Effects of different pineapple dietary fibres on the quality parameters and cost of beef species sausage

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own original work and that it has not previously, in its entire or part, been submitted at any other university for a degree.

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ABSTRACT

The nutrient profile of meat and meat products make them a major protein and minerals source for non- vegetarian human beings. However, their high fat content and the saturated fatty acid profile associate them with increased risk of lifestyle diseases and occurrences of cancers. Researchers have focused on fat replacement and fatty acid profile modification without compromising the physico-chemical and sensory characteristics of meat products. Leaner ingredients are expensive hence the use of low/non-calorie adding ingredients such as water, vegetable oils and oat bran. In this study, three pineapple dietary fibres (PDF), NSP 60, NSP 100 and NSP 200 with water binding capacities (WBC) of 1: 8; 1: 7.4; 1: 7.8 (g/g), respectively, were assessed for their WBC in species sausage at levels 0%, 0.5%, 1.0% and 1.5%. Water was added in accordance to the specific WBC capacity of the fibres, replacing pork back fat. The WBC of the fibre in the meat emulsion was assessed by extracting the loosely bound fluid by centrifugation. Fibres NSP 100 and NSP 200 proved to be of better water binding than NSP 60 which had the highest total expressible fluid (TEF) at all levels. Although differing significantly in WBC at all levels, all the fibres excellently bound water at 1% level. The three PDF (at 1% level) were then assessed with regard to chemical, physical, and textural attributes in species sausage. Proximate analysis showed that the control sausages (no fibre), differed significantly from the sausages containing PDF. Emulsion stability analysis was based on TEF, cooking loss and purge. Sausages containing NSP 200 PDF did not significantly differ to the control in terms of TEF and cooking loss. Sausages containing NSP 100 had the lowest cooking loss although not significantly different to the control and NSP 200 containing sausages. NSP 60 PDF performed significantly poorly in terms of TEF and cooking loss. The control had a significantly lower purge comparing to sausages containing which were not different. The pH value of the control was significantly higher than the samples containing fibres which also differed from each other. Inclusion of fibre in the species resulted in a significant increase in lightness, hue and chroma as compared to the control. Textural parameters for the control were significantly higher than the fibre containing sausages, except for cohesiveness which was similar for all sausages. This study concluded that NSP 100 could be the most suitable for use in species sausage, followed by the NSP 200 and lastly the NSP 60. Addition of PDF, in combination with water to a species

sausage can be a viable way of cutting costs since the formulation cost of all the fibre containing sausages was lower in comparison to the control. Fibre and water addition can be a positive means of reducing the lipid fraction in sausages and other meat products, increasing the dietary fibre component and hence improving the health status of meat product consumers.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

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

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DEDICATION

Dedicated to my son Siyabonga, hope it will be an inspiration for him to do better than I, my siblings Christine, Loveness, Godknows, Princess and Shepherd for their support, patience and believing in me. The greatest dedication is to the Almighty for making this possible.

CHAPTER 1

MOTIVATION AND DESIGN OF THE STUDY

1.1 Introduction

Meat and meat products have been a key component in the human diet both as a food as well as an essential ingredient in many other food products (Kerry *et al*., 2002). Meats of all types offer means of reducing malnutrition and increasing food security, especially in developing nations (McNeill & Van Elswyk, 2012). Meat and meat products are consumed mainly for their value as sources of proteins and essential amino acids, essential micronutrients such as vitamins (folic acid, vitamin B12, riboflavin), fat as well as various minerals such as zinc, calcium, selenium and iron (Neumann *et al.*, 2002; Valsta, 2005; Zhang *et al.,* 2010).

The saturated fatty acid (SFA) profile of meat and meat products have been positively linked with prevalent diseases such as cardiovascular disease (CVD), hypertension, coronary heart disease (CHD), hypercholesterolemia, colon, breast and prostate cancers as well as high blood pressure (Chizzolini *et al.*, 1999; Higgs, 2000; Jimenez-Colmenero *et al.*, 2001; Wagemakers *et al.*, 2009). The high fat content of meat products are also associated with other diseases such as obesity and high blood cholesterol levels (O'Neil, 1993; Chau & Huang, 2004). The demand by consumers for highly nutritious and healthier food products has become a global trend and the meat industry has not been left out. Consumers are highly conscious of the amounts of the nutrients they consume in the foods they eat; where meat fats and salts have been of great concern (Shutte, 2008; Pietrasik & Janz, 2010).

Hence, the meat industry has been forced to become more innovative; focusing more on highly nutritious, low fat products without compromising the textural and sensory qualities of the meat products (Verma & Banerjee, 2010). Fat plays a major role in the texture and sensory characteristics of emulsified meat products which explains substitutions that has been tried with, for example, hydrocolloids, connective tissue proteins, carbohydrates, dietary fibres and vegetable oils in various researches (Crehan *et al.*, 2000).

Dietary fibre not only provides different technological functions through fat content reduction, it also interacts with water, oil, and bile acid binding, it can be a bulking or swelling agent in food products, interacts with cation exchange and gelling properties as well as providing nutritional health benefits (Figuerola *et al.,* 2005; Gedikoglu *et al.*, 2013). Generally, fibre is a functional ingredient with the effect of improving digestion, reduction of constipation and diseases associated with high fat intake such as obesity, cancer and cardiovascular complications (Jimenez-Colmenero*,* 2000). The technological properties of dietary fibre also plays an economic role in food products by reducing cooking loss, formulation costs and enhancing texture (Fernandez-Gines *et al.*, 2004). The inclusion of dietary fibre in food products such as meat and confectionery is a way of taking advantage of the functional and technological benefits the ingredient offers. Use of functional ingredients has been adopted to increase protein content and replace and/or reduce fat content in meat products. The extensively growing interest in increasing fibre content in food products has seen an introduction of a variety of vegetable and fruit fibres in meat products (Gedikoglu *et al.*, 2013).

Oat bran and oat fibre have been reported to provide better flavour, texture and mouth-feel in beef and pork sausages (Desmond & Troy, 2004) while pea and wheat fibres retain water, decrease cooking loss and shrinkage without degrading sensory properties (Besbes *et al*., 2008). Pietrasik and Janz (2010) used pea and starch fibres in low fat bologna; showing low cooking and purge losses, increased water binding capacity, acceptable textural and sensory properties. Hydrated barley fibre positively improved juiciness and flavour in meat sausages (Verma & Banerjee, 2010). Although the use of cereal dietary fibres is more frequent; fruit fibres are considered to be of better quality due to their high total and soluble fibre content, water and oil binding capacity, colonic fermentability and much lower phytic and calorific value (Figuerola *et al.*, 2005).

The addition of apple and peach dietary fibres into processed meats have shown fewer changes in textural parameters such as juiciness, springiness, tenderness and cohesiveness (Mittal & Barbut, 1994). Fernandez-Gines *et al*. (2004) reported that lemon albedo, a major component of lemon peel, improved functional properties of meat products. Inclusion of lemon albedo to levels up to 7.5% resulted in sausages having similar sensory properties to the control sausages. Sausages containing 1.5% orange fibre had similar sensory and textural properties to the controls as discovered by Aleson-Carbonell *et al.* (2003).

Pineapple fruit production is a viable business in South Africa, especially in the Eastern Cape and northern KwaZulu Natal regions where the fruit is usually used for the manufacture of canned pineapples and pineapple juice (Anon., 2010; DAFF, 2012). The pineapple waste (cores and peels) presents the worldwide pineapple industry with unmanageable environmental waste which could be positively used for various economic products or processes. Sinha (1982), Mwaikambo (2006), and Sruamsiri (2007) have reported that the pineapple waste can be further used for extraction of juice and syrup used in beverages and confectionery. It can also be powdered into pineapple extract for other food applications as well as freshly ground and mixed with molasses and urea for use as cattle feed.

The enzyme bromalein is extracted from the cores and peels of pineapple fruit and is used in meat tenderisation, beer clarification, production of vegetable oils, dehydration of eggs and soya milk and bakery industries (Bartholomew, 2003; Dela Cruz Medina & Garcia, 2005; FAO, 2009). Juice from the skin can be used for vinegar production or further processed to alcohol (Ho-a-Shu, 1999). None the less, the use of pineapple waste in food systems is limited. However, there is a growing interest for the use of the components of pineapple peels (making up to approximately 35% of the whole fruit) and crowns, especially as a dietary fibre in food systems. Investigations of dietary fibres from the by-products of fruits and vegetables, with the view to explore their potential applications and their physiological activities have been reported, although not extensively (Chau & Huang, 2004; Gedikoglu *et al.*, 2013). Dietary fibres from fruit and vegetables are required for their desirable nutritional and physicochemical properties and could be of importance in the food industry (Huang *et al.*, 2011).

Sunspray Food Ingredients extracts dietary fibres from pineapple peels and cores by a series of alcoholic and alkali digestion procedures, washing with water, drying and grinding. The three dietary fibres used in this study were supplied by Sunspray Food Ingredients through Fibiz™, namely Fibiz™nsp60 [(water binding capacity (WBC) 1 g/8 g water)], Fibiz™nsp100 (WBC 1 g/7.8 g water) and Fibiz™nsp200 (WBC 1g /7.4 g water) normally referred to as NSP 60, NSP 100 and NSP 200 respectively. The principal objective of this study was to evaluate the effects of these three different pineapple dietary fibres (PDF) on the chemical (proximate), processing quality parameters (cooking yield, water holding capacity, purge) and physical (instrumental colour and texture) quality parameters in reduced fat species sausage.

1.2 Statement of the research problem

Lifestyle diseases such as cardio vascular disease, coronary heart disease and various organ cancers, contribute more than HIV/Aids in terms of morbidity and mortality; they actually accounted for 37% of all deaths, while HIV/Aids accounted for 30% in 2000 in South Africa (Anon., 2012a). The World Health Organisation, (WHO, 2012) attributed many of these disease-linked risk factors in part, to an inadequate diet, with a high consumption of energy-dense foods, saturated fat, sugar and salt, and a lack of micronutrients and fibre.

Wolmarans and Oosthuizen (2001) emphasised that fat should be consumed because it provides essential and needed fatty acids and energy, but that it should be consumed ‘sparingly’ because overconsumption is associated with obesity and other non-communicable chronic diseases of lifestyle (NCDs), particularly when combined with physical inactivity. South Africa is increasingly being affected by the NCDs predicament due to overconsumption of unhealthy fatty foods commonly associated with Western diets, especially by individuals who are financially affording (Vorster *et al*., 2004). Such diets are usually associated with reduced fibre intake and hence increasing the risk of disease (Steyn, 2006).

A study conducted by Trowell in 1960 revealed that Africans south of the Sahara rarely suffered from constipation, diverticular disease, irritable colon, ulcerative colitis, appendicitis, haemorrhoids, polyp, and cancer of the large bowel (NCDs). This was hypothesised to be due to natural African diets usually high in their fibre content (Trowell, 1976). More active lifestyles backed up with healthy diets that are high in fibre, minerals, vitamins as well as low ‘unhealthy fat’ can go a long way towards reducing the morbidity and mortality (WHO, 2012).

Pineapple production results in unmanageable waste which is of no or low value, and can have a negative effect on the environment if not handled properly. Further processing of pineapple waste to pineapple dietary fibre (PDF) can improve revenue to the pineapple processors and farming communities whilst inclusion of this fibre in meat products can be value adding and a disease combating strategy for the meat and food industry.

1.3 Objectives of the research

The aim of this study was to evaluate the effect of PDF as a partial fat replacer on quality characteristics of species sausages, with a view to make recommendations to the meat industry for producing good quality, healthier and more economic meat products.

1.3.1 Specific objectives of the research

Specific objectives of the research were:

- Development of low fat species sausage containing PDF and water but conforming to South African Regulation No. R. 2718 of 23 November 1990 (updated) of the Foodstuffs, Cosmetics and Disinfectants Act, 1972 (Act No. 54 of 1972), (Anon., 2012b).
- Determination of the optimal water binding capacity of the three different PDF (NSP 60, NSP 100 and NSP 200) in species sausage.
- Evaluation of purge, colour and pH changes in species sausage during storage for all three fibres at an established optimal fibre level.
- Evaluation of cooking loss and the texture profile of species sausage at an optimal fibre level after seven days of storage for all three fibres.
- Evaluation of proximate composition and dietary fibre content of species sausage at an optimal fibre level for all three fibres investigated.

1.4 Hypothesis

- The three different PDF, at different levels (0%, 0.5%, 1.0% and 1.5%) will hold the same amount of water in the species sausage emulsion.
- The quality characteristics of species sausages substituted with three PDF will be the same as the un-substituted species sausage.
- The three different PDF (NSP 60, NSP 100 and NSP 200) will impart the same effects on the quality parameters of the species sausages.

1.5 Delineation of the research

- Only three commercial pineapple dietary fibres (NSP 60, NSP 100 and NSP 200) were used.
- Only four different levels of PDF, namely 0.0 %, 0.5%, 1% and 1.5% were included in the sausage formulations.
- A single optimal level of 1% was chosen for all three PDF to determine the effects of the fibres on the chemical, physical and textural quality parameters of species sausage.
- Species sausages were manufactured according to SANS 885 guidelines.
- Water addition was based on the water binding capacity of the fibre in question.
- Only one type of species sausage, namely beef, was investigated.

1.6 Significance of the research

Meat and meat products are an essential part of a healthy diet; traditionally considered essential for growth and development (Higgs, 2000). Due to the superior nutrient profile of meat, it is of great importance to encourage the consumption of meat and meat products. However, there is substantial evidence showing that diets rich in fat cause obesity and are directly linked to colon cancer as well as cardiovascular diseases (Chizzolini *et al.*, 1999; Higgs, 2000; Jimenez-Colmenero *et al.*, 2001; Wagemakers *et al.*, 2009). The World Health Organisation (WHO, 2013) attributes about 30% of all global deaths to cardiovascular diseases (CVD) which is also the second leading cause of death in South Africa. More than half these deaths are premature, in that they occur before the age of 65 (Anon., 2012a). Reduced carbohydrate and fibre intakes in combination with high fat and sugar intakes are the usual dietary trends in South Africa. Deficiencies in micronutrients such as vitamin A, vitamin C, niacin, vitamin B6, calcium, iron, zinc are also still common in both child and adult populations (Anon., 2012a). There is a need to encourage healthy lifestyles in the entire population.

The use of fat replacers such as oils, hydrocolloids, proteins, fibres and water without compromising the textural and sensory parameters of the products can be a way of solving this paradox surrounding meat products. Healthier, fibre containing meat products have been produced with various fibres and resultant products are beneficial to both consumers and manufacturers who are increasingly health conscious and focused (Jimenez-Colmenero *et al*., 2001). Dietary fibre from pineapple waste can be usefully incorporated into food systems as a viable way of improving the health status of the food products as well as increasing the commercial value of the waste. The creation of a market for the pineapple waste fibre can be a means of creating employment as well as reducing waste disposal or control costs for the farmers.

Based on the technological or processing and functional characteristics of dietary fibre, healthier and cheaper products may be produced by use of PDF, hence improving the income of the pineapple farmer, pineapple processor as well the meat processor. An extensive understanding of the interactions between fibre, water and meat proteins will afford the meat industry some opportunities to develop optimum formulations and processing parameters at the lowest costs. In this study, essential information on how PDF can be effectively used in species sausage was obtained. Information regarding the best of the three PDF in terms of water binding, drip and cooking losses, proximate composition, texture and colour in the species sausage was also obtained. Based on this study, speculation on the potential use of PDF in other meat products such as burger patties and other sausage types as well other food products (juices and confectionery) was triggered. Further studies will afford consumers in future an opportunity to consume healthier affordable meat products without worrying about the contribution of these products to poor health.

1.7 Expected outcomes, results and contributions of the research

The result of the research will provide knowledge on the possibility of producing healthy low fat and low cost species sausages through replacing pork back fat with PDF and water will be generated. Effectiveness of the PDF on water holding and quality of the species sausages will be assessed, resulting in the establishment of the optimal level of fibre substitution as well as the best fibre to use.

At least one article will be sent for publication, and the research output will be presented at least at one international conference. An MTech qualification will be obtained on completion of the research project.

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CHAPTER 2

LITERATURE REVIEW

2.1 Role of meat in human diet

Meat has been part of the human diet from as early as humans existed. It has been a central component in the human diet, both as a food as well as an essential ingredient in many other food products (Kerry *et al.,* 2002). The ancient humans relied on the organised hunting of large animals as well as gathering fruits for their food. The domestication, raising and breeding of animals' dates back many centuries and this was seen as an organised way of improving meat production (FAO, 2009). Modern agriculture employs a variety of techniques to improve animal production and meat quality as desired by the producer or the consumer. Meat of all types offers a means of reducing malnutrition and increasing food security especially in developing nations (McNeill & Van Elswyk, 2012).

Meat has been consumed mainly for its usefulness as a source of proteins required for human body growth and muscle building, the high content of essential amino acids and iron is essential for general health and for children bone growth in lactating woman. The iron component also protects against anaemia in children and lactating mothers (Neumann *et al*., 2002; Heinz & Hautzinger, 2007). Products from livestock provide various nutrients, minerals and essential micronutrients which are not easy to obtain from plant based foods (Valsta *et al*., 2005; FAO, 2009). Consumption of meat and meat products can be used for special cultural and religious occasions as well as an indication of status because meat and meat products are held in high esteem and affluence in most communities with a prestige value (Kerry *et al.,* 2002). Meat is often regarded as the central food around which meals are planned, various types of meats are sometimes made the basis of festive and celebratory occasions, and from the popular as well as the scientific point of view and according to the Food Agricultural Organisation, it is regarded as a food of high nutritive value (FAO, 2009).

The World Health Organisation (WHO, 2013) reports that the consumption of meat varies depending on the economic status of a nation; more meat and meat products are consumed in the affluent Western world as compared to the consumption in poor African nations. Consumption also varies with cultural orientation as seen by the high consumption trend in the Western world as compared to the Asian world which considers meat animals as sacred. According to Higgs (2000), meat is traditionally considered a highly nutritious food, highly valued and is associated with good health and prosperity.

There is a variety of species from which meat is obtained namely; mammals such as cattle, sheep, goats, pigs, buffalos, camels, rabbits, etc., birds especially domestic fowls, turkeys and ducks, reptiles such as alligators and fish and various invertebrates. Despite this variety, domesticated animals such as cattle, sheep and, pigs referred to as red meat, and poultry, referred to as white meat are still the major meat producing species (Heinz & Hautzinger, 2007).

In most diets meat has been considered a source of fat, amino acids (proteins) and most of the essential micronutrients such as zinc, calcium, iron, selenium and vitamins (folic acid, vitamin B12, riboflavin) in the diet (Zhang *et al.*, 2010). Bender (1992) mentioned that meat and meat products are the highest contributors to the daily intakes of protein (36%), fat (23%), energy (15%), iron (16%) and calcium (5%) with red meat playing a major role in supplying the haeme molecule to women in premenopausal stages. Of the animal derived foods, meat and meat products provide the most energy, most of which is from fat (Suzanne & Lindsay, 2003). Givens and Gibbs (2006) stated that about 100g of cooked beef would provide sufficient daily required amounts of protein, vitamin B-12 and zinc. It also provides substantial amounts of riboflavin and iron.

Meat and meat products tend to be superior in nutritional value, mainly in terms of essential nutrients such as riboflavin, vitamin B-12, calcium, phosphorus, fat and protein as compared to their vegetarian counterparts. Most of the nutrients are more bio-available in meat or animal derived products than most plant foods (Suzanne & Lindsay, 2003; Biesalski, 2005). The bio-availability of folic acid is ten-fold higher from meat than vegetables (Biesalski, 2005). The fatty acid profile of meat or the meat products is highly superior to any other food product that is consumed with the same frequency (Higgs, 2000). However, the fatty acid profile of meat and meat products is associated with high incidence of diseases such as diabetes, cardiovascular disease (CVD), and many cancers (Verma & Banerjee, 2010). This will be discussed in more detail in the following sections.

2.2 Worldwide meat consumption trends

Loftas (1995) stated that meat, fish, milk and eggs provide approximately 13.5% of the world’s daily protein consumption. The amount of meat consumed in different countries varies enormously with social, economic and political influences, religious beliefs and geographical differences. The consumption of meat is very large in meat-producing areas such as Uruguay, Argentina, Australia and New Zealand, at 300 g per head per day compared with an average of 10 g in India, Indonesia and Sri Lanka (Bender, 1992). The United States and the United Kingdom, with a high income earning population are some of the nations which have had roughly stable per capita meat consumption in the past decades whilst China has had an increase from 3.6 kg in 1961 to 52.4 kg in 2002 (Brown, 2009).

According to the United States Department of Agriculture (USDA, 2010), South African beef and veal per capita consumption has ranged between 14 and 15.5 kg per annum from 2006 to 2010. On average, Sub-Saharan Africa has ranged between 13.3 and 14.4 kg between 1980 and 2005, whilst the world per capita meat consumption has increased from 30 kg to 41.2 kg during this period (FAO, 2009). There has been an increase in annual worldwide per capita consumption of meat to 42.20kg by 2011 (FAO, 2013). The World Health Organisation (WHO, 2013) estimates that the production of meat is expected to increase from 218 million tonnes in 1997, to 376 million tonnes by 2030. The source goes on to mention that a decrease in the prices of some meat cuts (especially poultry) and meat products has resulted in an extensive increase in their consumption, especially in the low income households and nations with low gross domestic product (GDP), as compared to 20-30 years ago. An increase in the incomes for most individuals also adds on to the overall increase in meat and meat products consumption.

Factors such as wealth, volume of livestock production and socio-economic status of the consumers tend to explain the high consumer patterns of meat and meat products by the Western population (Mann, 2000; Speedy, 2003). On average the worldwide meat consumption has increased by a rate of 10% per annum, although most of this is credited to other parts in the world other than the United Kingdom and the United States (Valsta *et al*., 2005). The demand for meat in developing countries has increased by 53% between the years 1982 and 1993, due to population increases as well as the movement of people into urban areas (Delgado, 2003). Such increases are dominated by Asia (Gill, 1999). India, however, had the lowest meat consumption in the world whilst Sub-Saharan Africa consumption declined from the past decade's consumption (FAO, 2009). Statistics released by the USDA-FAS in April 2013 indicate a 1.8% increase in worldwide meat consumption from the period 2008 to 2013; with poultry being the highest contributor to this increase followed by pork and lastly beef and veal (USDA-FAS, 2013). With the world population above 7 billion, this automatically implies that the demand and production of meat and meat products is also dramatically increasing. Lately, the rate of meat consumption has declined due to forces such as reduced population growth and the natural deceleration due to fairly high consumption levels already reached in some major countries that previously fuelled the increase (FAO, 2009). Table 2.1 shows the per capita meat consumption from 1964 and what it is expected to be in 2030 in the various world regions.

Table 2.1 Prediction of per capita meat consumption in the world till 2030 (FAO, 2009)

Region	Meat (kg/year)		
	1964-1966	**1997-1999**	**2030**
World	24.2	36.4	45.3
Developing Countries	10.2	25.5	36.7
Near East and North Africa	11.9	21.2	35
Sub-Saharan Africa[a]	9.9	9.4	13.4
Latin America and the Caribbean	31.7	53.8	76.6
East Asia	8.7	37.7	58.5
South Asia	3.9	5.3	11.7
Industrialised Countries	61.5	88.2	100.1
Transition countries	42.5	46.2	60.7

[a]Excludes South Africa

South Africa, usually described as a first world nation in a third world continent is Africa's leading economy, having a different meat consumption trend as compared to most of the Sub-Saharan African nations, which ranged between 30 and 42.5 kg per person per annum in 2013. The per capita meat consumption in South Africa is currently 58.6 kg per person annually in the same period; it is in the same bracket with developed nations such as Mexico, Bolivia, Russia, Norway and China (Anon., 2013a).

The FAO (2009) states that the meat consumption in South Asia is far lower than income could explain. Low meat consumption in countries such as Bangladesh is compensated for by high fish consumption (17.5 kg/capita/year) whilst the high milk consumption in India and Sri Lanka replaces the meat in these countries (Speedy, 2003). Based on the total meat consumption, beef consumption has been currently around 50% in Latin America, 41% in Sub-Saharan Africa and only 5% in China. According to the Ministry of Agriculture, Forestry and Fisheries (UK), the consumption of beef seems to be decreasing rapidly as compared to the other types of meat, (MAFF., 2001). Pork and poultry have enjoyed a highly extensive growth. The worldwide production of poultry has increased from 9 million metric tonnes (MMTs) in 1960, to 15 MMTs in 1970, 26 MMTs in 1980, 41 MMTs in 1990 and 68 MMTs in 2000 (Speedy, 2003).

Globally there have not been substantial changes in the production of all meat and meat products. Overall meat production has been on the increase probably due to the increase in population and an improvement in the income of the world population as well as some noted decreases in the prices of meat and meat products. Russia and China have fuelled an increase in beef production due to their increased demand for the products (USDA-FAS, 2013). However, worldwide beef and veal production has experienced a decrease of 2% from 2007 to 2012 (58.433 MMTs to 56.798 MMTs) whilst the consumption has decreased by a significant 4% according to the same source. Poultry and pork, however, have been on the increase in consumption between the same period with pork consumption increasing by roughly 10% (93.778 MMTs to 102.898 MMTs) and roughly 16% (74.963 MMTs to 86.837 MMTs) for the prior. At present, the consumption of pork meat accounts for 36% whilst poultry meat accounts for 33% and beef for 24% of all worldwide meat consumption (Anon., 2013a; FAO, 2013).

As much as consumers consider meat and meat products as a major protein source, and source of other nutrients, their consumption pattern is changing. Lately nutritionists are advising consumers to seek protein from alternative “healthier” sources for health reasons. Such influence has pushed for the change in attitude from red meat as a central part of a healthy diet in the health conscious individuals and the industrialized community as a whole (Schutte, 2008). Mostly females tend to avoid consumption of red meat and replace it with chicken (Kubberød *et al.,* 2002). Moreover, poultry seems to be the major source of cheaper meat cuts which most of the people are opting for worldwide (USDA-FAS, 2013; WHO, 2013).

2.3 Sausage type meat products

2.3.1 Origins of sausage

The term sausage refers to an extensive number of meat products, which consist of ground meat and fat, stuffed into a casing (Anon., 2013b). Sausage can be defined as a communited processed meat product made from red meat, poultry or a combination of these with water, binders and seasonings (Essien, 2003). This also involves the use of curing salt (sodium chloride with nitrite/nitrate) in some type of sausages, which contribute to the flavour and colour of the product (Toldra & Reig, 2007). It is said that the word sausage is derived from the Latin word “salsus” which means salted (Kim, 2006; Sebranek & Bacus, 2007). Sausage production has a history dating back to 3000 BC where it was first manufactured in Iraq. It is basically a logical outcome of efficient butchery as well as a traditional food preservation technique (Anon., 2013b). Chinese cooked sausage “lupcheong” has been known in that country for over 2500 years (Tolda & Reig, 2007). Sausages offer consumers a variety of different flavours and textures whilst allowing the producers to improve the safety and shelf-life of the product (Sebranek *et al*., 2005).

Depending on the region, the culture and the climatic conditions, different sausage types have been made. In Southern Europe, dry sausage was commonly made as they are less likely to spoil in the warm climate (Sebranek & Bacus, 2007). Modern dry-fermented sausage is an Italian invention around the 1730s and later adopted by other nations such as Germany (Toldra & Reig, 2007). Cooked sausage is popular in Northern Europe where the cold weather plays a role in the extension of shelf-life. Heavily spiced sausages are common in warm climates where spoilage is highly prone and the spices play the role of masking any off-flavours (Sebranek *et al*., 2005).

Most sausage products have names linked to their region or city of origin, e.g., Vienna sausage from Vienna, Austria, Frankfurters from Frankfurt, Germany and Bologna from Bologna, Italy. South African boerewors sometimes referred to as ‘farmer’s sausage’ is a traditional South African sausage inherited from the country’s pioneering forefathers during the 17th and the 18th centuries. It is derived from the Afrikaans word ‘boere’ which means farmer, and ‘wors’ which means sausage (Nel & Steyn, 2002; Charimba *et al*., 2010; Mathenjwa, 2010). The early South African settlers used to make and consume large quantities of sausage (wors) at stopovers during the pioneer trek, after which some would be stored for sustenance. Ever since these times until now, boerewors has been part of the South African culture (Hugo *et al*., 1993; Krijger, 2009; Anon., 2013b). Boerewors is usually grilled and consumed for breakfast or supper. The popularity of this sausage in South Africa holds a 2011 Guinness world record for making and braaing (grilling over an open fire) the longest sausage (Anon., 2011). Similar to this type of fresh sausage is species sausage which has different specifications but same ingredients as boerewors and governed by the same legislation. Braai

2.3.2 Classification of sausage

Sausages are characterised mainly by their processing procedures, ingredients, and origin. The classification is largely a reflection of their processing history and subject to regional differences of opinion. Sausage is a broad term referring to many products but can be arranged into several groups depending mainly on their preservation practices of fermentation, drying or cooking (Flores & Toldra, 1993). Degree of chopping, conditions of fermentation, extent of drying and ripening, final product texture, moisture content as well as desired final product quality can be some of the guidelines used in sausage classification (Toldra, 2002; Kim, 2006; Toldra & Reig, 2007). The severity of chopping is usually the most useful classification, separating course ground and emulsified products. Grinding the meat and mixing it with fat particles to form a uniform mix is used to prepare course ground products (Kim, 2006). Emulsified products are prepared by mixing, chopping and emulsifying ground meats with ice, salt, spices and curing salts to produce an emulsion (Pearson & Gillet, 1996). Most emulsified sausage are usually cooked and smoked, e.g., bologna, vienna, frankfurters and liver sausages (Essien, 2003). An outline of the common classification for sausage is shown in Table 2.2.

Table 2.2 Classification of sausages (Toldra, 2002; Kim, 2006; Mathenjwa, 2010)

Classification	Characteristics	Examples
Fresh sausage	Fresh meats (mainly pork); uncured, communited, seasoned and usually stuffed into casing; must be fully cooked before serving	Fresh pork sausage Bockwurst Breakfast sausage Boerewors (South Africa) Species sausage
Uncooked, smoked sausage	Fresh meats, cured or uncured, stuffed, smoked but uncooked; should be fully cooked before serving	Smoked, country-style pork sausage Mettwurst Kielbasa
Cooked, smoked sausage	Cured or uncured, communited, seasoned, stuffed into casings, smoked and fully cooked. Served cold but some can be heated before serving	Frankfurters Bologna Cotto salami Braunschweiger
Cooked sausage	Cooked not smoked, cured or uncured, communited, seasoned, stuffed into casings. served cold.	Liver sausage Liver cheese
Dry and semi-dry sausage	Cured meats; fermented air dried, stuffed into casings may be smoked before drying; served cold	Pepperoni Genoa salami Summer sausage
Cooked meat specialities	Specially prepared meat products; cured or uncured meats, cooked but rarely smoked, often made in leaves, generally sold in sliced packaged form, usually served cold	Luncheon meats Loaves Sandwich spreads Head cheese

An essential term also used in the classification or description of sausage is curing. This term is used for a variety of meat products depending on the country of origin as well as the product. Curing is basically the use of curing salt (usually sodium chloride with nitrite/nitrate) to alter the general colour and texture profiles of the product (Toldra, 2002). Curing can either be dry or wet. Dry curing is achieved by rubbing the curing salt on the product surfaces or mixing into a mincer. Wet or pickle curing involves pickle injection of cure solution into the piece by pumping or soaking the entire product in curing brine (Kim, 2006).

Curing is responsible for the colour status of most communited meat products. The typical red meat colour is dependent on myoglobin, which varies in accordance to the type of muscle and the age of the animal. Some muscles contain higher amounts of myoglobin than others whilst older animals also have higher myoglobin contents as compared to their younger counterparts (Toldra, 2002). The meat colour is affected by the oxidative state of the haeme cofactor in the myoglobin molecule which alternates between the Iron (II), Fe^{2+} (bright red)/ Iron (III), Fe^{3+} (brown) states. The bright red colour develops in a number of complicated reactions until NO^{-} myoglobin (Fe^{2+}) is formed or when the Iron (II) binds oxygen. Oxidation of the Iron (II) molecule to the Iron (III) form will results in the formation of Met-myoglobin (Fe^{3}+) which is brown in colour. Myoglobin, oxy-myoglobin and met-myoglobin usually occur together in equilibrium fresh meat (Varnam & Sutherland, 1995). Met-myoglobin is usually very low in a live muscle and only increases in post-mortem with depleting oxygen content (Honikel, 2008). Conditions that support the denaturation of the globin molecule enhance the oxidation of the Fe^{2+} to Fe^{3+} (met- myoglobin) form and hence the browning of the meat. Such factors include low pH, salts, ultraviolet light and low oxygen concentration (Lawrie & Ledward, 2006). Figure 2.1 represents the existence of three myoglobin forms in meat.

The addition of nitrates in processed meat products is very common as it produces the light pink colour which is considered by consumers as a sign of quality and freshness (Mapanda, 2011). The basic function of nitrite is to produce the characteristic desired pink colour in cured meats (Shahidi & Pegg, 1991). Nitrite, due to strong antioxidant properties, also inhibits lipid oxidation and thus maintains the desired meat product flavour (Sanz *et al*., 1997). Additionally, the nitrite possesses microbiological inhibiting properties; it inhibits the growth of spoilage microorganisms and pathogens such as *Clostridium botulinum* (Flores & Toldrá, 1993; Marco *et al*., 2006). The pink colour is formed as a result of the conversion of the nitrite to nitric oxide (NO), which subsequently reacts with myoglobin to form nitrosylmyoglobin. The NO-myoglobin (nitrosylmyoglobin) has a bright, attractive colour which is stabilised by heating. The resultant bright pink colour after heat treatment is nitrosylhemochromogen, which is responsible for the characteristic of cured meat (Aberle *et al*., 2001). The reaction occurring during colour development is as follows:

Myoglobin + nitric oxide (NO) ⟶ nitric oxide-myoglobin ⟶ nitrosylhemochromogen.

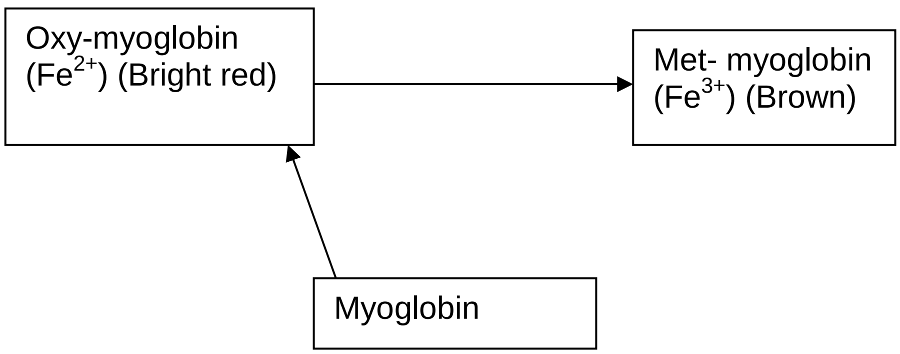

Figure 2.1: Different myoglobin states in meat products (Aberle *et al*., 2001).

2.4 Quality attributes of meat and sausage-type meat products

The quality of sausage to the consumer is greatly influenced by appearance at point of purchase. This is based mainly on the colour of the product and the fluid that is expressed from the product (purge). It is thus essential that the meat product is attractive in colour with limited amount of purge. This in emulsified meat products is influenced mainly by the pH of the meat and/or meat product; high pH values are associated with high water holding capacity and higher emulsion stability. Resultantly the products have lower purge values and are more stable in colour (Qiao *et al*., 2001). It is thus important that the meat used for sausage manufacture to be of good water holding capacity (in terms of pH) and of good colour, otherwise a sub-standard product is produced. An emulsion product with poor stability, poor water holding capacity will lose water during storage and during cooking, becoming undesirable to the consumers (Knipe, 2004).

Poor emulsion stability implies that the fat particles are free to react and can be become easily oxidised. Communited meat products are very prone to oxidation due to increased exposed surface area and an introduction of air and/oxygen and other elements that promote oxidation (Faustman *et al*., 2010). Fat oxidation results in production of rancid off-flavours in the meat products (Heinz & Hautzinger, 2007). Excessive exposure to heat and light will result in the greying of the product. Myoglobin is the haeme protein responsible for meat colour. The oxidation of the central iron atom within the haeme group is responsible for discoloration, a change from red oxy-myoglobin to brownish met-myoglobin. When ferrous haeme iron oxidizes to its ferric form, oxygen is released and replaced by a water molecule. This results in the greying of the meat product (Faustman *et al*., 2010). To improve emulsion stability in most meat products, phosphates are added. The role of phosphates is to increase the pH and thus improve water binding in the product and therefore increasing product yield (Puolanne *et al*., 2001; Peng *et al*., 2009). Pre-rigor meat, with high pH values, would achieve the same outcome. However, pre-rigor meat is seldom used as it spoils quickly since the high pH favours rapid bacterial growth (FAO, 2009).

The term quality is ambiguous and sometimes contradictory depending on the individual or the instant it is being used (Becker, 2000). It is defined by the International Organisation of Standardisation (ISO, 1994), as “the totality of features and characteristics of a product or service that bear on its ability to satisfy stated or implied needs”, whilst Juran, (1979) described it as conformance to requirements or fitness for purpose and Hofmann (1973) defined it as the sum of all sensoric, dietetic, hygienic, toxicological and technological (all intrinsic) characteristics of the product. These definitions are hardly relevant to the consumer perception of meat and meat products quality as consumers focus mostly on the price and appearance (extrinsic) (Becker, 2000).

Ernest (1995) classified meat and meat products quality into four categories which focus mainly on the intrinsic attributes. Most of these characteristics are not measurable by the consumer and might be of less importance at purchasing. Table 2.3 gives an outline of these categories and their characteristics. These characteristics, which are technical quality indicators, would be more relevant to the manufacturer than to the consumer (Schutte, 2008). The nutritional, hygienic-toxicological and sensory characteristics would be essential in the manufacturer’s product marketing and market success. The processing quality characteristics would definitely affect processibility and hence the costing of the product, easier processibility would imply lesser costs and less ingredients to improve product quality.

Table 2.3 Categories of meat and meat products quality and their characteristics (Ernest, 1995)

Product quality category	**Characteristics/ examples**
Nutritional value	Protein, fat, carbohydrate, ash content and digestibility.
Processing quality	Shear-force, sarcomere length, pH value, colour, fatness, water binding capacity (WBC)
Hygienic-toxicological quality	Residues, contaminants, micro-bacterial status, additives.
Sensory quality	Texture (tenderness, juiciness), flavour/odour, colour or appearance.

The perception of meat and meat product quality by consumers is a complex multi-attribute attitude based on expectation and experience. It is focused on before and after purchase evaluations categorised into search, experience and credence characteristics (Becker *et al*., 2000). The ‘search’ quality characteristic is mostly an expectation about quality which is based on appearance and colour and can be evaluated before purchase. Experience quality such as taste, tenderness and juiciness (organoleptic characteristics) can be evaluated after purchase or during use of the product. Credence quality (healthiness and safety), however, can under normal circumstances not be evaluated by the average consumer but only in faith and trust of provided information (Grunert *et al*., 2004).

Credence quality characteristics such as place of origin as well as place of purchase are of great importance to most consumers, especially in Europe and the developed world where consumers are quite sensitive to safety and health (Becker *et al*., 2000). The before purchase judgement is based on information blocks used to form quality expectations i.e., the cues (Steenkamp, 1990). The quality cues are characterised into two groups, namely the intrinsic and the extrinsic cues. The intrinsic cues refer to the physical product characteristics related to the product's technical specifications as well as physiological characteristics all of which can be physically measured. The extrinsic cues include the brand name, price distribution, outlet and packaging (Grunert *et al*., 2004). Table 2.4 outlines the quality attributes of meat and meat products as viewed by the consumers at buying, during use or consumptions as well as at points beyond buying or consumption.

Table 2.4 Categories of quality attribute cues (Becker, 2000; Grunert *et al*., 2004)

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

2.5. Species sausage manufacture

Fresh sausage is made from fresh ground meat (red meat, poultry or a mix of these species), fat (usually pork), salt and spices for taste, flavour and preservation. Depending on the type of sausage; vinegar and/or water, as well as cereal products, can be added, depending on the national or regional legislation. Most fresh sausage is consumed within 4-5 days of manufacture due to easy spoilage during storage. Fresh sausage preparation is usually by cooking in water, or deep fat frying in oil or grilling on a griller. Braaing (grilling over an open fire) is a popular sausage preparation procedure in most countries including South Africa (Anon., 2011).

Fresh sausage such as species sausage and boerewors are classified in South Africa as a ground meat product in which the muscle structure has undergone communition (mincing or dicing or chopping), the muscle structure becoming unrecognisable in fibrous form but becoming particulate in nature (Rust, 2007).

2.5.1 Regulations governing fresh sausage manufacture (Boerewors and species sausage)

All food products are guided by a standard, which could be local or internationally based. Most food products in South Africa are governed by the Foodstuffs, Cosmetics and the Disinfectants Act, 1972 (Act 54 of 1972). Composition and labelling of raw boerewors, raw species sausage and raw- mixed species sausage is governed by this legislation under Government Notice No. R. 2718 of 23 November 1990 (updated in 2012). Internationally the food products should meet the standards set on board by the International Organisation of Standardisation (ISO).

1. ***Guidelines governing the manufacture of boerewors in South Africa (R2718/ South Africa, 2012)*** (Anon., 2012).

Boerewors requirements include:

- Manufacture from meat of an animal of the bovine, ovine, porcine or caprine species or from a mixture of two or more thereof and contained in an edible casing.
- It contains at least 90% total meat content and a maximum of 30% fat.

- Contains no offal except where such offal is to be used solely as the casing of the raw boerewors.
- Contains no mechanically recovered meat.
- Can contain a maximum of 0,02 grams of calcium per 100 gram of the product mass.

It may also contain only:

- Real products or starch.
- Vinegar, spices, herbs, salt or other harmless flavourants;
- Permitted food additives;
- Water

2. *Guidelines governing the manufacture of species sausage in South Africa (R2718/ South Africa, 2012),* (Anon., 2012).

- Must be manufactured predominantly from the meat of a specific animal or bird species, and be contained in an edible casing,
- Must contain a minimum of 75% total meat content, of which
  - (i) a minimum of 75% shall be meat of the predominant species, which shall be mentioned in the name of the sausage.
  - (ii) a maximum of 25% may be meat of any one or more bovine, ovine, porcine or caprine species.
- Shall not contain more than 30% fat content.
- Shall contain no offal except where the offal is to be used solely as the casing of the raw species sausage.
- Shall contain no mechanically recovered meat.
- May contain a maximum of 0,02 g of calcium per 100 g of the product mass.

It may also contain only:

- Cereal products or starch.
- Vinegar, spices, herbs, salt or other harmless flavourants.
- Permitted food additives.
- Water.

2.6. Health and dietary concerns of meat and meat products

Meat and meat products have been associated with many diseases, most of which are inherent from the raising of livestock, some are resultant from its processing, storage and distribution whilst some arise from the components of the product itself. Meat safety, especially that of beef is of worldwide concern (Schroeder *et al*., 2007a). Consumers in the USA and Canada are very concerned about contaminations of meat by *E. coli* O157:H7 while *Bovine Spongiform Encephalopathy* (BSE) is commonly of concern in Japan (Schroeder *et al*., 2007a). Such perceptions, however, have been overblown by the media and *E. coli* O107:H7 can be controlled if the meat is properly cooked. Periodic detections of other microorganisms of significance such as *Campylobacte*r, *Salmonella* and *Listeria* are part of some of the concerns within the meat industry and caused severe financial loses to the Canadian beef industry between 2001 and 2004 (Schroeder *et al*., 2007b).

BSE outbreaks in 2000 caused a significant drop in the world wide per capita beef consumption (Jimenez-Colmenero *et al*., 2001; Roosen *et al.*, 2003). Such occurrences result in loss of consumers' confidence in the meat industry and scare them away from the meat products causing severe losses to the sector (Marsh *et al*., 2004). Other perceptions of unsatisfactory safety by the consumer are the risk of chemical residues of growth hormones as well as antibiotics (Schutte, 2008). Consumers in Germany are extremely sceptical about food quality compared to consumers from other European countries, as they are more suspicious in terms of food safety. German consumers pay extensive attention to issues such as country of origin due to the extent caused by the BSE discussion (Becker *et al*., 2000).

Recently there have been extensive cases of adulteration and mislabelling of meat products which are of great concern. The mislabelling, which is a breach to fair trade is common in meat products ranging from 8-30% in countries such as United Kingdom, United States, Brazil, Turkey, Mexico and Switzerland (Ballin, 2010). Consumers need to make informed decisions based on their lifestyles, religious beliefs as well as health status, in the case of allergic individuals (Ballin *et al.,* 2009). Such negative health implications are causing consumers to shun from meat products. The recent horse meat scandal across Europe received extensive media coverage and implicated most reputable meat products' manufacturers (Meikle & Neville, 2013;

Verbeke, 2013). The scandal resulted in the recalling of products worth millions and loss of revenue for most companies such as Tesco and BMC as well as entire European nations (Neville, 2013).

South Africa also had its own share of the donkey, water buffalo and game meat in many of its products (Anon., 2013c). Consumers in South Africa were concerned to note that even the reputable retailers such as Pick n Pay, Shoprite-Checkers, Spar, Food Lovers Market and Cambridge Food had their products implicated in this scandal (Knowler, 2012; Anon., 2013d). The damage to the meat industry and the agricultural sector is too early to predict but this could be extremely extensive. Table 2.5 outlines some of the meat and meat products components which are of major health concerns.

Table 2.5 Potential harmful elements in meat and meat products (Schutte, 2008)

Meat/ meat product constituent	**Potential harmful component**
Components present live in animals (natural or otherwise)	Fat Cholesterol Residues from environmental pollution
Elements added to the product during processing for technological, microbiological or sensory reasons	Salt Nitrite/nitrate Phosphates
Elements produced by technological treatment	Contaminants from disinfectants or detergents
Elements developed in storage or commercialisation phase	Pathogenic bacteria Formation of certain lipid oxidation products Migration of compounds from the packing material to the product

2.6.1 Diseases of lifestyle

Meat and meat products are important sources of highly valuable protein, vitamins and most essential nutrients (Valsta *et al*., 2005). Meat and meat products can be said to be an essential part of a healthy diet and has traditionally been considered an essential component to ensure adequate growth and development (Higgs, 2000). This reputation, however, has been dealt a major blow as the enthusiasm of the lipid hypothesis gathered pace, and meat has been associated with a large number of diseases of lifestyle or affluence. However, due to the need for most essential micronutrients such as iron, zinc and vitamin D, a positive opportunity for lean meat has been realised. Meat has been implicated in some prevalent diseases such as cardiovascular disease, cancer, hypertension and obesity (Jimenez-Colmenero *et al*., 2001).

There is substantial evidence showing that diets rich in fat cause obesity and are directly linked to colon cancer as well as cardiovascular disease (Crehan *et al.*, 2000). Meat obviously falls in this category as it is rich in fat which is high in saturated fatty acids (SFA) which are known to positively promote the occurrence of coronary heart disease (Higgs, 2000). Fat, heterocyclic amines, N-nitrosation products and iron are the basis for the potential development of cancer, especially colorectal cancer (Santorelli, *et al*., 2008). However, there is no evidence suggesting that abstinence from meat or vegetarianism presents less risk to diseases (Thorogood *et al*., 1994). Mostly, vegetarians are more health conscious (eat variety of foods and exercise) whilst most omnivorous individuals are least interested in this and sedentary. Omnivorous individuals' diets are rich in fat and protein with insufficient dietary fibre (Higgs, 2000).

Chizzolini *et al*. (1999) stated that high fat and cholesterol intake is associated with obesity, hypercholesterolemia, colon, breast and prostate cancers. Higgs (2000), however, argues that cholesterol intake has little influence on plasma cholesterol. The author mentions that although meat contains high amounts of SFA (50% of all fats in pork and beef, 51% in lamb and 30% in chicken), not all saturated fats increase cholesterol except for myristic acid, which has four times the cholesterol increasing potential of palmitic acid. Most meat contains minor amounts of this fatty acid as compared to other foods. There is an understanding that meat and meat products are suffering an unjustified blame as mostly meat lipids usually contain less than 50% saturated fatty acids (SFA) of which only 25 to 35% of these have antherogenic properties. A 100 g portion of meat usually contains less than 75 milligrams cholesterol (Romans *et al.*, 1994; Chizzolini *et al.*, 1999; Higgs, 2000). A study by Wagemakers *et al*. (2009), between 1989 and 1999, concluded that there was no significant association between consumption of red and processed meat products and serum cholesterol concentrations measured in 1999. They noted, however, that consumption of meat had a positive association with increasing blood pressure and waist circumference which is also a health risk factor.

2.6.2 Diseases associated with processed meat

Recently there has been an alarming increase in diseases associated with processed meat or processed meat products. Consumption of processed meats has been linked to health complications in many individuals' lives and lifestyle qualities, with indirect effects on morbidity and mortality (Schutte, 2008). Such diseases have proved an economic burden in most nations especially in the first world nations (United States and Europe) where they are highly prevalent. Medical attention and costs, low industrial productivity and reduced life expectancy for such individuals has become of global concern (Bloom *et al*., 2011). Diseases such as diabetes, emphysema, chronic bronchitis and cancers, such as brain tumours in children, leukaemia, and cancers of the kidney, liver, pancreas nasal cavity and urinary systems and most organs, have been implicated in the consumption of processed meat (Sarasua & Switz, 1994).

Processed meats contain saturated fat and iron which have been associated with carcinogenesis. The nitrates added during processing become reactants for the formation of N-nitroso compounds (NCOs), heterocyclic amines and amides (HCAs) and polycyclic aromatic hydrocarbons (PAHs); the mutagens formed during processes such as high temperature treatments and cooking (Sarasua & Switz, 1994; Cross *et al*., 2007). Most additives used in meat in the curing process and cooking methods, are directly linked to cancer as they produce mutagens and carcinogens in association with dietary fat. Individuals consuming large quantities of processed meat are prevalent sufferers of colorectal cancer due to N-nitrosodimethylamine (Santorelli *et al*., 2008), whilst exposure to PAH and HCA is known to cause DNA adducts and tumours in rodents in a variety of organs and tissues with similarity between experimental animals and humans. It has been noted that there is evidence showing association with increased gene mutations which predisposes progeny to tumour development at an early age in male mice treated with N-nitrosoethyluria before mating (Cross *et al*., 2007).

Exposure to NCOs during pregnancy can increase the risk of offspring to childhood cancers such as brain tumours, leukaemia as well as lymphomas, PAH will cause leukaemia after trans-placental exposure (Dietrich *et al.*, 2005). Research carried out by Peters *et al*. (1994) suggests there is evidence of an association between consumption of hot dogs and risk of leukaemia. This could be due to the direct ingestion of NCO precursors and other substances which are eventually transformed into leukemogens. The consumption of processed meats in childhood and cancer has a strong, positive association which is more consistent than maternal diet analysis. Bacon and sausage have been to some extent implicated in childhood brain tumour developments. Childhood leukaemia risk increases fivefold with consumption of processed meats (Peters *et al*., 1994).

A high level of saturated fat and cholesterol in processed meats increases the risk of diabetes. Components administered in meat processing and preparations such as the nitrates/nitrites are potential mediators to this disease. Advanced glycation end products developed during the processing are known to facilitate the development of diabetes (Sarasua & Switz, 1994). An investigation of the association between processed meat intake and diabetes in young and middle aged woman established a directly proportional relationship between meat consumption and type 2 diabetes. Bacon, hot dogs, sausage, salami and bologna showed a positive association with the risk of diabetes. These observations are not limited to the investigated group; the authors argue they apply to all population groups (Schulze *et al*., 2003).

Cross *et al*. (2007) also mentioned that processed meats are positively associated with pancreatic cancer in humans. A research study carried out by Larsson *et al.* (2006) from 1966 to 2006 assessed processed meat consumption and stomach cancer and concluded a positive association between the two, stomach cancers also thought to be credited to high amounts of salt, nitrites and potent carcinogens NCOs. The South African government has regulated a reduction of total salts in processed meat products to 850 mg by 2016 and 650 mg by 2019 to combat such occurrences (Anon., 2013e). Evidence also exists that the consumption of processed meat products worsens the symptoms of airway diseases such as emphysema and chronic bronchitis (Dallas, 2012).

2.7. Technologies for developing low fat meat products

Extensive research has been performed on fat replacement to improve the health quality of many meat products (Jimenez-Colemenero, 2000). The main goal of these research studies is to address the lipid fraction in meat products both quantitatively (fat reduction) and qualitatively (modification of fatty acid composition). Fat content has a basic effect on various physico-chemical and sensory characteristics such as providing flavour, mouth-feel, juiciness, texture, handling, bite and heat transfer. It is known to improve the tenderness and juiciness in the meat products. Removing significant amounts of fat from foods usually results in poor flavour and texture (Pearson & Gillet, 1999).

Consequently manufacturers are obliged to adjust these properties to produce an acceptable product. Flavour perception occurs through a cross-modal system (i.e., the senses of aroma, taste, and texture interact to form the perception). Changing any one of these modalities, can affect the overall perceived flavour. Fat has a significant effect on the partition of volatile compounds between the food and the air phases with lipophilic aroma compounds being the most affected. If fat content is reduced, the amount of lipophilic aromas in the flavour formulation also needs to be reduced to maintain the same profile of aroma release from the product (Bayarri, 2006). Figure 2.2 shows the various physico-chemical and sensory roles which fat plays in a food system.

The food industry has been struggling to be able to replace the fat in the food products while maintaining the quality attributes of the particular food products (Tokusoglu & Unal, 2003). Low calorie fat replacers have been extensively used to produce good tasting low fat meat products. This exercise, however, requires the manufacturer to understand the role played by the fat in the whole food system. It is the protein and molecular interactions (hydrogen, hydrophobic and disulphide bonds) in the formation of the gel network matrix as well as the morphological features of the meat products (emulsions, patties or restructured meats) which are of extreme importance (Sampaio *et al.*, 2004; Garcia *et al*., 2007).

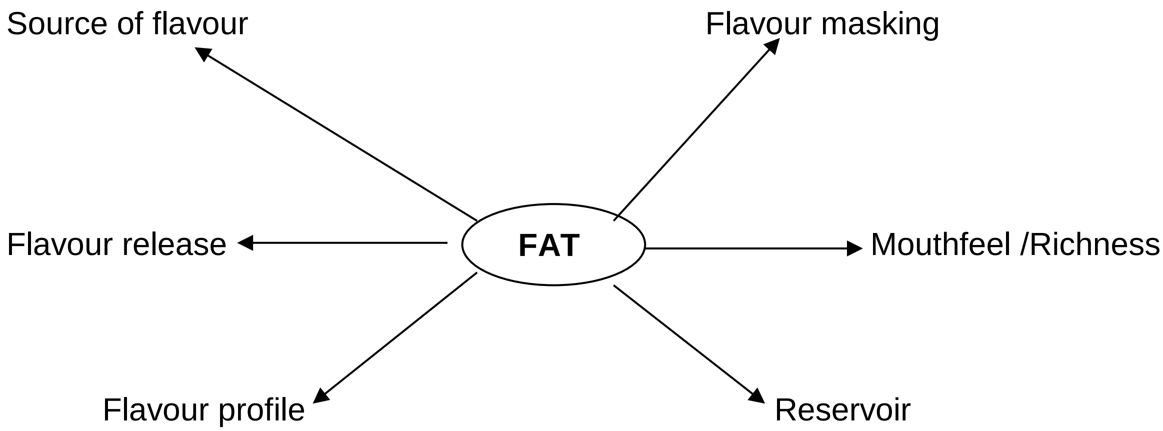

Figure 2.2 The role played by fat in food systems (Pearson & Gillet, 1999).

Rheological behaviour of the gel network matrix, as well as factors such as pH, temperature alterations, meat particle size, mechanical procedures, fat distribution in the protein matrix, process selection and end point characteristics are very crucial issues for fat reduction technology. The production of low-fat meat products is based on two principles: 1) the use of leaner raw materials (which raises the cost) and 2) the reduction of fat and calorie contents by adding water and other ingredients that contribute few or no calories. Non-meat ingredients that can contribute to desirable textural characteristics, particularly those ingredients that enhance water-holding ability have gained valuable use in this aspect (Jimenez-Colmenero, 1996).

Development of low fat products demands that a minimum desired fat level is established, which will vary between meat products (Allen *et al*., 1999; Jimenez-Colmenero, 2000). It should be based on a benchmark, usually the full-fat product. Low fat meat products with unacceptable palatability, flavour, taste and appearance will not sell, regardless of the health characteristics attributed to them (Tokusoglu & Unal, 2003). By using the correct design, the reformulated products can be manufactured and analysed for safety, sensory, nutritional and technological attributes. Consumer sensory test can be used to establish the acceptance of the low fat product. For example, a consumer test for ground beef product containing between 5% and 25% fat resulted in the product containing a 20% fat level scoring exceptionally high in terms of overall acceptability; this fat level was hence established as the benchmark for similar low fat products (Huffman *et al*., 1992). In pork sausage patties, a fat level of 40% (from range of 10 to 60%) was rated the highest for overall acceptability and hence used as standard for similar products (Huffman *et al*., 1992).

Although fat replacement may seem to be lucrative and easily achievable, it is important to consider the technological properties in connection with processing and storage. Mostly the fat is replaced with water, thus bringing into play the phenomenon of the fat-water binding in the meat product system. It becomes a problem if the added water is lost during heat processing or chilling (Claus & Hunt, 1991); purge loss during storage or slight temperature fluctuations can result in undesirable appearance as well as encourage microbiological growth (Jimenez-Colmenero, 2000). The development of low fat products should also focus on nutritional and sensory characteristics. Issues of safety, price and convenience and some non-consumer environmental aspects such as health, family or educational, general economic situation, climate and legislation should also be considered (Jimenez-Colmenero, *et al*, 2001). Principles surrounding the development of low-fat meat products are outlined in Figure 2.3.

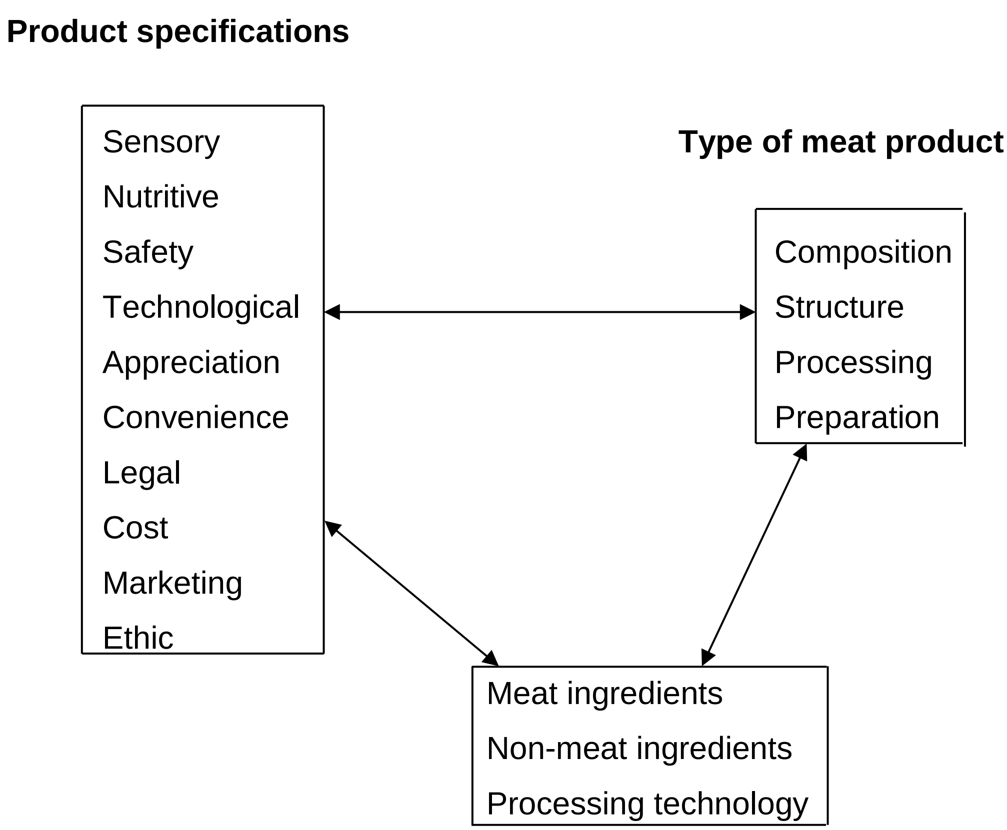

Figure 2.3 Principle factors affecting the development of low-fat meat products (Jimenez-Colmenero, *et al*., 2000).

The most commonly used fat replacers include water, carbohydrates, proteins (animal and vegetable based), vegetable oils and oat bran (Crehan *et al.*, 2000). Sampaio *et al*. (2004) reported that most of the fat replacers chemically resemble fats, proteins, or carbohydrates and are generally grouped as fat substitutes. A research study carried out by these authors concluded that frankfurters substituted with carrageen, cassava starch and oat bran had over 50% consumer acceptability. Crehan *et al*. (2000) studied the use of 2% maltodextrin in frankfurters formulated with 5%, 12% and 30% pork fat. All the frankfurter formulations had reduced cooking loss and similar scores in acceptability in terms of flavour and texture as compared to the control. Olive oil, with isolated protein, guar and xantham gums has been used as fat replacers in most meat products (Sampaio *et al*., 2004).

Cereal, fruit and legume fibres have been used in ground beef, pork and mortadella sausages resulting in an improvement in flavour, texture and mouth-feel (Garcia *et al*., 2007). The authors also found that there was no significant difference in the overall acceptability of the sausages substituted with 15% and 30% of these fibres as compared to the control, which contained no fibre. Table 2.6 outlines some of the fat replacers and their effects in different meat products.

Table 2.6 Effects of different fat replacers in the quality parameters of meat products

Fat replacer	Product	Characteristic	Authors
Sugar beet or wheat fibre	Ground beef sausage	• Improved flavour • Improved mouth-feel • Improved texture	Garcia *et al*., 2007
Oat fibre or pea fibre	Pork sausage	• Improved mouth-feel • Improved texture	Garcia *et al*., 2007
Apple, peach and orange fibres	Mortadella sausage	• Improved texture • Reasonable acceptability	Garcia *et al*., 2007
Carrageen, cassava starch, oat bran	Frankfurters	• Improved acceptability	Sampaio *et al*., 2004
Maltodextrin	Frankfurters	• Reduced cooking loss • Improved texture • Improved flavour • Overally acceptable	Crehan *et al*. (2000)

2.8. Pineapple: History and availability.

Pineapple (*Ananas comosus*) belongs to the *Bromeliaceae* family and is one of the edible varieties of this family which resembles about 2000 members (Luther & Sieff, 1998). Pineapple is the third most important tropical fruit in the world after banana and citrus. The fruit originates in the Americas particularly Brazil, Paraguay and Uruguay according to the Department of Agriculture, Forestry and Fisheries (DAFF, 2012), and has spread through the world by means of native distribution and by European explorers (Bartholomew, 2003). It is grown in India, Taiwan, Philippines, Brazil, Paraguay, Mexico, West Indies, Puerto Rico, USA, Ivory Coast and Kenya although Thailand is the major producer worldwide, whilst South Africa is amongst the world major producers (Anon., 2002). The pineapple plant has a history of more than a century in the Eastern Cape, South Africa (Anon., 2010). It is mainly produced in this region but also in the Northern KwaZulu Natal (Hluhluwe District) (DAFF, 2012). Approximately 75% of ripe pineapples produced worldwide are usually consumed fresh due to their short shelf-life, however, about 80% of the pineapples produced in South Africa are absorbed into the processing lines (canning and juice production) (DAFF, 2012).

Previously, pineapple has been used for making alcoholic beverages, for medicinal purposes as well as fibre for cloth, fishing lines and nets. Commercial pineapple processing originated in the 19th century in Hawaii and has led to an endless list of canned and other pineapple products on the market (Batholomew *et al*., 2003). The processing however, presents a great deal of unmanageable and underutilised waste, (usually 50% of the total pineapple weight) with undesirable environmental effects (De La Cruz Medina & Garcia, 2005; Mwaikambo, 2006). South African pineapple producers and processors also face the same predicament with waste management. Processing of the waste for its components that can be used in industry can be of economic benefit to the farmers as and the processors. It can be a means of additional employment to the landless agricultural labourers, especially in developing countries (Paul, 1980). This would also be a convenient and cost effective way that enables easy management of troublesome laws restricting waste (Huang *et al*., 2011).

The major products from pineapple include canned slices, chunks, pineapple crush, juice and fresh fruit cuts. The fruit has also been used for the production of marmalade, nectar, concentrate and many more products, as well as being an ornamental asset for display across the world (Morton, 1987; DAFF, 2012). Further processing of cores and skin produces syrup that is used in beverages and confectionery, vinegar or and/ or alcohol (Ho-a-Shu, 1999). The stem has been used in the extraction of the enzyme bromelain; which is used in meat tenderisation, in the brewery industry for beer clarification, production of vegetable oils, dehydration of eggs and soya milk and bakery industries. The enzyme also has medicinal uses where it has been used as relief for arthritis, digestive aid, and anti-inflammatory agent and for reducing blood clotting (Pavan *et al*., 2012).

The leaves produce a strong silky white fibre fibre used for the textile industry (Ketnawa *et al*., 2012). The fibre is usually extracted manually, mechanically or enzymatically and has been used for the manufacture of shoe thread, cloth and jewellery in countries such as the Fillipinos (from the 1590s), China, India and West Africa (Sinha,1982). The bulk of pineapple waste from processing is usually ground and mixed with molasses and urea for use as animal feed. Pineapple waste is known to be high in moisture and soluble carbohydrates, it is also tender and sweet, which are positive attributes to dairy cattle feeding (Mwaikambo, 2006). Dried core waste has been used to replace 50% roughage in animal feed without any negative implications on dairy cattle (Sruamsiri, 2007).

The use of pineapple waste in food systems has not been noted very widely. The information concerning the use of this fruit is quite scarce especially the use of the pineapple dietary fibre (PDF) in foods. However, recently, the pineapple peels (making up to approximately 35% of the whole fruit) and crowns have been extensively assessed for use in food systems (Ackom & Tano-Debrah, 2012). It is mostly the dietary fibre component that is enjoying growing interest in most food systems especially the juices and confectionery industries. Dietary fibres from the by-products and the pomace of apple, citrus fruits, grape skin and seed, mango, guava and pineapple have been investigated with the view to explore their potential applications and their physiological activities in various food systems (Chau & Huang, 2004).

In a world of rapid assimilation of natural resources, any attempt at the utilisation of agricultural waste is welcome (Paul, 1980). Such fibres are required for their desirable nutritional and physicochemical properties and could be of importance in the food industry (Huang *et al.*, 2011).

2.9. Dietary Fibre

Dietary fibre is a group of food components which is resistant to hydrolysis by human digestive enzymes and an essential requirement in the human diet. It consists of a variety of non-starch polysaccharides which include cellulose, hemicellulose, pectin, β-glucans and lignin (Prakongpan *et al*., 2002; Aleson-Carbonell *et al*., 2003; Figuerola *et al*., 2005). It is classified into two groups by means of its solubility in water as soluble dietary fibre (SDF) and insoluble dietary fibre (IDF). The dietary fibre is usually contained in the remnants of edible plant cells, cell walls of fruits, vegetables, pulses and cereals and make up most of the dietary fibre intake in the human diet (Fernandez-Gines *et al.*, 2004). Fibre from fruits and vegetables tend to have a considerably high proportion of soluble fibre while their cereal counterparts contain more insoluble cellulose and hemicellulose. The soluble to insoluble fibre proportions are essential to the fibre functional properties; fibre sources used as food ingredients should have a SDF/IDF ratio of around 1: 2 (Schneeman, 1987; Jaime *et al*., 2002).

2.9.1 Pineapple Dietary Fibre (PDF)

Research to extract dietary fibre from waste pineapple cores and peels have yielded positive results; Sunspray Food Ingredients in the Eastern Cape, South Africa, is producing dietary fibre from pineapple peels and cores (Ackom & Tano-Debrah, 2012). The usual extraction method comprises a series of alcoholic or alkali digestion and washing with water as well as filtration and drying (Prakongpan *et al*., 2002). Sunspray Food Ingredients uses a special water dialysis process with drying and grinding (Fibiz™, 2011).

There is great interest in the industry to rather use the peels for extraction of dietary fibre than to use it for the cheap less valuable livestock feed. Pineapple peels account for 34.7% of the whole fruit and contains approximately 42.2 g/100 g total dietary fibre (TDF). About 85% of the TDF is insoluble dietary fibre (IDF) whilst the remainder is soluble dietary fibre (SDF) (Huang *et al.*, 2011). The SDF is responsible for lowering cholesterol as well as regulating glucose whilst IDF decreases intestinal transit time and increasing faecal weight (Schneeman, 1987; Rodriguez *et al*., 2006). By shortening the gastro intestinal transit time, IDF prevents constipation and inhibits the development of many rectal cancers (Nawirska & Uklanska, 2008). A ratio of 30-50% SDF: 70-50% IDF is ideal to maintain good health (Schneeman, 1987).

PDF has superior water holding capacity (WHC) than by-product fibres obtained from citrus and passion seeds due to its chemical composition and a porous physical structure (Huang *et al*., 2011). It also returns more oil than most fibre counterparts. The high WHC of PDF renders it suitable for possible use in reducing drip loss and modifying texture in minced meat and other meat products (Sanchez-Alonso *et al*., 2007). Addition of PDF in, for example burger patties would increase cooking yields, whilst the ability to increase viscosity can be capitalised on in the beverage industries (Prakongpan *et al*., 2002). There is not much information regarding the use of PDF in meat products, an indication it has not been widely or adequately investigated.

The water and oil holding capacities, which are determined by hydrogen bonding and hydrophillicity, can be altered by interactions with other components in the food system such as starches and proteins hence modifying consistency texture and sensory characteristics (Rosell *et al*., 2009). Similar to most polysaccharides, the emulsifying properties of PDF are thought to be due to its ability to stabilise emulsions and not due to its action as emulsifier (Sanderson, 1981). The only negativity with pineapple as a source of dietary fibre is the low pH and high sugar content, thus poor extraction or purification processes may result in the fibre having adverse effects in food applications (Ackom & Tano-Debrah, 2012).

2.9.2 Dietary fibre as a functional ingredient

Dietary fibre plays an important role in human health; it is associated with prevention, reduction and treatment of some diseases such as diverticular, constipation, colonic cancer, diabetes and coronary heart diseases (Grigelmo-Miguel *et al*., 1999). According to Rodriguez *et al*. (2006), these effects can be credited to the dietary fibre interacting with the adsorption of lipids and the bioavailability of carbohydrates, the intestinal regulation by IDF and decrease of cholesterol levels by SDF. Authors such as Schneeman (1987), Nawirska & Uklanska (2008), Huang *et al.* (2011) and Ackom & Tano-Debrah (2012) have written on the issue of dietary fibre being defined as a functional ingredient and its contributions have proved beyond reasonable doubt that it falls amongst the functional ingredients.

Functional foods are defined as foods used to prevent and treat certain disorders and diseases, in addition to its nutritional value (Jimenez-Colmenero *et al*., 2001). Goldberg (1994) stated that the three basic requirements of a food to be regarded as functional are: 1) it should be a food (not capsules, tablets or powder) derived from natural occurring ingredients; 2) it can and should be consumed as part of the daily diet and; 3) once ingested, it must regulate specific processes such as enhancing biological defence mechanisms, preventing and treating specific diseases, controlling physical and mental conditions and delaying the aging process. Based on this definition, a functional ingredient then should be a major component that makes a functional food achieves its requirements/functionality. Dietary fibre can be said to be a functional ingredient in the diet, as it prevents and reduces the risk of a variety of diseases, and has certain positive aspects on the health of the individual. The inclusion of dietary fibre has been of importance in most foods which are at the end of the day defined as functional foods (Zhang *et al*., 2010).

2.9.3 Technological Functions of dietary fibre

Besides the nutritional importance, dietary fibre plays an important functional and technological role in food products i.e. it improves cooking, reduces formulation costs and enhances texture (Fernandez-Gines *et al*., 2004). It is also important in the water binding capacity (WBC), oil binding capacities (OBC), swelling capacities, viscosity, gel formation, bile acid binding capacity and cation exchange capacity of many products. Dietary fibre is an essential ingredient in many products as it acts as fat replacer, fat reducing agent during frying, volume enhancer, binder, bulking agent and stabiliser (Prakongpan *et al.*, 2002).

In emulsions and foams, the fibre plays a stabilising role whilst it displays fat-like characteristics in gels (Janvary, 2006). These properties are related to the porous matrix structure of the polysaccharide chains which hold water through hydrogen bonding (Figuerola *et al.*, 2005). Dietary fibre has been extensively used in a variety of products so as to improve their healthiness and acceptance to the consumer who has lately become highly health conscious. Dietary fibre has been used in many food products such as sausages and burger patties, confectionery products such as doughnuts and cakes as well as other products in the food industry for human consumption.

2.9.4 Uses of dietary fibre in meat products

Many types of dietary fibres from cereals, fruit and vegetables have been added to meat products for the purpose of improving their health status. The addition is based on the functionality of fibre as an ingredient or capitalising on the technological capabilities of fibre resembling fat (Vural *et al*., 2004). The major issue with fat replacement in meat products is usually an increase in hardness, significantly affecting product acceptability (Mittal & Barbut, 1994). Successful fat replacement of up to between 25-75% in beef patties and 66-75% in pork sausages with soy protein and oat bran respectively has resulted in acceptable products in terms of appearance, texture and taste (Anon., 1991; Mittal & Barbut, 1994; Choi *et al*., 2009).

Many authors such as Hughes *et al.* (1997), Pietrasik & Duda (2000), Jimenez-Colmenero *et al*. (2001), Tokusoglu & Kemal Unal (2003), Fernendez- Lopez, *et al*. (2008), Sanchez- Alonso (2008), Choi, *et al.* (2010), Pietrasik & Janz (2010), Sanchez-Zapata, *et al*. (2010), Verma & Banerjee (2010), Zhang, *et al.* (2010), Biswas, *et al*. (2011), Cava, *et al*. (2012) and Gedikoglu, *et al*. (2013) have noted an improvement in the technological properties such as water retention, reduced purge and cooking losses, reduced total expressible fluid improved gelling and more improved thicker batters of meat products, such as burger patties, frankfurters, vienna and bologna sausages. The dietary fibre sources in these studies included rice bran, apple pomace, oat bran, sugar-beet, pea, orange, lemon pulp, banana, wheat, hazelnut, peach, tomato and beetroot, just to mention a few.

Different fibres affect colour, texture, appearance, and oxidative stabilities differently, but depending on the level of incorporation, they tend to improve the technological, chemical, physiochemical as well as sensory quality characteristics of the meat products to which they are added (Decker, 2010). An improvement in shelf-life and oxidative stability in meat products has been noted by addition of dietary fibres associated with phenolic antioxidants (Troy & Kerry, 2010).

2.10 Pineapple dietary fibre from Fibiz ™

Summerpride Foods (PTY) Ltd., a company based in East London, South Africa produces dietary fibre from processed pineapple waste. The fibre is extracted from the flesh and the core of the fruit and trades as Fibiz™nsp. The fibre, of neutral taste and aroma, is extracted through a special water dialysis process. Fibiz™ is a pure natural pineapple cellulose comprising of approximately 80-90% dietary fibre that is 99% insoluble. The fibre is available in a wide range of particle sizes for different applications. The specific parameters of the fibres in terms of colour, pH, particle size, water and oil binding capacities are presented in Table 2.6, whilst Figures 2.4 to 2.9 represent macro and microscopical images of the three different fibres. The different processing extents result in NSP 60 being the finest (smallest particle size), followed by NSP 100 and lastly NSP 200 (coarse and largest particle size).

Table 2.7 The specific parameters of the three Fibiz™ pineapple dietary fibres.

Parameter/ Fibre type	NSP 60	NSP 100	NSP 200
Total dietary fibre (%)	81.1± 2	80 ± 4	83 ± 2
Insoluble (%)	99	> 99	> 99
Soluble (%)	< 1	< 1	< 1
Moisture (g/ 100g)	< 8	< 8	< 8
WBC (g/g fibre)	8	7.4	7.8
OBC (g/g fibre)	6	4.2	5.0
Particle size (µm)	<63	63><100	100><400
Colour:			
L/a ratio	7.06	4.44	5.54
a/b ratio	-0.009	0.10	-2.88
pH	4.45	4.37	4.53
Instrumental Lightness*	85.36	80.91	80.25

Parameters supplied by Fibiz™

*Parameters determined in the lab (BYK- Gardner GmbH, Ser. no: 220162 colorimeter (colour guide45º/0º)).

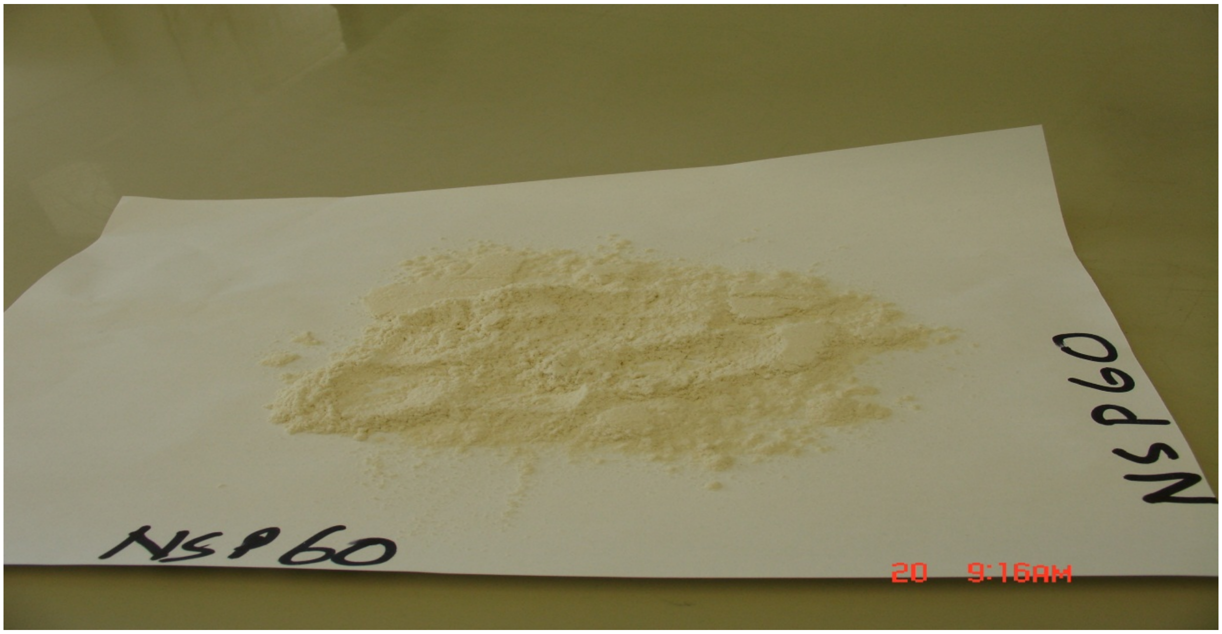

Figure 2.4 Photo of NSP 60

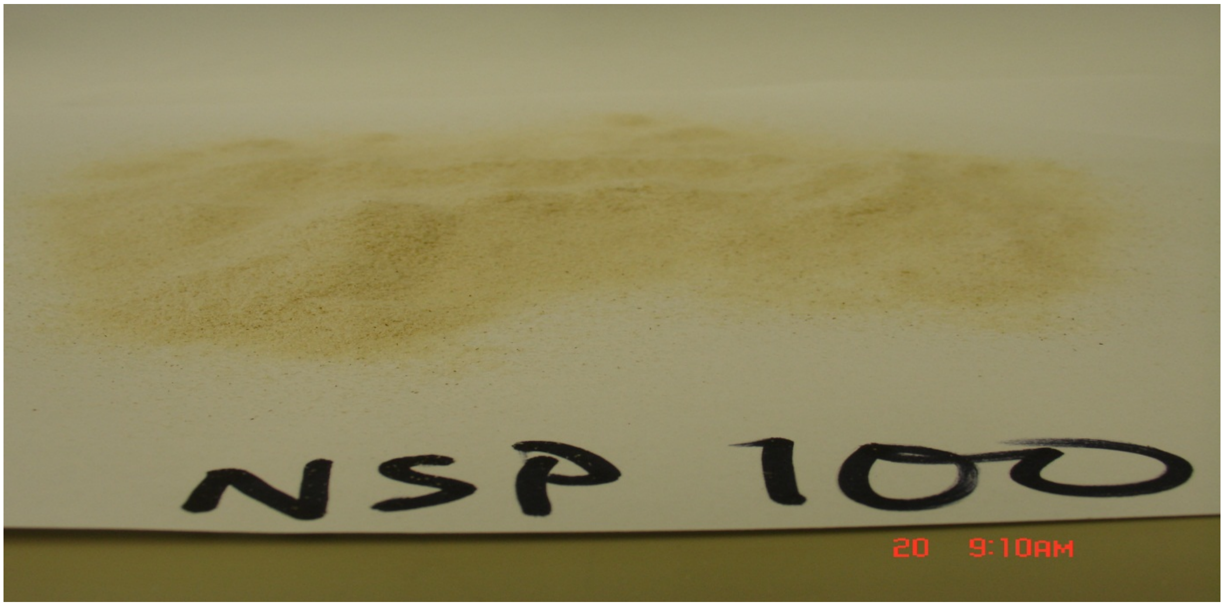

Figure 2.5 Photo of NSP 100.

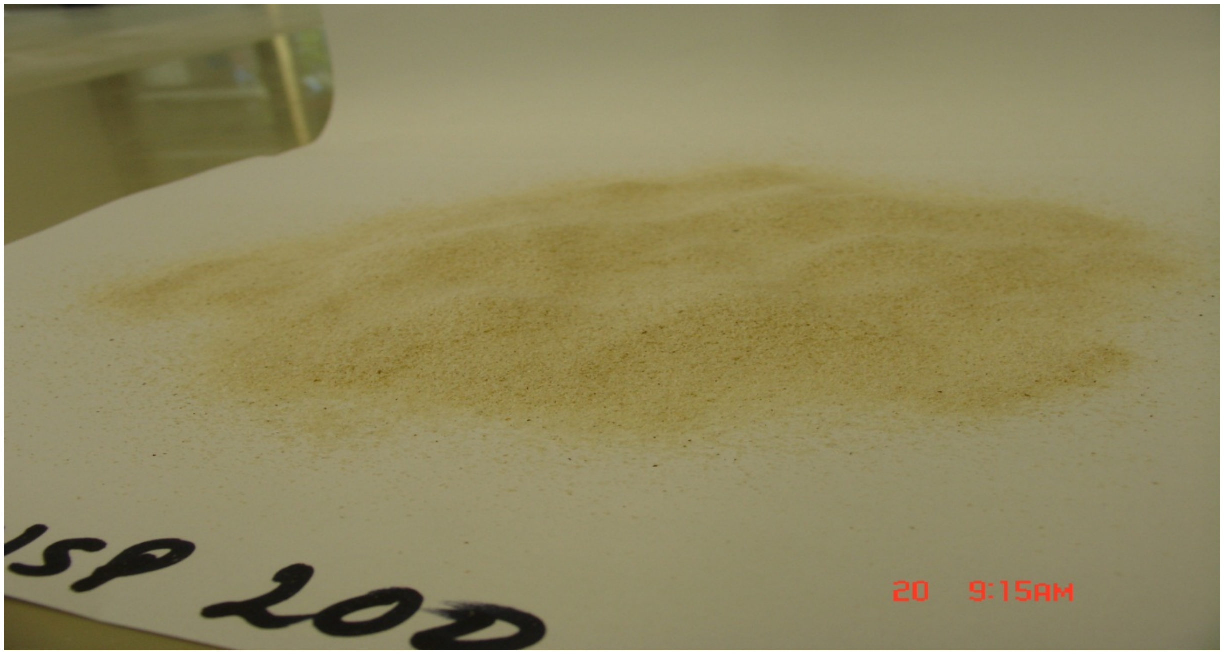

Figure 2.6 Photo of NSP 200

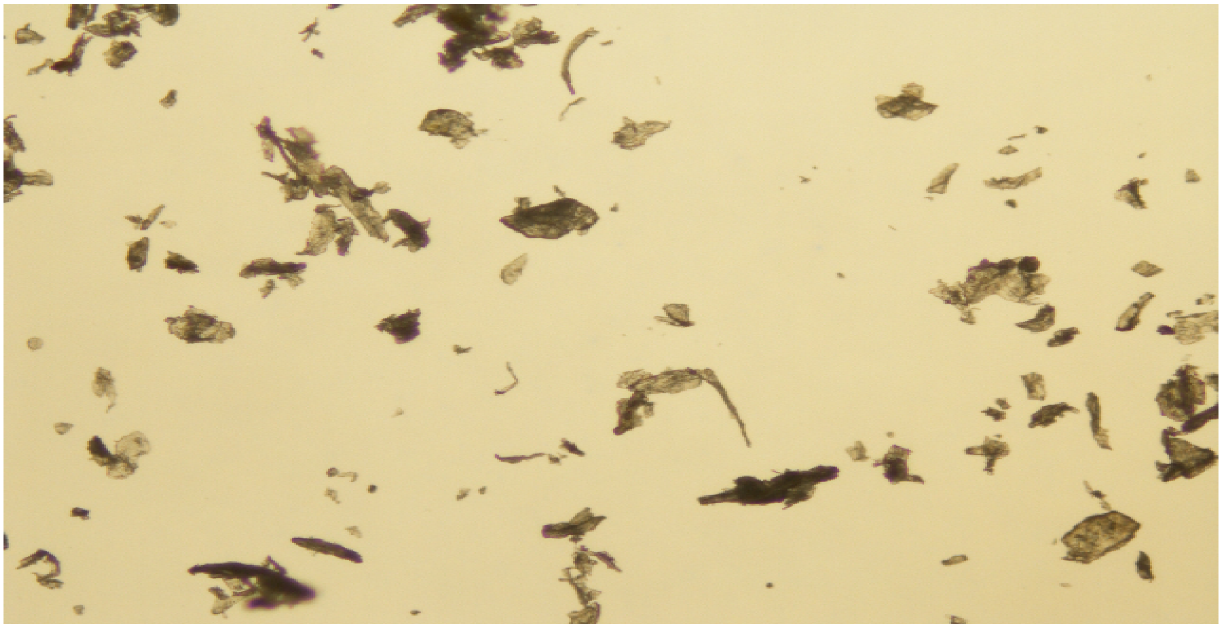

Figure 2.7 Microscopic view of NSP 60 at x 100 (light microscope Olympus CX31 at 100 (10 x 10) times magnification with a camera Nikon DS-Fi1 connected to the light microscope and saved in electronic format with the software Nikon Nis Elements Imaging software version 3.22).

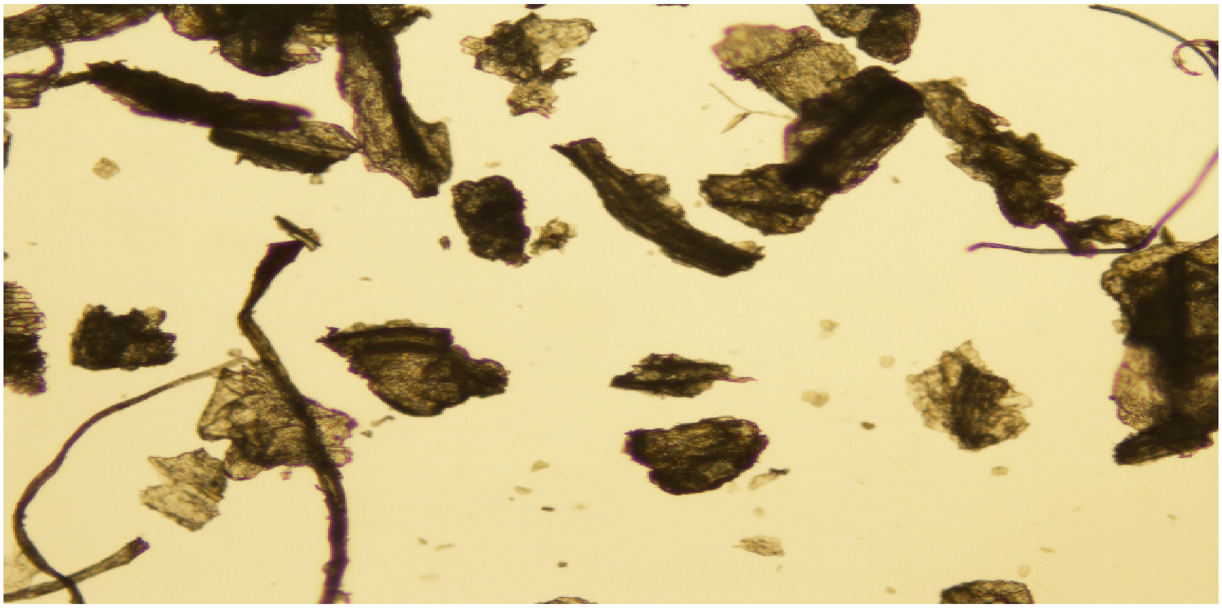

Figure 2.8 Microscopic view of NSP 100 at x 100 (light microscope Olympus CX31 at 100 (10 x 10) times magnification with a camera Nikon DS-Fi1 connected to the light microscope and saved in electronic format with the software Nikon Nis Elements Imaging software version 3.22).

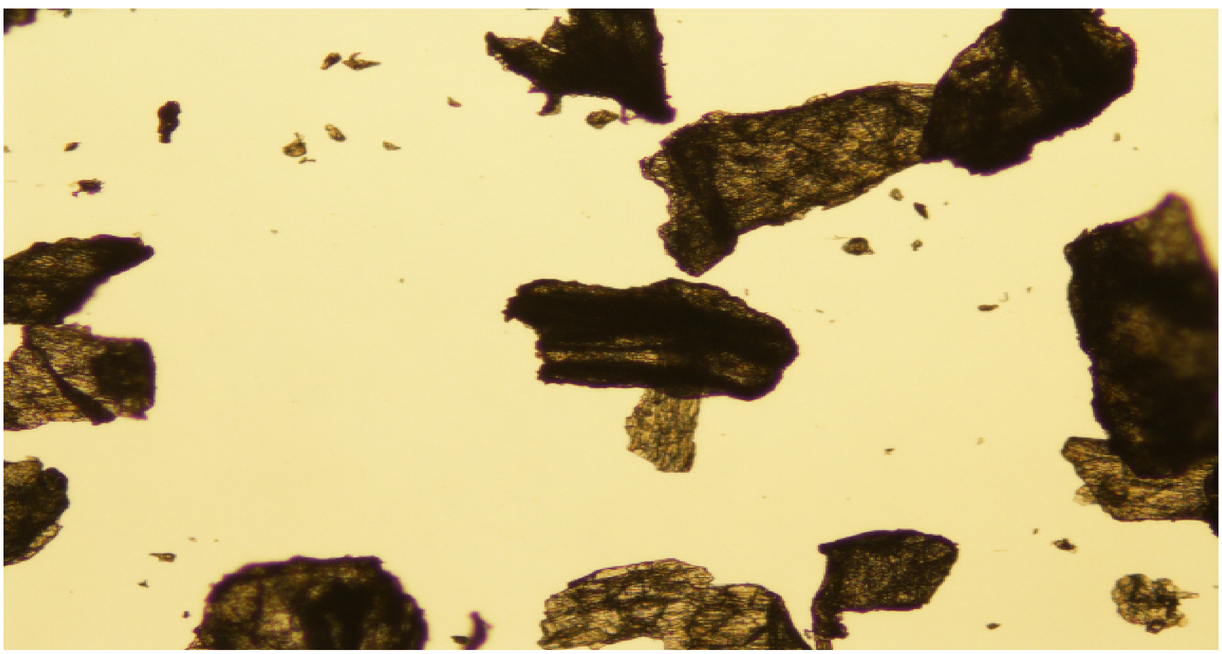

Figure 2.9 Microscopic view of NSP 200 at x 100 (light microscope Olympus CX31 at 100 (10 x 10) times magnification with a camera Nikon DS-Fi1 connected to the light microscope and saved in electronic format with the software Nikon Nis Elements Imaging software version 3.22).

This study focused on the production of a cheaper, “healthier” species sausage by incorporating pineapple dietary fibre and water. The three varieties of the Fibiz™nsp

(NSP 60, NSP 100 and NSP 200) and water were incorporated into beef species sausage in relation to their water binding capacities, replacing the same weight of pork back fat. The initial research stage was meant to determine and select an optimal level at which the fibres can bind added water in the sausage formulations. This was followed by the estimation of the eating quality (colour, texture, proximate composition, drip and cooking loss) of the species sausage at the selected optimal level. Lastly the cost of the manufactured fibre containing species sausages was determined and compared to the control.

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CHAPTER 3

ASSESSMENT OF THE EFFECTS OF DIFFERENT PINEAPPLE DIETERY FIBRE ON THE WATER HOLDING CAPACITY OF BEEF SPECIES SAUSAGE EMULSIONS.

Abstract

The nutrient profile of meat and meat products make them a major protein and minerals source for non-vegetarian human beings. However, their high fat content and the saturated fatty acid profile associates them with increased risk of diseases of lifestyle and occurrences of cancers of the bladder, colon, breast, kidney, liver, pancreas, prostate, rectus, and tumours of the brain. Researchers have focused on fat replacement and fatty acid profile modification without compromising the physico-chemical and sensory characteristics of meat products. Leaner ingredients are expensive hence the use of low/non-calorie adding ingredients such as water, vegetable oils and oat bran. In this study, three pineapple dietary fibres (PDFs), NSP 60, NSP 100 and NSP 200 with water binding capacities (WBC) of 1:8; 1:7.4; 1: 7.8 (g/g), respectively at levels 0%, 0.5%, 1.0% and 1.5% were used in combination with water to replace part of the fat in beef sausage. The WBC of the fibre in the meat emulsion was assessed by extracting the loosely bound fluid by centrifugation. The water amount in this fluid was obtained by evaporation whilst the remainder was the fat. The WBC of all the fibres differed at all substitution levels; however, all the fibres excellently bound water at the 1% level. NSP 100 bound the highest amount of water at 0.5 and 1% levels, and NSP 200 proved to be the best water binder at the 1.5% inclusion level. Hence, the addition of PDF in combination with water to beef sausage can be a viable way of cutting costs and reducing the lipid fraction; fibre, added at 1% level in the meat emulsion provided the best water binding ability.

3.1 Introduction

Species sausage is a fresh sausage product manufactured predominantly from the meat of a specific animal or bird species and is contained in an edible casing as specified by the Food, Cosmetics and Disinfectants Act of 1972, published under Government Notice No. R2718 of 1990 (updated) (Anon., 2012a). It can be described as an 'emulsion' or ground meat product in which the muscle structure has undergone communition (mincing/dicing or chopping) becoming unrecognisable in fibrous form but particulate in nature (Rust, 2007). It can be made from various species' wholesome muscles and fat of beef, mutton or pork or a mixture of two or more. Species sausage contains at least 75% total meat of which, 75% of the total meat should be the predominant species mentioned in the name and 25% can be of other species (Anon., 2012a). It may not contain more than 30% fat content according to S.A. legislation. It may contain cereal products or starch, vinegar, salt, herbs and other harmless flavourants, permitted additives as well as water (Anon., 2012a).

Concerns about potential health risk associated with consumption of high fat foods have led the food industry to develop new formulation or modify traditional products to make them healthier. Inulin, cereal and fruit fibres have been used for such purposes in the meat industry (Fenandez-Lopez *et al.*, 2008). Dietary fibre is a group of components which consist of a variety of non-starch polysaccharides (cellulose, hemillo-cellulose, pectin, B-glucans and lignin) resistant to hydrolysis by human digestive enzymes (Aleson-Carbonell *et al.*, 2003). The World Health Organisation (WHO, 2003) concluded that dietary fibre has a protective effect against weight gain and obesity, cardiovascular disease (CVD) infectious and respiratory diseases (Anon., 2012b).

Dietary fibre can be an effective tool in foods for improving technological properties such as water holding and gelling, which increases with the addition of fibre (Anon, 2012b; Sanchez-Alonso & Borderias, 2008). Water holding capacity (WHC) is defined as the quantity of water bound to the dietary fibre without application of an external force (except gravitational and atmospheric pressure), i.e. it is bound to the pores of the sample by capillary action under defined vapour tension. Water binding capacity (WBC) is the quantity of water that remains bound to the hydrated fibres after application of external force, usually pressure or centrifugation (Thebaudin *et al.*, 1997). Varnam and Sutherland (1995) defines WHC in meat as the ability to retain the tissue water present in its structure, whilst water binding capacity (WBC) is the ability to bind added water. These terms are however frequently used interchangeably as they are important factors in manufacturing properties of meat and meat products. Lawrie (1988) combines these terms in stating water holding capacity as the property of meat to retain its water during subsequent manipulations as well as retain added water during its processing.

The water retention by fibres is credited to the hydrophilic characteristic of all fibres as well as their porous structure (Prakongpan *et al.,* 2002). Water binding can be through surface tension in the pores of the matrix or through hydrogen, ionic bonds and/ or hydrophobic interactions (Thebaudin *et al.*, 1997). The porous matrix-polysaccharide structure of dietary fibre can bind water through hydrogen bonding, playing a role in water binding capacity (WBC), oil binding capacity (OBC), swelling capacity, viscosity and gel formation, bile acid binding capacity (BABC) and cation exchange capacity (CEC) in many products (Figuerola *et al.*, 2005; Biswas *et al*., 2011). Fruit fibres usually has high affinity for water due to the high soluble/insoluble ratio (approximately 29/71), (Grigelmo-Miguel *et al*., 1999). Soluble dietary fibres (SDF) bind water and forms gel-thickened networks while insoluble dietary fibres (IDF) have hygroscopic characteristics, swelling and can absorb up to 20 times their own weight of water (Thebaudin *et al.*, 1997).

Different dietary fibres have been shown to improve rheological characteristics and stability of forms and emulsions in meat products (Akoh, 1998; Crehan *et al.*, 2000; Hsu & Chang, 2001). According to Janvary (2006), dietary fibre has both fat and water binding properties. Some fibres display fat-like characteristics in gels but they also increase water holding capacity (WHC) in sausages (Alenso-Carbonell *et al.,* 2003). Dietary fibre can be a suitable replacement of fat and has been used in meat emulsion products (Hughes *et al*., 1997). Water holding capacity in meat is a very important factor as the quality of meat includes wholesomeness, nutrient content, palatability and capacity of muscles to retain fluids during handling and processing (Lawrie & Ledward, 2006). The components that support water holding yield more stable products with improved textural properties in terms of juiciness and tenderness (Claus & Hunt, 1991; Grigelmo-Miguel *et al*., 1999; Crehan *et al*., 2000; Shand, 2000). Inulin for example, provides fat related properties such as creaminess and juicy mouth-feel in food products (Keeton, 1994; Jimenez-Colmenero, 1996) whilst rice starch provides excellent flavour and mouth-feel properties (Mitchell, 2009). Incorporation of fruit fibres in foods has been proved to enhance hardness, consistency, viscosity and juiciness (Fischer, 2000; Fernandez-Gines *et al.*, 2003).

Rice bran fibre has been shown to improve stability and water retention in meat batters. Frankfurters with rice bran fibre had very low total expressible fluid (TEF) according to Choi *et al.* (2009). Sugar beet dietary fibre is known to increase moisture absorption in meat products (Vural *et al.*, 2004). In a study by Besbes (2008), the addition of pea and wheat dietary fibres in beef patties improved the WBC, thus increasing cooking yield and reducing shrinkage without affecting the sensory characteristics. It also resulted in lower production costs. High levels of oat bran were associated with decreased expressible moisture in low fat chicken frankfurters in a study by Chang and Capenter (1997). Peach dietary fibre added at levels of 17 and 29% increased viscosity, resulted in a drop in pH but did not affect cooking loss in frankfurters. The protein and collagen contents as well as sensory characteristics in frankfurters were not affected by the addition of the fibre (Grigelmo-Miguel *et al.,* 1999).

Pineapple dietary fibre (PDF), extracted from the cores and peels of pineapples, is known to have a superior water holding capacity (WHC) than most by-product fibres such as citrus and passion seeds, due to the chemical composition and a porous physical structure (Huang, *et al*., 2011). The PDF binds more oil than most fruit and vegetable fibre counterparts. The high WHC renders it suitable for possible use in reducing drip loss and modifying texture in minced meat and other meat products (Sanchez-Alonso, 2007). Addition of PDF increased yields after cooking in burgers, whilst the ability to increase viscosity can be capitalised on in the beverage industries (Prakongpan *et al*., 2002). Huang *et al.* (2011) showed that PDF have a higher water holding capacity (WHC) than most citrus pulp fibres.

The water and oil holding capacities, which are determined by hydrogen bonding and hydrophillicity, can be altered due to interactions with other components such as starches and proteins in the food system. Such interactions may result in modified consistency, texture and sensory characteristics (Rosell *et al*., 2009). Similar to most polysaccharides, the emulsifying properties of PDF are thought to be due to the ability to stabilise emulsions and not action as emulsifier (Sanderson, 1981). The only negative aspect with pineapple as a source of dietary fibre is the low pH and high sugar content. A low pH is usually associated with poor water holding/binding in meat emulsions

(Puolanne *et al.*, 2001). Poor extraction or purification processes may result in the fibre altering processibility or sensory characteristics in food applications (Ackom & Tano-Debrah, 2012).

This study focused on assessing the effects of three PDF at various levels on water holding/binding capacity in beef sausage. This was meant to establish optimal water holding fibre level for further study on the effect of the fibres on the physical, chemical and textural characteristics as well as eating quality of species sausage The vast availability of the pineapple in South Africa as well as the underutilisation of the waste from pineapple processing prompted an interest in the purification and the utilisation of this fibre in food systems. The socio-economic implications of using PDF and water in the species sausage formulations could result in production of lower cost, affordable protein source for lower income communities. Moreover, the use of pineapple dietary fibre in food systems is scarce, rendering this investigation some novelty.

3.2 Materials and methods

3.2.1 Raw materials

Vacuum packed lean beef meat consisting of 90% lean meat and 10% fat (Roelcor Meats specifications) was obtained from a reputable meat distributor in Cape Town and stored at -20°C until used. Pork back fat was obtained from a supplier in Stikland, Cape Town and stored at the same temperature. Salt, thyme, coriander and white pepper, used in the manufacture of a laboratory spice mix, and vinegar were all purchased at a local retail store. Three commercial pineapple dietary fibres (Fibiz™nsp 60, Fibiz™nsp 100 and Fibiz™nsp 200) of neutral taste and aroma were provided by Summerpride Foods (PTY) Ltd in East London, South Africa. The fibres differed in terms of water and oil holding capacities, colour, particle size and pH as previously described under the previous section (Section 2.10, Table 2.6).

3.2.2 Manufacture of beef sausage emulsions

Tables 3.1, 3.2 and 3.3 show the altered formulations used in the manufacture of the control and beef sausage batches with the three different pineapple dietary fibres (Fibiz™nsp 60, Fibiz™nsp 100 and Fibiz™nsp 200) at levels 0.5, 1.0 and 1.5% based on

Heinz and Hautzinger and (2007) Anon, 2012(c). Note that, for the formulations containing fibre, fat was replaced by the added fibre as well as the water to be bound by that fibre in accordance to Fibiz™ water binding specifications. Formulation B contained an extra 10 g of water and 10 g less fat whilst formulation C contained 10 g less water and 10 g more fat as compared to formulation A.

Table 3.1 Formulation of nine species sausage treatments/500 g batch for Fibiz™nsp 60 (WHC 1 g/8 g)

%Fibre	Control	0.5			1.0			1.5		
Ingredient		A*	B**	C***	A*	B**	C***	A*	B**	C***
Lean meat	285	285	285	285	285	285	285	285	285	285
PBF	130	107.5	97.5	117.5	85	75	95	62.5	52.5	72.5
Water	60	80	90	70	100	110	90	120	130	110
Vinegar	15	15	15	15	15	15	15	15	15	15
Spices	10	10	10	10	10	10	10	10	10	10
Fibre	0	2.5	2.5	2.5	5	5	5	7.5	7.5	7.5
Total (g)	500	500	500	500	500	500	500	500	500	500
TME****	83	78.5	76.5	80.5	74	72	76	69.5	67.5	71.5

BPF- Pork back fat

*Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre)

**Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre + 10 g extra water)

***Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre less 10g water)

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

For example: For Fibiz™nsp 60 (WHC 1 g/8 g) at 0.5% formulation A:

The original formulation (without fibre) contains 130 g pork back fat and 60 g water for a 500 g batch. The fibre and water added on 500 g batch were as follows:

Fibre amount = (0.5/100) x 500 g

= 2.5 g

Water amount equivalent to added fibre = 2.5 x 8 g

	= 20 g
Amount of fat in the formulation	= (130- 20- 2.5) g
	= 107.5 g.
Total amount of water in the formulation	= (60 + 20) g
	= 80 g

Table 3.2 Formulation of nine species sausage treatments/500 g batch for Fibiz™nsp 100 (WHC 1 g/7.4 g)

% Fibre	0.0	0.5			1.0			1.5		
Ingredient	%	A	B	C	A	B	C	A	B	C
Lean meat	57	285	285	285	285	285	285	285	285	285
Pork back fat	26	109	99	119	88	78	98	67	57	77
Water	12	78.5	88.5	68.5	97	107	87	115.5	125.5	105.5
Vinegar	3	15	15	15	15	15	15	15	15	15
Spices	2	10	10	10	10	10	10	10	10	10
Fibre	0	2.5	2.5	2.5	5	5	5	7.5	7.5	7.5
Total (g)	100%	500	500	500	500	500	500	500	500	500
TME*	83	78.5	76.5	80.5	74	72	76	69.5	67.5	71.5

BPF- Pork back fat

*Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre)

**Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre + 10 g extra water)

***Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre less 10g water)

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

Table 3.3 Formulation of nine species sausage treatments/500 g batch for Fibiz™nsp 200 (WHC 1 g/7.8 g)

% Fibre	0.0	0.5			1.0			1.5		
Ingredient	%	A	B	C	A	B	C	A	B	C
Lean meat	57	285	285	285	285	285	285	285	285	285
Pork back fat	26	108	98	118	86	76	96	64	54	74
Water	12	79.5	89.5	69.5	99	109	89	118.5	128.5	108.5
Vinegar	3	15	15	15	15	15	15	15	15	15
Spices	2	10	10	10	10	10	10	10	10	10
Fibre	0	2.5	2.5	2.5	5	5	5	7.5	7.5	7.5
Total (g)	100%	500	500	500	500	500	500	500	500	500
TME*	83	78.5	76.5	80.5	74	72	76	69.5	67.5	71.5

BPF- Pork back fat

*Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre)

**Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre + 10 g extra water)

***Replaced fat = weight of added water + fibre (contains water equivalent to the added fibre less 10g water)

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

All formulations were manufactured in triplicate using new batches of meat and fat. The meat and fat were thawed overnight at 4ºC and separately minced through a 6 mm dice. The minced meat and fat, vinegar, fibre and spice mix were mixed with gradual addition of crushed ice-water using a hand mixer, ensuring the temperature did not exceed 10ºC. The sausage meat emulsions were stored at 4ºC from which six samples of approximately 25 g were drawn from each batch for emulsion stability analysis.

3.2.3 Determination of the Water Holding Capacity (WHC)/emulsion stability in the sausage emulsion

Water binding capacity was determined by a modified procedure performed by Hughes *et al*. (1997). Six replicate samples of approximately 25 g sausage emulsion were weighed into 50 ml centrifuge tubes from each batch. These tubes were centrifuged at 3000 rpm for 1 minute. The tubes were submerged into a water bath at 70ºC for 30 minutes. After this the tubes were centrifuged again at 4000 rpm for another 3 minutes.

The fluid was transferred into pre-weighed crucibles which were then weighed before being dried overnight, cooled and reweighed to determine the amount of water and fat in the total expressible fluid (TEF). TEF was calculated as follows:

TEF = (weight of centrifuge tube + sample) - (weight of tube + pellet) and

%TEF = (TEF/sample weight) x 100, and

% Fat in TEF = [(weight of crucible + dried supernatant) - (weight of empty crucible)]/ TEF x 100

% Water in TEF = 100 - % Fat (Hughes *et al*., 1997).

3.3 Data analysis

Analysis of variance was performed on all variables accessed using GLM (General Linear Models) Procedure of SAS statistical software version 9.2 (SAS Institute Inc., Cary, NC, USA). Shapiro-Wilk test was performed to test for normality (Shapiro, 1965). Fisher's least significant difference was calculated at the 5% level to compare treatment means. A probability level of 5% (P = 0.05) was considered significant for all significance tests.

3.4 Results and discussion

3.4.1 Total Expressible Fluid (TEF)

All three fibres; NSP 60, NSP 100 and NSP 200 showed some degree of water holding in the beef sausage emulsions as shown by their total expressible fluid (TEF) values (Table 3.4), although different ($P<0.05$) to that of the control. These properties can be credited to the porous matrix structure of the polysaccharide chains which hold water through hydrogen bonding (Figuerola *et al.*, 2005). Although differing ($P<0.05$) between all samples, the TEF ranged from 13.25% in the control to 19.73% for the emulsion containing NSP 60 (Table 3.4). For the emulsions containing fibre, the one containing NSP 200 had the least mean value of TEF (14.39%), followed by the emulsions containing NSP 100 (16.20%) and NSP 60 (19.73%), (Table 3.4). The large particle size and the more porous structure of NSP 200 as shown in the previous section under 2.10,

(Table 2.6 and Figure 2.9) could explain its better interaction with water and other components such as fat and proteins in the sausage emulsions and hence improved emulsion stability.

Table 3.4 Average TEF, water and fat in TEF for sausage emulsions at all water levels

Sample	TEF± sd	Water in TEF± sd	Fat in TEF± sd
Control	$13.25^{a} \pm 3.15$	$68.79^{a} \pm 5.39$	$31.21^{a} \pm 5.39$
NSP 60	$19.73^{b} \pm 3.92$	$88.65^{b} \pm 9.06$	$11.35^{b} \pm 9.06$
NSP 100	$16.20^{c} \pm 1.81$	$81.59^{c} \pm 9.18$	$18.41^{c} \pm 9.18$
NSP 200	$14.39^{d} \pm 3.62$	$81.75^{c} \pm 8.88$	$18.25^{c} \pm 8.88$

*Values are means in which statistical analysis was performed on all data.
$^{a-d}$means within the same column with different superscripts differ significantly ($P \leq 0.05$).
sd- standard deviation

An analysis of the water levels for all beef sausage emulsions combined indicated that the control, which had the least amount of added water, had the lowest ($P<0.05$) TEF value (13.25%) and water in TEF (68.79%). Sausage emulsion samples containing water and fibre; had much higher values of both TEF and water in TEF; which differed ($P<0.05$) from the control and amongst each other (Table 3.5). As expected the samples containing 10 g less (C samples) had the lowest TEF value (16.07%), followed by the standard samples (A samples) and lastly the samples with extra 10 g water (B samples) at 19.09%. The fact that the B samples (10 g extra water) had the highest ($P<0.05$) TEF could be an indication the fibres could not bind any further amounts of water other than specified by Fibiz™. The fact that the standard samples (A samples) mean TEF was significantly different from the control, means that the fibres did not bind as much water as specified by Fibiz™ in the meat emulsions. Interaction between the fibres with the other components in the meat emulsions (fat, salt, proteins etc.) could have played a role in hindering the effectiveness of the fibres in binding the added water (Rosell *et al.*, 2009).

Table 3.5 Average TEF, and fat in TEF in sausage emulsions at various water levels

Sample	TEF± sd	Water in TEF± sd	Fat in TEF± sd
Control (no extra water	$13.25^{a} \pm 3.15$	$68.79^{a} \pm 5.39$	$31.21^{a} \pm 5.39$
Std water (A)	$17.72^{b} \pm 3.29$	$88.65^{b} \pm 4.40$	$11.35^{b} \pm 4.40$
Extra 10 g Water (B)	$19.09^{c} \pm 3.65$	$89.44^{b} \pm 3.87$	$10.56^{b} \pm 3.87$
Less 10 g Water (C)	$16.07^{d} \pm 3.29$	$86.17^{c} \pm 6.09$	$13.83^{c} \pm 6.09$

*Values are means in which statistical analysis was performed on all data.
$^{a\text{-}d}$Means within the same row with different superscripts differ significantly ($P \leq 0.05$).
sd- standard deviation
std- standard

Overall analysis of all sausage emulsions with the different fibres at the different water levels, A, B, and C (Table 3.6) indicated that the emulsion NSP 100C (10 g less water) had the lowest value of TEF (14.12%) which did not differ ($P>0.05$) from the control (13.21%). Samples NSP 100A, NSP 200 (A and C) and NSP 100B (no significant difference amongst each other) had TEF values respectively higher and different ($P<0.05$) from the control and NSP 100C. The samples NSP 200B and NSP 60 (A, B, C) had much higher TEF values differing ($P<0.05$) from the control and amongst themselves; NSP 60B recorded the highest TEF value of 22.83% (Table 3.6).

Table 3.6 Average TEF, water and fat in TEF for all fibres at all water levels

Sample	Water level	TEF ± sd	Water in TEF ± sd	Fat in TEF ± sd
Control		13.21^{f} ± 2.31	68.92^{e} ± 5.73	31.21^{e} ± 5.73
NSP 100C	Less 10g	14.12^{f} ± 1.79	82.90^{d} ± 7.45	17.10^{d} ± 7.45
NSP 100A	Standard	15.43^{e} ± 2.82	86.62^{bc} ± 5.41	13.38^{bc} ± 5.41
NSP 200C	Less 10g	15.21^{e} ± 1.98	84.79^{cd} ± 4.20	15.21^{cd} ± 4.20
NSP 200A	Standard	16.52^{e} ± 1.75	86.61^{bc} ± 2.13	13.39^{bc} ± 2.13
NSP 200B	Extra 10g	17.36^{d} ± 1.15	$87. 98^{b}$ ± 2.89	12.02^{b} ± 2.89
NSP 100B	Extra 10g	17.06^{de} ± 3.81	87.39^{bc} ± 4.24	12.61^{bc} ± 4.24
NSP 60C	Less 10g	18.89^{c} ± 2.80	90.82^{a} ± 2.98	9.18^{a} ± 2.98
NSP 60A	Standard	21.20^{b} ± 1.78	92.71^{a} ± 1.12	7.29^{a} ± 1.12
NSP 60B	Extra 10g	22.83^{a} ± 1.92	92.96^{a} ± 1.17	7.04^{a} ± 1.17

*Values are means in which statistical analysis was performed on all data.
$^{a-f}$Means within the same column with different superscripts differ significantly (P≤ 0.05).
sd- standard deviation

1. TEF at fibre levels 0% (control), 0.5%, 1.0% and 1.5%

An overall assessment of fibre levels alone (Table 3.7) indicated that the sausage emulsions containing 1% fibre level had the lowest TEF value (16.13%) although higher ($P \leq 0.05$) than the control (13.25%). The emulsions containing 1.5% fibre had a slightly higher mean TEF than emulsions containing 1% fibre, although not different ($P > 0.05$). The 0.5% fibre level emulsions had the highest TEF value of 17.29% which was different ($P \leq 0.05$) from the control and 1% emulsions but similar to the 1.5% emulsions (Table 3.7). The high total amount of fat typically found in meat emulsions strongly interacts with the WBC of fibres; this can be the explanation for the poor emulsion stability in the emulsions containing 0.5% fibre (Gullion & Champ, 2000).

Table 3.7 Average TEF, water and fat in TEF for all emulsions at various fibre levels

Fibre level	TEF± sd	Water in TEF± sd	Fat in TEF± sd
Control (0%)	$13.25^{a} \pm 3.15$	$68.79^{a} \pm 5.39$	$31.21^{a} \pm 5.39$
0.5%	$17.29^{b} \pm 4.65$	$83.62^{bc} \pm 9.86$	$16.38^{bc} \pm 9.86$
1.0%	$16.13^{c} \pm 3.52$	$82.98^{c} \pm 8.30$	$17.02^{b} \pm 8.30$
1.5%	$16.56^{bc} \pm 3.36$	$84.80^{b} \pm 10.40$	$15.20^{c} \pm 10.40$

*Values are means in which statistical analysis was performed on all data.
$^{a\text{-}d}$Means within the same column with different superscripts differ significantly ($P \leq 0.05$).
sd- standard deviation

The water component within the TEF followed the same trend as the TEF (Control < 1% < 1.5% < 0.5%). The fat component within the TEF decreased ($P \leq 0.05$) from the control, through to the 1% fibre level, then to the 0.5% level and finally the 1.5% levels which did not differ ($P > 0.05$) as shown in Table 3.7. The low amount of the fat component in the TEF for the 1.5% fibre level emulsions can be explained by the very low initial amounts of added fat in the sausage emulsion formulation. Interactions between fibre, fat and the other components in the food system could result in excessive amounts of loose water in the batter, resulting in more of it being expressed instead of fat during centrifugation. Hence, this could explain the low amounts of fat in the TEF for the 0.5% level, significantly similar to the 1.5 % level (Table 3.7).

2. TEF at different water levels

A comparison of water levels alone showed that the control samples had the lowest TEF value of 13.25%. For the emulsions containing fibre, the emulsion samples with 10 g less water (C samples) had the lowest TEF value of 16.07% followed by the A sample emulsions (with water added in equivalency to the WBC) at 17.72% and lastly the samples with the extra 10 g (B samples) having the highest TEF value of 19.09%. These TEF values differed significantly from the control and amongst each other (Table 3.5). Studies offering a comprehensive approach of fibre behaviour in food systems are scarce, usually it is the isolated physicochemical properties of the fibres that are studied, and they are highly unpredictable in food systems. Predictive modelling requires a better understanding of the structure and functional behaviour within the food matrix (Femenia *et al*., 1997).

3. TEF at 0.5% fibre level

Mean TEF of all sausage emulsions containing NSP 100 did not differ significantly (P>0.05) from the control (13.54%), the sample with water added in equivalency to the WBC of the fibre (NSP 100A) had a TEF value of 13.45% while the sample with 10 g less water (NSP 100C) had a mean TEF value of 14.01% and the sample with 10 g extra water (NSP 100B) recorded a 14.99% mean TEF value (Table 3.8). This was an indication the NSP 100 fibre bound almost all added water in the species sausage emulsion. Sausages containing other fibres had much higher TEF values with NSP 200A at 17.59%, NSP 200B at 17.30% and NSP 200C at 17.05%. These values differed (P≤0.05) from the control TEF but did not differ (P>0.05) to each other. NSP 60, which is the finest of the fibres, seemed to be the poorest water holder in the emulsion at 0.5% with values of 22.99% and 22.10% for A and C (not significantly different) whilst NSP 60B had the highest (P≤0.05) TEF value of 25.00% (Table 3.8). Grinding, drying, heating or extrusion cooking the fibre into a fine powder interacts with the physical structure of the fibre and therefore disrupts the water and oil binding capabilities (Gullion & Champ, 2000; Prakongpan *et al*., 2002; Dhingra *et al*., 2012).

Table 3.8 Average TEF for all emulsions at various fibre levels

Sample	Water level	0.5% fibre	1% fibre	1.5% fibre
Control		13.54^{e} ± 1.56	13.54^{e} ± 1.56	13.54^{e} ± 1.56
NSP 60 A	Standard	22.99^{ab} ± 1.42	20.78^{bc} ± 1.34	19.83^{c} ± 1.20
NSP 100 A	Standard	13.45^{e} ± 1.46	14.12^{e} ± 0.44	18.73^{c} ± 2.16
NSP 200 A	Standard	17.59^{c} ± 3.45	16.34^{cd} ± 1.15	14.80^{de} ± 1.76
NSP 60B	Extra 10g	25.00^{a} ± 1.25	21.85^{b} ± 1.18	21.65^{b} ± 1.11
NSP 100B	Extra 10g	14.99^{de} ± 1.2	14.53^{d} ± 2.11	21.67^{b} ± 2.06
NSP 200B	Extra 10g	18.30^{c} ± 1.64	16.98^{cd} ± 0.48	16.80^{cd} ± 0.62
NSP 60C	Less 10g	22.10^{b} ± 1.99	18.34^{c} ± 0.93	16.24^{de} ± 0.35
NSP 100C	Less 10g	14.01^{de} ± 1.70	13.26^{de} ± 2.17	15.08^{d} ± 1.67
NSP 200C	Less 10g	16.31^{cd} ± 3.33	15.32^{de} ± 0.54	13.9^{de} 9 ± 0.43

*Values are mean ± standard deviation in which statistical analysis was performed on all data.
$^{a-e}$Means within the same row with different superscripts differ significantly (P≤ 0.05).
sd- standard deviation

4. TEF at 1.0% fibre level

All mean TEF values at 1% fibre level showed a similar trend as with the 0.5% fibre level, samples with 10 g less water (C samples) having the lowest mean TEF values whilst the ones with an extra 10 g water (B samples) had the highest mean TEF values (Table 3.8). However, lower mean TEF values were observed at 1% level as compared to their 0.5% counterparts except for NSP 100A, which had a TEF value slightly higher than the 0.5% but not significantly different. The decrease in mean TEF from 0.5% to 1.0% was, however, not significant except for NSP 60B and NSP 60C, which recorded a decrease ($P \leq 0.05$) in TEF. This could be an indication of an improvement in the emulsion stability for the NSP 60 with an increase in fibre and decrease in fat quantities. High fat amounts in the 0.5% sausage emulsion could have been negatively interacting with the water holding activity of fibres. Conditions such as pH, ionic strength, nature of ions can influence the hydration properties of fibres (Gullion & Champ, 2000).

5. TEF at 1.5% fibre level

At fibre level 1.5%, samples containing the fibre NSP 100 had a notable increase in TEF as compared to the lower levels of 0.5% and 1.0%. The increase was significant ($P \leq 0.05$) for NSP 100A and NSP 100B samples but not ($P > 0.05$) for NSP 100C (Table 3.8); this was an indication of reduced emulsion stability. The samples containing fibres NSP 200 and NSP 60, however, showed an improvement in emulsion stability through a reduction in mean TEF although the decrease was not significant ($P > 0.05$). NSP 60 showed the best emulsion stability improvement with emulsions containing NSP 60C recording a significant ($P \leq 0.05$) decrease of 16.24% at 1.5% as compared to 18.34% at 1.0% fibre level. Further reduction of fat amount in the formulations could have been the positive booster in water binding, since fat interacts with or decreases water binding (Rosell *et al*., 2009).

3.4.2 Water and fat in TEF

1. Water and fat in TEF at 0.5% fibre level

Sausage emulsions containing NSP 60 had the highest amount of water in TEF (93.56%, 93.62% and 94.18% for A, C and B respectively), followed by sausage emulsions containing NSP 100 and lastly NSP 200 in all three formulations (A, B and C) as indicated in Table 3.9. The fat amounts in the TEF followed an inverse relationship to the water in TEF (Fig 3.1) with a significant negative correlation (r= -1.000; P<0.001). The meat emulsion with the highest water in TEF automatically had the lowest amount of fat in TEF (Table 3.10). NSP 60, which is specified to be of the highest WHC (1 g/ 8 g), seemed to be the poorest water binder in the meat emulsion, losing the highest water amount in the TEF.

Table 3.9 Average water in TEF for all emulsions at various fibre levels

Sample	Water level	0.5%	1.0%	1.5%
Control		$70.06^{f} \pm 4.09$	$70.06^{f} \pm 4.09$	$70.06^{f} \pm 4.09$
NSP 60 A	Standard	$93.56^{ab} \pm 0.37$	$93.02^{ab} \pm 0.59$	$91.56^{ab} \pm 1.17$
NSP 100 A	Standard	$88.51^{bc} \pm 2.61$	$80.26^{cd} \pm 3.53$	$91.10^{ab} \pm 1.24$
NSP 200 A	Standard	$84.77^{bc} \pm 1.65$	$86.04^{bc} \pm 0.9$	$89.02^{b} \pm 0.71$
NSP 60B	Extra 10g	$94.18^{a} \pm 0.18$	$92.10^{ab} \pm 0.98$	$92.61^{ab} \pm 0.95$
NSP 100B	Extra 10g	$86.66^{bc} \pm 1.12$	$83.85^{cd} \pm 4.80$	$91.67^{ab} \pm 0.76$
NSP 200B	Extra 10g	$85.36^{bc} \pm 3.51$	$88.30^{bc} \pm 1.61$	$90.26^{ab} \pm 0.5$
NSP 60C	Less 10g	$93.62^{ab} \pm 0.36$	$90.09^{ab} \pm 4.03$	$88.75^{bc} \pm 0.42$
NSP 100C	Less 10g	$84.01^{cd} \pm 1.85$	$74.72^{e} \pm 6.06$	$89.96^{ab} \pm 2.23$
NSP 200C	Less 10g	$80.46^{cd} \pm 1.8$	$84.40^{bc} \pm 2.09$	$89.53^{ab} \pm 0.95$

*Values are mean ± standard deviation in which statistical analysis was performed on all data.
$^{a-f}$Means within and between columns with different superscripts differ significantly (P≤ 0.05).
sd- standard deviation

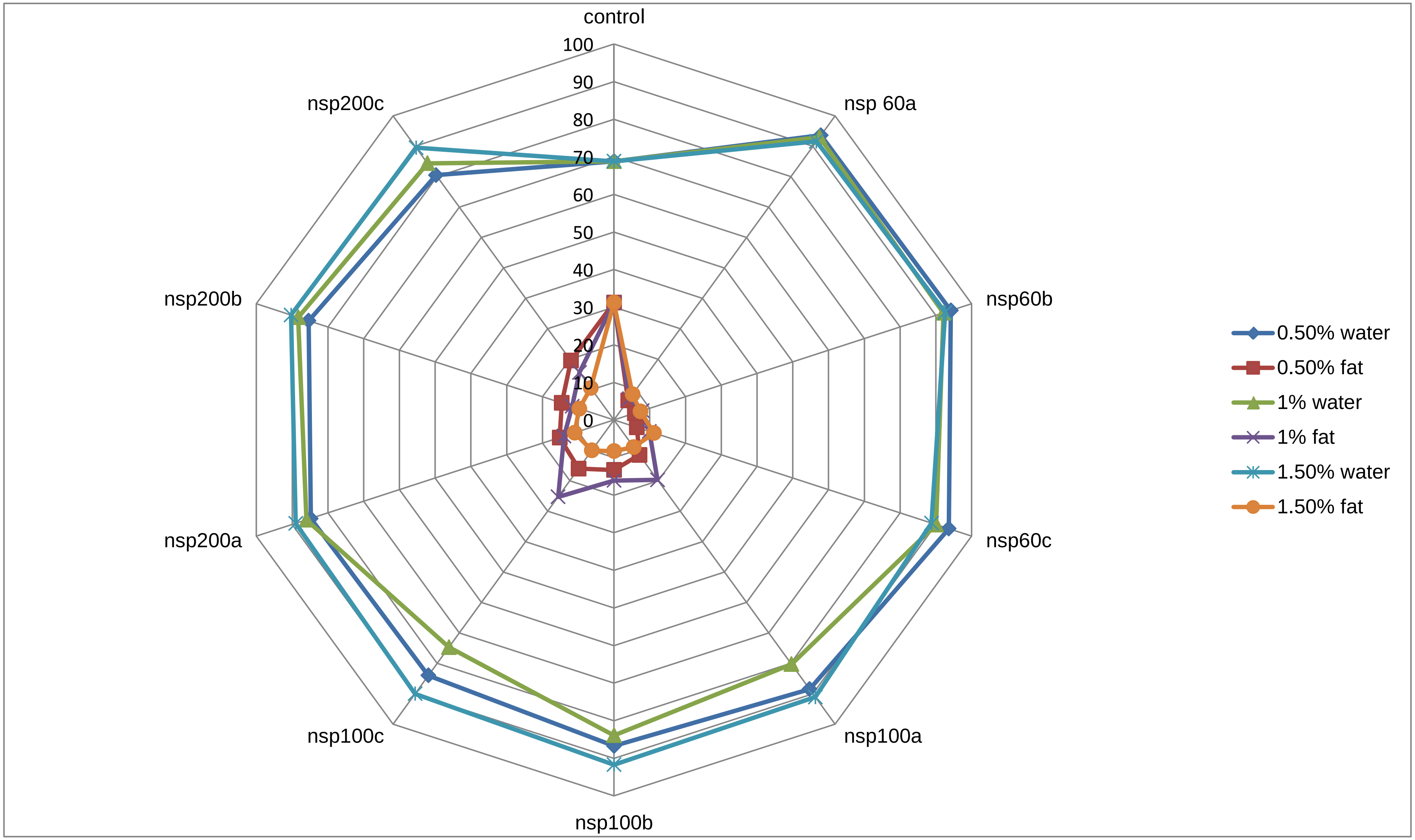

Figure 3.1 The inverse relationship between water and fat in TEF at all fibre levels

Table 3.10 Average fat in TEF for all emulsions at various fibre levels

Sample	Water level	0.5%	1.0%	1.5%
Control		$29.94^{f} \pm 4.09$	$29.94^{f} \pm 4.09$	$29.94^{f} \pm 4.09$
NSP 60 A	Standard	$6.44^{ab} \pm 0.37$	$6.98^{ab} \pm 0.59$	$8.44^{ab} \pm 1.17$
NSP 100 A	Standard	$11.49^{bc} \pm 2.61$	$19.74^{cd} \pm 3.53$	$8.90^{ab} \pm 1.24$
NSP 200 A	Standard	$15.21^{bc} \pm 1.65$	$13.96^{bc} \pm 0.9$	$10.98^{b} \pm 0.71$
NSP 60B	Extra 10g	$5.82^{a} \pm 0.18$	$7.90^{ab} \pm 0.98$	$7.39^{ab} \pm 0.95$
NSP 100B	Extra 10g	$13.34^{bc} \pm 1.12$	$16.15^{cd} \pm 4.80$	$8.33^{ab} \pm 0.76$
NSP 200B	Extra 10g	$14.64^{bc} \pm 3.51$	$11.70^{bc} \pm 1.61$	$9.74^{ab} \pm 0.5$
NSP 60C	Less 10g	$6.38^{ab} \pm 0.36$	$9.91^{ab} \pm 4.03$	$11.25^{bc} \pm 0.42$
NSP 100C	Less 10g	$15.99^{cd} \pm 1.85$	$25.28^{e} \pm 6.06$	$10.04^{ab} \pm 2.23$
NSP 200C	Less 10g	$19.54^{cd} \pm 1.8$	$15.60^{bc} \pm 2.09$	$10.74^{ab} \pm 0.95$

*Values are mean ± standard deviation in which statistical analysis was performed on all data.
$^{a-d}$Means within and between columns with different superscripts differ significantly ($P \leq 0.05$).
sd- standard deviation

The poor water holding could be due to interactions with the fat, protein and the spices in the species sausage emulsion. This is in agreement with Gullion and Champ (2000) and Rosell *et al*. (2009) who stated that the water binding of fibres can be altered depending on the components in a food system. Particle size, porosity, ionic form (ionic strength, types of ions in solution), pH, temperature, and stresses upon fibres also play different roles in water retention. Finely grinding can affect the kinetics of water uptake by altering the surface area; however a different scenario is observed if such a fibre is exposed to other components (Elleuch *et al*., 2011).

2. Water and fat in TEF at 1% fibre level

Meat emulsions containing NSP 60 still had the highest mean percentage water in the TEF with no significant difference ($P< 0.05$) to their 0.5% counterparts for all water levels A, B and C (Table 3.9). The amount of water in TEF decreased for all emulsions containing NSP 100 but not significantly except for the NSP 100C sample, which was lower ($P\leq 0.05$) than the 0.5 % counterpart. This could be credited to better interaction of the fibre with water when the fat is reduced (lower fat amount in emulsion mix at 1% than 0.5%).

All NSP 200 containing emulsions recorded an increase in water in the TEF as compared to the 0.5% emulsions, although the increase was not significant (P> 0.05), (Table 3.9). The amount of fat in the TEF changed (decreased or increased) inversely to the amount of water in the TEF (Fig 3.1) with a significant negative correlation (r= -1.000; P<0.001).

3. Water and fat in TEF at 1.5% fibre level

Emulsions containing NSP 60 fibre at 1.5% showed a decrease in water in the TEF for all water levels, A, B and C as compared to the same emulsions containing 1% fibre, although the change was not significant (P>0.05), (Table 3.10). The emulsions containing NSP 100 fibre at 1.5% however, showed significant increases in amounts of water in the TEF as compared to the 1% counterparts, as did the NSP 200 containing samples. This could be an indication that the fibres have poor interaction with large amounts of water or simply because the emulsion formulations had low fat amounts, hence the bulk part of the TEF is automatically water.

3.5 Conclusions

The results of this study indicate that fat replacement with pineapple dietary fibre and water can be a viable option for the industry to satisfy consumer need for low-fat healthy meat products. If added in proper amounts and levels, PDF can bind a considerable amount of water in beef sausage emulsions with low TEF as compared to the control (no added fibre) species sausage. The fibres NSP 100 and NSP 200 proved to be good water binders in beef sausage emulsions as indicated by their TEF values, which are closely comparable to that of the control emulsions. The water holding ability of NSP 100 was, however, poorer at 1.5%, whilst the other fibres, NSP 60 and NSP 200 showed some improved water holding capabilities at the higher 1.5% level. NSP 60 proved to be the poorest water binder in all emulsions at all fibre levels rendering it the less viable fibre of choice in beef sausage manufacture. A comparison of fibre levels indicated that the 1% fibre level had the lowest TEF although not significantly different from the 1.5% fibre level. From these results, it is concluded that a level 1% for NSP 60, NSP 100 and

NSP 200 fibres substitution seems to be the best option to consider for beef sausage manufacture. It will therefore, be of great value to the meat industry, the health conscious consumers, pineapple farmers and processors to investigate the effects of these three PDF (at 1% level), on the physical, chemical and textural quality parameters of beef sausages.

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CHAPTER 4

ASSESSMENT OF THE EFFECTS OF DIFFERENT PINEAPPLE DIETARY FIBRES ON THE PHYSICAL, CHEMICAL AND TEXTURAL CHARACTERISTICS OF BEEF SPECIES SAUSAGE.

Abstract

The effect of three pineapple dietary fibres (PDF) in species sausage was investigated with regard to physical, chemical and textural attributes. Four beef sausage samples were manufactured, namely the control and three sausages containing 1% of three different PDF (NSP 60, NSP 100, NSP 200) and water (replacing pork back fat). The fibres differed in water binding capacity (WBC) and the water was added in accordance to the specific WBC capacity of the fibre in question. The sausages were analysed for proximate composition where the results indicated that the control differed significantly from the species sausages containing fibre in terms of moisture, protein, total fat, ash and total fibre. The samples containing the three different PDF were mostly similar in terms of proximate attributes though with minor differences. The sausages were analysed for emulsion stability [(based on total expressible fluid (TEF)], cooking loss and purge. The sausage samples containing NSP 200 PDF did not differ from the control in terms of total expressible fluid (TEF) and cooking loss. The samples containing NSP 100 had the lowest percentage cooking loss although not significantly different to the control and sausages containing NSP 200. Samples containing NSP 60 PDF had higher values of TEF as well as cooking loss in comparison to the control. Although all the three fibre containing sausage samples did not differ in terms of purge, they differed from the control which had a much lower purge value. The pH value of the control was higher than the samples containing fibres which also differed from each other. Inclusion of fibre in the species sausage resulted in an increase in lightness, hue and chroma as compared to the control. The control had higher textural values than fibre containing sausages, with the exception of cohesiveness which did not significantly differ in all sausages. Based on these observations the PDF NSP 100 could be concluded to be the

most suitable for use in species sausage emulsions, followed by the NSP 200 and lastly the NSP 60.

4.1 Introduction

Research into new products is continuous in the meat industry due to consumer demands as well as the ferocious competition within the food industry. These researches are mainly focused at producing healthy options to the available meat products; which are frequently accused of causing a variety of pathologies (Jimenez-Colmenero, 2000). Fat, a major component in emulsified meat products, is an important source of energy and essential fatty acids as well as carrier of fat soluble vitamins (Vural *et al*., 2004; Choi *et al*., 2009). Additionally fat plays an important role in stabilisation of meat emulsions, reduction of cooking losses, improving texture, tenderness, juiciness and mouth feel (Kim *et al.,* 2010). Potential health risks associated with consumption of high fat foods have led the food industry to develop new formulations or modify traditional products to make them healthier. Inulin, cereal and fruit fibres and water have been used for such purposes in the meat industry (Fenandez-Lopez *et al*., 2008).

The success of any food product however is dependent on its quality in terms of flavour, texture, stability in storage, nutritional value, colour, palatability, yield and cost of production (Heinz & Hautzinger, 2007; Mapanda, 2010). Low-fat meat products that are not acceptable in terms of palatability or appearance will not sell regardless of the health characteristics attributed to them (Jimenez-Colmenero, 2000). A decrease in intramuscular fat content would decrease meat and meat product attributes especially flavour and juiciness (Chizzolini *et al.*, 1999). Production of low-fat meat products has seen a variety of non-meat ingredients and/or additives being included, usually to offset the undesired effects of formula changes and thus maintaining the product characteristics to compete with non-substituted original products (Keeton, 1994; Giese, 1994).

Most non-meat ingredients and/or additives are classified as: added water, non-meat proteins (soy, surimi, dairy proteins, gluten, albumin, etc.), carbohydrates (gums or hydrocolloids, starches and maltodextrins and cellulose derivatives), or other products such as functional mixtures, vegetable oils and synthetic products (Jimenez- Colmenero, 1996). Heinz and Hautzinger (2007) classify the non-meat ingredients into three categories based on their origin, namely the chemical/synthetic (salts, phosphates and nitrates), plant and animal origins.

Most ingredients are functional, as they have the ability to introduce or improve certain quality characteristics of the food product. Functionality is also attributed to an ingredient’s ability to provide additional physiological and health benefits beyond their basic nutrition (Thomas & Earl, 1994; International Life Sciences Institute, 1999; American Dietetic Association, 2004; Health Canada, 2004; International Food Information Council, 2006). The functional properties of ingredients include their impact on taste, flavour, appearance, colour, texture, water binding, counteracting fat separation and preservation (Heinz & Hautzinger, 2007). The inclusion of functional ingredients in meat products is not limited to providing desirable textural, chemical and sensory properties but also an attempt to change the meat products’ image in these health conscious days (Fernandez-Gines *et al*., 2004). The World Health Organisation (WHO, 2003) concluded that dietary fibre (DF), a common functional ingredient, has a protective effect against weight gain and obesity, cardiovascular disease (CVD), infectious and respiratory diseases (Anon., 2012a).

The incorporation of cereal, fruit and vegetable fibres into meat products is a common trend in the meat industry. These practices should pay attention to the nutritional factors, the safety of the products, technological and/or processibility factors, general consumer appreciation, legal regulations as well as the costs of the products (Jimenez-Colmenero, 2000). The water retention and water holding properties of dietary fibre makes it a suitable meat products’ ingredient in combination with water as it minimises production costs, reduces shrinkage and cooking loss, as well as drip loss during storage without affecting sensory properties (Besbes *et al*., 2008; Biswas *et al*., 2011). Pea, wheat, hazelnut pellicle, cauliflower, oat fibres and cellulose have shown to improve cooking yields and improving texture in various ground meat products (Todd *et al*., 1989; Hughes *et al*., 1997; McDonagh *et al*., 2005; Turhan *et al*., 2005).

Inclusion of fibres is usually associated with textural changes such as increased hardness as reported by Fernandez-Gines *et al*. (2004) when lemon albedo was added into bologna, the juiciness perception decreased as well. Apple, peach and orange fibres however, decreased the hardness in bolognas (Biswas *et al*., 2011), whilst potato starch and pea fibre produced lower hardness and springiness in patties (Trout *et al*., 1992). Depending on the type and quantities of the fibres, colour parameters such as lightness (L), redness (a*) and yellowness (b*) either increase, decrease or remain significantly unchanged in different meat products (Trout *et al*., 1992; Ho *et al*., 1997; Elgiasim & Wesali, 2000; Devatkal *et al*., 2004; Fernandez-Gines *et al*., 2004; Turhan *et al*., 2005; Dolatowski & Karwowska, 2006; Naveena *et al*., 2006; Choi *et al*., 2007).

Addition of carrot in sobrassada, a raw, cured sausage originally from the Balearic Islands, improved sensory and textural properties, positively modified organoleptic properties until a 3% fibre level, at which the properties started to decline (Eim *et al*., 2008). Peach fibre addition in meat balls increased acceptability (Grigelmo-Miguel *et al*., 1999), whilst wheat fibres did not affect overall palatability in beef burgers (Mansour & Khalil, 1997). Peach, apple and orange fibres had a negative correlation with texture of sausage and other meat products (Keeton, 1994; Garcia *et al*., 2007; Fernandez-Lopez *et al*., 2008).

The other common non-meat ingredients include meat extenders, which are usually cheap legume proteins used in combination with more expensive meat protein to produce overall acceptable protein contents at low cost. Such ingredients are very common in developing countries where the majority of the population cannot afford expensive protein of animal origin (Heinz & Hautzinger, 2007). Fillers are low protein plant abstracts such as cereals, roots, tubers and vegetables or starches and flours. These components are added to “fill up” product volumes or add new components that are not usually inherent in meat such as carbohydrates or fibre (Heinz & Hautzinger, 2007).

In an attempt to reduce the fat content in meat products, various procedures have been followed, either on their own or in combination and they are based on the following approaches:

- Selection of suitable meat ingredients in terms of composition and functionality (based on the breed, feeding, age, sex and part from which the raw material is drawn from the animal).
- Use of non-meat ingredients that lend desirable textural characteristics, especially those that enhance water holding ability (for example water, dietary fibres, starches, plant and/or animal proteins, cereal flours and various other proteins have been used).

- Adoption of appropriate manufacturing and/or preparation technologies either to induce certain functional characteristics or vary final product composition (process stages such as pre-blending, physical manipulation and heat treatments), (Jimenez-Colmenero, 1996).

It is essential when investigating new formulations, to assess the product's nutritional composition in comparison to the target composition in terms of the fat, carbohydrate, protein, water, cholesterol content and the fatty acid composition of the final product (Paneras & Bloukas, 1994). Sensory parameters of firmness, elasticity, greasiness, coarseness, juiciness, saltiness, spiciness, colour and overall acceptability are usually assessed as well (Jimenez-Colmenero, 2000). Gas chromatography-odour assessment and gas chromatography-mass spectrometry have been used to assess flavour changes (Azarnia *et al*., 2012). Instrumental texture profile analysis (TPA), tests to determine levels of hardness, chewiness, cohesiveness, springiness and gumminess, which are dependent on the type and form of products are popularly assessed using the Instron texture analyser. The Warner Blatzler shear press and the Kramer shear apparatus are the other less popular instruments used for texture analysis (Bourne, 1978; Biswas *et al*., 2011).

In this study, three different commercial pineapple dietary fibres [(PDF), (NSP 60, NSP 100 and NSP 200)] were incorporated into a low fat beef sausage at 1% level. Water was added in equivalence to the amount of added fibre based on the specific water holding capacity (WHC) of the fibre in question, replacing an equal weight of fat from the formulation. The effects of the fibres on colour, purge and pH changes over time, cooking losses, water binding, textural properties and proximate composition were assessed.

4.2 Materials and methods

4.2.1 Sources of ingredients

Vacuum packed lean beef meat, consisting of 90% lean meat and 10% fat (90/10) (Roelcor Meats specifications), was obtained from a reputable meat distributor, Cape Town) and stored at -20^{o}C until used. Pork back fat was obtained from a supplier in

Stikland, Cape Town and stored at the same temperature. Salt, thyme, coriander and white pepper, used in the manufacture of a laboratory spice mix, and vinegar were all purchased at a local supermarket. The sheep casings were purchased from Crown National, Cape Town. Three commercial pineapple dietary fibres (NSP 60, NSP 100 and NSP 200) of neutral taste and aroma were provided by Summerpride Foods (PTY) Ltd., East London, South Africa. The different properties of the fibres are outlined under the previous section (Section 2.10, Table 2.6).

4.2.2 Manufacture of species sausage

All sausages were manufactured according to the South African guidelines: Government Notice No. R2718 of 1990 (updated) of the Food, Cosmetics and Disinfectants Act of 1972 (Anon., 2012b). Figure 4.1 shows an overview of the steps performed during the sausage manufacture and all quality assessments on the sausage.

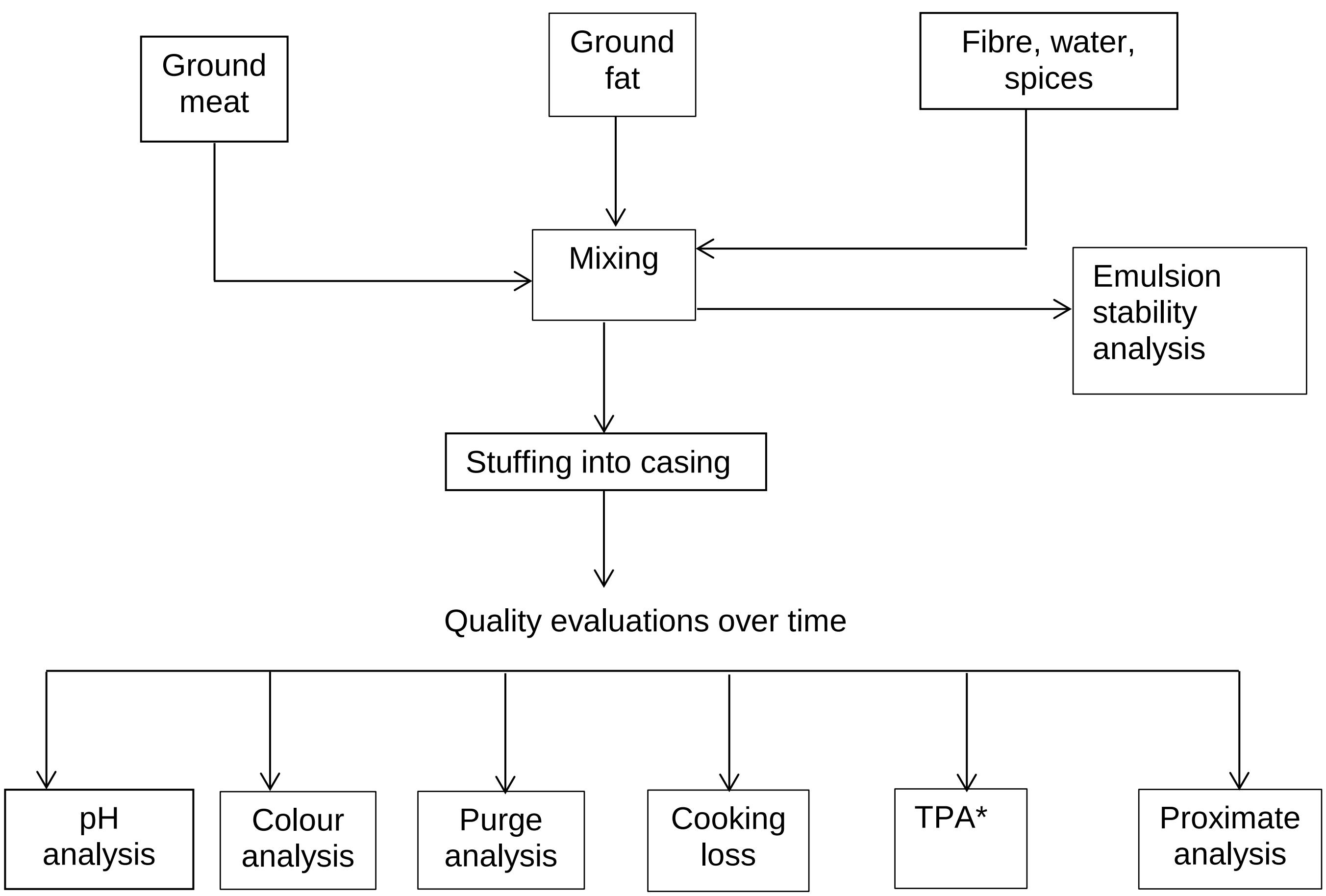

Figure 4.1 A summary of all activities.

*TPA – Texture profile analysis

The adjusted formulations used in the manufacture of the control, the different species sausage batches containing the three different PDF at 1.0% level are shown in Tables 4.1. Note that: for the formulations containing fibre, fat was replaced by an equal weight of the added fibre as well as the water to be bound by that fibre in accordance to Fibiz™ water binding specifications as described under the previous section (Section 2.10, Table 2.6).

Table 4.1 Formulation of species sausage per 500 g batch for all fibres at 1% level

Sample/ingredient	Control (g)	NSP60 (g)	NSP100 (g)	NSP200 (g)
Lean beef	285	285	285	285
Pork back fat	130	85	88	86
Water	60	100	97	99
Vinegar	15	15	15	15
Spices	10	10	10	10
Fibre	0	5	5	5
Total	500	500	500	500
TME*	83	74	74.6	74.2

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

All formulations were manufactured in six replicate batches. The meat and fat were thawed overnight at 4°C and separately minced through a 6 mm dice. The minced meat and fat, vinegar, fibre and spice mix were mixed with gradual addition of crushed ice-water using a hand mixer, ensuring the temperature did not exceed 10°C. Six samples of approximately 25 g each were drawn from each sausage meat emulsion batch for emulsion stability analysis, making a total of 36 samples for the control and all the different fibre containing sausages. The rest of the emulsions were stuffed into 20 mm sheep casings, packaged into punnets containing absorbent paper, covered with cling wrap as normally done in supermarkets, weighed and stored at 4°C for further analysis. For each day of analysis, four samples were drawn from each of the manufactured six batches for each formulation, making a total of 24 samples (6 for each day). Of the four samples drawn, random computer generated numbers were allocated as a means to reduce bias in the order of analysis for days 0, 2, 4 and 7. The pH and colour analysis were performed from day 0 to day 7 on all the samples, whilst purge started at day 2, cooking loss and texture profile analysis (TPA) were performed only on the day 7 samples. The remaining sausages from each batch were vacuum packaged and stored at -60°C for proximate analysis.

4.2.3 Emulsion stability

Emulsion stability was determined by a modified procedure performed by Hughes *et al*. (1997). Six replicate samples of approximately 25 g sausage emulsion from each batch were weighed into 50 ml centrifuge tubes. These tubes were centrifuged at 3000 rpm for 1 minute (Jouan MR1812 model 11174584 centrifuge, Thermo electron Industries, Germany). After centrifugation the tubes were submerged into a water bath at 70°C for 30 minutes. After this the tubes were centrifuged again at 4000 rpm for another 3 minutes. The expressed fluid was transferred into pre-weighed crucibles which were then dried overnight (100°C), cooled in a desiccator and reweighed to determine the amount of water and fat in the total expressible fluid (TEF). The TEF was calculated as follows:

TEF = (weight of centrifuge tube + sample) – (weight of tube + pellet) and

% TEF = (TEF/ sample weight) x 100, and

% Fat in TEF = [(weight of crucible + dried supernatant) - (weight of empty crucible)]/ TEF x 100

% Water in TEF = 100 - % Fat (Hughes *et al*., 1997).

4.2.4 Chemical analysis

Homogenised samples of each of the six replicate batches of the four beef sausage treatments (three containing fibres and the control) were analysed in duplicate for percentages of moisture, total fat, protein, ash and dietary fibre i.e. 12 samples for each formulation.

- The moisture content was analysed by drying 2.5 g sample at 100°C for a period of 24 hours and
- Ashing was done at 500ºC for a period of 6 hours (AOAC, 2005). One gram samples of the control
- Sausages were analysed for protein content using the Kjeldhal method as described in AOAC (1992) methods of analysis and the Government Gazette

(2010). The protein concentration in the sample was determined as Nitrogen x 6.25.

- The total fat content was determined by extracting the fat with a 2:1 mixture of chloroform-methanol (Lee *et al*., 1996).
- Sausages were analysed for crude fibre, neutral detergent fibre (NDF) and acid digestible fibre (ADF) based on the AOAC (2002) methods of analysis using the Fibertec system.

In total 12 samples were chemically analysed for each attribute from each formulation (Control, NSP 60, NSP 100 and NSP 200).

4.2.5 pH changes during storage

Sausage samples were stored at 4°C and pH measured at days 0, 2, 4 and 7. The pH readings were taken from each sample at three centre positions at each time (days) using a calibrated HANNA pH Temperature Meter (HI 99163). At each of the above mentioned times (days), 18 pH readings were taken for each of the sausage formulations (Control, NSP 60, NSP 100 and NSP 200) at each time (day).

4.2.6 Purge analysis during storage

Accurately weighed and packed samples in punnets containing absorbent paper, stored at 4°C, were removed from the trays, dried with an absorbent paper towel and weighed to analyse for purge loss at days 2, 4 and 7. Six purge readings were obtained from each sausage type (Control, NSP 60, NSP 100 and NSP 200) at each time (day) and calculated as follows:

%Purge = (Initial weight of sausage - weight of sausage after storage) x 100.

4.2.7 Colour analysis

Sausage samples were analysed for colour attributes at days 0, 2, 4 and 7. At each of these times, colour measurements were recorded at three randomly selected positions in line with the method described by Honikel (1998) using the colour guide 45º/0º colorimeter (BYK-Gardner GmbH, Ser. no: 220162). The colour measurements was expressed by the coordinates L*, a* and b* of the CIELab colorimeter space (Minolta, 2007). 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. The Hue angle (h_{ab}) (º) and Chroma (C*) were also calculated as follows, using the L*, a* and b* values:

Hue angle (h_{ab}) = $\tan^{-1}$ (b*/a*)

Chroma (C*) = $\sqrt{(a^*)^2 + (b^*)^2}$ (Minolta, 2007).

The Hue angle (h_{ab}) is defined as starting at the positive side of the a* axis of the chromaticity diagram and is expressed in degrees (º), meaning that 0º would indicate red and 90º would indicate yellow. Chroma (C*) is a measure of the difference from a grey of the same lightness (Mackinney & Little, 1962). Chroma (C*) has a value of 0 at the centre of the chromaticity diagram (central grey) and extending outwards according to the distance from the centre, indicating that the colour increases in brightness (Minolta, 2007). In total, 18 colour coordinate readings were recorded for each sausage formulations (Control, NSP 60, NSP 100 and NSP 200) at each time (day).

4.2.8 Cooking loss analysis

Day 7 samples were assessed for cooking loss after being assessed for colour, pH and purge. The sausage samples were accurately weighed, after which they were oven cooked (Defy Multifunction Thermofan, 831) until the sausage centre temperature reached 70^{o}C for 3 minutes. Temperature was monitored using a KIMO TR 151 temperature probe inserted into the sausage. The cooked sausage was then accurately weighed to determine cooking loss as follows:

(Initial weight of sausage - weight of sausage after cooking) x100 %

A total of six samples were assessed for cooking loss for each formulation (Control, NSP 60, NSP 100 and NSP 200).

4.2.9 Texture profile analysis

Five sausage pieces (2.5 cm height x 2 cm diameter) were prepared from each of the cooked sausage samples at day 7. The sausage pieces were analysed for hardness, cohesiveness, gumminess, springiness and chewiness using the Instron Universal Testing Machine (Instron ID 3344K6233, Advanced Lab Solutions, S.A.). A circular plate of 5 cm diameter was attached to a 2000 N load cell and the sample compressed to

50% its original height at cross head speed of 200 mm/min in two cycles as described by Desmond and Troy (2001). A total of 30 samples were analysed for the textural properties for each formulation (Control, NSP 60, NSP 100 and NSP 200).

4.2.10 Statistical analysis

Analysis of variance was performed on all variables accessed using GLM (General Linear Models) Procedure of SAS statistical software version 9.2 (SAS Institute Inc., Cary, NC, USA). Shapiro-Wilk test was performed to test for normality (Shapiro, 1965). Fisher's least significant difference was calculated at the 5% level to compare treatment means. A probability level of 5% was considered significant for all significance tests.

4.3 Results and discussion

The emulsion stability, chemical composition, total meat equivalent, textural properties, and cooking loss of all the species sausage [(Control and the samples containing the three different fibres (NSP 60, NSP 100 and NSP 200)] are summarised in Table 4.2

4.3.1 Total Meat Equivalent (TME) and fat maximum percentage (analysed)

In this study the TME values of the beef sausage were within the recommended specified limit of 60% in accordance to the South African standard [(SANS 885:2011 third edition of the processed meat products, (Communited, uncured no or partially heated products)] as shown in Table 4.3. The fat maximum percentage (analysed) was also within the specified limits of not more than 30% with the control containing the highest fat amount of 28.56% (Anon., 2012b).

Table 4.2 Effects of PDF on physico-chemical characteristics

	Fibre type			
	Control ± sd	NSP 60 ± sd	NSP 100 ± sd	NSP 200 ± sd
Chemical composition				
Moisture (%)	$58.1^{a} \pm 0.80$	$68.1^{c} \pm 2.27$	$60.6^{ab} \pm 3.58$	$62.8^{b} \pm 2.39$
Fat (%)	$28.6^{a} \pm 1.24$	$16.0^{b} \pm 1.16$	$15.2^{b} \pm 0.75$	$15.5^{b} \pm 0.62$
Protein (%)	$16.2^{a} \pm 0.76$	$13.3^{b} \pm 1.27$	$13.9^{b} \pm 1.31$	$12.8^{b} \pm 1.02$
Ash (%)	$2.8^{a} \pm 0.1$	$2.2^{b} \pm 0.11$	$2.0^{c} \pm 0.13$	$2.0^{c} \pm 0.08$
Total fibre (%)	$0.4^{a} \pm 0.03$	$0.6^{bc} \pm 0.04$	$0.6^{b} \pm 0.05$	$0.6^{c} \pm 0.04$
NDF (%)	$2.2^{a} \pm 0.10$	$3.5^{c} \pm 0.15$	$3.7^{b} \pm 0.17$	$3.8^{b} \pm 0.10$
ADF (%)	$0.8^{a} \pm 0.06$	$1.4^{b} \pm 0.06$	$1.4^{b} \pm 0.09$	$1.55^{c} \pm 0.13$
TME (calculated)[α]	85.6	73.0	72.2	72.5
Emulsion stability				
TEF (%)	$19.6^{a} \pm 2.07$	$24.2^{b} \pm 1.06$	$23.1^{b} \pm 2.46$	$20.2^{a} \pm 1.93$
Fat in TEF (%)	$32.9^{a} \pm 9.87$	$13.4^{b} \pm 1.80$	$32.8^{a} \pm 5.57$	$28.7^{a} \pm 5.00$
Water in TEF (%)	$67.2^{a} \pm 9.87$	$86.6^{b} \pm 1.80$	$67.2^{a} \pm 5.57$	$71.3^{a} \pm 5.00$
Cooking loss (%)	$31.0^{a} \pm 4.06$	$37.3^{b} \pm 3.49$	$28.3^{a} \pm 5.21$	$30.0^{a} \pm 4.20$
Textural properties				
Hardness (N)	$11.5^{a} \pm 3.53$	$11.2^{ab} \pm 1.85$	$6.3^{b} \pm 1.35$	$8.6^{bc} \pm 0.73$
Chewiness (N)	$482.5^{a} \pm 80.39$	$317.6^{d} \pm 34.54$	$164.9^{b} \pm 47.41$	$251.1^{c} \pm 29.81$
Cohesiveness (ratio)	$2.8^{a} \pm 0.86$	$2.8^{a} \pm 0.96$	$2.2^{a} \pm 0.12$	$2.9^{a} \pm 0.68$
Gumminess (N)	$55.4^{a} \pm 9.74$	$38.3^{d} \pm 4.34$	$19.9^{b} \pm 5.72$	$30.8^{c} \pm 3.22$
Springiness (mm)	$7.3^{a} \pm 0.49$	$6.9^{c} \pm 0.25$	$6.4^{b} \pm 025$	$6.6^{bc} \pm 0.24$

*Values are mean ± standard deviation in which statistical analysis was performed on all data with the exception of TME which was measured once per treatment.
[α]TME = % Lean meat + % Total fat
[a-d]Means within the same row with different superscripts differ significantly ($P \leq 0.05$)

4.3.2 Chemical composition

The sausages formulated with NSP 60 had significant (P≤0.05) higher moisture content (68.14%) as compared to the samples formulated with NSP 100, NSP 200 and the control (Table 4.3). The control, containing the least amount of added water, had the lowest moisture content value of 58.08%, although this was similar (P>0.05) to the moisture content of the sausage containing NSP 100, which indicates that NSP 100 binds additional water added to the sausage emulsion. Once bound the water becomes part of the fibre matrix. The porous and the hydrophilic nature of the fibre can be the possible means by which it binds water (Figuerola *et al.*, 2005).

The total fat content of the control species sausage, which had the highest added fat in the formulation, was higher (P≤0.05) at 28.56%, as compared to that of the sausages containing fibres NSP 60, NSP 100 and NSP 200. The fat contents between sausages containing fibres NSP 60, NSP 100 and NSP 200 did not differ (P>0.05) from each other with values of 15.95%, 15.17% and 15.47%, respectively; a finding attributed to the low amounts of fat added in the sausage emulsions containing fibre (Table 4.2). Such a trend is in line with Choi *et al*. (2010) who noted an inverse relation between fat content and added water in sausages.

The protein content of the control sausage was higher (P≤0.05) than the rest of the formulations at 16.15%; while the sausages containing the different fibres did not differ (P>0.05) in protein content, ranging from 12.83 to 13.28% (Table 4.2). This could be explained by the availability of meat protein in the added fat in the formulation which was highly reduced in the sausage samples containing the fibres. As expected, the control formulation, without any added fibre, contained lower (P≤0.05) total fibre content than the NSP 60, NSP 100 and NSP 200 formulations. Due to the high amounts of water added in the fibre containing formulations, and a reduced amount of fat, this could have been contributory to the lower (P≤0.05) ash content in the fibre containing sausage formulations as compared to the control (Table 4.3).

4.3.3 Emulsion stability as indicated by TEF, fat and water in TEF

The total expressible fluid (TEF) values of the control (19.6%) was lower (P≤0.05) than the samples with the added NSP 60 and NSP 100 fibres, however similar to the sample with added NSP 200 fibre at 20.2%. Samples containing fibres NSP 60 and NSP 100 had higher ($P \leq 0.05$) TEF values of 24.2% and 23.1%, respectively. For NSP 200, this could be an indication that the fibre managed to merge well and stabilise the emulsion. The chemical structure of the fibre could improve its superiority in stabilising emulsions. The bigger particle size of NSP 200, the high water binding capacity (1 g/7.8 g) and high oil binding capacity (1 g/5 g according to Fibiz™ specifications) could explain the superiority of NSP 200 in stabilising the meat emulsion. The fat content in TEF was lower ($P \leq 0.05$) in the formulation containing NSP 60 at 13.4% as compared to the control and the other two formulations containing NSP 100 and NSP 200; which ranged from 28.7% to 32.9%, respectively. Such a trend could be attributed to the NSP 60 having a superior ability to bind fat in the emulsion as specified by its high oil binding capacity (OBC) of 6.0 according to Fibiz™ specifications.

Although NSP 60 is attributed to be the highest water binder (Fibiz™ specification), it proved to be the weakest in the emulsion as it had the highest ($P \leq 0.05$) water content (86.6%) in the TEF. The control, NSP 100 and NSP 200 containing sausage emulsions did not differ ($P \geq 0.05$) in terms of water in the TEF ranging from 67.2% to 71.3% (Table 4.2). Excessive grinding of the NSP 60 fibre to small fine particles (Section 2.10, Table 2.6; Fibiz™ specifications) could have played a role in interacting with the porous structure and the binding sites of the fibre resulting in it being a poor water binder (Gullion & Champ, 2000; Prakongpan *et al*., 2002; Dhingra, 2012). The effect of a fibre in an emulsion is usually affected by its chemical structure, porosity, particle size, ionic form, pH as well as the types of ions in the system (Elleuch *et al*., 2011).

4.3.4 Cooking loss

Samples containing fibres NSP 100 and NSP 200 had the lowest cooking loss values of 28.3% and 30.0%, respectively (Table 4.2). These values, however, did not differ ($P > 0.05$) from the control (31.0%). However, the sample containing NSP 60 had a higher ($P \leq 0.05$) cooking loss than any other treatments/ or samples. This is a further indication of the weakness of NSP 60 fibre in strengthening the species sausage emulsion. Fibres NSP 100 and NSP 200 reduced the cooking loss (improved cooking yield), although not significant ($P > 0.05$) in comparison to the control. This trend is supported by numerous researchers who have documented an improvement in cooking yield through addition of fibres in meat emulsions. Crehan *et al*. (2000) and Hughes *et* *al*. (1997) reported an improvement in cooking yield in frankfurters with fat replaced with maltodextrin and oat fibre, respectively. Spent brewer's grain fibre extracts were also found to reduce cooking loss in burger patties (Kim *et al*., 2013).

4.3.5 Textural properties

The inclusion of fibre and water into the beef sausage formulations had some significant effects on the textural properties of the sausage. In all cases the control samples had the highest values of hardness, chewiness, gumminess and springiness as shown (Table 4.2). All these values differed ($P \leq 0.05$) from the samples containing fibres except for the hardness in the NSP 60 containing sausage which was similar ($P > 0.05$) to the control. The improvement in textural properties are in line with the findings of Salcedo-Sandoval *et al*. (2013), who noted the same trend with addition of konjac jell (with physio-chemical characteristics similar to dietary fibres) in frankfurters. The decrease in the textural properties of hardness, springiness, chewiness and gumminess can be attributed to the addition of water (Grigelmo-Miguel *et al*., 1999; Crehan *et al*., 2000; Choi *et al*., 2014). Fat replacement with different fibres has been shown to improve textural properties by many researchers (Barbut & Mittal, 1996; Pietrasak *et al*., 2010; Biswas *et al*., 2012). Pineapple fibre and water addition seemed to be a positive way of improving the textural properties of the beef sausages, hence can be positivity in the meat industry. Sensory evaluation can be used to assess the validity of this assumption. The cohesiveness, however, did not differ ($P > 0.05$) in all samples.

4.3.6 Instrumental colour

Colour parameters of lightness, chromacity coordinates [(a* and b* values), (green-red and blue yellow characteristics respectively)], hue and chroma as affected by the different fibres and storage times are outlined in Tables 4.3, 4.4 and. An overall analysis of variance (ANOVA) for all sausage samples indicated that storage time alone and fibre addition alone had significant ($P \leq 0.05$) effects on the colour parameters of lightness, hue and chroma (Table 4.3). Fibre addition in combination with storage time had an effect ($P \leq 0.05$) on the colour parameters of lightness, hue and chroma of the species sausages (Table 4.3). However, fibre in combination with storage time did not have an effect ($P > 0.05$) on these parameters. For the chromacity coordinates (a* and b*) fibre alone did not have an effect (P>0.05) while storage time as well as fibre in combination with storage time had a significant effect.

Table 4.3 P-values after ANOVA on colour, pH and purge with fibre, storage time and fibre/storage time as the main effects

Main effects	Dependent variables						
	L*	a*	b*	Hue	Chroma	pH	Purge
Fibre	<0.001	0.115	0.880	0.001	0.017	<0.000	0.000
Time	0.041	0.000	0.000	<0.000	<0.000	0.580	0.000
Fibre/time	0.918	0.000	0.000	0.071	0.279	0.000	0.352

1. Effects of PDF and storage time on lightness

Collectively, the lightness (L*) of all sausage samples was lowest at day zero but increased with storage time (Table 4.5). The changes in lightness were not significant (P>0.05) from day zero to day four, after which the lightness increased (P≤0.05) at day seven. The increase in lightness could be due to oxidation of the fat in the sausage emulsion in storage resulting in greying and hence a lighter colour (Sebranak *et al*., 2005). Analysis of individual species sausage formulations indicated that the lightness of the sausages was lowest (P≤0.05) for the control (highest fat amount), which did not contain any added fibre and higher for the samples containing fibre (NSP 100 had the highest lightness) as shown in Table 4.4. Sanchez- Zapata (2010) added tiger nut fibre and noted the same trend in pork burgers. This is however, in contrast with observations by Crehan *et al*. (2000) who stated that the highest fat containing samples had highest lightness for frankfurters with maltodextrin.

Generally, lightness, redness and yellowness values of meat products have shown to be affected by the colour of the added dietary fibre sources (Jimenez-Colmenero *et al*., 2003; Eim *et al*., 2008; Saricoban *et al*., 2008). The addition of PDF, which is light in colour as well as water, could attribute to the higher values of lightness in the fibre containing species sausages. The added water and fibre can also affect the colour attributes by interacting with the light scattering properties of a product (Varnam & Sutherland, 1995). The lightness of the sausages containing NSP 60, NSP 100 and NSP 200 however, did not follow the lightness trend of the independent fibres, e.g.,

Table 4.4 Effects of PDF and storage time on colour, pH and purge

	Dependant	Variables					
Sample	L*	a*	b*	Hue	Chroma	pH	Purge
Control	44.23[a] ± 3.68	6.11[a] ± 2.88	11.38[a] ± 3.09	60.55[a] ± 10.24	13.30[a] ± 2.22	5.04[a] ± 0.11	2.08[a] ± 0.69
NSP 60	46.87[b] ± 2.58	5.15[b] ± 2.61	13.09[b] ± 2.64	68.19[b] ± 8.07	14.18[b] ± 1.90	4.99[ab] ± 0.07	5.35[b] ± 1.08
NSP 100	51.71[c] ± 2.56	5.29[b] ± 3.53	12.87[b] ± 2.94	67.45[b] ± 9.96	14.39[b] ± 2.26	4.97[b] ± 0.10	5.66[b] ± 0.89
NSP 200	48.69[b] ± 3.15	5.87[b] ± 2.82	12.98[b] ± 2.03	65.83[b] ± 8.70	14.51[b] ± 1.92	4.86[c] ± 0.12	5.34[b] ± 1.39

*Values are mean ± standard deviation in which statistical analysis was performed on all data.
Means for the control, NSP 60, NSP 100 and NSP 200 were average values over a seven day storage period
[a-d]Means within the same column with different superscripts differ significantly (P≤0.05)

Table 4.5 Effects of storage time on colour, pH and purge for all sausages

	Dependant	Variables					
Time (days)	L*	a*	b*	Hue	Chroma	pH	Purge
0	47.57[a] ± 4.02	8.66[a] ± 2.57	13.85[a] ± 2.19	57.88 [a] ± 6.34	16.55[a] ± 1.88	4.97[a] ± 0.06	
2	47.13[a] ± 4.58	6.05[b] ± 2.61	12.34[b] ± 3.37	62.01[b] ± 9.78	14.06[b] ± 1.03	4.99[a] ± 0.16	3.93[a] ± 1.63
4	47.66[a] ± 4.35	4.49[c] ± 1.66	12.23[b] ± 2.99	69.48[c] ± 5.32	13.25[c] ± 1.68	4.96[a] ± 0.12	4.52[b] ± 1.76
7	49.14[b] ± 3.03	3.22[d] ± 1.84	11.91[b] ± 1.97	74.16[d] ± 6.76	12.52[c] ± 1.07	4.96[a] ± 0.12	5.36[c] ± 1.78

*Values are mean ± standard deviation in which statistical analysis was performed on all data.
Means are for all the sausages combined at different days of storage
. [a-d]Means within the same column with different superscripts differ significantly (P≤0.05)

NSP 60 fibre, which resembles the lightest in accordance to Fibiz™ specifications (Table 4.1), resulted in sausages with the lowest values of lightness. A possible interaction with the other components in the sausage emulsion can be the reason for this.

Sausage formulations in relation to storage time indicated that the sample containing NSP 100 had the highest lightness from day 0 until day 7 whilst the control had the lowest lightness values over the same period (Figure 4.2). The fact that the sausages containing NSP 100 fibre were the lightest during the entire storage period is in contrast with the Fibiz™ specifications in which the NSP 100 fibre has the lowest lightness. The interruption of the fibre components with the components of the emulsion could be reasons for such a trend in lightness (Rosell *et al*., 2009).

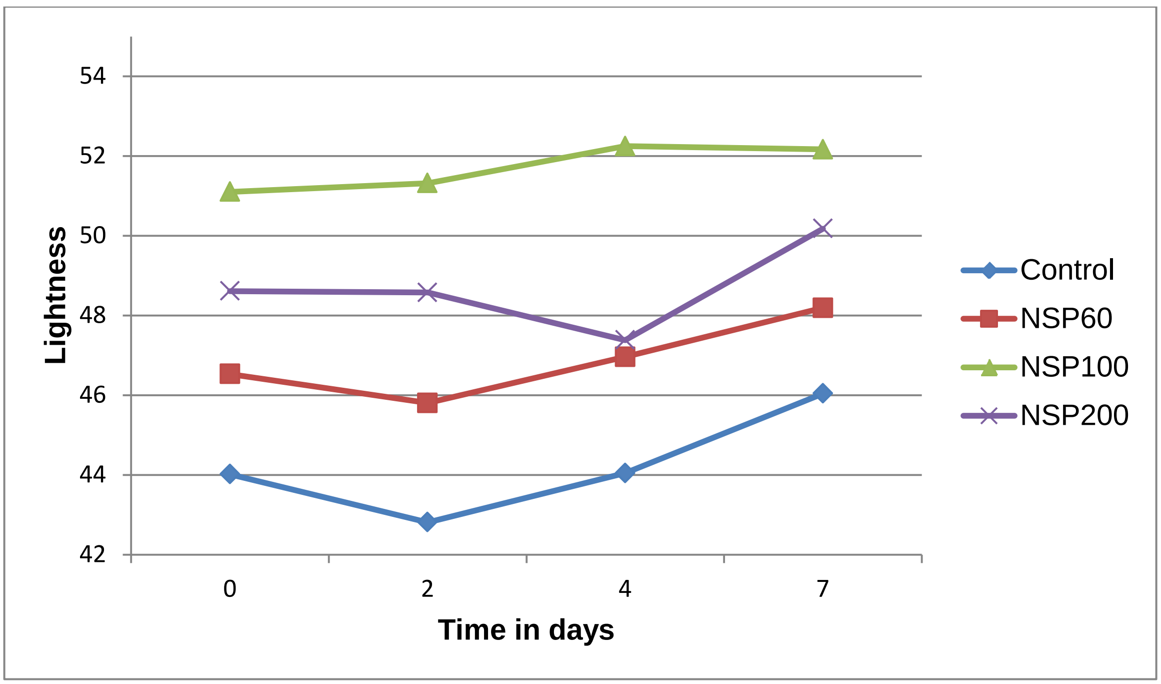

Figure 4.2 Average lightness (L* values) during storage.

2. Chroma changes per sample during storage

Overall chroma analysis for all the sausages decreased with storage time as shown in Table 4.5. This decrease in vividness of sausages could be caused by, the reduction in redness due to myoglobin oxidation to metmyoglobin resulting in the sausage colour becoming more grey (MacDougall, 2002). Mincing, exposure to light, bacterial growth and lipid oxidation are known to destroy the metmyoglobin reductase system, hence increasing the rate of discolouration (Varmam & Sutherland, 1995). There was a decrease (P≤0.05) in chroma from between days 0, 2 and 4 from 16.55 to 13.25. The decrease in chroma from day 4 to day 7's 12.52 was not significant (P>0.05). However, amongst the sausage formulations themselves, (Control, NSP 60, NSP 100 and NSP 200), the control had the lowest (P≤0.05) chroma of 13.30.

The fibre containing samples had higher chroma values (14.18-14.51) although not different (P>0.05) from each other. The high fat amount in the control could be interacting with the vividness of the species sausage colour. The differences in the light scattering properties of the fat and fibres in the sausage emulsions could be the cause of the different colour parameters between the control and the fibre containing species sausages (Varnam & Sutherland, 1995). During the 7 day storage period, the control had the lowest chroma, NSP 100 had the highest chroma at day 0 which decreased with time and became constant between day 4 and day 7 whilst NSP 60 and NSP 200 almost maintained as steady decrease in their chroma values until day 7 (Figure 4.3).

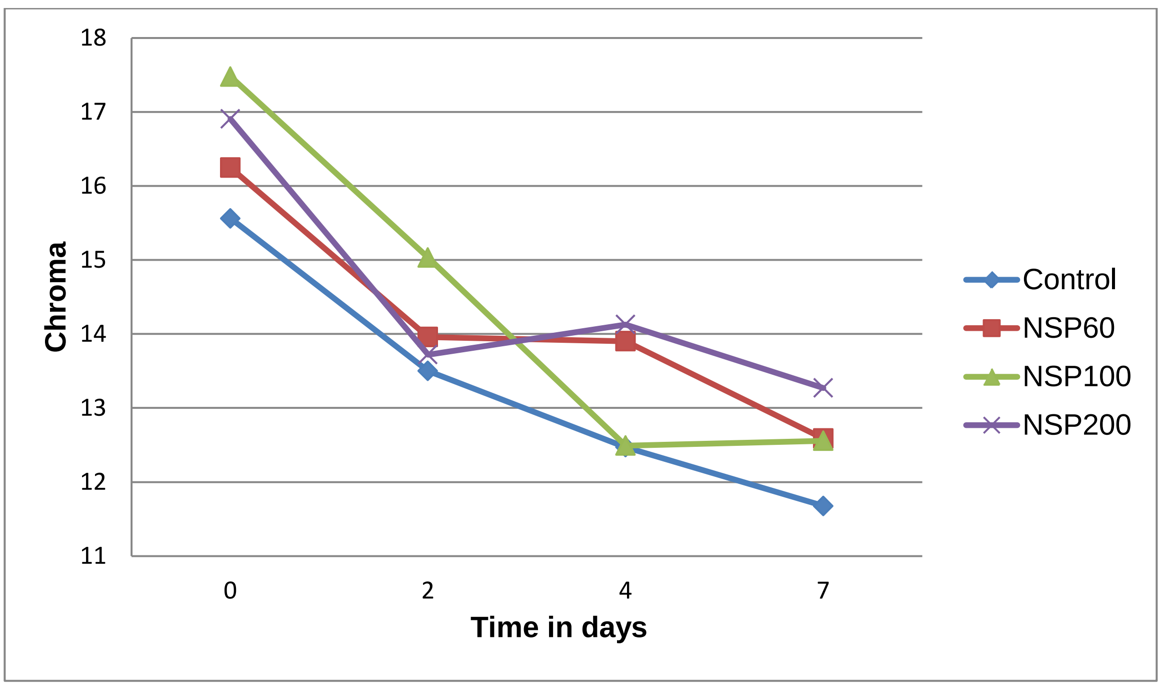

Figure 4.3 Average chroma changes during storage.

Formation of metmyoglobin in storage as well as fat oxidation in the species sausage could be the cause for the reduction in chroma for all the sausage samples (Varmam & Sutherland, 1995; MacDougall, 2002; Lawrie & Ledward, 2006).

3. Chromacity coordinates a (green-red) and b* (blue-yellow) changes*

An overall analysis of the green-red chromacity coordinate (a*) for all species sausages showed a reduction in redness from 8.66 at day zero to 3.22 at day seven (Table 4.5). These changes were significant (P≤0.05) between all days 0, 2, 4 and 7. The fading of the red colour can be attributed to the oxidation of the oxymyoglobin (bright-red) to the metmyoglobin form which is brownish-green in colour as well as denaturation of the globin moiety during storage (Jakobsen & Beterlsen, 2002; Lawrie & Ledward, 2006). Oxidation of the meat oxymyoglobin and denaturing of the globin protein structure can be triggered by high amounts of oxygen, presence of free radicals from lipid oxidation, low pH, heat, salt and exposure to light in storage (Lawrie & Ledward, 2006).

A comparison of the different species sausage samples (Control, NSP 60, NSP 100 and NSP 200) over the entire storage period indicated that addition of fibre caused a reduction in the redness. The control had a significant high (P≤0.05) value of 6.11 while fibre containing samples (NSP 60, NSP 100 and NSP 200) had significantly lower values ranging from 5.15 to 5.87 (not significantly different from each other, P>0.05), (Table 4.4). The addition of whiter fibre and colourless water can possibly account for this trend. Moreover, inclusion of fibre into the sausage emulsion might have an effect on the light scattering properties hence resulting in totally different colour parameters as compared to the control. An analysis of individual sausage formulations (Control, NSP 60, NSP 100 and NSP 200) through the different days of storage showed a similar trend (among samples) of a reduction in redness from day zero to day seven, from around 8.00 to around 2.55 as indicated in Figure 4.4. This can still be attributed to the shift towards the brownish-green of metmyoglobin during storage (Jakobsen & Beterlsen, 2002; Lawrie & Ledward, 2006).

An overall analysis of the blue-yellow chromacity coordinate (b*) for all species sausages showed a reduction in yellowness from 13.85 at day zero to 11.91 at day seven (Table 4.5). The changes were significant (P≤0.05) between day 0 and the rest of the days (2, 4 and 7); although the latter were not different (P>0.05). A comparison of the different species sausage samples (Control, NSP 60, NSP 100 and NSP 200) over the entire storage period indicated that addition of fibre caused an increase in the yellowness. The control had a lower (P≤0.05) b* value of 11.38 while fibre containing samples (NSP 60, NSP 100 and NSP 200) had higher (P≤0.05) values ranging from 12.87 to 13.09 (not significantly different amongst each other, P>0.05), (Table 4.4).

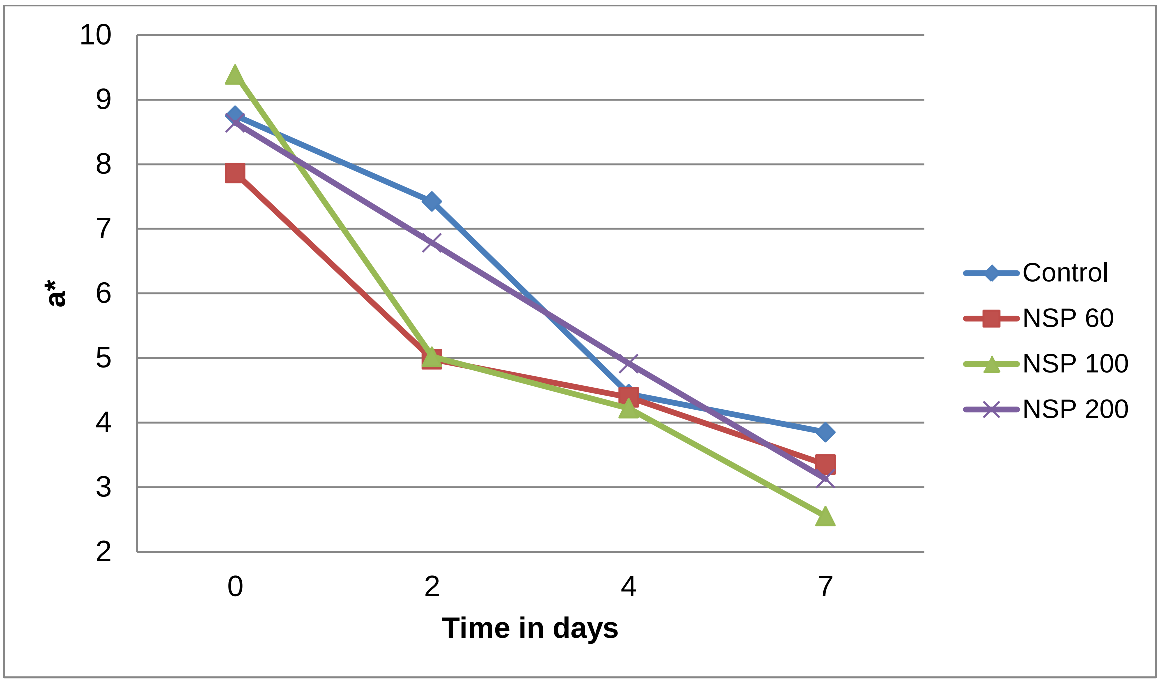

Figure 4.4 Average a* values during storage.

The addition of fibre resulted in the decrease in loss in a* and increase in b*, which is interpreted as an increase in hue (h*) angle towards the yellow, with an overall loss in chroma (C*), which is an indication of the colour becoming more grey (MacDougall, 2002). The whiter/yellower fibre added to the meat emulsions could possibly explain such an increase between fibre containing samples and the control.

An analysis of individual samples (Control, NSP 60, NSP 100 and NSP 200) during the different days of storage showed a mixed trend amongst all samples (different increases/decreases). However, although with different changes amongst days, the b* value at day 0 was the highest for all samples (Figure 4.5). This is an indication of a reduction in yellowness over time for all samples.

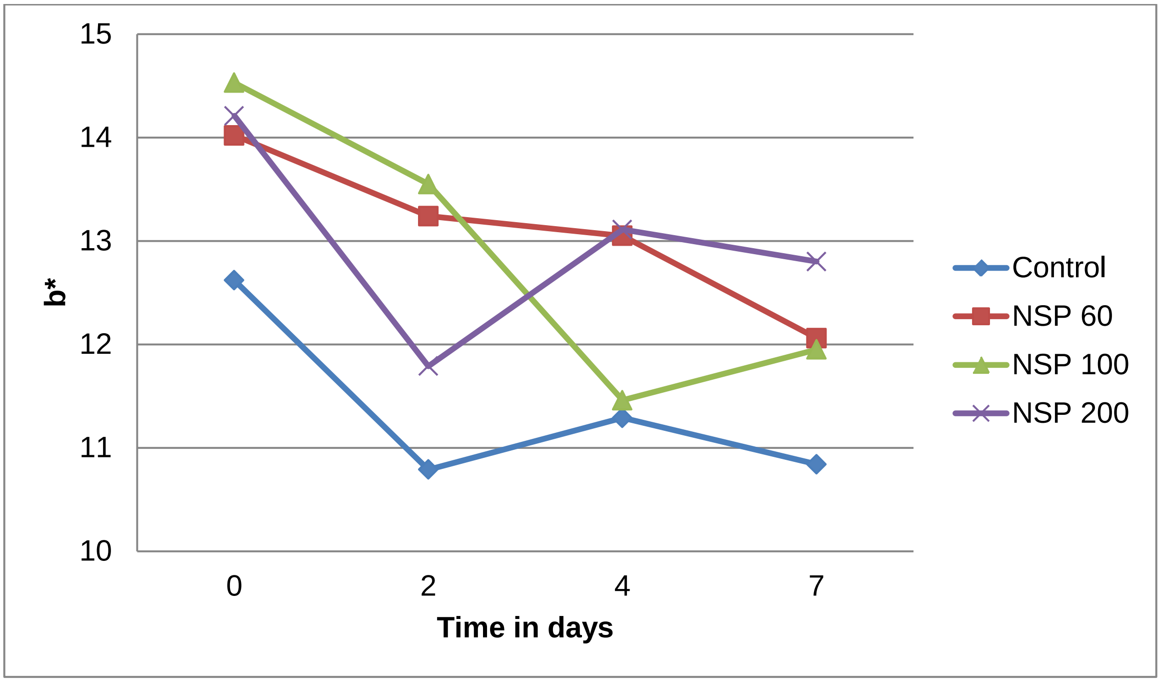

Figure 4.5 Average b* values during storage.

4. Hue changes

An overall assessment of all the sausage samples over time showed a general increase in hue values from day 0 to day 7; from 57.88 to 74.16 (Table 4.4). A comparison of the sausage formulations alone indicated that the control had a significant lower hue value, while the fibre containing samples (NSP 60, NSP 100 and NSP 200) had higher hue values although not significantly different from each other (Table 4.4). The hue values of all samples, the control, NSP 60, NSP 100 and NSP 200 samples, increased over storage time (Figure 4.6).

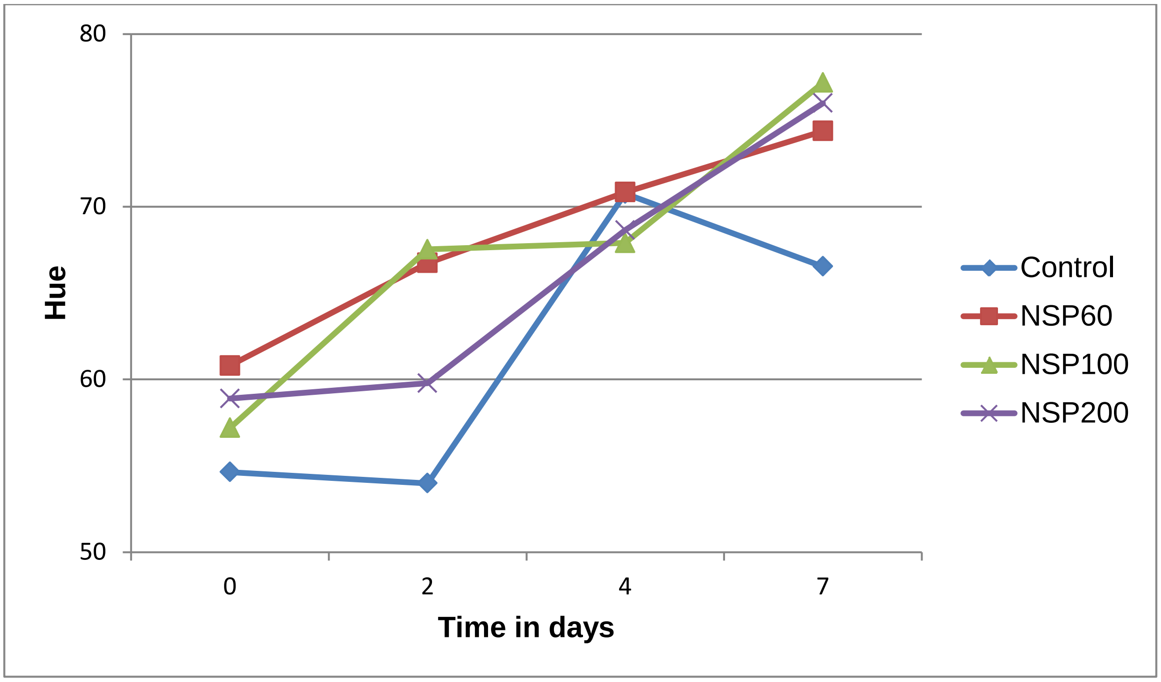

Figure 4.6 Average hue changes during storage.

4.3.7 pH changes

Analysis of variance results indicated an overall significant effect of fibre on pH, as did fibre in combination with time. However, time during storage did not have a significant effect on pH (Table 4.3). The average overall pH of all sausages at day 0 was 4.97 and increased, although not significantly to 4.99 at day 2. There was a decrease in pH to 4.96 at day 4, which was maintained until day 7 (Table 4.5). The pH differences were, however, not significant (P>0.05). The pH drop can be attributed to an increase in the activities of lactic acid bacteria, which probably increase in population over time (Fernandez-Lopez *et al*., 2008).

For the different samples (control, NSP 60, NSP 100 and NSP 200), the control sample had the highest overall pH followed by NSP 60 which was not significantly different to the control (Table 4.4). The sample containing NSP 200 recorded the lowest (P≤0.05) pH of 4.86 which differed from the rest of the samples. The low pH values for all the fibre containing samples (NSP 60, NSP 100 and NSP 200) could be influenced by the low pH values of PDF which ranges between 4.37 and 4.53 (Section 2.10, Table 2.6). The same observations were noted by Jeong and Park (2006) who reported a decrease in the pH value of loaf bread due to the addition of makgeolli powder, the fibre rich waste component obtained from rice-wheat traditional Korean wine. The authors speculated the effects to be due to organic acids, saccharides and lactic acid bacteria. Saricoban *et al*. (2008) also noted a decrease in pH for meat emulsion systems with added lemon albedo fibre.

However, based on Fibiz™ specifications, NSP 200 containing sausages are expected to have the highest pH value, as the fibre alone has a high pH value of 4.53 compared to the pH values of 4.45 and 4.37 for NSP 60 and NSP 100, respectively. It is the overall interaction of the fibre with the other components in the emulsion that determines the overall physico-chemical properties of the products. Lee *et al*. (2008) and Choi *et al*. (2010) stated that the addition of fibre, increases, has no effect, or reduces pH values of meat products, depending on the type of fibre. Thus, based on these results, NSP 60 had no significant effect on sausage initial pH; NSP 100 containing sausage had a significantly lower initial pH compared to the control but no different to the NSP 60 sausage. NSP 200 fibre caused a significant decrease in initial pH (4.86), when compared to the control and all the other fibre containing sausages.

The pH changes for the individual samples over a 7 day storage period are shown in Figure 4.7. The control sample had the highest average pH for the whole period from day 0 to day 7. All fibre containing sausages had significantly lower pH values at day 0; comparing to the control, however, at day 7, only NSP 200 containing sausages had significantly lower pH. The control, NSP 60 and NSP 100 samples had a similar trend of increasing pH from day 0 to day 2 which then started declining until day 7. Further storage would result in a further pH decline as this would be attributed to lactic acid bacteria (LAB) activity (Fernandez-Lopez *et al*., 2008). NSP 200 samples, however, showed an immediate pH decline at day 2, an increase at day 4 and finally a decline at day 7. This trend, however, is difficult to explain.

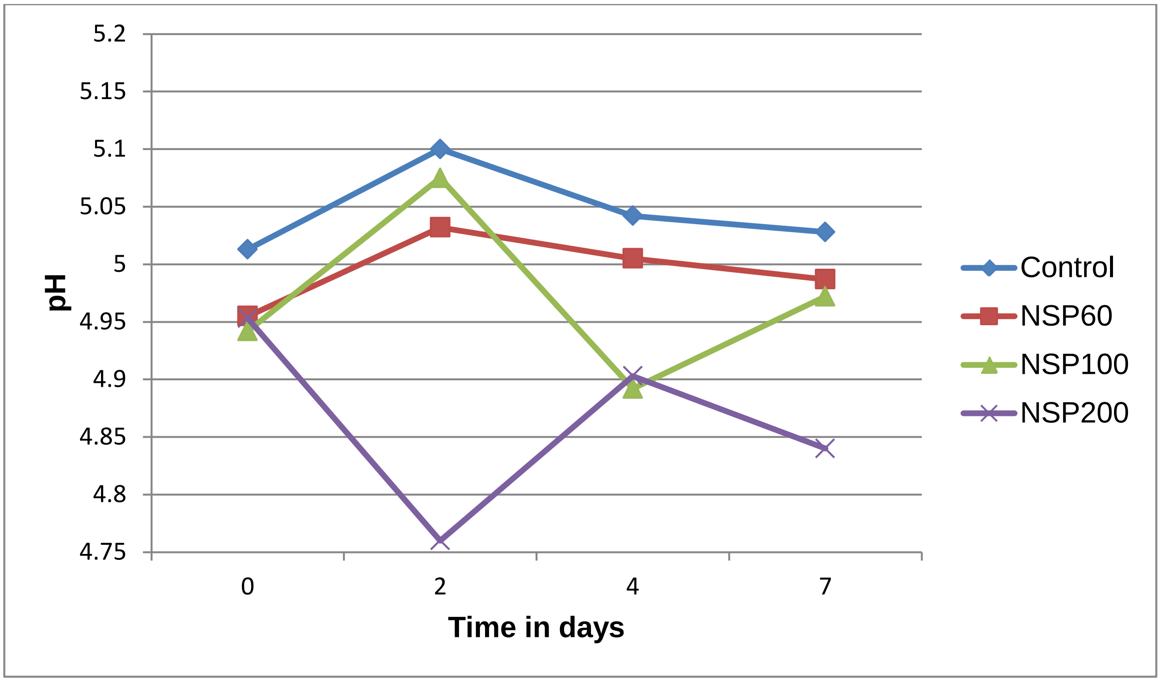

Figure 4.7 pH changes during storage.

4.3.8 Purge changes

Analysis of variance indicated that the addition of fibre alone and storage time alone had effects (P≤0.05) on purge in the beef sausages. Fibre addition in combination with storage time did not have any significant effect on the sausage purge (Table 4.3). The purge values within all samples over the 7 day period are shown in Figure 4.8. The purge values of all the sausages increased (P≤0.05) from 3.93% at day 2, to 4.52% at day 4, and then 5.36% at day 7 (Table 4.5). This is an expected trend as most fresh sausage products lose fluid through drip during storage (Besbes *et al*., 2008; Biswas *et al*., 2012).

A comparison of the different fibre samples indicated that the control had the lowest (P≤0.05) purge (2.08%) when compared to the fibre and water containing samples, (NSP 60, NSP 100 and NSP 200) which had high purge ranging between 5.35% and 5.66%. These purge values did not differ (P>0.05) among one another (Table 4.4). The low purge in the control was expected since the control contained the least amount of water per formulation as compared to the fibre containing samples (Table 4.1). Fat removal and addition of water alters the emulsion moisture content, dilutes the ionic strength, and disturbs the emulsion microstructure and meat matrix functionality thereby causing the failure of the meat matrix to entrap water (Shand, 1999; 2000). However, the addition of fibre should counter-act most of these changes.

Purge values for individual beef species sausage samples over time indicated the control had the lowest purge loss over the whole period from day 2 to day 7 when compared to the fibre containing samples (Figure 4.8). The percentage purge for the control was 1.64% at day 2 and increased to 2.65% at day 7. For the samples NSP 60, NSP 100 and NSP 200 the purge loss ranged from 4.46% at day 2 and increased to 6.56 at day 7. For all the samples, however, (Control, NSP 60, NSP 100 and NSP 200) the purge increased from day 2 to day 7.

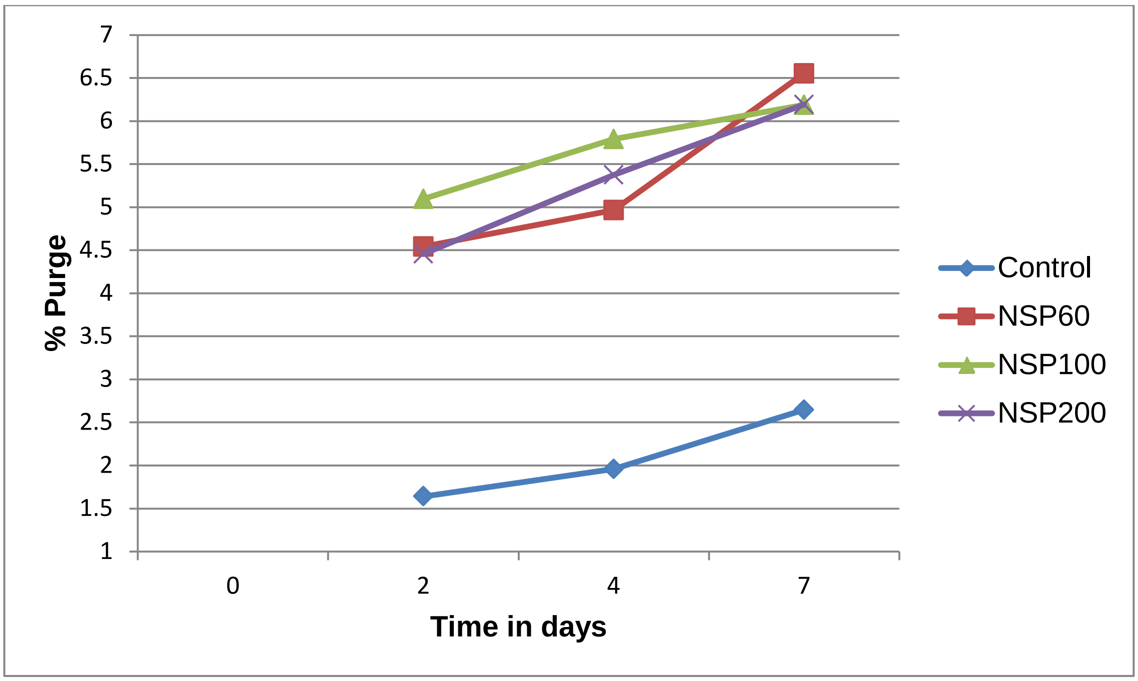

Figure 4.8 Purge changes during storage.

4.4 Conclusions

Technologically, it is possible to replace fat using pineapple dietary fibre and water in order to produce low-fat healthier species sausages. The resultant sausages are supposed to be completely comparable in quality attributes to the species sausage on the market if the difference is only due to the addition of fibre and water. The chemical, physical and textural quality parameters of the PDF and water containing species sausage does not make them of any less or poor quality as compared to the basic species sausage (control). In this study the storage capability, in terms of pH, colour and purge, of the PDF containing species sausage was similar to the control sausage which did not contain any additional water or PDF. Addition of water and fibre can, however, increase purge values in sausages in storage, which is a negative in terms of sausage quality and storage stability. The sausages containing NSP 200 performed quite well and close to the control in terms of emulsion stability based on TEF, purge and cooking loss. The PDF, NSP 100 can be of more economic value in low fat meat products followed by NSP 200 and lastly NSP 60. The pH, colour and textural properties of all fibre containing sausages, although differing slightly, were in the same range and it is debatable whether a consumer would notice the differences. However, further research is required to assess how the PDF and water containing sausage will be accepted by consumers in comparison to the other sausages in the market.

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CHAPTER 5

THE ECONOMIC IMPLICATIONS OF REPLACING PORK BACK FAT WITH PINEAPPLE DIETARY FIBRE AND WATER IN BEEF SAUSAGE.

Abstract

This study investigated the effects of incorporation of three pineapple dietary fibres (PDFs) on the formulation costs of beef species sausage. Four sausage formulations were manufactured, namely the control (no fibre), three formulations containing the three PDF (NSP 60, NSP 100 and NSP 200) added at 1% level. Based on the water holding capacity (WHC) of each added fibre, an equivalent amount of water was added into the fibre containing sausage formulations. The total amount (weight) of added fibre and water replaced an equal amount of pork back fat in the species sausage formulations. The total cost per kg of each species sausage formulation was calculated based on the prices of the added ingredients. The results indicated that the substitution of pork back fat with PDF and water in species sausages reduced formulation costs as compared to the control which had the highest cost per kg. The formulation containing NSP 60 fibre had the lowest formulation cost, followed by NSP 200 and lastly NSP 100.

5.1 Introduction

Consumers regard processed meat products as disease causing and cancer promoting leading to meat processors manipulating the fatty acid composition, encouraging proper portion control to decrease fat consumption and reduce calorific intake (Jimenez-Colemenero, 2000; Ovesen, 2004a, 2004b; Valsta *et al*., 2005). The production of low-fat meat products is based on two principles: 1) the use of leaner raw materials (which raises the cost) and, 2) the reduction of fat and calorie contents by adding water and other cheaper ingredients that contribute to few or no calories (cost reduction), (Jimenez-Colmenero, 1996). Addition of unsaturated fatty acids, such as stable oleic acid, omega-3-fatty acids from fish oils, dietary fibres from plants, minerals, antioxidant vitamins, bioactive peptides and other health improving elements have been investigated or used to improve the nutritional viability and healthiness (functionality) of meat products (Whitney & Rolfes, 2002; Besbes *et al*., 2008; McClements & Decker, 2008; Moon *et al*., 2008; Choi *et al*., 2009; Decker & Park, 2010). Attention by manufacturers is growing on the role food components play in preventing diseases by modulating physiological systems through anti-carcinogenicity, anti-mutagenicity, anti-oxidative and anti-aging activities (Dentali, 2002; Pszczola *et al*., 2002; Arihara, 2006).

Such functional food products must be health promoting while also tasting good, convenient and reasonably priced for them to be regularly purchased by consumers (Decker & Park, 2010). Healthiness of a product may enhance the perceived value of food, but it is useless if the sensory quality fails to attract consumers. Improving the food supply must be done without dramatically altering consumer needs such as food quality, convenience and costs (Decker & Park, 2010). Various studies have indicated that fibre fortification into meat products at nutritionally significant levels without compromising the sensory acceptance is achievable (Besbes *et al*., 2008; Choi *et al*., 2009; Salazar *et al*., 2009; Yilmaz & Gecgel, 2009). Dietetic fibres are not only used as potential fat replacers but also for their possible health effects (Eastwood, 1992; Hughes *et al*., 1997; Grigelmo-Miguel, *et al*., 1999; Desmond & Troy, 2004).

Food and meat products quality is judged based on the intrinsic and extrinsic cues; where the intrinsic cues relate to the physical attributes of the product, such as tenderness and colour, whilst the extrinsic cues include origin, price, product presentation and brand (Becker, 2000). Consumers make purchasing decisions based on these and some other attributes although not all are influential at point of purchase (Troy & Kerry, 2010). Issues of safety, price and convenience and some non-consumer environmental cues such as health, family or educational aspects, general economic situation, climate and legislation should also be considered as they affect consumer purchase decisions (Jimenez-Colmenero, *et al.*, 2001).

It has been noted that the developing world consumes on average one-third of the meat and meat products per capita compared to the rich developed world (Delgado, 2003). Poverty in the developing world could be the major contributor to such under-consumption of meat and meat products, a vital component in the human diet (Valsta *et al*., 2005; Heinz & Hautzinger, 2007). Consumers in industrialised countries, where socio-economic conditions are favourable, focus mainly on low fat, low salt and low cholesterol products, which are perceived as “healthier” (Jimenez-Colmenero, 1996). Consumers in the rapid economically growing developing countries are, however, not being left out in this trend (Jimenez-Colmenero, 2000). With the global population growing rapidly, food product development is needed as a means to provide sufficient, affordable food of desired quality as well as increasing sustainability of food supply systems (Linnemann *et al*., 2006).

South Africa, although considered an upper middle class country with vast wealth, the majority of its households are either of outright poverty or of continuous vulnerability to becoming poor (May, 2000). South African consumers are very price sensitive regarding purchases of food products, with meat and meat products included. Taljaard *et al*. (2006) states that South African meat demand is influenced by five factors, namely disposable income, own price of meat products, meat price related to other products, changes in size and structure of the population and changes in consumers’ taste and preferences. The first three factors are economic factors although non-economic factors are becoming more influential as compared to the past (Taljaard *et al*., 2006).

Surveys conducted by Statistics South Africa (SSA) between 2006 and 2011 established that 42.2% of South African households lived below the lower bound poverty line (LBPL), with most affected being the black households and females in general (Armstrong *et al*., 2009). Although there had been improvements, 32.3% of the South African population still survived under the same circumstances in 2011 (SSA, 2014). Considering the contribution of meat and meat products in human diets, and the economic status of individuals, especially in poor countries or communities, the formulation of low cost meat products can contribute substantially towards reducing malnutrition and improving food security (Whitney & Rolfes, 1999). Due to the high levels of poverty and high prices of meat and meat products, it is of importance that alternative measures be explored to lower the costs of these commodities so as to combat malnutrition and improve the consumption of meat products. Researchers and manufacturers are advocating the use of non-meat ingredients such as extenders, binders or fillers in emulsion type meat products (Heinz & Hautzinger, 2007). The goal of the inclusion of non-meat proteins in emulsified meat products is to provide for more affordable, high protein quality products (Yetim *et al*., 2001).

In this study, three commercial pineapple dietary fibres (PDF) were used in combination with water to replace fat in a species sausage formulation as a means to improve the healthiness (not measured) as well as reducing the cost of the final product. The fibres, provided by Fibiz™, were extracted from flesh and cores of pineapples (pineapple processing waste) using a special water dialysis process, drying and grinding. The fibres differed in terms of water and oil holding capacities, colour, particle size and pH as indicated under the previous section (Section 2.10; Table 2.6).The three fibres (1% level) and water were incorporated in species sausage formulation, replacing pork back fat in turn. Finally, sausage production costs per kilo sausage (based on the added ingredients) was determined and compared to the control sausage formulation.

5.2 Materials and methods

5.2.1 Source of ingredients

Vacuum packed lean beef meat consisting of 90% lean meat and 10% fat (Roelcor Meats specifications) was obtained from a reputable meat distributor in Cape Town and stored at -20°C until used. Pork back fat was obtained from a supplier in Stikland, Cape Town and stored at the same temperature. Salt, thyme, coriander and white pepper, used in the manufacture of a laboratory spice mix, and vinegar were all purchased at a local retail store. Three commercial pineapple dietary fibres (NSP 60, NSP 100 and NSP 200) of neutral taste and aroma were provided by Summerpride Foods (PTY) Ltd., East London, South Africa. The specific parameters of the fibres are outlined under the previous section (Section 2.10; Table 2.6).

5.2.2 Manufacture of species sausage

All sausages were manufactured according to the South African guidelines: Government Notice No. R2718 of 1990 (updated) of the Food, Cosmetics and Disinfectants Act of 1972 (Anon., 2012). Figure 5.1 shows an overview of the steps during sausage manufacture. The adjusted formulations used in the manufacture of the species sausage batches with the three different pineapple dietary fibres at 1.0% level and the control are shown in Table 5.1. Note that: for the formulations containing fibre, fat was replaced by an equal weight of the added fibre as well as the water to be bound by that fibre in accordance to Fibiz™ water binding specifications (Section 2.10; Table 2.6).

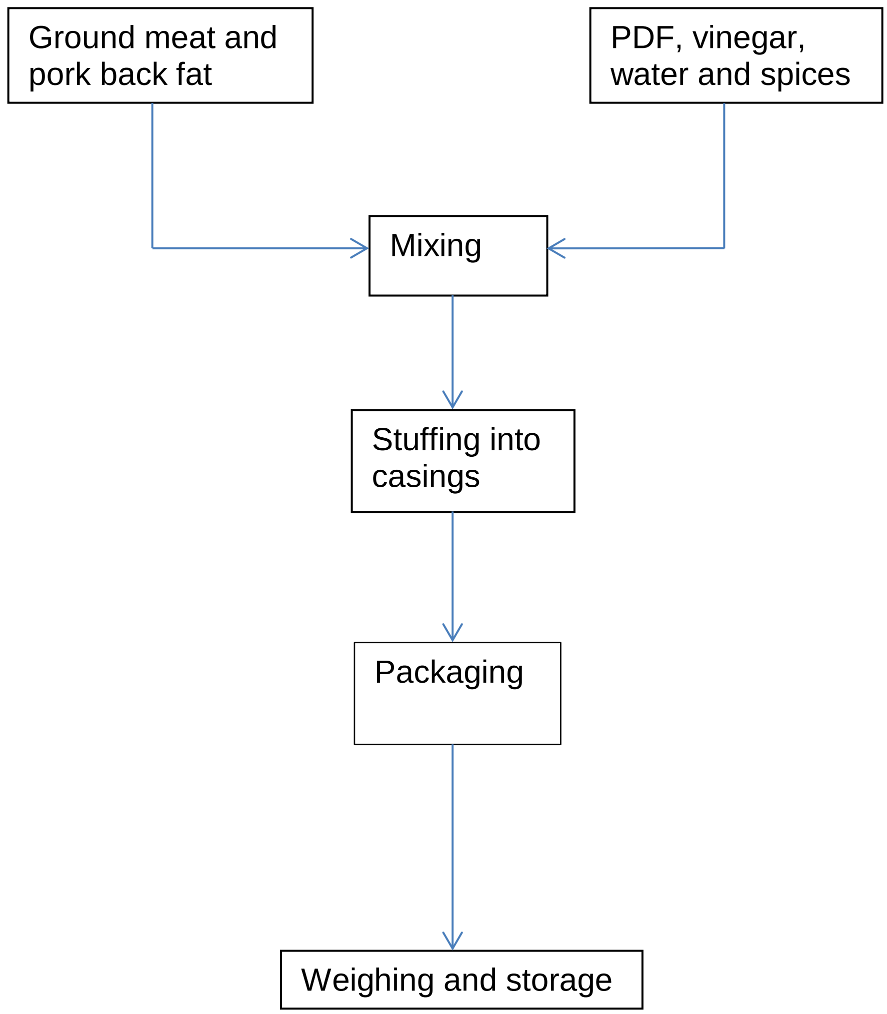

Figure 5.1 Summary of sausage manufacture.

The meat and fat were thawed overnight at 4°C and separately minced through a 6 mm die. The minced meat and fat, vinegar, fibre and spice mix were mixed with gradual addition of crushed ice-water using a hand mixer, ensuring the temperature did not exceed 10°C. The sausage emulsions were stuffed into 20 mm sheep casings and stored at 4°C as shown in Figure 5.1.

Table 5.1 Formulation of species sausage per 500 g batch for all fibres at 1%

Sample/ingredient	Control (g)	NSP60 (g)	NSP100 (g)	NSP200 (g)
Lean beef	285	285	285	285
Pork back fat	130	85	88	86
Water	60	100	97	99
Vinegar	15	15	15	15
Spices	10	10	10	10
Fibre	0	5	5	5
Total	500	500	500	500
% TME*	83	74	74.6	74.2

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

5.2.3 Costing

To determine the costs of the different sausages, the prices of the individual ingredients were used in the calculations. The percentage values of each of the ingredients were converted into the mass of the ingredients per kg of species sausage. The mass of the ingredient was multiplied by the unit cost of the ingredient to obtain its contribution to the total sausage product. The prices of sausages PDF and water were compared to the control to determine if they would be cheaper or more expensive.

5.3 Results and discussion

A summary of the costs of all the manufactured beef sausages; the control as well as those containing the three different pineapple fibres are shown in Table 5.2. Based on these results, the sausages containing NSP 60 PDF were the cheapest (R32.88/kg) to produce as compared to the control and the sausages containing fibres NSP 100 and NSP 200. This can be attributed to the high specified water holding capacity (WHC) of the NSP 60 fibre (Section 2.10; Table 2.6). The high WHC implies that a larger volume of water, an ingredient which has a low cost, is added in the sausage emulsion.

Table 5.2 Formulation costs for control versus NSP 60, NSP 100 and NSP 200 PDF and water containing beef sausages (South African Rand as determined in June 2014)

Treatment	Ingredient	Ingredient %	Ingredient mass (g/kg sausage)	Unit cost (Rand/kg)	Total cost/kg (Rand)
Control					
	Lean beef	57	570	42.10	24.00
	PBF	26	260	18.20	4.73
	Water	12	120	0.01	0.001
	Vinegar	3	30	7.99	0.24
	Spices	2	20	4.00	0.08
	Fibre	0	0	0.00	0.00
	Casing				5.18
Grand Total					**34.23**
NSP 60					
	Lean beef	57	570	42.10	24.00
	PBF	17	170	18.20	3.09
	Water	20	200	0.01	0.002
	Vinegar	3	30	7.99	0.24
	Spices	2	20	4.00	0.08
	Fibre	1	10	28.80	0.29
	Casing				5.18
Grand Total		100	1000		**32.88**

NSP 100					
	Lean beef	57	570	42.10	24.00
	PBF	17.6	176	18.20	3.20
	Water	19.4	194	0.01	0.002
	Vinegar	3	30	7.99	0.24
	Spices	2	20	4.00	0.08
	Fibre	1	10	26.20	0.26
	Casing				5.18
Grand Total		100	1000		**32.96**
NSP 200					
	Lean beef	57	570	42.10	24.00
	PBF	17.2	172	18.20	3.13
	Water	19.8	198	0.01	0.002
	Vinegar	3	30	7.99	0.24
	Spices	2	20	4.00	0.08
	Fibre	1	10	26.20	0.26
	Casing				5.18
Grand Total		100	1000		**32.89**

*****Water- Unit cost of industrial water in Cape Town was R12.51/kL (R0.01251/L ≈ R0.01/kg)

*PBF- Pork back fat

Per calculation, the other PDF containing sausages, (NSP 100 and NSP 200) were also cheaper to produce than the control, at R32.89/kg and R32.96/kg respectively. The cost of the control's ingredients was higher at R34.23/kg. Although the cost differences between the PDF containing sausages and the control species sausage may seem small and insignificant, such differences would be of great significance in industry where bulk amounts are produced.

5.4 Conclusions

The outcomes of this study indicated that substitution of pork back fat with pineapple dietary fibre and water has a positive effect in reducing formulation costs of species sausages. In addition to improving the health status of the species sausage by reducing the fat content and introducing the dietary fibre component, which is usually very low in most meat products, a combination of PDF and water can be of positive implications in the meat industry. Further research to determine the sensory effects of the PDF, exploring if more of it can be included in the species sausages as well as other emulsion type meat products is recommended. This would assist in realising the economic potential and further utilisation of the PDF in many sausage type meat products.

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CHAPTER 6

GENERAL DISCUSSION AND CONCLUSIONS

Consumers are aware of the relationship between health and diet, which makes them selective when it comes to the food and the products they purchase and/or consume (Jimenez-Colmenero *et al*., 2001; Wagemakers *et al*., 2009). The high fat amounts, saturated fatty acid profile and other components such as preservatives used to improve the processibility, microbiological stability, sensory and textural parameters in meat products are positively linked with prevalence of diseases of lifestyle such as cardiovascular disease, hypertension, colon and some cancers (Chau & Huang, 2004). These are some of the reasons consumers are shunning away from the meat products and looking for other 'healthier' protein sources. Moreover, most of these meat products are highly priced and unaffordable to the general low income communities. Meat processors are paying extensive attention to produce acceptable high quality low fat meat products to get back the lost market. This, however, has proved to be an uphill task, as the fat replacement techniques and fat replacers are usually expensive, making the products unaffordable (Jimenez-Colmenero, 1996).

Several fat replacers such as hydrocolloids, connective tissues proteins, carbohydrates, dietary fibres and vegetable oils have been used in the food industry with the view to produce 'healthier' low fat food products (Crehan *et al.*, 2000). Dietary fibre is a functional ingredient with bile acid binding ability and has an effect of improving digestion, reducing constipation, and various diseases (Gedikoglu *et al*., 2013). This polysaccharide complex is gaining extensive attention as an ingredient in the meat and other food industries. Dietary fibre is known to provide technological functions through interaction with water and oil binding; it can be a bulking and swelling agent and has gel forming and antioxidant capacity. It can function as a stabiliser, improves viscosity, body and mouth-feel in food systems (Gedikoglu *et al*., 2013, Figuerola *et al.*, 2005). The technological properties of dietary fibre play an economic role in reducing formulation costs in food products as well as reducing water loss and cooking losses in meat products. Cereal, vegetable, fruit and plant wastes and their fibres have been incorporated in meat products in this regard (Gedikoglu *et al*., 2013).

The aim of this study was to assess the effect of three (NSP 60, NSP 100 and NSP 200) different pineapple dietary fibres (PDF) on the physico-chemical characteristics of beef species sausages with the view to develop a healthy, affordable product. The sausages were manufactured under the South African guidelines: Government Notice No. R2718 of 1990 (updated) of the Food, Cosmetics and Disinfectants Act of 1972 (Anon., 2012). The fibres were extracted from processed pineapple flesh (waste) through a water dialysis process, drying and milling. This objective was achieved by undertaking the following:

- Assessing and identifying the optimal level with regards to water binding in the species sausage emulsions containing the three PDF and water.
- Assessing the physico-chemical, shelf-life characteristics and cost of PDF containing species sausage at the optimal PDF level.

The fibres were incorporated at levels 0% (control), 0.5%, 1.0% and 1.5%, with an equivalent amount of water added based on the specific water holding capacity (WHC) of the fibre in question. The total weight of the added water and fibre replaced an equal weight of pork back fat (PBF) in the species sausage formulation. Emulsion stability was assessed through determination of total expressible fluid (TEF). The study revealed that fat replacement with PDF and water can be a viable option to satisfying the growing consumer need for low-fat healthier species sausages/meat products. Sausages containing proper amounts of PDF bound a considerable amount of water, with TEF values comparable to the control. The control had a significantly low TEF value of 13.25% as compared to the fibre containing sausages which also significantly differed among themselves. Fibre variety NSP 200 proved to be the best in stabilising the sausage emulsions with a TEF value of 14.39%, followed by NSP 100 at 16.20%, NSP 60 being the poorest at 19.73%. The TEF values for all fibre containing species sausages were found to be lowest at 1% (16.13%) and 1.5% level (16.56%) fibre level which were not significantly different. The 1.0% and 1.5% PDF levels had the lowest TEF values of 16.13% and 16.56% respectively which differed from the 0.5% PDF level which had a value of 17.29%. Hence the optimal fibre level of 1.0% was considered for the assessment of the effects of the three fibres on the pH, purge, cooking loss, textural, shelf-life and proximate characteristics, as well as total formulation cost, of the species sausages.

The pH values of the fibre and water containing species sausages were significantly lower than the control; however, fibre addition did not result in any significant pH changes during storage. Fibre and water incorporation significantly increased purge, purge values also significantly increased during storage between days 2, 4 and 7 for all sausages. The fibres NSP 100 and NSP 200 fared well in terms of cooking loss which was similar to the control, NSP 60 compared poorly in this regard ($P \leq 0.05$). Although most of the textural properties, with the exception of cohesiveness, differed significantly from the control for all the fibre containing species sausages, it is debatable whether consumers would notice such differences.

Addition of fibre resulted in significant increase in lightness, hue and chroma as compared to the control [no difference between all fibres]. These would be considered lighter with more saturated vivid meat colour (positive aspect). During the seven day storage period, the average lightness, only increased significantly at day 7 whilst hue increased ($P \leq 0.05$) from day 0 to day 7. Chroma decreased significantly from day 0 through day 2 to day 4, the decrease to day 7 was not significant. Extensive increases in lightness along with reduction in vividness (chroma)/greying is considered a negative in some meat products. It is, however, debatable if such colour differences can be perceivable and play a role in consumer purchase and/or consumption behaviours of the sausages.

Since water was added in the fibre containing sausages, this was reflected by the higher moisture contents in the fibre containing sausages as compared to the control, the replacement of fat in these sausages also resulted in significantly lower total fat values in the fibre containing sausages. The protein content, although significantly lower in the fibre containing sausages (12.8-13.9%) than the control (16.2%), was still higher than other protein sources such as eggs and milk, thus the sausages can therefore still be considered to be a high protein source (Anon., 2010; Anon., 2014). As expected, the PDF containing sausages had significantly higher values of total fibre in comparison to the control. Based on the ingredients used, the formulation containing NSP 60 was the cheapest (R32.88)/kg followed by NSP 100 and NSP 200 at R32.89/kg and R32.96/kg respectively, lastly the control had the highest formulation of cost of R34.23/kg. Such differences can be considered minor but can be highly significant in industry where bulk volumes of sausages are produced. The following conclusions can therefore be made from this study:

1. Substitution of pork back fat (PBF) with any of the three PDF formulations and water can be a positive means of producing low fat, healthier and stable species sausage emulsions.
2. For all the three fibre formulations used, at various substitution levels, the 1% level produced the most stable species sausage emulsions.
3. Addition of PDF and water resulted in increased moisture and fibre contents and reduced fat, protein and ash contents in species sausages.
4. Addition of PDF and water caused positive changes in the colour attributes of lightness, chroma and hue; storage time had a mixed effect on colour attributes of the sausages.
5. Addition of PDF and water resulted in reduced pH values which were apparently not affected by storage time.
6. Species sausages containing PDF had lower textural attributes with the exception of cohesiveness which was similar to the control for all sausages.
7. Addition of PDF and water resulted in increased purge, which, increases by a similar margin to that of the control during the 7 day storage period.
8. Addition of NSP 100 and NSP 200 results in cooking loss similar to the control, NSP 60 performs poorly in this regard.
9. Substitution of PBF with PDF and water is an economical viable activity as it results in reduced formulation costs for species sausages which can be a cheaper, healthier protein source for low income communities.
10. Utilisation of PDF in the meat industry can be a positive way of using cheap underutilised pineapple waste, which is an environmental problem, usually traded for close to nothing as cattle feed. This will result in an increase in revenue for the farmers and processors as well as creating employment in the pineapple producing regions.

It is recommended that further research be carried out to assess the effects of the PDF on sensory characteristics of beef species sausage. Furthermore, an assessment of the fibre effects on the quality characteristics of other sausage-type and other meat products is recommended. Since dietary fibre has various functional and technological attributes, it would be recommended that the investigations into the use of PDF not be limited to meat products but to other food products such as bakery and confectionery as well the juices industries.

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APPENDICES

Appendix 1 ANOVA for TEF- Optimal fibre level determination

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	1378.12	35	39.37	16.02	0.0001
FT	494.75	2	274.37	100.65	0.0001
WL	392.41	3	130.80	53.22	0.0001
FL	22.83	2	11.42	4.64	0.0129
FT*WL	152.94	6	25.49	10.37	0.0001
FT*FL	259.87	4	64.97	26.43	0.0001
WL*FL	32.68	6	5.45	2.22	0.0518
FT*WL*FL	22.63	12	1.89	0.77	0.68
Error	167.13	68	2.46		
Corrected total	1545.25	103			

FT- Fibre type
WL- Water level
FL- Fibre level

Appendix 2 ANOVA for water in TEF- Optimal fibre level determination

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	8792.88	35	251.23	31.97	0.0001
FT	1078.86	2	539.43	68.65	0.0001
WL	6349.63	3	2116.54	269.35	0.0001
FL	133.55	2	66.78	8.50	0.0005
FT*WL	121.45	6	220.24	2.58	0.0262
FT*FL	502.68	4	125.67	15.99	0.0001
WL*FL	326.93	6	54.49	6.93	0.0001
FT*WL*FL	279.79	12	23.32	2.97	0.0022
Error	534.34	68	7.86		
Corrected total	9327.22	103			

FT- Fibre type
WL- Water level
FL- Fibre level

Appendix 3 ANOVA for Fat in TEF- Optimal fibre level determination

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	8792.88	35	251.23	31.97	0.0001
FT	1078.86	2	539.43	68.65	0.0001
WL	6349.63	3	2116.54	269.35	0.0001
FL	133.55	2	66.78	8.50	0.0005
FT*WL	121.45	6	20.24	2.58	0.0262
FT*FL	502.68	4	125.67	15.99	0.0001
WL*FL	326.93	6	54.49	6.93	0.0001
FT*WL*FL	279.79	12	23.32	2.97	0.0022
Error	534.34	68	7.86		
Corrected total	9327.22	103			

FT- Fibre type

WL- Water level

FL- Fibre level

Appendix 4 ANOVA for lightness for control and samples at 1% fibre level

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	1168.13	35	33.38	5.17	0.0001
Sample	711.79	3	237.26	36.76	0.0001
Sample (Rep)	376.38	20	18.82	2.92	0.0007
Day	55.45	3	18.48	2.86	0.0441
Sample*Day	24.52	9	2.72	0.42	0.9183
Error	387.30	60	6		
Corrected total	1555.44	93			

Appendix 5 ANOVA for hue for control and samples at 1% fibre level

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	6261.70	35	178.91	4.77	0.0001
Sample	778.39	3	259.46	6.92	0.0005
Sample (Rep)	1436.50	20	71.82	1.92	0.0290
Day	3406.99	3	1135.66	30.28	0.0001
Sample*Day	639.82	9	71.09	1.90	0.0710
Error	2137.80	57	37.51		
Corrected total	8399.50	92			

Appendix 6 ANOVA for chroma for control and samples at 1% fibre level

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	303.66	35	8.68	4.50	0.0001
Sample	21.42	3	7.14	3.70	0.0165
Sample (Rep)	39.28	20	1.96	1.02	0.4569
Day	221.12	3	73.71	38.19	0.0001
Sample*Day	21.84	9	2.43	1.26	0.2793
Error	113.86	59	1.93		
Corrected total	417.52	94			

Appendix 7 ANOVA for pH for control and samples at 1% fibre level

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	0.92	35	0.03	3.77	0.0001
Sample	0.41	3	0.14	19.42	0.0001
Sample (Rep)	0.24	20	0.01	1.74	0.0511
Day	0.01	3	0.00	0.66	0.5798
Sample*Day	0.25	9	0.03	4.08	0.0004
Error	113.86	59	1.93		
Corrected total	417.52	94			

Appendix 8 ANOVA for purge for control and samples at 1% fibre level

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	209.35	31	6.75	14.98	0.0001
Sample	153.40	3	51.13	113.45	0.0001
Sample (Rep)	26.59	20	1.33	2.95	0.0019
Day	26.25	2	13.12	29.12	0.0001
Sample*Day	3.11	6	0.52	38.46	0.0001
Error	17.58	39	0.45		
Corrected total	226.92	70			

Appendix 9 ANOVA for cooking loss for control and samples at 1% fibre level

Source	Sum of squares	DF	Mean square	F-value	P-value
Model	278.22	3	92.74	5.05	0.0091
Sample	278.22	3	92.74	5.05	0.0091
Error	367.08	20	18.35		
Corrected total	645.30	23			

Appendix 10 ANOVA for textural properties for control and samples at 1% fibre level

Source	Sum of squares	DF	Mean square	F-value	P-value
Hardness					
Model	106.13	3	35.38	7.78	0.0012
Sample	106.13	3	35.38	7.78	0.0012
Error	90.99	20	4.55		
Corrected total	197.12	23			
Cohesiveness					
Model	1.52	3	0.51	0.95	0.4367
Sample	1.52	3	0.51	0.95	0.4367
Error	10.72	20	0.54		
Corrected total	12.24	23			
Gumminess					
Model	3188.44	3	1062.81	32.20	0.0001
Sample	3188.44	3	1062.81	32.20	0.0001
Error	594.19	18	33.01		
Corrected total	3782.63	21			
Springiness					
Model	2.56	3	0.85	8.61	0.0008
Sample	2.56	3	0.85	8.61	0.0008
Error	1.88	19	0.10		
Corrected total	4.44	22			
Chewiness					
Model	255575.67	3	85191.89	37.37	0.0001
Sample	255575.67	3	85191.89	37.37	0.0001
Error	41035.01	18	2279.72		
Corrected total	296610.68	21			

Appendix 11 ANOVA for proximate properties for control and samples at 1% fibre level

Source	Sum of squares	DF	Mean square	F-value	P-value
Moisture					
Model	331.40	3	110.47	11.59	0.0001
Sample	331.40	3	110.47	11.59	0.0001
Error	190.59	20	9.53		
Corrected total	521.98	23			
Fat					
Model	766.24	3	255.41	266.12	0.0001
Sample	766.24	3	255.41	266.12	0.0001
Error	19.20	20	0.96		
Corrected total	785.44	23			
Protein					
Model	34.61	3	11.54	9.07	0.0006
Sample	34.61	3	11.54	9.07	0.0006
Error	24.16	19	1.27		
Corrected total	58.77	22			
Dietary fibre					
Model	0.29	3	0.10	55.70	0.0001
Sample	0.29	3	0.10	55.70	0.0001
Error	0.34	20	0.00		
Corrected total	0.32	23			
Ash					
Model	2.86	3	0.95	84.43	0.0001
Sample	2.86	3	0.95	84.43	0.0001
Error	0.21	19	0.01		
Corrected total	3.07	22			

fibiz rrv1 Dietary F

Product Data and Specification Sheet nsp 200

Description

fibiz™ is a non starch polysaccharide dietary fibre extracted from fruit grown in the Eastern Cape region of South Africa. Produced in a BRC certified factory (incorporating HACCP), fibizTM is a pure natural fruit cellulose, comprising approximately 80-90% dietary fibre that is 99% insoluble.

Two categories offibiz™ are available; fibiz™nsp, extracted from the flesh and core of the fruit and fibiz™ natural, comprising of cellulose fibres from the peel of the fruit. Both categories are available in a wide range of particle sizes to suit your specific application.

Specification

Physical attributes:	
Analytical	
Total Dietary Fibre (AOAC 985.29)	83% (±2%)
-Insoluble	>99% (±2%)
-Soluble	<1%
Moisture (g/1OOg)	<8%
Total Sugars (g/1OOg)	<1
- Energy (KJ/1OOg)	120
pH	4.53
Ash (g/1OOg)	1.1
Bulk Density	0.25
Hygroscopicity	Zero
Heavy Metals (Hg, Pb, Cd) (mg/1OOOg)	<0.06
Arsenic as As (mg/1OOOg)	<0.25
Particle Size (micron jJm)	100><400
Sensory	
Colour - Ub Ratio	5.54
- a/b Ratio	-2.88
Taste	Neutral
Aroma	Neutral
Microbial	
Total Microbial/Plate count	::;;1 OOcfu/g
Yeast & Mould	::;;1 OOcfu/g
Bacillus Cereus	::;;1 OOcfu/g
E Coli, Coliforms	No growth
Salmonella	Absent

Functional & Nutritional Information

Binding Capacity (g/g fibre)	
- Water (CHAU et al. (2003))	7.8
- Oil (CHAU et al. (2003))	5.0
Minerals (Na,K,Fe,Zn,Ca,)(mg/1OOOg)	4 828
Protein (g/1OOg)	4.1
Allergens	
-Others	none
- Gluten, Soy, nuts,	none
Pesticides, Insecticides	none
GMO	non GMO
Enzymatic Activity	absent
Chemical Modifications	none
Fat (g/1OOg)	0.2

General Information

Kosher	certified
Halaal	certified
BRC (incorporating HACCP)	certified

Packaging, Labeling, Storage & Shelf Life
- 1Okg paper bag, multi layered with a PE Inner lining. (or per customer specification)
-Each package is labeled as fibizTMnatural or fibizTMnsp detailing the content as dietary fibre.
- Store in a dry place at room temperature in original sealed packaging.
- Shelf Life is 12 months from production date if stored as specified above.

Extraction Process
A special water dialysis process producing a natural Dietary Fibre from Fruit. No colourants, flavoumnts, bleaches or preservatives are added.

Samples and Information

Please feel free to contact us should you require any further information or samples.

all about the fruit! Summerpride

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East London, South Africa
Tel: +27 (0) 43 731 '1770

Version 2, September 2011

fibiz Tiv1 Dietary F bre

Product Data and Specification Sheet nsp 60

Description

fibiz ™ is a non starch polysaccharide dietary fibre extracted from fruit grown in the Eastern Cape region of South Africa. Produced in a BRC certified factory (incorporating HACCP), fibiz™ is a pure natural fruit cellulose, comprising approximately 80-90% dietary fibre that is 99% insoluble.

Two categories of fibiz™ are available; fibiz™nsp, extracted from the flesh and core of the fruit and fibiz™ natural, comprising of cellulose fibres from the peel of the fruit. Both categories are available in a wide range of particle sizes to suit your specific application.

Specification

Physical attributes:	
Analytical	
Total Dietary Fibre (AOAC 985.29)	81.1% (±2%)
-Insoluble	99%
-Soluble	<1%
Moisture (g/1OOg)	<8%
Total Sugars (g/1OOg)	<1
- Energy (KJ/1OOg)	100
pH	4.45
Ash (g/1OOg)	1.1
Bulk Density	0.25
Hygroscopicity	Zero
Heavy Metals (Hg, Pb, Cd) (mg/1OOOg)	<0.06
Arsenic as As (mg/1OOOg)	<0.25
Particle Size (micron m)	<63
Sensory	
Colour - *Ub* Ratio	7.06
- a/b Ratio	-0.009
Taste	Neutral
Aroma	Neutral
Microbial	
Total Microbial/Plate count	$100cfu/g
Yeast & Mould	$1OOcfu/g
Bacillus Cereus	$1OOcfu/g
E Coli, Coliforms	No growth
Salmonella	Absent

Functional & Nutritional Information

Binding Capacity (g/g fibre)	
- Water (CHAU et al. (2003))	8
- Oil (CHAU et al. (2003))	6
Minerals (Na,K,Fe,Zn,Ca,)(mg/1 OOOg)	3 403.8
Protein (g/1OOg)	3.2
Allergens	
-Others	none
-Gluten, Soy, nuts,	none
Pesticides, Insecticides	none
GMO	non GMO
Enzymatic Activity	absent
Chemical Modifications	none
Fat (g/1OOg)	0.4

General Information

Kosher	certified
Halaal	certified
BRC (incorporating HACCP)	certified

Packaging, Labeling, Storage & Shelf Life

- 1Okg paper bag, multi layered with a PE Inner lining. (or per customer specification)
- Each package is labeled as fibiz™natural or fibizTMnsp detailing the content as dietary fibre.
- Store in a dry place at room temperature in original sealed packaging.
- Shelf Life is 12 months from production date if stored as specified above.

Extraction Process

A special water dialysis process producing a natural Dietary Fibre from Fruit. No colourants, flavourants, bleaches or preservatives are added.

Samples and Information

Please feel free to contact us should you require any further information or samples.

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Summerpride Foods (PTY) Ltd
Burgersdorp Rd.
East London, South Africa

Version 2, September 2011

fibiz™ Dietary F bre

Product Data and Specification Sheet nsp 100

Description

fibiz™ is a non starch polysaccharide dietary fibre extracted from fruit grown in the Eastern Cape region of South Africa. Produced in a BRC certified factory (incorporating HACCP), fibiz™ is a pure natural fruit cellulose, comprising approximately 80-90% dietary fibre that is 99% insoluble.

Two categories offibiz™ are available; fibiz™nsp, extracted from the flesh and core of the fruit and fibiz™ natural, comprising of cellulose fibres from the peel of the fruit. Both categories are available in a wide range of particle sizes to suit your specific application.

Specification

Physical attributes:

Analytical	
Total Dietary Fibre (AOAC 985.29)	8QS{, (±4%)
-Insoluble	>99%(±4%)
-Soluble	<'1%
Moisture (g/1OOg)	<8%
Total Sugars (g/1OOg)	<1
- Energy (KJ/1DOg)	170
pH	4.37
Ash (g/1OOg)	1.5
Bulk Density	0.25
Hygroscopicity	Zero
Heavy Metals (Hg, Pb, Cd) (mg/1OOOg)	<0.06
Arsenic as As (mg/1OOOg)	<0.25
Particle Size (micron l-Jm)	63><100

Sensory

Colour - Ub Ratio	4.44
-alb Ratio	0.10
Taste	Neutral
Aroma	Neutral

Microbial

Total Microbial/Plate count	s100cfli/g
Yeast & Mould	s1OOcfu/g
Bacillus Cereus	s100cfu/g
E Coli, Coliforms	No growth
Salmonella	Absent

Functional & Nutritional Information

Binding Capacity (g/g fibre)	
- Water (CHAU et al. (2003))	7.4
- Oil (CHAU et al. (2003))	4.2
Minerals (Na,K,Fe,Zn,Ca,)(mg/1 OOOg)	5133
Protein (g/1OOg)	5.2
Allergens	
-Others	none
- Gluten, Soy, nuts,	none
Pesticides, Insecticides	none
GMO	non GMO
Enzymatic Activity	absent
Chemical Modifications	none
Fat (g/1OOg)	0.3

General Information

Kosher	certified
Halaal	cetiified
BRC (incorporating HACCP)	certified

Packaging, Labeling, Storage & Shelf Life

- 1 Okg paper bag, multi layered with a PE Inner lining. (or per customer specification)
-Each package is labeled as fibiz™natural or fibiz™nsp detailing the content as dietary fibre.
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Please feel free to contact us should you require any further information or samples.

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