} \pm 0.64$	$0.44^{bc} \pm 0.05$	$0.46^{abc} \pm 0.03$	$0.49^{ab} \pm 0.07$	$0.49^{a} \pm 0.07$	0.05
Gumminess (N)	$8.3^{c} \pm 2.0$	$10.9^{bc} \pm 2.5$	$11.6^{bc} \pm 6.5$	$14.3^{ab} \pm 4.1$	$15.5^{a} \pm 3.6$	3.64
Springiness (mm)	$5.3^{c} \pm 0.6$	$5.1^{c} \pm 0.5$	$5.6^{bc} \pm 0.5$	$6.5^{a} \pm 0.6$	$5.9^{b} \pm 0.6$	0.52

*Statistical analyses were performed on all data with the exception of phosphorus, TME and pH, as these were measured only once per treatment

SD - Standard Deviation

LSD = Least Significant Difference (P=0.05)

¤TME = % Lean Meat + % Total Fat

$^{a-e}$Means within the same row with different superscripts differ significantly ($P \leq 0.05$)

Total Meat Equivalent (TME)

In this study the TME values of the hams formulated with 0.70, 0.53 and 0% phosphate were higher than the targeted value of 95% and therefore exceed legal requirements, whereas the TME value of the 0.18% phosphate level ham was lower (93.28%) (Table 3). Once more the reason for this variation is unknown but may be linked to this sample having a lower protein and higher moisture content thus resulting in the calculated difference.

Cooked yield

The decrease in phosphate levels resulted in an increase ($P \leq 0.05$) in the cooked yield of the restructured ostrich ham (Table 3). This is attributed to the gelling properties of the increased carrageenan content. During cooking, water and water-soluble components are released from myofibrils caused by the heat denaturation of the muscle proteins (Lawrie, 1998). Carrageenan develops a gel layer on the surface of the ham, which has a sealing effect thereby decreasing the loss of the internal components (Levie, 1963; Lawrie, 1998). The cooked yield levels observed in this experiment (85.9 to 94%) are substantially lower that that of Fisher *et al.* (2000), who found that an ostrich ham-like product formulated with 0.3 and 1.5% phosphate produced a cooking yield of 99.21 and 99.42%, respectively. This difference could be due to different processing techniques, i.e. Fisher *et al.* (2000) tumbled the meat for 20 min, whereas in this study, the meat was tumbled for 6 h.

Instrumental colour

The lightness (L* value) of the samples was in the range of 48.13 to 51.75, the redness (a* value) was between 8.27 and 9.84 and yellowness (b* values) ranged from 11.45 and 13.02 units (Table 3). The ham formulated with 0.35% phosphate, was found to be the lightest (51.75) and least red (8.27) in colour. However, the instrumental colour measurements of the different ostrich ham samples revealed no tendencies with relation to the decrease in phosphate levels. This result is supported by an observed variation in the composition of each of the sample slices. Ostrich meat is known to have a darker colour than other red meat types (Hoffman & Fisher, 2001). This is also evident in this study where the range of a* values (redness) in ostrich ham (8.27 to 9.84) are much higher than that of, for example, restructured beef steaks (3.82 to 5.94) (Colmenero *et al.,* 2003). Though not measured, it was observed that storage of the ham under lighting conditions (exposure of ham to light) between manufacture and consumption led to browning of the product (decrease in redness). Fernández-Ginéz (2003) reported that the light has a pro-oxidant effect that provokes a decrease in a* values due to oxidation and degradation of the nitroso-pigment. This rapid oxidation warrants further investigation.

Instrumental textural properties

The effect of the variation of the composition within each sample slice was reflected in the results for instrumental texture as no significant pattern was observed with the incremental decrease in the phosphate levels (Table 3). However, significant differences in hardness, cohesiveness and gumminess were only observed with relation to the extreme manipulation of phosphate (0.70 and 0%) during this experiment. The 0.53%, 0.35% and 0.18% did not show a significant effect on the mentioned characteristics. Although not significant, the observed increase in the measured textural properties may be the results of increased levels of iota-CGN that forms a firm cohesive gel structure during cooling. These findings are in agreement with results by Ulu (2006), who studied the effect of carrageenan on the cooking and textural properties of low fat meatballs.

Fatty acid composition

The fatty acid profiles (% of total fatty acids) of the five ostrich ham formulated with 0.70%, 0.53%, 0.35%, 0.18% and 0% phosphate are depicted in Table 4. Ostrich meat is known for its favourable fatty acid profile (intramuscular ostrich fat contains 16.50% polyunsaturated n-3 fatty acids) as well as for its low intramuscular fat content (Sales, 1998; Sales *et al.,* 1996). In relation to individual fatty acids, ostrich ham showed a higher percentage of oleic acid (C18:1n-9) ranging between 23.26% and 29.63%, followed by palmitic acid (C16:0) ranging between 14.74% and 18.19%, and then linoleic acid (C18:2n-6), ranging between 12.48 and 15.20 (Table 4). These results agree with the fatty acid profile reported previously for ostrich meat (Hoffman & Fisher, 2001; Horbanczuk *et al*., 1998; Sales, 1998; Sales *et al.* 1996). Since no fat was added during the manufacturing process no variation in the fatty acid profile was expected. It must then be assumed that the differences in the fatty acid profile was due to either random error in sampling or a reduced fat content for the specific batch.

To assess the possible nutritional impact of the ham, the P:S ratio, the PUFA n-6:n-3 ratio and the desirable fatty acids (DFA), were determined (Table 4). To improve the health status of a population, a n-6:n-3 PUFA ratio of less than 4 and a P:S ratio of more than 0.45 is recommended (Wood *et al.,* 2004; Simopoulos, 2004). In the present study, the P:S ratio of all the treatments are above the recommended value of >0.45 (ranging between 0.58 and 0.75). The ham formulated with 0.53, 0.35 and 0% phosphate are close to the recommended n-6:n-3 <4.0 (2.57, 3.62 and 4.10, respectively), whereas the ham with 0% and 0.18% phosphate had a ratio higher than what is recommended. Therefore, the ostrich ham formulated with 0.53, 0.35 and 0% phosphate proved to be the most desirable in terms of fatty acid composition since it complies to the recommended values of both P:S and n-6:n-3 ratios.

Table 4 Fatty acid composition (%) of ham manufactured with decreasing phosphate levels.

Fatty acids (%)	Phosphate level				
	0.70%	**0.53%**	**0.35%**	**0.18%**	**0.00%**
Saturated Fatty Acids					
6:0	4.91	8.26	9.04	9.58	7.73
8:0	0.44	0.37	0.09	n/d	n/d
10:0	0.08	0.04	n/d	n/d	n/d
11:0	0.63	0.59	0.45	0.29	0.28
12:0	0.34	0.29	0.28	0.22	0.23
13:0	0.55	0.51	0.58	0.43	0.50
14:0	0.67	0.60	0.48	0.37	0.42
15:0	0.55	0.55	0.57	0.49	0.52
16:0	18.19	19.20	16.87	14.74	15.61
18:0	11.88	10.80	12.53	11.32	13.57
20:0	0.15	0.12	0.14	0.12	0.15
22:0	0.08	0.07	0.09	0.50	0.72
24:0	0.15	0.14	0.18	0.16	0.16
24:0	0.20	1.24	1.00	2.99	1.34
Mono-unsaturated Fatty Acids					
14:1	0.07	0.03	0.08	n/d	n/d
15:1	0.08	0.07	0.06	0.30	0.83
16:1	3.87	4.33	3.32	2.57	2.91
18:1 n-9t	0.27	0.24	0.28	0.36	0.27
18:1 n-9c	29.63	27.10	26.07	23.26	26.97
20:1	0.25	0.21	0.30	0.37	0.30
22:1 n-9	0.26	0.25	0.43	0.48	0.71
24:1	0.21	0.31	0.26	0.46	0.64
Poly-unsaturated Fatty Acids					
18:2 n-6t	0.06	0.04	0.07	0.11	0.10
18:2 n-6c	15.20	12.48	14.41	14.32	14.01
18:3 n-6	0.07	0.04	0.04	0.07	0.00
18:3 n-3	1.83	4.77	2.86	2.85	2.33
20:2	0.29	0.24	0.42	0.57	0.90
20:3 n-6	0.23	0.26	0.35	0.32	0.39
20:3 n-3	0.39	0.39	0.39	0.54	0.73
20:4 n-6	7.19	4.76	5.86	9.91	5.69
20:5 n-3	0.26	0.51	0.62	0.43	0.53
22:2	0.14	0.07	0.08	0.13	0.15
22:5 n-3	0.67	0.78	1.04	1.05	0.81
22:6 n-3	0.22	0.37	0.78	0.68	0.50
Total	100.00	100.00	100.00	100.00	100.00
Total fatty acid profile					
∑SFA	4.86	6.51	5.53	6.03	5.57
∑MUFA	4.30	4.92	3.99	4.02	4.37
∑PUFA	3.32	3.76	3.51	4.52	3.52
∑TUFA	7.62	8.67	7.50	8.54	7.89
DFA	9.11	10.32	9.14	10.20	9.72
P:S	0.68	0.58	0.64	0.75	0.63
n-6	2.84	2.67	2.70	3.60	2.72
n-3	0.42	1.04	0.75	0.81	0.66
n-6:n-3	6.74	2.57	3.62	4.43	4.10

SFA = Saturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids; TUFA = Total Unsaturated Fatty Acids; DFA = Desirable Fatty Acids (C18:0 + TUFA); n/d = not detected.

Sensory characteristics

The sensory profiling results for meaty aroma and flavour, ostrich meat aroma and flavour, spicy aroma and flavour and mealiness are presented in Table 5 and Figure 1.

A meaty aroma was found by the panel members to be the highest ($P \leq 0.05$) in the ham formulated with 0.35% (30.9), followed by 0.53 and 0% (23.0 and 23.6, respectively) phosphate. Also, the ham formulated with 0.35% phosphate was found to have the strongest meaty flavour that differed significantly ($P \leq 0.05$) from the rest of the ham treatments. Thus a 0.35% phosphate level in combination with 1% carrageen produced a product with a strong meat flavour. An ostrich meat aroma and flavour for the ham formulated with 0.18 and 0% phosphate was found to be stronger ($P \leq 0.05$) than the rest of the ham treatments. Panel members were not able to discriminate ($P > 0.05$) between the ham formulated with 0.7, 0.53 and 0.35% phosphate as pertaining to ostrich aroma and flavour. Therefore, a phosphate level in ostrich ham of 0.18% and lower, does not conceal the typical aroma and flavour of ostrich meat even though spices, ginger and garlic, were included at a constant level in all five treatments. The latter spices were included in the formulae in an attempt to mask the typical ostrich aroma and flavour. The panel members noticed a spicy aroma and flavour in all the ham treatments, although no significant patterns were associated with the decrease in phosphate levels. Mealiness was defined by the trained panel as a mouth feel experienced when the meat pieces separate upon chewing which is indicative of the degree of cohesion between the meat pieces of the restructured ham. No pattern in the analysis of mealiness in relation to the various phosphate treatments was observed.

Correlations between objective and sensory measurements relevant to this study are depicted in Table 6. Neither fat, protein, moisture, nor phosphate showed any correlation with any of the sensory attributes. The same lack of correlation was observed in the colour values L*, a* and b*. However, ash and cooked yield showed a high correlation with the same set of characteristics (spicy flavour, spice aroma and mealiness), though inversely so (ash was positively correlated with these characteristics, while cooked yield was negatively correlated). This phenomenon is difficult to explain, but could be ascribed to the “diluting” effect of higher yield (Table 3) on the intensity of these characteristics as experienced by the panellist. Similarly it may be possible that a higher yield may result in less ash per similar sample size. The high positive correlations of ash and these sensory characteristics may therefore still be due the aforementioned diluting effect of the higher yield. The fact that no correlation was found between fat, protein, moisture, ash, phosphate, cooked yield, colour values (L*, a* and b*) and ostrich aroma and flavour, could be ascribe to the inability of the instrumental measurements to register the variation in the composition of restructured ostrich ham. However, the sensory characteristic of mealiness, a mouth feel as defined by the sensory panel, can logically be related to the measurements of instrumental textural analysis. Mealiness was found to negatively correlate with hardness ($r = -0.900$; $P = 0.037$), gumminess ($r = -0.885$; $P = 0.046$), cohesiveness ($r = -0.952$; $P = 0.012$) and springiness ($r = -0.967$; $P = 0.007$). This indicates that decreasing levels of phosphate (coupled

with increasing levels of carrageenan) has a negative impact on the textural quality of the product as perceived by a trained taste panel.

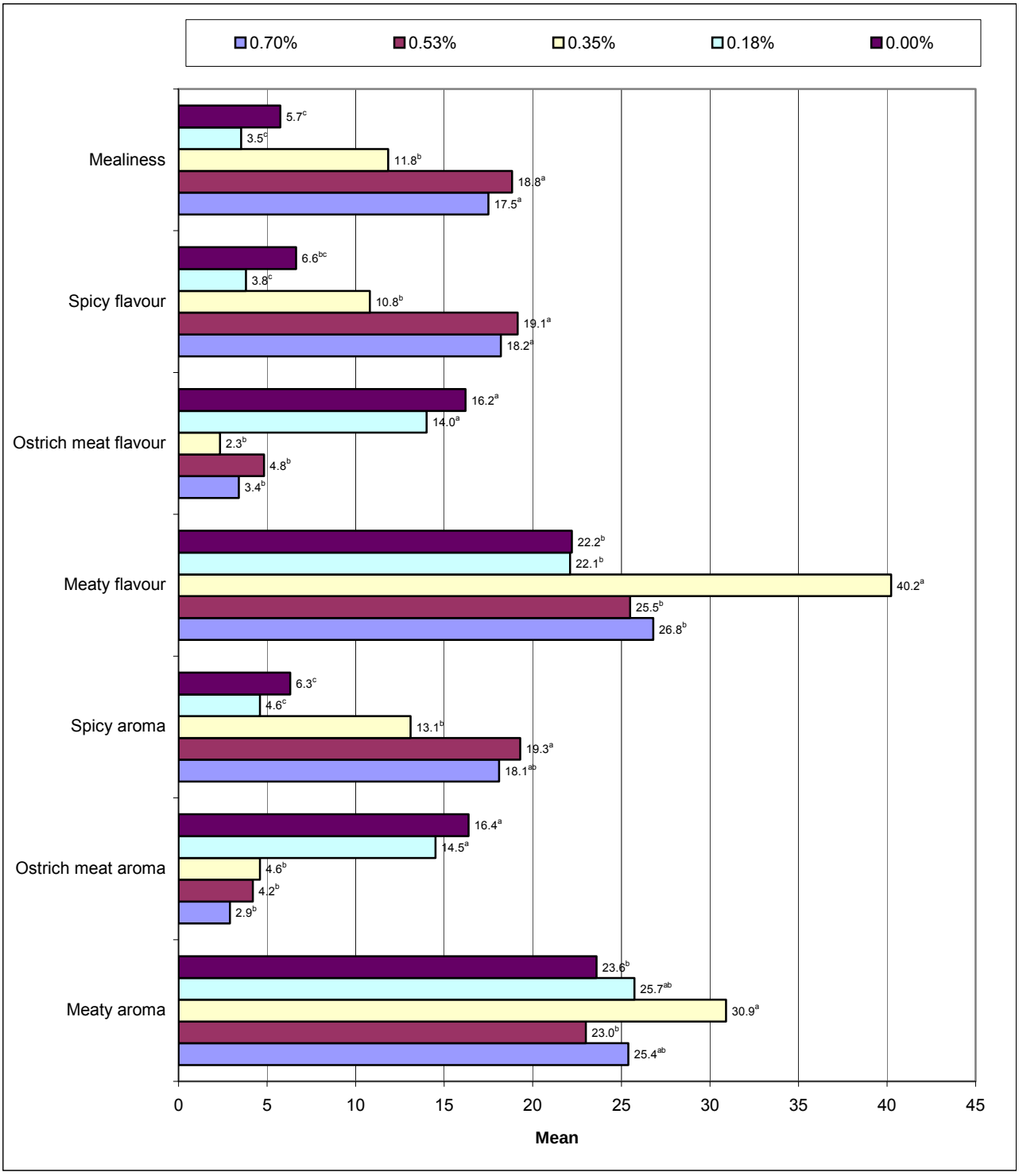

Figure 1 Means (± SD) for the sensory analysis of ostrich ham manufactured with decreasing levels of phosphate.

Table 5 Means (± SD) for the sensory analysis of ostrich ham manufactured with decreasing levels of phosphate.

Characteristic	Scale	Phosphate level					LSD
		0.70%	0.53%	0.35%	0.18%	0.00%	
Meaty aroma	0 = None 100 = Strong	25.4^{ab} ± 12.5	23.0^{b} ± 10.3	30.9^{a} ± 15.8	25.7^{ab} ± 14.3	23.6^{b} ± 15.3	5.88
Ostrich meat aroma	0 = None 100 = Strong	2.9^{b} ± 6.6	4.2^{b} ± 7.8	4.6^{b} ± 7.4	14.5^{a} ± 13.0	16.0^{a} ± 14.4	4.41
Spicy aroma	0 = None 100 = Strong	18.1^{ab} ± 17.6	19.2^{a} ± 16.8	13.1^{b} ± 11.8	4.6^{c} ± 8.2	6.3^{c} ± 10.7	5.48
Meaty flavour	0 = None 100 = Strong	26.8^{b} ± 14.4	25.5^{b} ± 14.5	40.2^{a} ± 18.5	22.1^{b} ± 15.4	22.2^{b} ± 16.4	5.08
Ostrich meat flavour	0 = None 100 = Strong	3.4^{b} ± 8.7	4.8^{b} ± 7.9	2.3^{b} ± 5.0	14.0^{a} ± 14.9	16.2^{a} ± 18.1	4.29
Spicy flavour	0 = None 100 = Strong	18.2^{a} ± 14.8	19.1^{a} ± 13.2	10.8^{b} ± 9.9	3.8^{c} ± 7.5	6.6^{bc} ± 11.0	5.38
Mealiness	0 = None 100 = Prominent	17.5^{a} ± 14.4	18.8^{a} ± 16.2	11.8^{b} ± 10.0	3.5^{c} ± 4.2	5.7^{c} ± 8.8	4.29

$^{a-e}$Means within the same row with different superscripts differ significantly ($P \leq 0.05$)

SD - Standard Deviation

LSD - Least Significant Difference ($P=0.05$)

Table 6 Correlations between sensory and objective measurements of ostrich ham manufactured with decreasing levels of phosphate.

	Meat aroma		Ostrich meat aroma		Spicy aroma		Meat flavour		Ostrich meat flavour		Spicy flavour		Mealiness	
	r	P	r	P	r	P	r	P	r	P	r	P	r	P
Total fat (%)	-0.750	0.144	-0.053	0.932	0.256	0.678	-0.748	0.146	0.115	0.854	0.375	0.534	0.291	0.635
Protein (%)	-0.175	0.778	-0.397	0.508	0.563	0.323	0.231	0.708	-0.344	0.571	0.592	0.293	0.580	0.306
Moisture (%)	0.331	0.586	0.519	0.371	-0.703	0.186	-0.023	0.971	0.409	0.494	-0.765	0.132	-0.726	0.165
Ash (%)	-0.104	0.868	-0.839	0.076	0.873	0.053	0.110	0.860	-0.742	0.151	0.888	0.044	0.876	0.052
Phosphate (%)	-0.076	0.904	-0.786	0.115	0.790	0.112	0.064	0.919	-0.695	0.193	0.814	0.103	0.789	0.112
Cooked Yield (%)	0.260	0.672	0.797	0.106	-0.911	0.031	-0.045	0.943	0.678	0.208	-0.949	0.014	-0.924	0.025
L*	0.509	0.381	0.111	0.859	-0.199	0.748	0.613	0.272	-0.016	0.979	-0.276	0.653	-0.218	0.724
a*	-0.745	0.149	0.295	0.630	-0.096	0.878	-0.857	0.063	0.443	0.455	0.395	0.950	-0.056	0.928
b*	0.098	0.876	0.675	0.211	-0.674	0.212	0.027	0.965	0.581	0.305	-0.698	0.190	-0.676	0.210
Hardness (N)	0.168	0.787	0.846	0.071	-0.899	0.039	-0.071	0.910	0.746	0.148	-0.982	0.033	-0.900	0.037
Gumminess (N)	-0.146	0.815	0.938	0.018	-0.896	0.040	-0.362	0.549	0.885	0.046	-0.871	0.055	-0.885	0.046
Cohesiveness	0.017	0.978	0.932	0.021	-0.955	0.011	-0.266	0.666	0.853	0.066	-0.949	0.014	-0.952	0.012
Springiness (mm)	0.136	0.828	0.845	0.071	-0.961	0.009	-0.295	0.630	0.765	0.132	-0.967	0.007	-0.967	0.007

r – Correlation value

P – Probability value ($P \leq 0.05$)

Consumer sensory analysis

Table 7 and Figure 2 illustrate the degree of liking of the three samples of ham according to a group of 100 consumers.

Table 7 Mean values (±SE) for degree of liking of ostrich ham manufactured with decreasing levels of phosphate.

Phosphate level	Means of overall acceptability for		
	Total group (n=100)	Female consumers (n=59)	Male consumers (n=41)
0.70%	6.5[a] ± 0.1	6.4[a] ± 0.2	6.8[a] ± 0.3
0.35%	6.4[a] ± 0.1	6.4[a] ± 0.2	6.4[a] ± 0.3
0.00%	5.4[b] ± 0.1	5.4[b] ± 0.2	5.3[b] ± 0.3
LSD	0.40	0.45	0.88

SE - Standard Error

LSD - Least Significant Difference (P=0.05)

[a-e]Means within the same column with different superscripts differ significantly (P≤0.05)

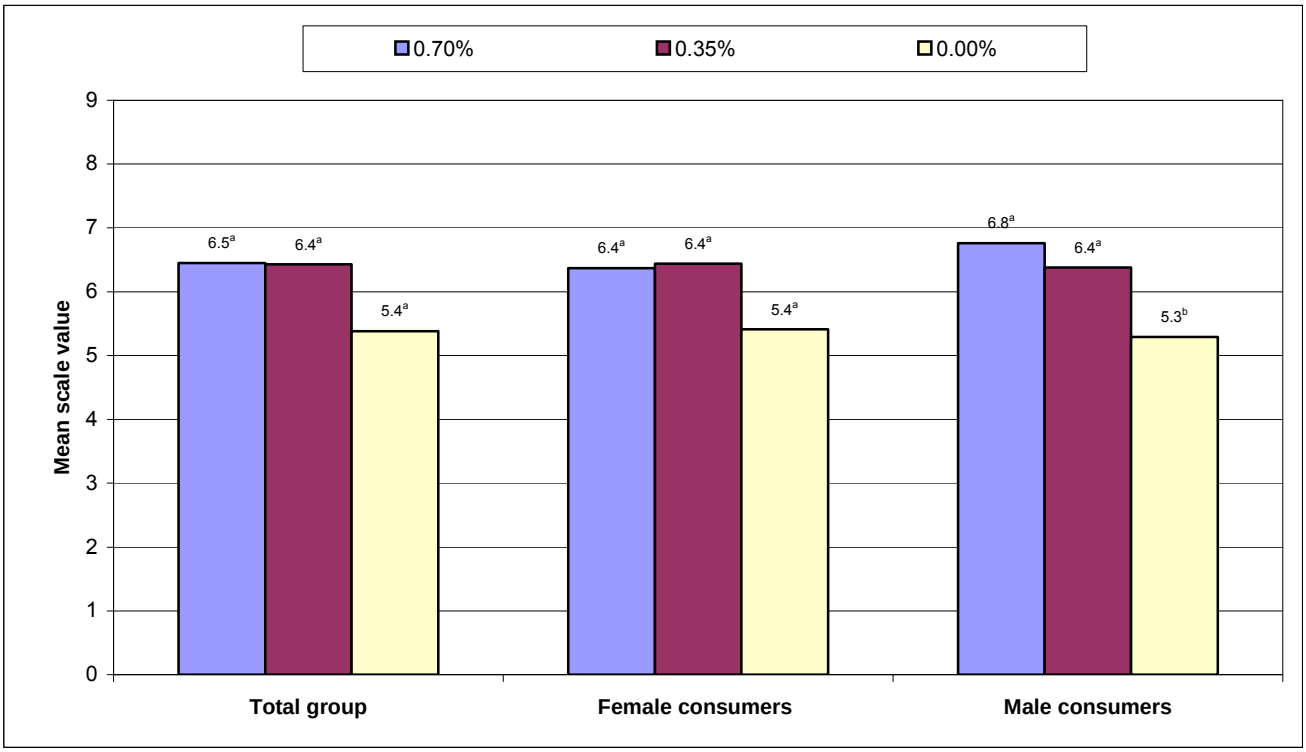

Figure 2 Mean values for degree of liking of ostrich ham manufactured with decreasing levels of phosphate.

Consumers were unable to discriminate in their degree of liking between the ham formulated with 0.7 and 0.35% phosphate (*P*>0.5*)*. The latter two samples were thus preferred equally. However, the ostrich ham prepared with 0% phosphate was found to be significantly (*P*≤0.5) less preferred. The same response pattern was found in the results of both male and female consumers. Therefore it can be concluded that the phosphate level in ostrich ham can be successfully reduced to an acceptable level of 0.35%.

The frequency scores in Table 8 and Figure 3 give an indication of the distribution of preference over the nine classes of the hedonic scale and therefore acceptability.

Table 8 Distribution of frequency (%) for preference of ostrich ham manufactured with decreasing levels of phosphate (n=100).

Hedonic classes	**Phosphate level**		
	0.70%	**0.35%**	**0.00%**
Dislike extremely (1)	1	1	3
Dislike very much (2)	2	1	7
Dislike moderately (3)	1	4	6
Dislike slightly (4)	11	8	21
Neither like nor dislike (5)	6	9	10
Like slightly (6)	23	17	18
Like moderately (7)	27	34	20
Like very much (8)	25	23	11
Like extremely (9)	4	3	3

Chi-square $x^2_{(DF = 16)} = 29.9$, $P = 0.02$

The chi-square value ($x^2 = 29.9$, $P = 0.02$) indicates that there were sufficient evidence for association between phosphate level and acceptability of the product. More than 50% of the respondents scored between 6 and 9 on the nine-point hedonic scale, ranging from 1 = dislike extremely, through 5 = neither like nor dislike, to 9 = like extremely for all the attributes, which indicates that all samples can be considered as acceptable. The ham formulated with 0.7% phosphate had the highest ranking score (added values of responses 6 to 9) of 79%, followed by the 0.35% phosphate level ham at 77%. However, only 52% of the consumers found the ham formulated with 0% phosphate as acceptable. These results serve as a further conformation that further product development is necessary to produce a feasible phosphate-free ostrich ham to the consumer.

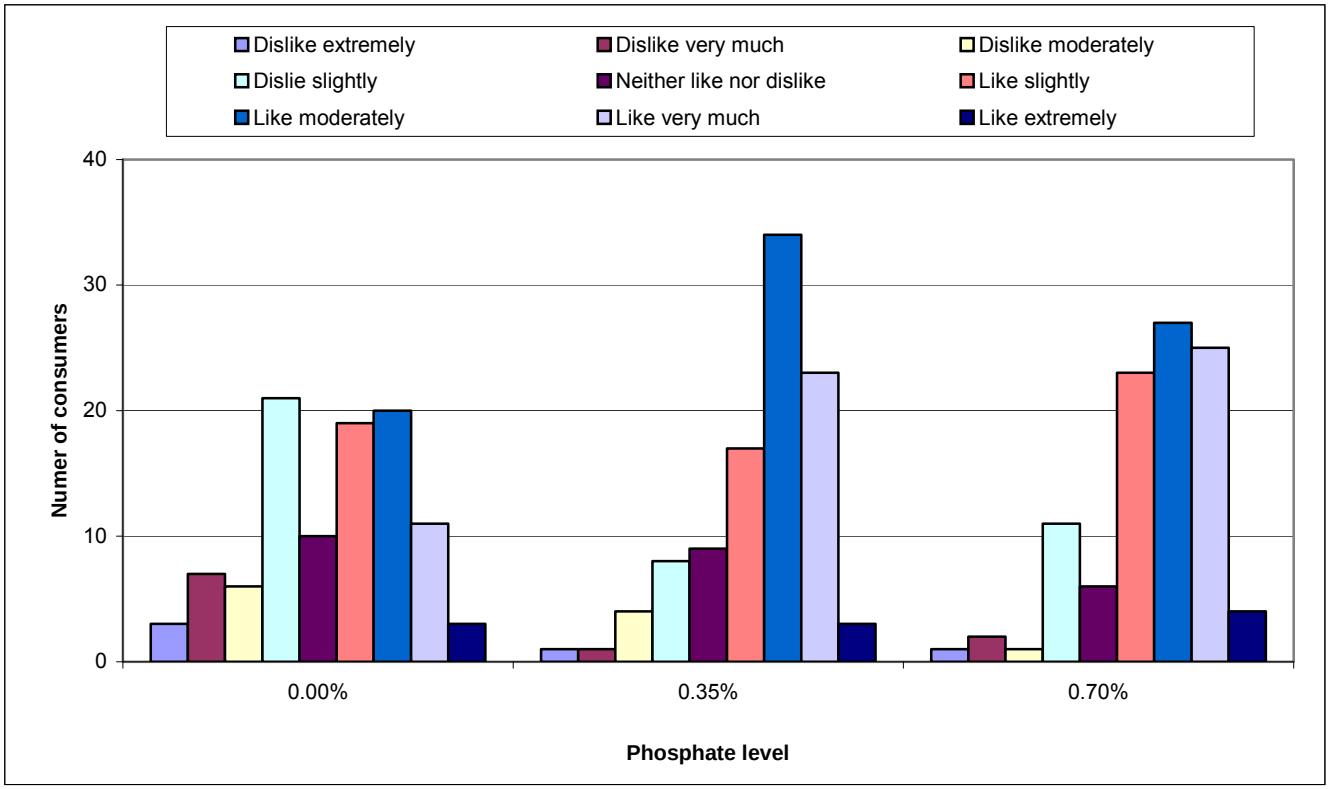

Figure 3 Distribution of frequency (%) for preference of ostrich ham manufactured with decreasing levels of phosphate (n=100).

CONCLUSION

The results from this study indicate that the manufacture of a reduced phosphate ostrich ham is a viable option for the ostrich meat industry. Due to the variation of the composition within the samples of each treatment, no significant tendency was found with decreasing levels of phosphate with relation to the chemical composition and physical properties measured. However, decreasing levels of phosphate showed significant increases in the cooked yield, which could be attributed to the water binding ability of the increased levels of carrageenan. The low fat content and favourable fatty acid profile of ostrich ham makes it a healthy option for the consumer. Sensory panel results revealed that the phosphate level in ostrich ham could be reduced to an acceptable level of 0.35%. Further research should investigate the use of other alternatives to substitute phosphate and focus on optimising the processing technique (i.e. tumbling time) for optimum myofibrillar protein extraction in order to produce a product with optimum textural and sensory quality. Further research should also include the use of antioxidants to control colour changes and shelf life studies of the product.

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Chapter 5

The effect of different levels of salt (NaCl) on the physical, chemical and sensory characteristics of ostrich bacon

ABSTRACT

The effect of decreased salt (NaCl) levels in ostrich bacon was investigated on the physical, chemical and sensory properties thereof. Treatments consisted of five targeted salt levels of 3.5, 2.75, 2.0, 1.25, and 0.5%. Upon chemical analysis, the actual salt content of the five bacon treatments was found to be 3.58, 2.44, 2.22, 1.26 and 0.76%. Decreased salt levels had no significant effect on the L*, a* and b* colour coordinates of the five treatments. The P:S ratio of all the bacon treatments were above the recommended value of 0.45, whereas only the bacon formulated with 2.0, 1.25 and 0.5% had n-6:n-3 ratios lower than the recommended maximum value of 4.0. The effect of increased levels of salt on the bacon sensory characteristics was also investigated. Panellists found the bacon treatment with 3.5% level salt to have a significant higher ($P \leq 0.05$) ostrich aroma (38.2) and ostrich flavour (37.8) than the rest of the treatments. Though not significant ($P > 0.05$), there seemed to be an observable decrease in ostrich aroma and flavour with decreased levels of salt. The sensory panel found that the bacon treatment with 1.25% salt level had the most prominent smoky bacon aroma (33.2) and smoky bacon flavour (31.4) and differed significantly ($P \leq 0.05$) from the rest of the treatments. As expected, a significant difference ($P \leq 0.05$) in saltiness was found between the five bacon treatments with increased levels of salt, with the bacon treatment with a salt content of 0.5% as the least salty (13.7), and the treatment with a salt level of 3.5% as the most salty (71.6). Significant correlations ($P \leq 0.05$) were found between the sensory characteristics recorded and objective measurements. Saltiness, scored by the trained panel, was positively correlated ($P \leq 0.05$) with the percentages salt ($r = 0.943$; $P = 0.016$) and ash ($r = 0.965$; $P = 0.007$) and negatively correlated with the percentage moisture ($r = -0.911$; $P = 0.031$). Ostrich meat aroma and flavour was highly correlated with the percentage salt ($r = 0.947$; $P = 0.014$ and $r = 0.988$; $P = 0.001$, respectively) in the product. A consumer panel found all five bacon treatments to illustrate a high degree of liking, with 2.75 and 2.0% scoring the highest degree of liking pertaining to saltiness and overall product acceptability. It is concluded that the sodium chloride levels in ostrich bacon can be successfully reduced to produce acceptable low salt ostrich bacon.

Keywords: Ostrich meat, Bacon, Reduced salt

INTRODUCTION

The sodium intake of the average person frequently exceeds the maximum nutritional recommendation. Epidemiological studies indicate a positive association between excessive intake of sodium, blood pressure and prevalence of hypertension (Altschul & Grommet, 1980; Appel *et al.,* 2006; Chobanian & Hill, 2000; Cutler *et al.,* 1997; Dahl, 1972; Gibson *et al.,* 2000; He *et al.,* 2000; Law *et al.,* 1991; Law, 1997; MacGreggor *et al.,* 1989; Svetkey *et al.,* 1999). Tuomilehto *et al.* (2001) found that high sodium intake correlated positively with mortality and risk of coronary heart disease, independent of other cardiovascular risk factors, including blood pressure. These results provide evidence of the harmful effects of high sodium intake in the adult population. The main source of sodium in the diet is salt (NaCl). On a population basis, it has been established that the consumption of more than 6 g NaCl/day/person is associated with an age-related increase in blood pressure. Therefore, it has been recommended internationally that the total amount of dietary salt should be maintained at about 5–6 g/day (Aho *et al.*, 1980; WHO, 1990). However, it is recognised that genetically salt susceptible individuals and individuals suffering from hypertension will particularly benefit from low-sodium diets, and in the latter case the salt content should range between 1-3 g/day.

According to Engstron *et al.* (1997), meat products are one of the main contributors to the high dietary sodium intake in the form of salt added during processing. Sodium is also a part of various other additives used when preparing meat products, e.g. monosodium glutamate, curing salt, sodium phosphates and sodium citrate. However, the amount of sodium from other additives is much lower compared to the amount of sodium from sodium chloride (NaCl).

Salt is known as an essential ingredient in processed meat products such as bacon for its positive effects on texture, taste and shelf life (Desmond, 2006; Claus & Sørheim, 2006; Drosinos *et al.,* 2006; Flores *et al.,* 2007; Gelabert, 2003; Li, 2006; Qvist, 1994; Ruusunen & Puolanne, 2005; Terrell, 1983). Salt contributes to the texture of processed meat products by its ability to solubilise the functional myofibrillar proteins in meat. This activates the proteins to increase hydration and the water binding capacity, ultimately increasing the binding properties of proteins thereby improving the texture. Increasing the water holding capacity of the meat reduces cooking loss, thus increasing tenderness and juiciness of the meat product. Salt also has a taste enhancing effect in meat products, with the perceived saltiness mainly due to the Na^+ with the Cl^- anion modifying the perception (Ruusunen & Puolanne, 2005). The latter is especially true for a product such as bacon. Salt also decreases water activity (a_w) and this can affect the shelf life of a product (Sofos, 1984; Wirth, 1989). Reducing sodium chloride (NaCl) levels below those typically used without any other preservative measure has been shown to reduce shelf life (Madril & Sofos, 1985; Sofos, 1983, 1985). Whiting *et al.* (1984) found that reducing the level of salt by 60% to 1.5% resulted in a more rapid growth in natural flora of frankfurters. Reducing the salt level by 50% to 1.25% in ground pork resulted in slight increases in the growth of *Lactobacillus* spp. (Terrell, 1983).

As a result of the ongoing campaign by public health authorities, meat technologists responded to the international trend of producing low salt food products. This is reflected in various studies on reducing the salt content of processed meat products (Barbut & Mittal, 1989; Barbut *et al.,* 1988a,b; Bertino *et al.,* 1982; Brandsma, 2006; Byun *et al.,* 2002; Cáceres *et al.,* 2006; Collins, 1997; Colmenero *et al.,* 2005; Crehan *et al.,* 2000; Gelabert *et al.,* 2003; Guàrdia *et al.,* 2006; Ruusunen *et al.,* 2003). Apart from lowering the level of salt added to products, Desmond (2006) exemplifies three major approaches to reduce the salt content in processed foods, namely the use of salt substitutes, the use of flavour enhancers, and optimising the physical form of salt so that it becomes more taste bioavaliable (therefore less salt is needed).

Bacon, a smoked cured meat product, contains a high salt content (g/100 g) of 2.5 to 3.9 g, containing 1.0 to 1.54 g sodium. However, health authorities have recommended proposed targets (g/100 g) of a maximum of 3.0 g salt equivalent to 1.4 g sodium content in bacon (Desmond, 2006). Ostrich meat is frequently marketed and perceived as a healthy alternative to other red meats due to its favourable nutritional properties - low cholesterol and intramuscular fat and generally high omega-3 polyunsaturated fatty acid content (Alonso-Calleja *et al.,* 2004; Capita *et al.,* 2006; Fisher *et al.,* 2000). Relative to beef, ostrich meat is characterised by a higher ultimate pH (>6.2) (Botha *et al.,* 2006), lower collagen and higher pigment content, similar cooking loss, darker visual appearance, similar sensory tenderness, higher polyunsaturated fatty acid content and similar cholesterol content (Sales, 1996, 1998; Walter *et al.,* 2000). The high pH value of ostrich meat makes it an ideal processing meat, since the natural water holding capacity is high (Fisher *et al.,* 2000).

With the beneficial effects of the health and processing characteristics of ostrich meat, this study was designed to develop a healthier and more acceptable alternative to traditional bacon and also to investigate the effect that salt reduction has on the chemical, textural and sensory properties of ostrich bacon.

MATERIALS AND METHODS

Bacon manufacture

This experiment was preceded by a development phase of which the details are in Annexure 1.
Five different bacon treatments were produced (Table 1). Demembraned ostrich (*Struthio camelus* var. *domesticus*) steaks (*Iliofibularis* muscle) (Fisher *et al.,* 2000) were obtained from a local European Union approved abattoir, Mosstrich (2 Mkuzi Street, Mossdustria, Mossel Bay, South Africa). All five treatments were produced from the same meat batch. The steaks (± 600 g) were individually vacuum-packed and stored at -18°C until used. The composition of the enhancement solutions (brine) were sodium tri-polyphosphate (STPP), sodium erythorbate, curing salt (NaCl + 0.6% nitrite), sodium chloride, sugar and garlic (Table 1). All the ingredients were provided by a single provider, Deli Spices (25 Bertie Avenue, Epping 2, Cape Town, South Africa).

Four demembraned steak meat pieces per treatment (Table 1) were weighed individually prior to injection, using a multiple needle injector at 2-3 bar to a target of 25% of uninjected weight, and reweighed to monitor the actual injected percentage. The injector was drained and flushed between treatment solutions. The injected meat pieces were placed in narrow containers where brine was added, or discarded, for the product to fall within ±1% deviation from the target gain of 25%. To ensure minimum surface exposure, immersed meat pieces were covered with plastic and chilled for 24 h at 4°C. After 24 h, the cured meat was weighed and hung for 15 h at 4°C for the meat surface to dry. For the calculation of salt retainment, an assumed loss of 10% during drying and 5% during smoking was used (Table 1).

Plastic hooks of known weight were inserted into the labelled dried meat pieces and hung in a smokehouse. Ten thermocouple probes (2 probes per treatment) were inserted in random selected steaks, through the thickest section of the meat pieces. Two probes were placed in the smokehouse to monitor the temperature inside. All the thermocouples were connected to a data-logging system and temperature readings were monitored at 10 min time. Meat pieces were cold smoked for 30 min to a core temperature of 29 - 32°C. When removed from the smokehouse, the smoked meat pieces were immediately individually vacuum-packed, frozen at -18ºC and reweighed 24 h after frozen storage.

Smoked meat pieces were removed from the freezer and left for 4 h at 4ºC prior to slicing. The smoked meat pieces were sliced in the processing laboratory (at ambient temperature) into 4 mm thick slices. Randomly selected slices of each of the four meat pieces (replicates) per treatment were individually vacuum-packed (Multivac C200, Germany) and labelled. The sliced smoked bacon samples were stored at -18ºC until their pre-assigned days for physical, chemical and sensory analysis.

Processing yield

Injected, cured, dried, smokehouse and frozen yields were determined by dividing the weight of the injected, cured, dried, smoked or frozen product by the weight of the product in its initial state (raw product), multiplied by 100.

Table 1 Formulations and yield calculations of five ostrich bacon treatments.

Ingredients	Salt levels														
	3.5%			2.75%			2.0%			1.75%			0.5%		
	Brine (%)	Product Raw (%)	Product Smoked (%)	Brine (%)	Product Raw (%)	Product Smoked (%)	Brine (%)	Product Raw (%)	Product Smoked (%)	Brine (%)	Product Raw (%)	Product Smoked (%)	Brine (%)	Product Raw (%)	Product Smoked (%)
STPP	3.50	0.70	0.82	3.50	0.70	0.82	3.50	0.70	0.82	3.50	0.70	0.82	3.50	0.70	0.82
Salt	13.90	2.78	3.27	10.70	2.14	2.52	7.50	1.50	1.76	4.30	0.86	1.01	1.10	0.22	0.26
Curing salt[#]	1.00	0.20	0.23	1.00	0.20	0.23	1.00	0.20	0.23	1.00	0.20	0.23	1.00	0.20	0.23
SE	0.25	0.05	0.06	0.25	0.05	0.06	0.25	0.05	0.06	0.25	0.05	0.06	0.25	0.05	0.06
Sugar	5.00	1.00	1.18	5.00	1.00	1.18	5.00	1.00	1.18	5.00	1.00	1.18	5.00	1.00	1.18
Garlic	1.00	0.20	0.23	1.00	0.20	0.23	1.00	0.20	0.23	1.00	0.20	0.23	1.00	0.20	0.23
Water	75.35	15.07	17.73	78.55	15.71	18.48	81.75	16.35	19.23	84.95	16.99	19.99	88.15	17.63	20.74
BRINE	100.00	20.00	23.53	100.00	20.00	23.53	100.00	20.00	23.53	100.00	20.00	23.53	100.00	20.00	23.53
Meat		80.00	94.12		80.00	94.12		80.00	94.12		80.00	94.12		80.00	94.12
SUBTOTAL		100.00	117.65		100.00	117.65		100.00	117.65		100.00	117.65		100.00	117.65
Production losses	*Curing*	-10.00	-11.76	*Curing*	-10.00	-11.76	*Curing*	-10.00	-11.76	*Curing*	-10.00	-11.76	*Curing*	-10.00	-11.76
	Smoking	-5.00	-5.88	*Smoking*	-5.00	-5.88	*Smoking*	-5.00	-5.88	*Smoking*	-5.00	-5.88	*Smoking*	-5.00	-5.88
TOTAL		85.00	100.00		85.00	100.00		85.00	100.00		85.00	100.00		85.00	100.00

NaCl + 0.6% nitrite

STPP - Sodium tri-polyphosphate

SE - Sodium erythorbate

Chemical analyses

Homogenised samples of each of the four replicates of the five bacon treatments were analysed in duplicate for total percentages of moisture, protein and ash (AOAC, 2005). For protein content, dried and defatted samples were ground with a pestle in a mortar until a fine powder was obtained. Subsequently 0.1 mg of the powder was used per sample and inserted into a foil wrap designed for the Leco protein analyser (Leco Fp-528). The protein concentration in the sample was determined as Nitrogen x 6.25. The moisture content was analysed by drying 2.5 g sample at 100ºC for a period of 24 h and ashing was done at 500ºC for a period of 6 h. The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform:methanol (Lee *et al.*, 1996). The pH of refrigerated (4ºC) bacon samples was measured with the use of a calibrated (standard buffers pH 4.0 and 7.0) portable Testo 502 pH-meter. Homogenised samples of each of the four replicates of the five bacon treatments were analysed by Elsenburg Production Technology Laboratory (Department Agriculture, Elsenburg, Western Cape, South Africa) for total percentage of salt (NaCl) according to the AOAC methods (AOAC, 2005).

Physical analyses

Instrumental colour measurements of the bacon were recorded on one slice obtained from each of the four bacon replicates per treatment. A colour-guide 45º/Oº colorimeter (Cat no: 6805; BYK-Gardner, USA) was used. The bacon slices (1.5 to 2.0 cm thick) of each treatment were allowed to "bloom" for 30 min at room temperature (18-19ºC) prior to colour measurements. Four colour measurements were recorded for each slice at randomly selected positions and expressed by the coordinated L*, a* and b* of the CIELab colorimetric space (MINOLTA, 1998). In the colour space L* indicates lightness and a* and b* are the chromaticity coordinates, where a* is the red-green range, and b* the yellow-blue range of the colour spectrum.

Fatty acid composition analysis

Fatty acid methyl esters (FAME) were prepared from the extracted total lipids (Lee *et al.,* 1996) according to the procedures published by Morrison and Smith (1964). The FAME were analysed with a gas-liquid chromatograph (Varian Model 3300), equipped with flame ionisation detection and two 30 mm fused silica megabore DB-225 columns of 0.53 mm internal diameter (J&E Scientific, Folsom, CA). Gas flow rates were: hydrogen 25 ml/min and nitrogen (carrier gas) 5-8 ml/min. The temperature program was linear at 4ºC/min with initial and final temperatures of 160°C and 220°C (held for 10 min), respectively. The injector temperature was 240°C and the detector temperature

250°C. FAME were identified by comparison of the retention times to those of a standard FAME mixture (Nu-Chek-Prep Inc., Elysian, Minnesota).

Sensory analysis

The purpose of the sensory analysis was to determine the effect of salt reduction on the sensory quality characteristics and to ascertain the overall degree of liking of the ostrich bacon treatments. Frozen (-18ºC) vacuum packed sliced bacon were stored in a refrigerator at a constant temperature of 4ºC, 2 h prior to sensory analysis. Eight thawed bacon slices (2 slices from each of the four bacon replicates per treatment) were pan fried in canola oil in an electric frying pan on heat setting no. 8 (range 1 to 12) for 2 min on each side. The fried bacon slices were thereafter wrapped in waxed paper and stored in containers at 4ºC until subsequent sensory analysis.

Descriptive sensory analysis was performed to ascertain the sensory quality characteristics. The panellists were chosen based on their experience in sensory analysis and on their availability. Panellists were trained in accordance with the generic descriptive analysis technique as described by Lawless and Heymann (1998). An eight member panel was trained in two interactive sessions to familiarise the panellists with the treatments and to identify the sensory characteristics to be evaluated. A questionnaire was compiled during the first training session. The questionnaire was refined and tested during the second training session. An unstructured line scale ranging from 0-100 mm was used to analyse the sensory characteristics (Annexure 6). Table 2 depicts the characteristics and definitions used. The sensory tests were performed in individual booths in a temperature (21ºC) and light controlled (equivalent to daylight) room. One sample of each of the five treatments was served to the panellists in a randomised order in five sessions. Distilled water, apple and crackers were given to the panellists in between treatments. Each sample was coded with randomly selected three digit numbers and served at a refrigeration temperature of 6-10ºC.

For the determination of degree of liking, a hundred consumers (73 females, 27 males) were recruited among staff and students at the University of Stellenbosch, South Africa. The consumers tested the bacon, without any knowledge as to the formulation of the products. Each consumer received one sample of each treatment, coded with three-digit codes, in a random order. Testing was done individually in a temperature (21ºC) and light controlled (equivalent to daylight) room. The traditional nine-point hedonic scale ranging from 1, dislike extremely; 2, dislike very much; 3, dislike moderately; 4, dislike slightly; 5, neither like nor dislike; 6, like slightly; 7, like moderately; 8, like very much; to 9, like extremely, was used. The latter instrument is used to test preference and acceptability. Panellists were asked to assign an order to the samples in accordance to overall preferences and acceptability and in this study, treatments were considered acceptable if 50% or more of the responses were between 6 to 9 on the hedonic scale (Annexure 7).

Table 2 Verbal definitions of sensory characteristics for the descriptive sensory analysis of bacon.

Characteristic	Definition	Scale
Ostrich meat aroma	The intensity of an ostrich meat aroma, perceived by sniffing	0 = None 100 = Strong
Smoky bacon aroma	The intensity of a smoky bacon aroma, perceived by sniffing	0 = None 100 = Strong
Ostrich meat flavour	The intensity of an ostrich meat flavour, perceived by tasting	0 = None 100 = Strong
Smoky bacon flavour	The intensity of a smoky bacon flavour, perceived by tasting	0 = None 100 = Strong
Saltiness	The intensity of the saltiness, perceived by tasting	0 = None 100 = Strong

Statistical analysis

A complete randomised design with five treatments and different numbers of replicates for different measurements, were performed. A one-way analysis of variance (ANOVA) was performed on all the data using SAS version 9.1 statistical software (SAS, 1999). The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). In some cases deviations from normality were the cause of one or two outliners, which were removed before the final analysis (Glass *et al.,* 1972). Student's t-Least Significant Difference (LSD) was calculated at a 5% significant level to compare treatment means. Pearson correlation coefficients were calculated between objective and descriptive sensory variables. For the consumer data, scores were subjected to one-way (Treatments) and two-way (Treatments x Gender) ANOVA. The Shapiro-Wilk test was performed to test for non-normality (Shapiro & Wilk, 1965). Student's t-Least Significant Difference (LSD) was calculated at a 5% significant level to compare treatment means. Also, an RxC contingency table (Rows = Treatments; Columns = Degree of liking) of frequency was set up and tested for association using Chi-square.

RESULTS AND DISCUSSION

Processing yields

All the treatments were injected to a target 25% of initial weight, which was attained within *ca* 1% (Table 3).

Table 3 Processing yields of five ostrich bacon treatments.

Processing yields	Salt level				
	3.5%	**2.75%**	**2.0%**	**1.75%**	**0.5%**
Raw meat weight (kg)	5.99	6.79	7.73	5.85	5.96
Target meat weight (kg)[#]	7.49	8.49	9.67	7.31	7.45
Injected meat weight (kg)	7.53	8.53	9.68	7.31	7.50
Yield (*injected*) (%)[a]	125.66	125.60	125.13	125.02	125.94
Cured meat weight (kg)	7.39	8.39	9.21	7.08	7.37
Yield (*cured*) (%)[a]	123.39	123.60	119.10	121.01	123.65
Dried meat weight (kg)	7.26	8.26	9.03	6.95	7.17
Yield (*dried*) (%)[a]	121.21	121.7	116.84	118.89	120.45
Smoked meat weight (kg)	7.00	8.08	8.87	6.82	6.98
Yield (*smoked*) (%)[a]	116.75	119.05	114.72	116.65	117.11
Frozen meat weight (kg)	6.79	7.84	8.84	6.60	6.75
Final yield (*frozen*) (%)[a]	113.32	115.52	114.37	112.87	113.29

[#]Raw meat weight x 1.25

[a] (Specific meat weight / raw meat weight) x 100

All products were formulated for a final yield of 105% (Table 1), however, the observed actual yields were all higher (*ca.* 112-116%; Table 4). The theoretical salt content (for 105% yield) should be 3.5%, 2.75%, 2.0% and 0.5%, respectively. However, based on the actual yield, the theoretical salt content would be higher. On analysis (Table 4), the salt (NaCl) content for the respective treatments was 3.58, 2.44, 2.22, 1.26 and 0.76%, respectively. The difference between the actual salt level and the targeted theoretical salt level (based on theoretical yields) were on average ± 0.22% per total bacon weight. This difference could be the result of a random sampling error.

Table 4 Theoretical and actual salt levels (%) of five bacon treatments.

Salt level (%)[a]	Bacon yield (%)	Theoretical salt level (based on actual yield) (%)[b]	Actual analysed salt level (%)
3.5	113.32	3.77	3.58
2.75	115.52	3.00	2.44
2.0	114.37	2.17	2.22
1.25	112.87	1.34	1.26
0.5	113.29	0.53	0.76

[a]Based on theoretical yield of 105%

[b](Actual yield / 105) x salt level based on theoretical yield of 105%

Descriptive characteristics

The chemical composition and instrumental colour measurements of the five bacon treatments with decreased levels of salt are presented in Table 5.

Chemical composition

The moisture content of the bacon increased significantly ($P \leq 0.05$) with decreasing levels of salt (Table 5). Though, the results from this study are not in agreement with the results of Pexara *et al.* (2006) who found that an increase in salt level addition did not effect the moisture content of "gyros", it agrees with the result of Fernández-Martín *et al.* (2002) who found that increase salt levels, decreased the moisture content of pork batters. Since no fat was added during the manufacturing process, no difference in the lipid content between the five bacon treatments with decreased levels of salt would be expected. Although there were significant differences in fat content ($P \leq 0.05$) in this study, no trend in differences could be seen. Similarly, no trend was found in the protein content of the bacon treatments with decreased levels of salt (Table 5), also possibly as a result of sampling error or unexplained factors. The results of this study agree with Pexara *et al.* (2006) who found that the level of salt had no significant affect on the protein content of "gyros". The ash content of the bacon seemed to decrease as the levels of salt decreased. However, a significant difference ($P \leq 0.05$) was only observed between the bacon treatments with extreme manipulation of salt levels (3.5 and 0.5%) (Table 5). These results also supports that of Pexera *et al.* (2006) who found that an increase in ash content was observed when salt was added in the formulation of "gyros".

Table 5 Means (± SD) of the descriptive characteristics of bacon treatments*.

	Salt level					LSD
	3.50%	**2.75%**	**2.0%**	**1.25%**	**0.50%**	
Chemical Composition						
Moisture (%)	71.9^{c} ± 0.3	72.5^{c} ± 0.4	76.4^{b} ± 0.3	76.2^{b} ± 0.0	78.3^{a} ± 0.4	0.91
Fat (%)	2.0^{a} ± 0.2	2.2^{a} ± 0.1	1.5^{b} ± 0.0	1.6^{b} ± 0.1	2.2^{a} ± 0.1	0.34
Protein (%)	20.1^{ab} ± 0.0	21.3^{a} ± 1.5	18.5^{c} ± 0.1	19.9^{b} ± 0.3	17.7^{c} ± 0.1	1.19
Ash (%)	4.8^{a} ± 1.6	4.1^{ab} ± 0.0	4.3^{ab} ± 0.0	3.1^{ab} ± 0.2	2.6^{b} ± 0.1	1.91
pH	6.22	6.25	6.24	6.22	6.20	n/a
Instrumental colour						
Lightness (L*)	34.0^{b} ± 1.2	35.9^{a} ± 2.9	33.8^{b} ± 1.6	31.1^{c} ± 2.2	33.0^{b} ± 1.7	1.68
Redness (a*)	15.2^{a} ± 0.9	12.7^{b} ± 1.7	12.5^{b} ± 1.5	11.9^{b} ± 1.0	12.1^{b} ± 1.5	1.15
Yellowness (b*)	10.8^{a} ± 1.1	10.3^{ab} ± 1.2	9.2^{bc} ± 1.8	8.3^{c} ± 1.4	9.2^{bc} ± 1,4	1.18

*Statistical analyses were performed on all data with the exception of pH, as these were measured only once per treatment

SD - Standard Deviation

LSD = Least Significant Difference (P=0.05)

$^{a-e}$Means within the same row with different superscripts differ significantly ($P \leq 0.05$)

Instrumental colour

Colour is the first quality attribute that influences a consumer's purchasing intent (Risvik, 1994). In this investigation, it seemed that decreased levels of salt in ostrich bacon had no significant affect on the colour of the product. The bacon with 1.25% salt level was the lightest (L*) and least yellow (b*) in colour (31.12 and 8.37, respectively) and differed significantly ($P \leq 0.05$) from the rest of the treatments, whilst the bacon with 3.5% salt level was significantly ($P \leq 0.05$) more red (a*) (15.25) than the other treatments. In view of the fact that the added nitrite level in this study was kept constant, the increased red colour of the 3.5% bacon treatment could be the result of a possible sampling error or natural variation in sample.

Fatty acid composition

The fatty acid profiles (% of total fatty acids) of the five ostrich bacon treatments with 3.5, 2.75, 2.0, 1.25 and 0.5% salt levels are depicted in Table 6. Ostrich meat is also known for its favourable fatty acid profile (intramuscular ostrich fat contains 16.50% polyunsaturated n-3 fatty acids), as well as for its low intramuscular fat content (Sales, 1998; Sales *et al.,* 1996). In relation to individual fatty acids, ostrich bacon showed a high percentage of oleic acid (C18:1n-9; 17.94 - 24.84%), followed by palmitic acid (C16:0; 12.26 - 19.29%) and then linoleic acid (C18:2n-6; 12.41 - 16.54%) (Table 6). These results agree with the fatty acid profile reported previously for ostrich meat (Horbanczuk *et al.*, 1998; Sales, 1998; Sales, Marais, & Kruger, 1996; Hoffman & Fisher, 2001). Since no fat was added during the manufacturing process, no variation in the fatty acid profile was expected. It could therefore be assumed that the differences in the fatty acid profile were due to natural variation of fat content of the specific batch. To assess the possible nutritional impact of the bacon, the P:S ratio, the PUFA n-6:n-3 ratio and the desirable fatty acids (DFA), were determined (Table 6). To improve the health status of a population, a n-6:n-3 PUFA ratio of less than 4 and a P:S ratio of more than 0.45 is recommended internationally (Wood *et al.,* 2004; Simopoulos, 2004). In the present study, the P:S ratio of all the treatments are above the recommended value of more than 0.45. The bacon formulated with 3.5, 1.25 and 0.5% salt levels had a n-6:n-3 ratio of less than 4.0 (3.43, 2.13 and 2.26, respectively), whereas the bacon with 2.75% and 2.0% salt had a ratio higher than what is recommended.

Table 6 Fatty acid composition (%) of bacon manufactured with decreasing salt levels

Fatty acids (%)	Salt level				
	3.5%	**2.75%**	**2.0%**	**1.25%**	**0.5%**
Saturated Fatty Acids					
6:0	6.57	8.01	7.19	9.28	10.06
8:0	0.11	0.32	0.18	0.78	0.14
10:0	n/d	n/d	n/d	0.09	n/d
11:0	0.72	0.93	1.02	0.68	0.57
12:0	0.45	0.54	0.64	0.36	0.31
13:0	0.86	0.96	1.19	0.52	0.55
14:0	0.68	0.76	0.87	0.52	0.41
15:0	0.78	0.78	0.92	0.45	0.45
16:0	13.33	16.85	19.29	14.75	12.26
18:0	16.77	15.14	18.20	12.42	13.94
20:0	0.20	0.24	0.24	0.16	0.18
21:0	0.57	0.94	0.87	0.39	0.66
22:0	0.57	0.94	0.88	0.39	0.11
24:0	1.05	1.51	1.14	1.93	0.81
Mono-unsaturated Fatty Acids					
14:1	0.11	0.11	0.15	n/d	0.07
15:1	0.09	0.10	0.13	0.11	0.45
16:1	1.91	1.34	1.18	2.97	2.07
18:1 n-9t	0.43	0.48	1.20	0.56	0.23
18:1 n-9c	20.74	19.05	17.94	22.31	24.84
20:1	0.29	0.28	0.24	0.52	0.33
22:1 n-9	0.55	0.65	0.52	0.15	0.63
24:1	0.30	0.58	0.27	0.26	0.30
Poly-unsaturated Fatty Acids					
18:2 n-6t	0.06	0.08	0.17	0.13	0.08
18:2 n-6c	16.54	12.58	13.21	12.41	12.96
18:3 n-6	0.07	0.08	0.12	n/d	n/d
18:3 n-3	2.12	1.30	1.20	3.17	2.48
20:2	0.38	0.47	0.48	0.69	0.44
20:3 n-6	0.56	0.54	0.60	0.09	0.18
20:3 n-3	0.83	0.51	0.48	0.31	0.75
20:4 n-6	8.12	10.63	6.88	7.73	7.94
20:5 n-3	1.03	0.67	0.81	1.15	1.53
22:2	0.17	0.67	0.23	0.09	0.08
22:5 n-3	1.58	1.74	1.33	2.48	1.66
22:6 n-3	1.80	0.94	0.89	2.37	2.91
Total	100.00	100.00	100.00	100.00	100.00
Total fatty acid profile					
∑SFA	3.49	3.67	3.31	5.84	6.30
∑MUFA	1.98	1.72	1.30	3.62	4.41
∑PUFA	2.74	2.34	1.67	4.20	4.82
∑TUFA	4.72	4.06	2.97	7.82	9.22
∑DFA	6.10	5.24	4.13	9.53	11.39
P:S	0.78	0.64	0.50	0.72	0.76
n-6	2.09	1.85	1.33	2.78	3.28
n-3	0.61	0.40	0.30	1.30	1.45
n-6:n-3	3.43	4.63	4.42	2.13	2.26

SFA = Saturated Fatty Acids; MUFA = Monounsaturated Fatty Acids; PUFA = Polyunsaturated Fatty Acids; TUFA = Total Unsaturated Fatty Acids; DFA = Desirable Fatty Acids (C18:0 + TUFA); n/d = not detected.

Sensory characteristics

The sensory profiling results for aroma, flavour and saltiness are presented in Table 7 and Figure 1. Correlations between instrumental and sensory measurements relevant to this study are depicted in Table 8.

Panellists found the bacon treatment with 3.5% level salt to have a significant higher ($P \leq 0.05$) ostrich aroma (38.2) and ostrich flavour (37.8) than the rest of the treatments (Table 7). Though not significant ($P > 0.05$), there seemed to be an observable decrease in ostrich aroma and flavour with decreased levels of salt. The flavour enhancing effect of salt in meat products (Ruusunen & Puolanne, 2005) is evident in this study in that the bacon formulated with the highest salt content brought the typical, unique ostrich aroma and flavour to the fore. These findings correspond with the significant correlation that was found between ostrich aroma (r = 0.947, $P = 0.014$) and ostrich flavour (r = 0.988, $P = 0.001$) and the total percentage salt content in the product (Table 8). Ostrich aroma (r = 0.994, $P = 0.001$) and ostrich flavour (r = 0.991, $P = 0.001$) was also found to be highly correlated with the instrumental colour a* (redness) value of the product (Table 7). No further correlations were found between ostrich aroma and ostrich flavour and objective measurements of fat, protein, moisture, ash and other instrumental colour characteristics.

The sensory panel found that the bacon treatment with 1.25% salt level had the most prominent smoky bacon aroma (33.2) and smoky bacon flavour (31.4) and differed significantly ($P \leq 0.05$) from the rest of the treatments (Table 7). Panellists were not able to indicate a significant ($P > 0.05$) distinction in smoky bacon flavour between the rest of the treatments. A significant negative correlation was found between the smoky bacon aroma (r = -0.972, $P = 0.005$) and smoky bacon flavour (r = -0.875, $P = 0.051$) and the b* value of the objective colour measurements (Table 8). However, the study did not yield any underlying reason for the latter correlation. No further significant correlations ($P > 0.05$) were found between smoky bacon aroma and objective measurements of salt content, fat, protein, moisture, ash, L* and a* values.

As expected, a significant difference ($P \leq 0.05$) in saltiness was found between the five bacon treatments with increased levels of salt, with the bacon treatment with a salt content of 0.5% as the least salty (13.7), and the treatment with a salt level of 3.5% as the most salty (71.6) (Table 7). These findings correspond with the significant correlation (r = 0.943, $P = 0.016$) between the saltiness and the total percentage salt content in the product (Table 8). A significant ($P \leq 0.05$) negative correlation was observed between saltiness and the moisture content of the product (r = -0.911, $P = 0.031$). Also, a significant ($P \leq 0.05$) correlation was observed between saltiness and the ash content of the product (r = -0.965, $P = 0.007$). No further significant correlations ($P > 0.05$) were found between saltiness and objective measurements of fat, protein, moisture, L*, a* and b* values.

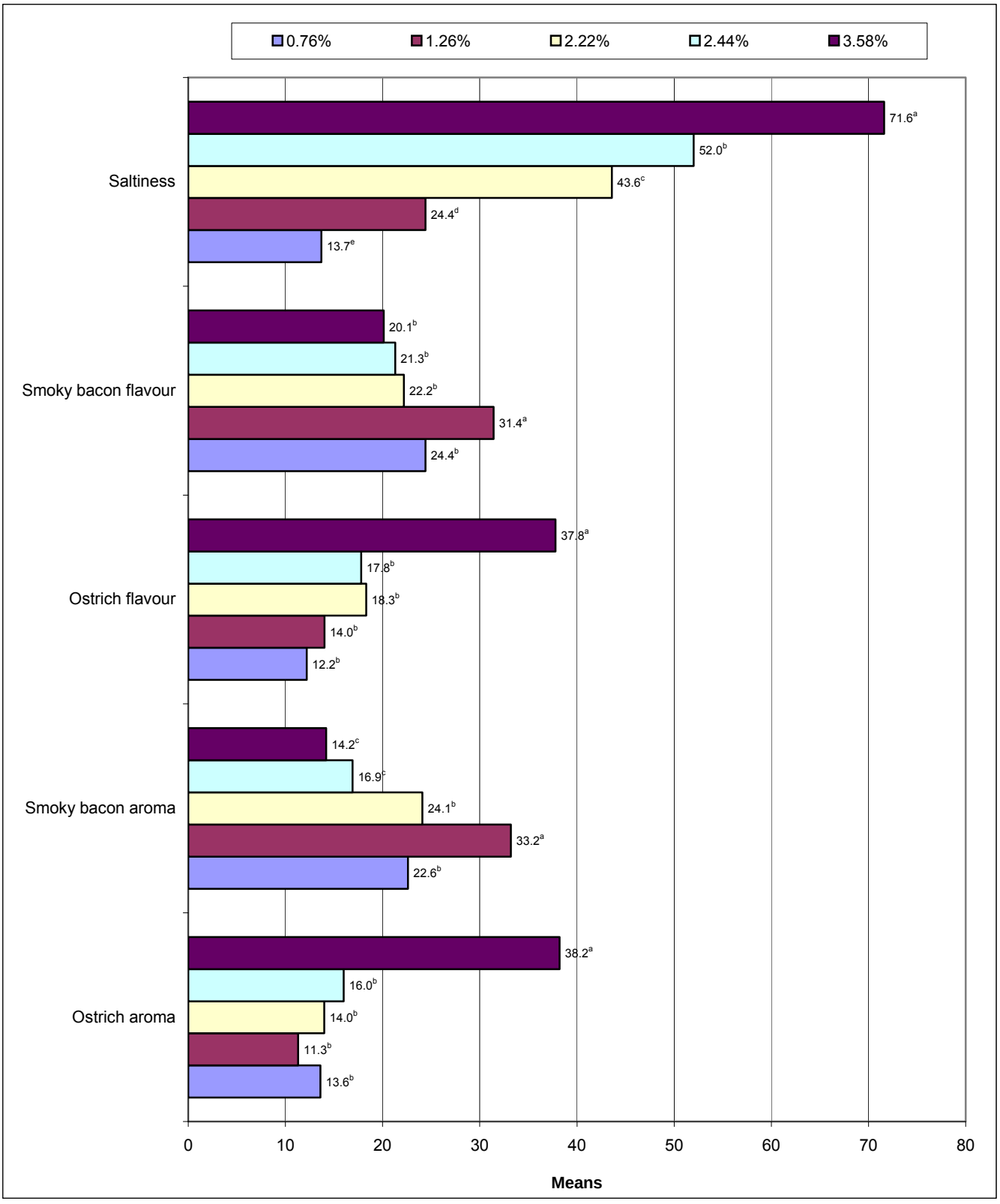

Figure 1 Mean values for the sensory analysis of bacon manufactured with decreased levels of salt.

Table 7 Means (± SD) for the sensory analysis of ostrich bacon manufactured with decreasing levels of salt.

Characteristic	Scale	Salt level					LSD
		3.5%	2.75%	2.0%	1.25%	0.5%	
Ostrich aroma	0 = None 100 = Strong	38.2[a] ± 20.7	16.0[b] ± 14.4	14.0[b] ± 15.9	11.3[b] ± 13.5	13.6[b] ± 15.0	7.02
Smoky bacon aroma	0 = None 100 = Strong	14.2[c] ± 12.2	16.9[c] ± 13.4	24.1[b] ±20.0	33.2[a] ± 21.4	22.6[b] ± 13.7	5.62
Ostrich flavour	0 = None 100 = Strong	37.8[a] ± 20.0	17.8[b] ± 15.2	18.3[b] ± 18.9	14.0[b] ± 14.6	12.2[b] ± 12.9	6.72
Smoky bacon flavour	0 = None 100 = Strong	20.1[b] ± 18.8	21.3[b] ± 14.7	22.2[b] ± 16.0	31.4[a] ± 18.6	24.4[b] ± 14.7	5.03
Saltiness	0 = None 100 = Strong	71.6[a] ± 21.8	52.0[b] ± 22.7	43.6[c] ± 21.5	24.4[d] ± 15.1	13.7[e] ± 22.7	6.68

[a-e]Means within the same row with different superscripts differ significantly ($P \leq 0.05$)

SD - Standard Deviation

LSD - Least Significant Difference ($P=0.05$)

Table 8 Correlations between sensory and objective characteristics of ostrich bacon manufactured with decreasing levels of salt.

	Ostrich aroma		Ostrich flavour		Smoky bacon aroma		Smoky bacon flavour		Saltiness	
	r	P	r	P	r	P	r	P	r	P
Salt (%)	0.947	0.014	0.988	0.001	-0.701	0.187	-0.641	0.243	0.943	0.016
Fat (%)	0.243	0.696	0.085	0.891	-0.655	0.230	-0.441	0.456	0.074	0.905
Protein (%)	0.285	0.641	0.348	0.565	-0.310	0.610	-0.131	0.833	0.611	0.273
Moisture (%)	-0.709	0.179	-0.756	0.139	0.678	0.208	0.528	0.359	-0.911	0.031
Ash (%)	0.691	0.195	0.805	0.100	-0.617	0.266	-0.678	0.208	0.965	0.007
L*	0.271	0.659	0.281	0.646	-0.825	0.085	-0.852	0.066	0.588	0.296
a*	0.994	0.001	0.991	0.001	-0.741	0.151	-0.641	0.243	0.862	0.059
b*	0.798	0.104	0.776	0.122	-0.972	0.005	-0.875	0.051	0.848	0.069

r – Correlation value

P – Probability value (*P*≤0.05)

Consumer sensory analysis

Table 9 and Figure 2 illustrate the degree of liking of saltiness of the five treatments of bacon according to a group of 100 consumers.

Table 9 Mean values (±SE) for the degree of liking of the saltiness of the five bacon samples manufactured with decreasing levels of salt.

Salt level	Means of acceptability of saltiness for		
	Total group (n=100)	Female consumers (n=73)	Male consumers (n=27)
3.50%	$6.0^{d} \pm 0.3$	$6.2^{c} \pm 0.2$	$5.6^{c} \pm 0.2$
2.75%	$6.8^{ab} \pm 0.3$	$6.8^{ab} \pm 0.2$	$6.7^{ab} \pm 0.2$
2.00%	$7.0^{a} \pm 0.3$	$7.0^{a} \pm 0.2$	$7.3^{a} \pm 0.2$
1.25%	$6.5^{bc} \pm 0.3$	$6.6^{abc} \pm 0.2$	$6.3^{b} \pm 0.2$
0.50%	$6.3^{cd} \pm 0.3$	$6.4^{bc} \pm 0.2$	$6.1^{bc} \pm 0.2$
LSD	0.41	0.50	0.75

SE – Standard Error

LSD = Least Significant Difference (P=0.05)

$^{a-e}$Means within the same column with different superscripts differ significantly (P≤0.05)

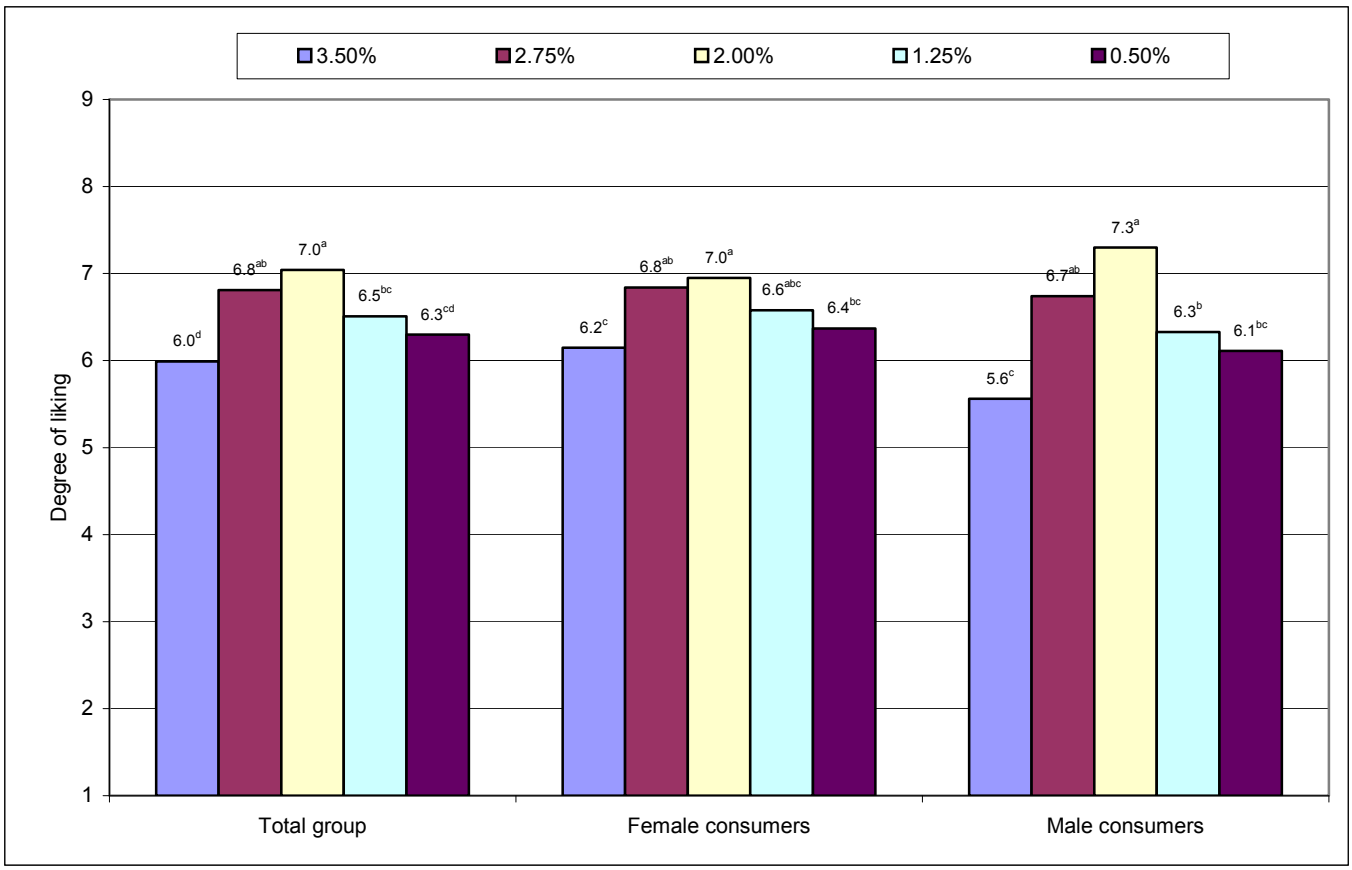

Figure 2 Mean values for degree of liking of the saltiness of the five bacon samples manufactured with decreasing levels of salt.

As reflected in Table 9, the total group of consumers were less inclined to differentiate between the various treatments with regard to degree of liking. The saltiness of bacon treatments formulated with 2.75%, 2.0% and 1.25% salt levels were most liked (6.8, 7.0 and 6.5, respectively), whereas the saltiness of the treatments formulated with 0.50 and 3.5% were found to be least likeable (6.3 and 6.0, respectively). The same phenomenon was found among the female consumers, though the male consumers indicated a higher degree of liking for the samples with 2.75% and 2.0% salt and a lower degree of liking for the bacon containing the highest level of salt. The frequency scores in Table 10 and Figure 3 give an indication of the acceptability of the saltiness of the products.

Table 10 Acceptability (% frequency scores) of ostrich bacon manufactured with decreasing levels of salt (n=100).

Hedonic classes	Salt level				
	3.5%	2.75%	2.0%	1.25%	0.5%
Dislike extremely (1)	1	1	0	0	0
Dislike very much (2)	7	1	0	1	0
Dislike moderately (3)	4	2	2	5	2
Dislike slightly (4)	9	7	2	7	9
Neither like nor dislike (5)	9	5	8	8	8
Like slightly (6)	16	13	15	21	16
Like moderately (7)	26	30	25	20	38
Like very much (8)	18	24	31	20	15
Like extremely (9)	10	17	17	18	12

Chi-square $x^2_{(DF = 32)} = 54.6$, $P = 0.01$

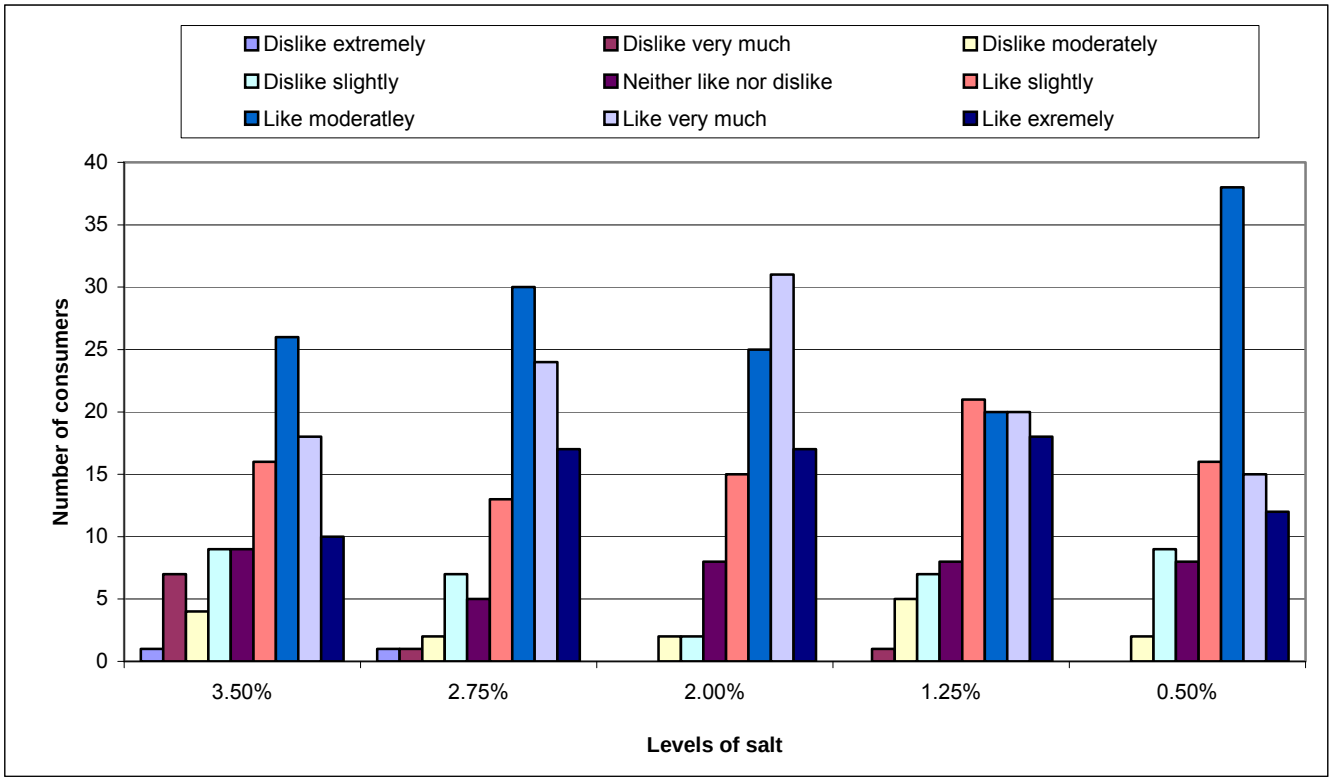

Figure 3 Acceptability (% frequency scores) of ostrich bacon manufactured with decreasing levels of salt (n=100).

The chi-square value (x^2 = 54.6, *P* = 0.01) indicates that there were sufficient evidence for association between salt level and degree of liking of the saltiness of the product. More than 50% of the respondents scored between 6 (*Like slightly*) and 9 (*Like extremely*) on the nine-point hedonic scale for saltiness (Table 10). Therefore, all the samples can be considered as acceptable in saltiness. Bacon formulated with 2.00 and 2.75% salt illustrated an extremely high degree of acceptability with a high percentage of consumers scoring the samples between 6 and 9 on the hedonic scale (88 and 84% respectively), followed by the bacon with 0.50 and 1.25% salt at 81 and 79%, respectively. The bacon with 3.50% salt had the lowest percentage of consumers scoring the sample on the positive side of the hedonic scale (70%) and may be considered as the least acceptable in saltiness of the five bacon formulations. These results correspond clearly with the previous findings (Table 9) as the saltiness of the 2.00% salt was also rated by the consumers as most acceptable saltiness and the 3.50% salt treatments as least acceptable.

Table 11 and Figure 4 illustrate the overall degree of liking of the five treatments of bacon according to the gender of a group of 100 consumers.

Table 11 Mean values (±SE) for the overall degree of liking of the five bacon samples manufactured with decreasing levels of salt.

Salt level	**Means of overall acceptability for**		
	Total group (n=100)	**Female consumers (n=73)**	**Male consumers (n=27)**
3.50%	$6.2^{c} \pm 0.1$	$6.3^{b} \pm 0.2$	$5.9^{b} \pm 0.2$
2.75%	$7.0^{ab} \pm 0.1$	$6.9^{a} \pm 0.2$	$7.0^{a} \pm 0.2$
2.00%	$7.2^{a} \pm 0.1$	$7.2^{a} \pm 0.2$	$7.3^{a} \pm 0.2$
1.25%	$6.7^{b} \pm 0.1$	$6.8^{ab} \pm 0.2$	$6.7^{ab} \pm 0.2$
0.50%	$6.7^{b} \pm 0.1$	$6.8^{ab} \pm 0.2$	$6.6^{ab} \pm 0.2$
LSD	0.42	0.51	0.78

SE – Standard Error

LSD - Least Significant Difference (P=0.05)

$^{a-e}$Means within the same column with different superscripts differ significantly (P≤0.05)

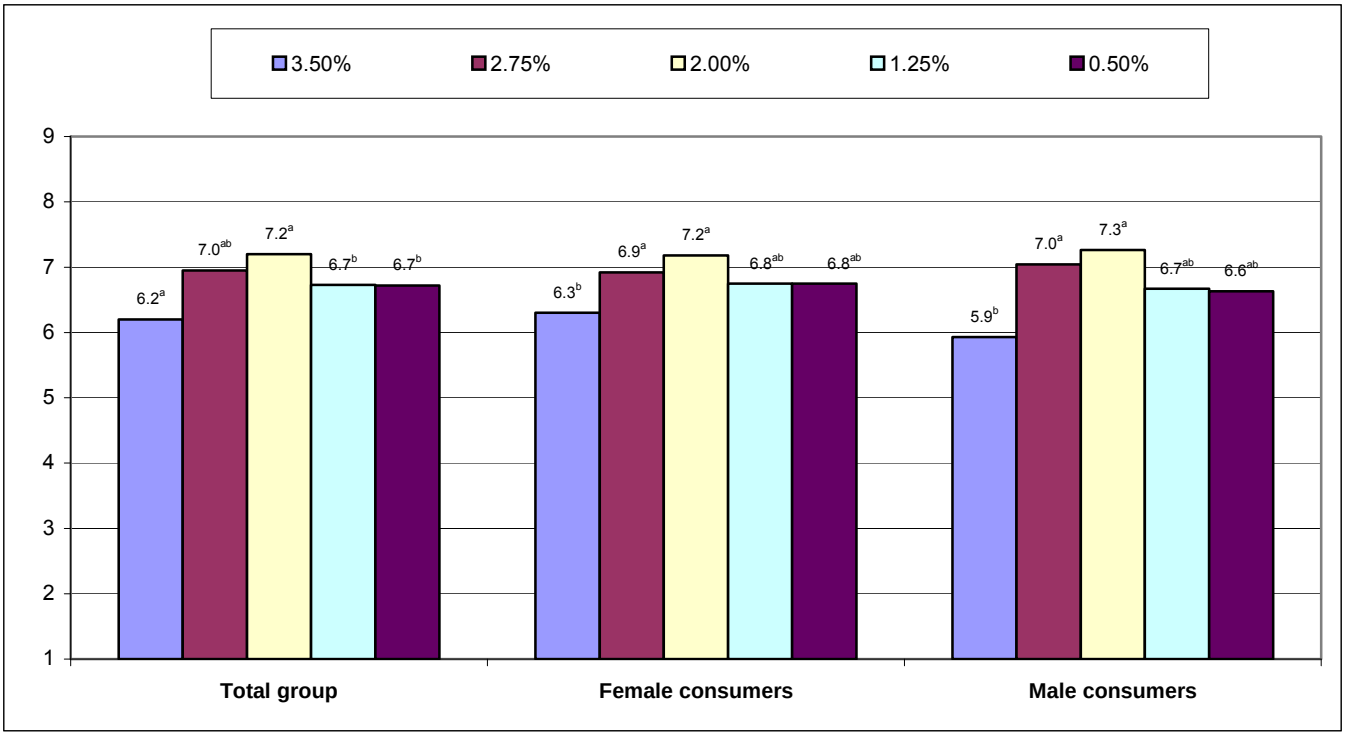

Figure 4 Mean values for the overall degree of liking of the five bacon samples manufactured with decreasing levels of salt.

The 2.0% salt treatment showed a higher overall degree of liking than the 3.5, 1.25 and 0.5% salt treatment, but did not differ significantly (P>0.05) from the sample with 2.75% salt (Table 11). Therefore, it can be assumed that the treatments with 2.0 and 2.75% salt are equally and the most preferred treatments among the consumers. The male and female consumers illustrated similar tendencies with 2% having the highest degree of liking. Furthermore, the response pattern between the female and male consumers did not differ from each other and indicates the 3.5% salt treatment to be the significantly least likeable product. The frequency scores in Table 12 and Figure 5 give an indication of the overall acceptability of the product.

The chi-square value (x^2 = 50.2, P = 0.02) indicates that there were sufficient evidence for association between the salt level and degree of liking of the overall product. More than 50% of the respondents scored between 6 (*Like slightly*) and 9 (*Like extremely*) on the nine-point hedonic scale for overall degree of liking of the product (Table 12). Therefore, all the samples can be considered as acceptable. Bacon formulated with 2.00% and 2.75% salt illustrated an extremely high degree of acceptability with a high percentage of consumers scoring the samples between 6 and 9 on the hedonic scale (86 and 83% respectively), followed by the bacon with 1.25 and 0.5% salt at 76 and 72%, respectively. The bacon with 3.5% salt had the lowest score of 68% and may be considered as the least acceptable of the five bacon formulations. These results correspond clearly with the previous findings (Table 11) as the overall acceptability of the 2.0% salt was rated by the consumers as most acceptable and the 3.5% salt treatments as least acceptable.

Table 12 Acceptability (% frequency scores) of ostrich bacon manufactured with decreasing levels of salt (n=100).

Hedonic classes	Salt level				
	3.5%	**2.75%**	**2.0%**	**1.25%**	**0.5%**
Dislike extremely (1)	2	0	0	0	0
Dislike very much (2)	6	2	0	0	1
Dislike moderately (3)	2	2	1	5	4
Dislike slightly (4)	17	6	4	10	15
Neither like nor dislike (5)	5	7	9	9	8
Like slightly (6)	20	20	15	24	23
Like moderately (7)	25	22	32	21	22
Like very much (8)	16	31	25	19	19
Like extremely (9)	7	10	14	12	8

Chi-square $x^2_{(DF = 32)} = 50.2$, $P = 0.02$

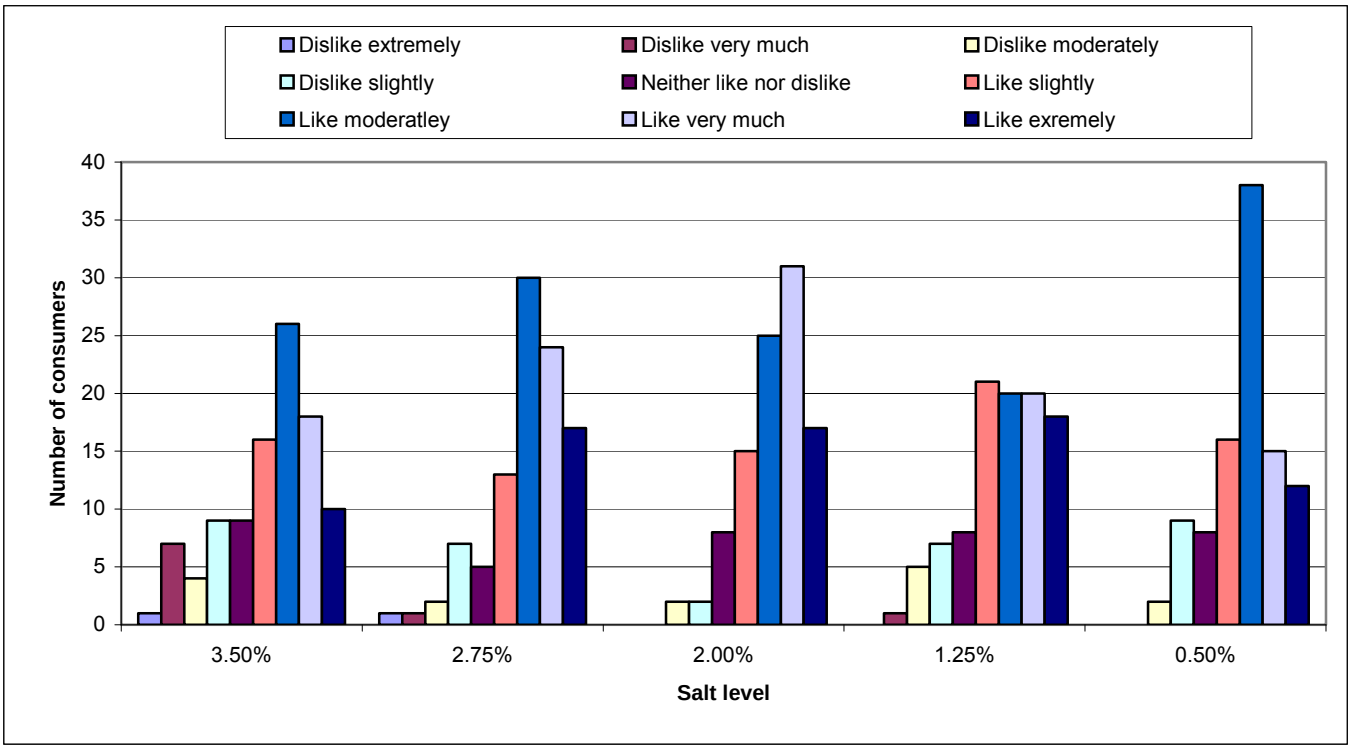

Figure 5 Acceptability (% frequency scores) of ostrich bacon manufactured with decreasing levels of salt (n=100).

It is clear from the above results that there is a positive relationship between the saltiness and the overall acceptability of the products. Consumers perceived the saltiness of the bacon with 2.0% salt as the most acceptable and the bacon with 3.5% salt as the least acceptable overall product. However, it is to be noted that consumers were not able to distinguish significantly in the saltiness and overall acceptability between the bacon with 0.5, 1.25 and 2.75% salt level. Various studies

indicated that there seems to be a positive consumer attitude towards reduced sodium meat products. This positive attitude agrees with the sensory acceptability and preference for some of the manufactured low salt meat products (Guàrdia *et al*., 2006; Malherbe *et al.,* 2003). Considering that South African pork bacon has a general salt content of 3.0%, it would seem possible to reduce the salt content in ostrich bacon obtaining a product with only 2% salt. A further reduction of the salt in ostrich bacon can be done by molar substitution with potassium chloride (KCl) or a mixture with KCl/potassium lactate without modifying either acceptability or preference.

CONCLUSION

The results from this study indicate that the manufacture of ostrich bacon with decreased sodium chloride content is an extremely viable option for the industry. All the bacon treatments had good physical characteristics and resulted in acceptable products based on their chemical composition and sensory scores. The low fat content and favourable fatty acid profile of ostrich bacon also makes it a healthy option for the consumer. Further research could include the use of sodium chloride replacements i.e. KCl and/or potassium lactate, to reduce the sodium content of ostrich bacon to a minimum.

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Chapter 6

GENERAL DISCUSSION AND CONCLUSIONS

Ostrich meat is gaining more attention in the marketplace and is increasingly marketed as a healthy alternative to other red meats due to qualities such as leanness, low cholesterol content and favourable fatty acid profile (Sales & Horbanczuk, 1998). This is the result of a worldwide trend in increased consumer awareness for the relationship between health and diet. Considering the fact that there is an over supply of ostrich meat on the export-orientated South African ostrich meat market mainly due to *Avian influenza*, the option arises to explore the viability of producing value added meat products derived from ostrich meat for the export market. Therefore, this study focused on the development of healthy value added ostrich meat products that would maintain the health characteristics generally associated with ostrich meat. There are a number of commercially available value added ostrich meat products of which most have been derived from transferring traditional technologies applied to the traditional red meat species to ostrich meat. However, in order to maintain the ostrich meat's healthy characteristics, ostrich meat products were developed by reformulating the meat derivatives so as to decrease or eliminate those elements that are negative to human health.

It is clear from the literature that the main elements that are harmful to human health and which are added during processing of meat products for technological, microbiological, or sensory reasons, are saturated animal fat, salt (NaCl) and phosphate. Health risks associated with a high intake of saturated fat are linked to the development of major chronic diseases such as cardiovascular heart diseases, obesity and cancer (Kuller, 1997; Weisburger, 1997). A high sodium intake is positively correlated with risk of coronary heart disease, independent of other cardiovascular risk factors, including blood pressure (Tuomilehto *et al*., 2001) and the presence of excessive amounts of phosphates in the diet may influence the calcium, iron and magnesium balance in the human body, and can increase the risk of bone diseases (Calvo & Park, 1996; Sandberg *et al.,* 1999).

Using generally accepted scientific research designs, this research investigated the possibility to develop three viable value added ostrich meat products, namely polony, bacon and ham, in which saturated fat, sodium chloride, and phosphate, respectively are key ingredients. Therefore, with the beneficial effects of unsaturated fat, decreased salt (NaCl) and phosphate reduction, together with the health and processing characteristics of ostrich meat, this study was designed to develop both a healthier and acceptable alternative to traditional value added meat products. Hence, the objectives of this study were:

- to investigate the effect of the replacement of pork fat with olive oil on the physical, chemical, and sensory characteristics of ostrich polony;
- to investigate the effect of replacement of sodium tri-polyphosphate (STPP) with iota-carrageenan (CGN) on the physiochemical and sensory characteristics of restructured cooked ostrich ham, and;
- to investigate the effect of salt (NaCl) reduction on the chemical, textural and sensory characteristics of ostrich bacon.

The results from this study proved that the manufacture of ostrich polony with olive oil is a viable option for the industry. The polony formulated with 5, 10 or 15% olive oil had good physical characteristics and resulted in acceptable products based on their chemical composition and sensory scores. The low fat content and favourable fatty acid profile of ostrich polony formulated with 5 and 10% olive oil, proved to maintain and enhance the health characteristics of ostrich meat. Since the sensory panel could not distinguish between the polony within the 5 to 15 % olive oil range, the final decision on acceptable level may be financially driven. Further research on ostrich polony should include the use of antioxidants to control colour changes and shelf life studies of the product.

The manufacture of a reduced phosphate ostrich ham (replacing phosphate with carrageenan) was found to be a viable option for the ostrich meat industry. Due to the variation of the composition within the samples of each treatment, no significant tendency was found with decreased levels of phosphate with relation to the chemical composition and physical characteristics measured. However, decreasing levels of phosphate showed significant increases in the cooked yield, which could be attributed to the water binding ability of the increased levels of carrageenan. It is clear that the low fat content and favourable fatty acid profile of ostrich ham makes it a healthy option for the consumer. Sensory panel results revealed that the phosphate level in ostrich ham could be reduced to an acceptable level of 0.35%. Further research should investigate the use of other alternatives to substitute phosphate and focus on optimising the processing technique (i.e. tumbling time) for optimum myofibrillar protein extraction in order to produce a product with optimum textural and sensorial quality. Further research on ostrich ham should also include the use of antioxidants to control colour changes and shelf life studies of the product.

The manufacture of ostrich bacon with a decreased sodium chloride content was found to be a viable option for the industry. All the bacon treatments had good physical characteristics and resulted in acceptable products based on their chemical composition and sensory scores. The low fat content and favourable fatty acid profile of ostrich bacon also makes it a healthy option for the consumer. Further research on ostrich bacon should include the use of sodium chloride replacements, i.e. potassium chloride (KCl), to reduce the sodium content of ostrich bacon to a minimum.

In conclusion, the results of this study proved that viable value added products can be made from ostrich meat. In addition, this study has shown that meat products manufactured from the meat of ostrich are able to meet the key requirements set by the meat industry and satisfy the consumer perceptions and needs. In order to exploit these research findings to its fullest, and to expand on the knowledge gained in this study, follow-up investigations need to be undertaken to refine the processing techniques to optimise product quality.

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ANNEXURE 1

THE DEVELOPMENT PHASE OF THE PRODUCT DEVELOPMENT PROCESS

The development phase in which prototypes of products were developed preceded the product development process. A brief discussion on the development phase of the three value added ostrich meat products used in this study, namely polony, ham and bacon, follows. During this phase, prototypes of products were evaluated by a focus group and their comments were used as inputs to determine the ultimate composition of the products that were used in this study. Tables 1 and 2 reflect the stepwise development of the various products. In this section, only the basic processing steps are discussed as the full procedures followed to manufacture the various products are given in detail in the respective chapters.

1. Polony

A standard formulation generally used in other red meat sources, were used. The main purpose of the development phase of ostrich polony was to determine the levels of olive oil to be used as an independent variable in the formulation.

Table 1 The development phase of ostrich polony

Trial	% Olive oil	Other ingredients added	Comments
1	0, 10, 20, 25		25% olive oil unacceptable
2	5, 7.5, 10		Too little distinguishable difference between these levels
3	0, 5, 10	Ginger	Successfully masks the ostrich aroma and flavour
4	0, 5, 10, 15, 20		Accepted

The objective of the first trial was to determine the extreme level of olive oil. It was found by the focus group that the product with 25% olive oil was unacceptable due to its yellow colour and too soft texture. The polony prepared with 20% olive oil was therefore chosen as the upper limit. The intermediate olive oil levels were investigated during a second trial. The focus group found little sensory difference between 5, 7.5 and 10% olive oil levels. It was suggested that ginger (2 g/kg) should be added to mask the ostrich aroma and flavour of the product to make it more acceptable to the consumer. The focus group found that it successfully masked the ostrich aroma and flavour. It was concluded from the focus groups' inputs that five different levels of olive

oil in 5% increments (minimum 0%, maximum 20%) was to be used together with ginger in the final experimental procedure.

2. Ham

A standard formulation generally used for other red meat sources, was used. The main purpose of the development phase of ostrich ham was to determine the decreasing levels of phosphate together with increasing levels of carrageenan that were to be used as independent variables in the formulation of the product and to investigate various processing techniques to produce optimum myofibrillar protein extraction that would bound the meat pieces together. Table 2 listed the processing steps followed.

Table 2 The development phase of ostrich ham

Trial	% Phosphate/ % Carrageenan (of total product weight)	Processing technique	Comments
1	0.7/0	Injected and vacuum tumbled for 20 min	Insufficient protein extraction
2	0.7/0	Tumbled for 20 min	Insufficient protein extraction
3	0.7/0	Tumbled for 6 h in 30 min intervals (20 min tumble and 10 min rest)	Insufficient protein extraction
4	0.7/0; 0.35/0.2; 0/0.4	Muscles passed through a meat mincing machine without any cutting blades or plates and subsequently tumbled for 6 h in 30 min intervals (20 min tumble and 10 min rest)	Sufficient protein extraction
5	0.7/0; 0.53/0.1; 0.35/0.2; 0.18/0.3; 0/0.4	Muscles passed through a meat mincing machine without any cutting blades or plates and subsequently tumbled for 6 h in 30 min intervals (20 min tumble and 10 min rest)	Sufficient protein extraction

During the first trial, the meat pieces did not bind together due to insufficient protein extraction. During the second trial, the injection stage was omitted and the product was only tumbled for 20 min. The meat pieces were still not bound together. A longer tumbling period of 6 h in 30 min intervals (20 min tumble and 10 min rest) produced a stickier exudate, evident of sufficient protein extraction. Although the meat pieces bound together, a small amount of liquid was still released

after cooking. During the fourth trial, meat pieces were first passed though a mincing machine without any cutting blades or plates to open the meat structure to facilitate brine penetration and protein extraction, without reducing the particle size. Meat pieces were subsequently tumbled for 6 h in 30 min intervals (20 min tumble and 10 min rest). This resulted in good protein extraction and lipid binding. The phosphate/carrageenan relationship as developed for trial five was considered to be successful to use in the experimental phase.

3. Bacon

A standard formulation generally used in other red meat sources, was used. The focus group suggested five decreasing levels of salt (NaCl). No further development was needed and the product was ready to be used in the experimental phase.

ANNEXURE 2

QUESTIONNAIRE FOR DESCRIPTIVE SENSORY ANALYSIS OF OSTRICH POLONY

JUDGE NO	NAME OF PANEL MEMBER

INSTRUCTIONS:

- Compare the 3-digit codes on the tray and questionnaire; evaluate the samples from left to right, compare the three experimental samples with the control sample
- Refresh your mouth with water and biscuit between samples/characteristics

Colour Light 0 ---------100 Dark	0_|_____|__100
Processed meat aroma None 0 ---------100 Strong	0_|_____|__100
Ostrich meat aroma None 0 ---------100 Strong	0_|_____|__100
Olive oil aroma None 0 ---------100 Strong	0_|_____|__100
Processed meat flavour None 0 ---------100 Strong	0_|_____|__100
Oily mouthfeel None 0 ---------100 Prominent	0_|_____|__100
Firmness Soft 0 ---------100 Firm	0_|_____|__100
Juiciness Feeling of dryness in mouth 0 ---------100	0_|_____|__100

ANNEXURE 3

QUESTIONNAIRE FOR DESCRIPTIVE SENSORY ANALYSIS OF OSTRICH HAM

JUDGE NO	NAME OF PANEL MEMBER

INSTRUCTIONS:

- Compare the 3-digit codes on the tray and questionnaire; evaluate the samples from left to right, compare the three experimental samples with the control sample
- Refresh your mouth with water and biscuit between samples/characteristics

Meat aroma None 0 ---------100 Strong	0_|_____|__100
Ostrich meat aroma None 0 ---------100 Strong	0_|_____|__100
Spicy aroma None 0 ---------100 Strong	0_|_____|__100
Meat flavour None 0 ---------100 Strong	0_|_____|__100
Ostrich meat flavour None 0 ---------100 Prominent	0_|_____|__100
Spicy flavour None 0 ---------100 Strong	0_|_____|__100
Mealiness None 0 ---------100 Prominent	0_|_____|__100

ANNEXURE 4

QUESTIONNAIRE FOR DESCRIPTIVE SENSORY ANALYSIS OF OSTRICH BACON

JUDGE NO	NAME OF PANEL MEMBER

INSTRUCTIONS:

- Compare the codes on the tray and questionnaire; evaluate the samples from left to right, and compare the five experimental samples
- Refresh your mouth with water and biscuit between samples/characteristics

Ostrich aroma **None 0 ---------100 Strong**	0_|_____|__100
Smoky bacon aroma **None 0 ---------100 Strong**	0_|_____|__100
Ostrich flavour **None 0 ---------100 Strong**	0_|_____|__100
Smoky flavour **None 0 ---------100 Strong**	0_|_____|__100
Salty taste **None 0 ---------100 Strong**	0_|_____|__100

ANNEXURE 5

QUESTIONNAIRE FOR CONSUMER SENSORY ANALYSIS OF OSTRICH POLONY

QUESTIONNAIRE: OVERALL ACCEPTABILITY OF OSTRICH POLONY **JUDGE NO:**_____

NAME OF JUDGE: _____

INSTRUCTIONS

- PLEASE TASTE THE 5 SAMPLES IN THE ORDER PRESENTED, I.E. FROM **LEFT TO RIGHT**.
- **RINSE YOUR MOUTH WITH** WATER **BEFORE BEGINNING. RINSE YOUR MOUTH BETWEEN THE SAMPLES.**
- **RANK THE SAMPLES ACCORDING TO** OVERALL ACCEPTABILITY **ON THE FOLLOWING SCALE. IN EACH CASE,** CIRCLE THE NUMBER NEXT TO THE PREFERRED DEGREE OF LIKING

CODE		CODE		CODE		CODE		CODE	
9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

THANK YOU VERY MUCH FOR YOUR INVALUABLE ASSISTANCE, PLEASE COLLECT A SMALL "GIFT" AS YOU LEAVE THE SENSORY AREA

ANNEXURE 6

QUESTIONNAIRE FOR CONSUMER SENSORY ANALYSIS OF OSTRICH HAM

QUESTIONNAIRE: OVERALL ACCEPTABILITY OF OSTRICH HAM **JUDGE NO:**_____

NAME OF JUDGE: _____

INSTRUCTIONS

- PLEASE TASTE THE 5 SAMPLES IN THE ORDER PRESENTED, I.E. FROM **LEFT TO RIGHT**.
- **RINSE YOUR MOUTH WITH** WATER **BEFORE BEGINNING. RINSE YOUR MOUTH BETWEEN THE SAMPLES.**
- **RANK THE SAMPLES ACCORDING TO** OVERALL ACCEPTABILITY **ON THE FOLLOWING SCALE. IN EACH CASE,** CIRCLE THE NUMBER NEXT TO THE PREFERRED DEGREE OF LIKING

CODE		**CODE**		**CODE**	
9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

THANK YOU VERY MUCH FOR YOUR INVALUABLE ASSISTANCE, PLEASE COLLECT A SMALL "GIFT" AS YOU LEAVE THE SENSORY AREA

ANNEXURE 7

QUESTIONNAIRE FOR CONSUMER SENSORY ANALYSIS OF OSTRICH BACON

QUESTIONNAIRE: OVERALL ACCEPTABILITY OF OSTRICH BACON **JUDGE NO:_____**

NAME OF JUDGE: _____

INSTRUCTIONS

- PLEASE TASTE THE 5 SAMPLES IN THE ORDER PRESENTED, I.E. FROM **LEFT TO RIGHT**.
- **RINSE YOUR MOUTH WITH** WATER **BEFORE BEGINNING. RINSE YOUR MOUTH BETWEEN THE SAMPLES.**

RANK EACH SAMPLE ACCORDING TO YOUR PREFERRED DEGREE OF LIKING **OF THE**

SALTINESS

OF THE SAMPLE AND ENCIRCLE THE NUMBER NEXT TO THE PREFERRED DEGREE OF LIKING

CODE		CODE		CODE		CODE		CODE	
9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

RANK EACH SAMPLE ACCORDING TO

OVERALL ACCEPTABILITY

ON THE FOLLOWING SCALE AND ENCIRCLE THE NUMBER NEXT TO THE PREFERRED DEGREE OF LIKING

CODE		CODE		CODE		CODE		CODE	
9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely	9	Like extremely
8	Like very much	8	Like very much	8	Like very much	8	Like very much	8	Like very much
7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately	7	Like moderately
6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly	6	Like slightly
5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike	5	Neither like nor dislike
4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly	4	Dislike slightly
3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately	3	Dislike moderately
2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much	2	Dislike very much
1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely	1	Dislike extremely

THANK YOU VERY MUCH FOR YOUR INVALUABLE ASSISTANCE, PLEASE COLLECT A SMALL "GIFT" AS YOU LEAVE THE SENSORY AREA