Effect of balanced dietary protein on the physico-chemical quality and sensory attributes of rabbit meat from New Zealand White and Californian rabbits

By

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Declaration

I, Anela Makebe, declare that this dissertation has not been submitted to any University and that it is my original work conducted under the supervision of Dr Z.T. Rani. All assistance towards the production of this work and all references contained herein have been accordingly acknowledged.

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Dr Z.T. Rani

List of abbreviations

WBSF	Warner Bratzler Shear force
L*	Lightness
a*	Redness
b*	Yellowness
CL	Cooking loss
WHC	Water holding capacity
NZW	New Zealand white
CAL	Californian
AI	Aroma intensity
NS	Not Significant
OF	Overall flavour intensity
MFT	Muscle fibre and overall tenderness

General Abstract

The study was conducted at the University of KwaZulu-Natal, Ukulinga Research farm Pietermaritzburg, South Africa (SA) with the aim of investigating the effect of balanced dietary protein on physico-chemical quality and sensory attributes of New Zealand white (NZW) and Californian (CAL) rabbits. A total of eighty (80) NZW and CAL rabbits were allocated to a diet composed of six balanced dietary protein levels (T1 = 126g/kg, T2 = 143g/kg, T3 = 161g/kg, T4 = 178g/kg, T5 = 196g/kg and T6 = 213g/kg) at weaning age (35 days) for a period of 56 days. The rabbits were fed twice a day at 08:00 am and t 16:00 pm with water provided *ad libitum*. Meat quality traits which include pH, colour (L*, a* and b*), water holding capacity, cooking loss, shear force and drip loss were measured. No significant effects were found for pH values between the two breeds at pH_{45} and pH_{24}. No significant differences were observed in colour (L*, a* and b*), water holding capacity (WHC), drip loss (DL), cooking loss (CL) and shear force values of meat. Sensory attributes of the meat from New Zealand (NZW) and Californian (CAL) were also evaluated using different tribes (Xhosa, Zulu and Shona), gender and ages with different cooking methods (cooking and frying). In this study, the first bite was rated superior ($P < 0.05$) in NZW breed for cooked meat. High scores were observed in overall flavour intensity for fried meat in NZW breed ($P < 0.05$). In relation to tribes, Shona tribe gave higher scores ($P < 0.05$) for both cooked and fried meat for all sensory properties. Age was observed to have a significant impact whereby the highest scores ($P < 0.05$) for sustained impression of juiciness from fried meat were given by respondents in age group 26-30 years. High sensory evaluation scores ($P < 0.05$) were observed in both females and males in fried meat than cooked meat for all sensory characteristics. Highest scores ($P < 0.05$) were detected in overall flavour intensity of fried meat in all tribes. The sensory scores for fried meat were significantly higher ($P < 0.05$) than cooked meat across age group between 21-25 and 26-30 years of age. It was concluded that the physico-chemical quality of NZW and

CAL rabbits was not altered by the balanced dietary protein, and consumer's demonstrated to have a higher preferred fried meat than cooked meat based on the scores given by the respondents.

Key words: Rabbit Meat, Consumer sensory evaluation, Colour, Age, Gender, Cooking method, Tribe.

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Dedication

I dedicate this work to my parents Mr S. Makebe and Mrs N.L Makebe and the entire Makebe Family, ooZikhali!

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CHAPTER 1

General introduction

1.1 Background

Nowadays, modern animal production including rabbits have gained more emphasis and attention in the area of research. Their early sexual maturity, high productivity rate, and short pregnancy period as well the ability to breed at any time of the year has brought rabbit production system into fame (Bhattacharjya *et al*., 2020). In comparison to other species, rabbits pose biological advantages as they can play a significant role in enhancing animal protein production, especially in developing countries, including South Africa (Foster *et al*., 2019). Unlike poultry, rabbits have economic advantages due the fact that these animals can be successfully grown on high forage diets and low-grain (Bharathy *et al*., 2022), thus reducing ongoing competition between animals and humans for grains.

The meat from rabbits is found to be nutritive and healthy as compared to other kinds of meat such as beef, mutton and pork (Dalle Zotte, 2014). Recently, customers are becoming more concerned in healthy living habits like balancing diet by choosing nutritional foods that are low in cholesterol and high protein (Crovato *et al*., 2022). Rabbit meat has low concentration of fat as well as low cholesterol (Kallas, and Gil, 2012). Apart from this, rabbit meat is easily digested, flavourful and has no religious rules prohibit (Bhattacharjya *et al*., 2020). Given that rabbit is nutritious compared to other species, it is then suggested for consumption especially for humans suffering with heart related diseases (Para *et al*., 2015).

The most common rabbit breeds mainly used for meat worldwide include New Zealand White (NZW) and Californian (CAL) due to their good growth characteristics and high meat-to-bone ratio (Salihu, 2021). Despite the fact that NZW and CAL are capitalizing in terms of the above-mentioned traits, few studies have been conducted in attempt to investigate the effect of balanced dietary protein on their meat quality , especially in South Africa (SA). Balanced dietary protein is important due to the reason that it reduces or inhibit factors such as heat stress conditions (Maharjan *et al*. 2021). Proteins are composed of amino acids that a rabbit's body utilizes to function efficiently, build muscle and gain weight (Singh *et al*. 2021). Feeding with dietary protein improves animal performance, maintain well-being and enhance meat quality (Wang *et al*. 2021). Various studies have been conducted on examining meat quality of other species such as broilers and pigs as affected by the dietary protein (Sterling *et al*. 2006 and Wang *et al*. 2022). Furthermore, a study by Liu *et al*. (2015) confirmed that dietary protein content positively affected meat quality in pigs. This current study was then proposed to investigate the effect of balanced dietary protein on the physico-chemical properties and sensory attributes of rabbit meat from NZW and CAL rabbits.

1.2 Problem statement

Several researchers have anticipated that white meat consumption will increase by 35.4 kg in 2024, due to an ever-increasing human population in the world (Delport *et al*. 2017). Livestock species experience health-related issues that affect their meat and products. For example, pork products were removed from the market due to the outbreak of Listeriosis (Fasanmi *et al*., 2017). The possible options such as prioritizing rabbit farming have to be considered so as to meet protein needs of consumers (Śmiecińska *et al*. 2022). In this regard, there is an urgent need to find alternative protein sources representing white meat. Rabbit could be then a potential alternative species as its meat pose nutritional health benefits compared to other species (Para *et al*. 2015).

1.3 Justification

Protein is very essential in rabbit's diet to support healthy growth more especially when in growing phase and supply source of energy (Birolo *et al*. 2022). Proteins comprise amino acids, which a rabbit's body requires to function properly, build muscle and put on weight (Singh *et al*. 2021). The effect of balanced dietary protein on meat quality of NZW and CAL rabbits is not fully understood. Such information is critical in making recommendations on which breed respond positively when fed balanced dietary proteins. In general, rabbit's meat is healthy compared to other species, due to its low concentration of fat, low levels of cholesterol and high protein (Para *et al*., 2015). Owing to its nutritional health benefits, rabbit meat is thus recommended for consumption by people with hypertension and diabetes (Para *et al*., 2015). Provided that poultry industry is mostly affected by disease outbreak like Avian Influenza (Fasanmi *et al*., 2017), rabbit meat can be the potential alternative protein source which possess similar health beneficial effects of white meat. Hence, SA stands to gain a significantly greater market share in the commodity by improving rural families' diets as well as creating a stable source of income through rabbit production.

1.4 Study Aim

The overall aim of the study was to investigate the effect of balanced dietary protein on the physicochemical quality and sensory attributes of rabbit meat from New Zealand White and Californian Rabbits. The specific objectives were;

1. To determine the effect of balanced dietary protein on physicochemical quality of New Zealand White and Californian rabbits;
2. To assess the sensory attributes of New Zealand white and Californian rabbit meat fed a balanced dietary protein

1.5 Hypothesis

1. There is no effect of balanced dietary protein on physico-chemical quality of New Zealand white and Californian rabbits;
2. There is no effect of balanced dietary protein on sensory attributes of meat from New Zealand white and Californian rabbits.

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CHAPTER 2

Review of literature

2.1 Introduction

Rabbit meat production is becoming increasingly popular as an alternative to food shortages in developing countries like India and South Africa (Chakrabarti *et al*., 2017). Rabbits have the ability to consume high-fibre, low-grain diets that minimise competition with humans for feed ingredients, rabbits are assumed to reach maturity weight quickly (Finzi, 2000; Abu *et al*., 2008). According to (Özturk and Kose, 2017), increasing household incomes and human population growth in both emerging and developed regions, as well as Sub-Saharan Africa (SSA), are contributing to an increase in the need for inexpensive animal protein. This increase is restricted by challenges of animal feed scarcity and urban settlements hence it is necessary to discover different feed resources and other species to meet human demands (Rust and Rust, 2013).

Globally, red meat consumption has decreased and is partially replaced by white meat products that are leaner (Merlino *et al*., 2017). Rabbit meat is highly desirable due to its nutritional qualities. In comparison to beef, pork, and poultry meat, rabbit meat is lower in sodium, fat and cholesterol (Hernandez and Gondret, 2006). As a result, rabbit meat is becoming more acknowledged as a "functional food" (Petrescu and Petrescu-Mag, 2018). Its consumption, for instance, lowers the risk of metabolic syndrome (Becerra-Tomas *et al*., 2016). Consumers are reluctant to consume rabbit meat since it is an unfamiliar and distinct meat, which leads to a low demand and a poor supply (Duarte, 2011).

Meat quality refers to the qualities of meat that may be measured scientifically for research purposes, such as its physical and chemical attributes (Joo *et al*., 2013). Consumers define meat quality in different ways and at time this may differ with culture (Borgaard and Anderson, 2004; Monin, 2004; Xazela *et al*., 2011). The current review discusses the physicochemical quality and sensory attributes of NZW and CAL rabbits fed a balanced dietary protein.

2.2 Rabbit farming

Rabbit farming is a satisfying and profitable business with high returns on investment (Onebunne, 2013). Domestic rabbits (*Oryctolagus cuniculus*) are abundant, providing protein, fibre, research models, and companionship. The rabbit has a rapid growth rate and high reproductive potential (Hassan *et al*., 2012), which consume low grain and high roughage diets throughout the year (Irlbeck, 2001) and breeds all throughout the year (Hassan *et al*., 2012). In addition to short gestation periods and early sexual maturation, Hassan *et al*. (2012) reported that the species can rebreed shortly following kindling and that generation intervals are short as well.

2.2.1 Significance of rabbit production

It is recommended that rabbits be used as a protein source as the reproductive rate of other livestock breeds is slower, and poultry is prone to Avian Influenza (Plague, 2010). Furthermore, rabbit production has many advantages which includes generation of employment, increase in farmer's income, producing meat with high quality and increasing food security (Mailafia *et al*. 2010). In addition, (Hecimovich, 2010; Local Harvest, 2011) reported that rabbits produce a white meat that is rich in protein, most appealing, low cholesterol and fat content. The majority of the world's producers of rabbits are small-scale farmers with limited resources who maintain their operations in order to increase their production of meat and profit (Lukefahr, 2007; Moreki, *et al*. 2011). Rabbits have several benefits, including high prolificacy, early maturity, fast growth, efficient feed conversion, and efficient use of space (Mailafia *et al*., 2010). Moreover, considering the increasing grain prices, rabbits are the preferred livestock species to raise due to their low grain requirements compared to other livestock species (Ruhul, Taleb, and Rahim, 2011). The droppings of rabbits are rich in nitrogen and phosphorus, which helps to fertilize the soil. Small rural-based industries can be created through the sale of quality pelts used in the fur garment industry and for making art crafts (Wambugu, 2015).

2.2.2 Challenges of rabbit production

One of the major problems in rabbit farming, according to (Oseni *et al*. 2008), is the insufficient information on rabbit management in smallholder units. Lack of stable and established markets is one of the factors contributing to the rabbit production industry to lag, unsatisfactory promotion, inconsistent product supply, unjustified costs, and competition from other meats (Mailu, 2012). According to Adu(2005), banks are willing to lend money for the construction of rabbit hatchets, but the requirements for the loans are tight and make them best suited for individuals who are already stable financially. Farmers' lack of market knowledge and marketing skills is a contributing factor to their decision to begin rabbit farming (Gono *et al*. 2013 ; Kabir, 2005). Religious beliefs can either restrict or promote the development of a potential business such as rabbit farming (Appiah and Tracoh, 2011). According to Gono *et al*. (2013), one of the major constraints to commercial rabbit keeping in the tropical regions is insufficient nutrition due to a lack of feed. Ramodisa (2007) noted that farmers and advisors lack technical knowledge about rabbit farming.

2.3 Rabbit breeds

There is great potential for rabbits in South Africa, both for large-scale commercial meat production and rural development (Oseni, 2012). They can be reared intensively on small areas of land, reach slaughter weight early, resulting in quick returns on financial investment (Abu, Onifade, Abanikannda and Obiyan, 2008; Oseni, 2012). New Zealand White rabbits have been regarded as the best breed for meat production, followed by Californian rabbits. In comparison to other meat breeds, these breeds have large litters, excellent mothering abilities, carcass characteristics, and the best bone-to-meat ratio (Dairo *et al*., 2012).

2.4 Nutritional composition of rabbit meat

Castellini *et al*. (1998), suggested that rabbit meat can be a potential alternative source of meat because of its high protein, low fat, and low cholesterol content, compared to red meat. Considering that rabbit meat contains bioactive properties that can benefit human health, it is regarded as a functional food (Maria *et al*. 2006). Rabbit meat has been regarded as one of the greatest white lean meats on market which is juicy and tender. According to Hernandez *et al*., (2007), rabbit meat has a low purine concentration and no uric acid. According to Pla *et al*. (2004), rabbit meat is almost cholesterol free and has lower salt content it is therefore ideal for people with heart disease.

Table 2. 1: Nutritional composition (% unless stated otherwise) of meat

Meat composition		Moisture (%)	Dry matter (%)	Protein (%)	Fat (%)	Energy (1 MJ/kg and 2cal/kg	Reference
Rabbit	1	-	20-23	20-22	10-12	7-8	Crovato *et al*. (2022);
	2	67.9	-	20.8	10.2	1749	
Chicken	1	-	20-23	19-21	11-13	7-8	Munyaneza *et al*. (2022)
	2	67.6	-	20.0	11.0	1782	
Turkey	1	-	38-42	19-21	20-22	10-12	Ayadi *et al*. (2009)
	2	58.3	-	20.1	20.2	2618	
Beef	1	-	40-50	15-17	27-29	11-14	USDA (1963)
	2	55.0	-	16.3	28.0	3168	
Lamb	1	-	40-50	14-18	26-30	11-14	Fielding (1991); Rajic *et al*.
	2						(2022)
		55.8	-	15.7	27.7	3124	
Pork	1	-	50-55	10-12	42-48	17-20	Rajic *et al*. (2022)
	2	42.0	-	11.9	45.0	4510	

2.5 Meat quality as influenced by dietary protein

Usually, the quality of feed is determined from its protein content, protein function as to improve the growth of the animal. When metabolizable protein supply of the basal diet can fulfil the protein requirements (NRC, 2007) therefore, the growth performance will increase as well (Barajas *et al*. 2011; Ortiz, 2013). Increase of the growth efficiency will affect the meat and fat production (Owens, 1993; Mansos, 1998). Numerous studies have been conducted to find the optimal feed protein level to get high meat production and low-fat meat. According to (Wang *et al*., 2020a, 2020b), dietary protein levels should be adjusted to meet the protein needs of animals and these levels should provide proper protein delivery, and promote efficient protein absorption and utilization.

In a study conducted by Khatun *et al*. (2021), dietary protein levels showed a non-significant effect on pH of breast meat of hilly chicken. In contrary, Min *et al*. (2012) reported a significant effect of dietary protein on pH of leg muscle of broilers. Khatun *et al*. (2021), observed that dietary protein levels did not influence drip loss and cooking loss of breast meat. Yang *et al*. (2007); Widyaratne and Drew; (2011) found a non-significant effect of dietary protein on water holding capacity and shear force in both leg and breast muscle of broilers. These results disagree with Niu *et al*. (2009) who stated that dietary protein content increased the water holding capacity of broilers. In addition, Niu *et al*. (2009) found different dietary protein levels not affecting L* and b* but increased a* with increasing dietary protein levels

2.6 Meat quality parameters

2.6.1 Meat pH

Muscle pH is considered a significant contributor to meat quality parameters such as colour, tenderness, water-holding capacity, and shelf life by (Kim *et al*. 2014). Anaerobic glycolysis and pre-slaughter stress have an impact on muscle metabolism (Frizzell *et al*. 2017; Chauhan and England, 2018). Poor carriage to slaughter, poor lairage circumstances and slaughter protocol are main determinants of pre-slaughter stress (Frizzell *et al*. 2017). Dark, firm, and dry meat (DFD) is normally associated with high meat pH, while pale, soft, and exudative (PSE) meat is associated with low meat pH (Wattanachant, 2008). In addition, a high ultimate pH stimulates the development of microorganisms consequently reducing the shelf-life of meat, through development of bad odours (Gallo *et al*. 2003). Such meat is undesirable to consumers thus resulting in economic losses. If the pH value is higher than (5.8 and 6) then it is possible to be rejected by consumers since it has a dark appearance, tough, and is indigestible to consume (Viljoen *et al*. 2002).

2.6.2 Meat colour

Colour has been reported as one of the most contributors to appearance (Fletcher *et al.* 2000). Moreover, Hutchings (2003), highlighted that meat colour determines freshness and healthiness that is pleasing to the consumers. Pre-slaughter stress has an effect on muscle metabolism (Frizzell *et al*. 2017) as well as anaerobic glycolysis (Chauhan and England, 2018). Furthermore, poor lairage conditions and slaughter procedure are main determinants of pre-slaughter stress (Frizzell *et al*. 2017). The most important pigments responsible for meat colour are myoglobin and haemoglobin. Meat translates its colour due to chemical reactions concerning myoglobin, such as oxygenation, oxidation or the addition of a carbon monoxide molecule, and reduction, which plays a crucial part in sustaining the colour of meat after slaughter.

2.6.3 Cooking loss

Jama *et al*. (2008) defined cooking loss as the weight loss of meat throughout the cooking process and is considered as one of the variables used to evaluate the quality of meat. Higher cooking losses specify a reduction in water holding capacity. Cooking loss has an impact on the appearance of the meat and is of importance due to its accountability on the variation of in juiciness. A high cooking loss is associated with less optimum eating quality. Sebsibe, (2006) reported that lower cooking losses, shows improved juiciness of the meat.

2.6.4 Tenderness

Tenderness is one of the eating qualities characteristics that determines most consumers' choices (Polkinghorne and Thompson, 2010). According to Pannier *et al*. (2014), tenderness is positively correlated with juiciness. Shear force is used to evaluate meat tenderness, and its high value is associated with tougher meat (Cavitt *et al*. 2004). The outcome of shear force demonstrates the hardiness of meat. For the Warner-Bratzler Shear Force test, the meat samples should be evenly round and of the same diameter. Muchenje *et al*. (2009a), reported other factors that have an influence on tenderness which include the age of an animal, muscle location, sex, breed and ante-mortem stress.

2.6.5 Water holding capacity

Water holding capacity refers to the ability of meat to retain water through processing and storage (Bowker and Zhuang, 2015). It is one of the most essential factors influencing the value and price of meat and its products, according to (Barbera, 2019). This attribute is determined using filter papers to determine water loss (Grau and Hamm, 1956). Wright *et al*. (2005) added that consumers criticize fresh meat because of abnormalities in palatability, a sensory quality of meat, caused by fluid lost during processing and packing of meat.

2.6.6 Drip loss

The term drip loss refers to the fluids that are lost without mechanical force from a piece of meat, mainly water and protein (Fischer, 2007). It is related with sensory qualities such as firmness and juiciness, according to Gil *et al*. (2008). Warner Bratzler shear force is considered to be high in muscles with a high drip loss. Logan *et al.* (2019) reported that meat freshness is highly dependent on WHC, which is affected by drip loss. Otto *et al.* (2004) confirmed that drip loss is of high financial importance as it impacts economic revenues.

2.7 Sensory evaluation

Sensory evaluation is a scientific method for measuring, analyzing, and interpreting the quality of meat. Several methods can be used in meat sensory evaluation such as instrumental. Ngambu *et al*. (2012) reported that meat value is determined by consumer opinion, which justifies their purchase decisions. When sensory evaluations of meat are being done, consumers from different countries and segments of affluence are encouraged to participate, since they all have different preferences and motives (Sveinsdóttir *et al*., 2009).

2.7.1 Aroma and flavour

Flavour can be defined as the taste and aroma of meat experienced throughout chewing (Moody, 1983). Aroma properties and flavour enhancers are considered taste-active compounds that determine meat flavour (Stelzleni and Johnson, 2007). Natural flavour of meat varies between animal species (Lee *et al*. 2004), lipid concentration (Miller, Moeller, Goodwin, Lorenzen, and Savell, 2000), meat pH (Calkins and Hodgen, 2007) and the cooking method used (Webb *et al*. 2005). According to Ngambu *et al*. (2012) flavour development is highly influenced by lipids. Moody, (1983) stated that during production, handling, and cooking process, lipids act as solvents for volatile compounds. Despite reports disagreeing on what age group is the most acceptable for flavour intensity, the intensity increases with animal age (Simela *et al*. 2003).

2.7.2 Meat juiciness

Meat juiciness is the dampness during the first bite and sustained juiciness due to the fat present in the meat. According to Muchenje *et al*. (2008), well-marbled carcasses have a high level of meat juiciness. This is in agreement with Webb *et al*. (2005) who stipulated that intramuscular lipids and moisture level of the meat determine meat juiciness. Lawrie (2006) reported that young animals' meat gave an initial impression of juiciness but subsequently became dry since they did not have much fat.

2.7.3 Tenderness

Tenderness is a vital sensory characteristic of meat and a major quality factor (Sebsibe, 2006). Several factors influence the tenderness of meat during cooking, including collagen content and heat stability (Muchenje *et al*. 2009). Consumers' overall satisfaction, purchasing decisions, and willingness to pay are all influenced by the tenderness and juiciness of the meat (Banović *et al*. 2009). Meat tenderness is affected by animal type, genotype, diet, age of the animal, degree of fatness, and muscle position (Muchenje *et al*. 2008). Tenderness improves with muscle ageing (Simela, 2005). Muchenje *et al*. (2009) reported that myofibrillar protein proteolysis and sarcomere length are responsible for the majority of the difference in tenderness between aged and young meat.

2.8 Summary

The increasing human population in developing and developed countries has resulted in increased demand for animal protein. Rabbit farming has a potential in filling the gap in shortages of animal protein supply and this can assure food and nutrition security as well as economic growth of the country. There is little knowledge about rabbit production and the majority of people are not familiar with rabbit meat and its health benefits. Rabbits are easy to be managed, have short generation interval and high prolificacy in that case small holder famers could gain more profit, job creation and ensuring of food security.

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CHAPTER 3

Effect of balanced dietary protein on physicochemical meat quality of New Zealand White and Californian rabbits

Abstract

The objective of the study was to investigate the effect of balanced dietary protein on physico-chemical meat quality of different sexes and breeds of New Zealand White (NZW) and Californian (CAL) rabbits. A total of eighty (80) NZW and CAL rabbits were allocated to six balanced dietary protein levels (T1=126g/kg, T2= 143g/kg, T3= 161g/kg, T4=178g/kg, T5= 196g/kg and T6= 213g/kg) at weaning age (35 days). The diets were formulated to meet the rabbit's nutritional requirements, complete and balanced. The rabbits were fed twice a day at 08:00 am and 16:00 pm with water provided *ad libitum*. The rabbits were then slaughtered after a period of 56 days and 8 hours of fasting at Rota master farm located 100 km from UKZN. Meat quality traits including pH, colour (L*, a* and b*), water holding capacity, cooking loss, shear force and drip loss were measured. The results of the current study showed no effects of balanced dietary protein on pH, colour, WHC, cooking loss, tenderness and drip loss on meat quality of New Zealand White and Californian rabbits. It was therefore concluded that the physicochemical quality of NZW and CAL rabbits was not affected by the balanced dietary protein.

Key words: Rabbit meat, Colour, pH, Drip loss, Cooking loss, Tenderness.

3.1 Introduction

Demand for meat products is expected to increase across the globe as the world population rises, particularly in developing countries (Romanov *et al*., 2022). In South Africa, meat is considered as one of the most expensive food commodity, thus creating financial pressure to most consumers in the country (Delport *et al*., 2017). South Africa is faced with increasing population growth, with its most people living below the poverty line and unable to meet the minimum requirement or daily recommended minimum protein of 70g by FAO (1987). The FAO recommends that at least 50% of that protein should be animal protein. Despite this, poultry farming is however faced by number of challenges such as import penetration, disease outbreaks and harsh environmental conditions with respect to heat stress (Maqsood *et al*., 2021). In this regard, there is a need to find alternative animal protein sources that have a fast growth rate such as rabbit.

A study by Dalle Zotte (2014) revealed that meat from rabbits is nutritious and healthy compared to beef, mutton and pork. Rabbit meat poses excellent dietary properties and nutritive value (Petrescu and Petrescu-Mag, 2018). It is low in fat content with a favourable proportion of saturated, monosaturated polyunsaturated and fatty acid (Bouzaida *et al*., 2021). Rabbit meat is rich in protein with excellent essential amino acid (Sayed and Ali, 2022). According to Castrica *et al*. (2022), rabbit meat has been reported to have low cholesterol and sodium contents on average of 47 mg/100 g and 42 mg /100 g, respectively. In addition, rabbit meat is also a significant source of high micronutrients and it does not contain uric acid unlike red meat (Petracci and Leroy, 2018).

Amongst the physicochemical properties, pH, colour, water holding capacity (WHC), drip loss, cooking loss (CL) and tenderness are known as the key measures of meat quality (Simonová *et al*., 2009). The above-mentioned meat quality traits are largely influenced by type of feed which is fed and consumed by the animals. Dietary protein has been reported to have an effect on meat quality of broilers as it changes carcass composition, lowers muscle pH and increase meat yield (Tesseraud *et al*., 2003; Sterling *et al*., 2006). Wang *et al*. (2022), observed an improvement in meat quality attributes such as tenderness, drip loss and colour in pigs fed different dietary protein levels. It is, however, not clear whether dietary protein supplementation have an influence in different breeds of rabbits. NZW and CAL are the most popular rabbit breeds that are commercially used worldwide especially for meat production purposes (El-Badry *et al*., 2019; Daszkiewicz and Gugołek, 2020). The commercial rabbit meat production industry in South Africa has been non-existent, however recently rabbit meat has gained more emphasis and attention in the area of research. September (2021) and Hoffman (2005) reported low consumption patterns of rabbit meat in South Africa. Furthermore, the quality of meat is influenced by type of breed as well as type of feed offered to animals (Xazela *et al*., 2011). Understanding the physicochemical properties of NZW and CAL as influenced by balance dietary protein will help in making decisions on which breed will be desired for meat production. The objective of the study was, therefore, to determine the effect of balanced dietary protein on physico-chemical quality of NZW and CAL rabbits. The null hypothesis states that a balanced dietary protein will have no adverse effect on the physico-chemical quality of NZW and Cal rabbits.

3.1 Materials and Methods

3.1.1 Study Site

The study was conducted at the University of KwaZulu-Natal (UKZN), Ukulinga Research farm Pietermaritzburg, South Africa which is positioned at 30° 24’S, 29° 24’E and altitude ranges from 80 700 to 775m above sea level. The mean annual rainfall is 735mm, which mostly occurs between October and April. All experimental measures were accepted and approved by the Animal Research Ethics committee at the University of KwaZulu-Natal, South Africa (Reference number: AREC/00002707/2021).

3.1.2 Animal housing

A total of eighty (80) rabbits from two commercial rabbit strains (New Zealand White and Californian) were used for this study. 56 rabbits were from NZW, 8 rabbits were slaughtered before feeding trial, the remaining 48 rabbits were allocated to 6 dietary treatments, Californian rabbits were 24 and allocated to 6 dietary treatments. They were obtained from Future Farmers Farm which is located in Howick, KwaZulu-Natal, South Africa 29, 8 km apart from UKZN. The rabbits were chosen randomly at the weaning stage at 35 days of age and were delivered to the farm in plastic crates in a closed vehicle suitable aerated early hours of the morning to avoid heat stress. At the outset of the trial, each rabbit was labelled, and its body weight was recorded. The rabbits were allocated randomly to individual cages inside the rabbit house. The housing had a concrete floor with wood shavings below the cages that were used to absorb urine. Rabbits were kept at optimum room temperature (22° C).

3.1.3 Experimental diets

The feeding program was divided into two four-week phases starting at weaning, with dietary protein levels being reduced in each subsequent period sustaining the same relative difference between levels. Within each period, six levels of balanced protein were applied (T1=126g/kg, T2= 143g/kg, T3= 161g/kg, T4=178g/kg, T5= 196g/kg and T6= 213g/kg) with 8 rabbits under each dietary treatment. The experimental feeds were produced using the Winfeed 3 to ensure that the diets were properly. Win feed is a software program used to formulate animal feed according to animal nutrient requirements at the lowest cost (Kasima, 2019). These feeds were mixed and then blended on the farm. The two basal feeds contained 4.9 and 8.1 g digestible lysine (dLys)/kg, respectively, each feed containing 10.0 MJ DE/kg. The amino acid levels used were the same in both basal feeds, were based on those recommended by De Blas *et al.*

(1998) as were the major and minor mineral contents, and energy. After all the ingredients were mixed, all feeds were pelleted by a commercial company. Ingredients and nutrient composition are presented in Table 3.1. The chemical composition of these diets is presented in Table 3.3 and Table 3.4.

Table 3. 1: Ingredients and nutrient composition in the low and high basal protein feeds

Ingredients	Low protein basal (kg)	High protein basal (kg)
Barley	114	68.3
Oats	150	50
Wheat bran	62.7	-
Molasses	0.75	2.5
Sunflower hulls	-	60
Soy bean 46	-	67.4
Sunflower 37	-	82.3
Lucerne meal 15%	165	165
Limestone	2.4	1.3
Salt	1.7	1.85
Monocalcium phosphate	0.1	0.1
Oil sunflower	0	4.05
Robenidine	0.05	0.05
L-lysine HCL	0.25	0.15
L-threonine	0.1	0.5
DL Methionine	0.3	0.75
Vit+min premix	0.75	0.75
Crude protein	117	170
Crude fibre	9.38	12.63
Gross energy (MJ/KJ)	14	17

Metabolizable energy (MJ/KJ)	14	17

Table 3. 2: Proportions of high and low protein basal feeds used for each dietary treatment and feeding period

Protein	Period 1		Period 2	
	HP	LP	HP	LP
1	20	80	0	100
2	36	64	16	84
3	52	48	32	68
4	68	32	48	52
5	84	16	64	36
6	100	0	80	20

Table 3. 3: Proximate chemical analysis of the six experimental diets for period 1 (g/kg)

Experimental diets	Crude protein	Crude Fiber	Gross Energy (MJ/KJ)	ME[1] (MJ/KJ)
1	127	10.1	17.5	14.4
2	137	12.3	16.8	13.8
3	144	10.3	17.6	14.4
4	153	10.8	17	13.9
5	161	15.4	16.9	13.9
6	170	10	17	13.9

[1] estimated as GE * 0.82

Table 3. 4: Proximate chemical analysis of the six experimental diets for period 2 (g/kg)

Experimental diets	Crude Protein	Crude Fiber	Gross Energy (MJ/KJ)	ME[1] (MJ/KJ)
1	117	8.9	17.2	14.1
2	125	10.1	16.7	13.7
3	134	9.6	16.8	13.8
4	142	9.5	16.9	13.9
5	151	12.9	17.6	14.4
6	159	12.2	17.1	14

[1] estimated as GE * 0.82

3.2 Slaughter

At the end of the trial after 56 days , rabbits were subjected to 8 hours of fasting, six rabbits from each treatment were randomly picked for slaughter. The rabbits were transported by a bakkie in plastic crates on a closed vehicle suitable aerated to the Rota master farm abattoir which is 100 km away from the research farm. The rabbits were fasted for 8 hours and were given clean water. They were electrically stunned and bled immediately. Carcasses were stored in a cold room for 15-30 minutes and chilled at 3-4°C.

3.3 Meat sample preparation

Samples were randomly taken from *longissimus dorsi* muscle, labelled and kept in a cooler box filled with ice at 4°C. Samples were then conveyed using the same bakkie to Dietetics Human nutrition laboratory (UKZN-PMB) Campus for meat quality analysis.

3.4 Physicochemical analysis

3.4.1 pH determination

Meat pH was measured at 45 minutes and 24 hours *post mortem* on *Longissimus* muscle using a pH meter that has a sharp electrode (Crison pH 25 Instruments S.A., Alella, Spain). Standard pH solutions of pH 4, pH 7, and pH 9 were used to calibrate the pH meter before taking measurements.

3.4.2 Determination of meat colour

Meat colour (Lightness; L*, redness; a*, yellowness; b*) was measured 45 minutes after slaughter from the longissimus muscle using a Minolta colour guide 45/0 BYK-Gardner GmbH machine. The mean of the replicates was used for analysis.Chroma and Hue angle were calculated as follows: Chroma= (a^2+b^2) *0.5 and Hue angle= $[\tan^{-1}(b^*)/(a^*)]$.

3.4.3 Water holding capacity

Water holding capacity was assessed using the texture analyser technique by pre-weighing (8 g) of samples which were inserted in-between filter-papers and pressed under a texture analyzer with a pressure of 30 kg for 5 min. Water holding capacity was calculated as: **WHC =** (water content -water loss) / water content) * 100.

3.4.4 Drip loss

Drip loss analysis was conducted using a method adapted from Zhang *et al*. (2009). The samples were quickly cut into blocks weighing between 2-3 grams using a knife. Initial weights were recorded for the sample weights (W1). The samples were hooked and hung in a plastic container using wire steel, and the container was properly sealed to prevent the samples from touching the bottle's sides. After 72 hours in a cold room (4°C), samples were taken, carefully dried to remove excess moisture from the meat's surface, and reweighed (W2).

$$Drip\ loss\ (\%) = [(W1 - W2)/ W1] \times 100$$

3.4.5 Warner-Bratzler shear force and cooking losses determination

Samples were first weighed (W1) then cooked in a water bath for 45 minutes at 85°C, cooled and were reweighed (W2) for determination of cooking loss. Cooking loss was estimated as **Cooking loss (%) = [(W1 –W2)/W1] × 100** Yang *et al*. (2010).

The samples were then used to determine WBSF values after cooking loss was measured. Three 10 mm-width subsamples were cored parallel to the meat's grain. Using a Warner Bratzler (WB) shear device mounted on an Instron (Model 3344) Universal testing apparatus (cross head speed at 400mm/min, one shear in the center of each core), the samples were sliced parallel to the direction of the fibers.

3.5 Statistical analysis

Physicochemical properties were analysed using the General linear models' procedure (GenStat 20th edition, VSN International, 2022). Analysis of variance was used to evaluate treatment means, and simple linear regression with groups was used to analyse the response of the variables of interest to dietary protein. Tukey's significant difference test was used to compare means at $P < 0.05$. The Model used was:

$$Y = a \pm bx$$

Where:

Y = Variate being regressed

a = Constant term

b = Regression coefficient

x = dietary protein level

3.7 Results

3.7.2 Physico-chemical properties

Table 3.5 and Table 3.6 illustrate that the balanced dietary protein did not have an influence ($P > 0.05$) on pH. However, pH_{45} ranged from 6.35 to 6.73 and pH_{24} ranged from 5.60 to 5.93. Same applies with the regression results there was no linear effect observed between pH and the experimental diets.

Table 3. 5: Mean values for meat pH of NZW and CAL as influenced by balanced dietary protein

Parameter	Breed	126	143	161	178	196	213	SEM
pH_{45}	NZW	6.730[a]	6.420[a]	6.650[a]	6.610[a]	6.660[a]	6.570[a]	0.04372
	CAL	6.600[a]	6.350[a]	6.400[a]	6.650[a]	6.400[a]	6.650[a]	0.0583
pH_{24}	NZW	5.930[a]	5.990[a]	5.970[a]	5.910[a]	5.980[a]	5.900[a]	0.03619
	CAL	5.750[a]	5.700[a]	5.650[a]	5.850[a]	5.600[a]	5.850[a]	0.04323

List of abbreviations: NZW= New Zealand White, CAL= Californian, SEM= standard error of means

Table 3. 6: The effect of balanced dietary protein on the pH of meat from NZW and CAL rabbits using linear regression with groups1

Parameter	Estimate	SE	t(20 df)	t pr.	R^2
pH_{45}					0.907
Constant	6.443	0.122	52.74	<.001	
Protein	0.0186	0.0314	0.59	0.561	
Breed NZW	0.175	0.173	1.01	0.322	
Protein*Breed NZW	-0.0220	0.0444	-0.50	0.625	
pH_{24}					0.597
Constant	5.6933	0.0946	60.16	<.001	
Protein	0.0114	0.0243	0.47	0.643	
Breed NZW	0.277	0.134	2.07	0.051	
Protein*Breed NZW	-0.0183	0.0344	-0.53	0.601	

[1] Reference breed was CAL

Table 3.7 and Table 3.8 indicate that the experimental diets had no effect on colour coordinates ($P > 0.05$). Lightness (L*) ranged from (40.92 to 52.90, redness (a*) ranged from 3.06 to 10.85, yellowness (b*) ranged from 10.90 to 13.33, Chroma (9.07 – 16.94) and Hue angle (50.62 to 66.73).

Table 3. 7: Mean values for meat colour co-ordinates of NZW and CAL as influenced by balanced dietary protein

Parameter	Breed	126	143	161	178	196	213	SEM
L*	NZW	49.44^{a}	49.95^{a}	52.40^{a}	49.73^{a}	51.71^{a}	49.97^{a}	0.6482
	CAL	43.69^{a}	47.19^{a}	40.92^{a}	42.99^{a}	43.78^{a}	43.45^{a}	1.399
a*	NZW	8.715^{a}	6.995^{a}	5.350^{a}	5.590^{a}	3.060^{a}	5.875^{a}	0.7502
	CAL	9.300^{a}	9.150^{a}	9.600^{a}	10.855^{a}	9.445^{a}	9.370^{a}	0.6895
b*	NZW	12.43^{a}	11.34^{a}	10.26^{a}	10.90^{a}	8.38^{a}	11.65^{a}	0.5871
	CAL	12.32^{a}	13.14^{a}	11.97^{a}	12.80^{a}	12.79^{a}	12.04^{a}	0.4978
Chroma	NZW	15.19^{a}	13.33^{a}	11.58^{a}	12.59^{a}	9.07^{a}	13.07^{a}	0.7856
	CAL	15.50^{a}	16.08^{a}	15.36^{a}	16.94^{a}	16.03^{a}	15.32^{a}	0.6841
Hue angle	NZW	55.13^{a}	58.46^{a}	62.54^{a}	66.00^{a}	66.73^{a}	63.63^{a}	2.2569
	CAL	53.41^{a}	55.20^{a}	53.06^{a}	50.62^{a}	53.27^{a}	52.14^{a}	1.820

List of abbreviations: L*= Lightness, a*= redness, b*= yellowness, NZW= New Zealand White, CAL= Californian, SEM= standard error of means.

Table 3. 8: The effect of balanced dietary protein on the colour coordinates of meat from NZW and CAL rabbits using linear regression with groups[1]

Parameter	Estimate	SE	T (20 df)	t pr.	R^2
a* (redness)					-2.534
Constant	9.37	1.60	5.86	<.001	
Protein	0.071	0.410	0.17	0.864	
Breed NZW	-0.86	2.26	-0.38	0.706	
Protein*Breed NZW	-0.807	0.580	-1.39	0.180	
b* (yellowness)					-0.713
Constant	12.7	1.27	10.01	<.001	
Protein	-0.045	0.325	-0.14	0.891	
Breed NZW	-0.63	1.79	-0.35	0.728	
Protein*Breed NZW	-0.301	0.460	-0.65	0.520	
L* (Lightness)					-2.677
Constant	44.6	2.59	17.20	<.001	
Protein	-0.267	0.666	-0.40	0.693	
Breed NZW	5.41	3.67	1.47	0.156	
Protein*Breed NZW	0.417	0.942	0.44	0.662	
Hue angle					-1.753
Constant	54.4	5.01	10.86	<.001	
Protein	-0.42	1.25	-0.32	0.750	
Breed NZW	0.60	7.09	0.08	0.934	
Protein*Breed NZW	2.44	1.82	1.34	0.195	
Chroma					0.607
Constant	15.8	1.67	9.46	<.001	
Protein	0.017	0.429	0.04	0.969	

Breed NZW	-1.11	2.36	-0.47	0.645
Protein*Breed NZW	-0.655	0.607	-1.08	0.293

[1] Reference breed was CAL

Table 3.9 and Table 3.10 show no differences on water holding capacity of meat from New Zealand White and Californian rabbits fed balanced dietary. WHC values ranged from 10.06 to 18.59% for NZW and 16.57 to 19.89 % or CAL rabbits.

Table 3. 9: Mean values for water holding capacity of NZW and CAL as influenced by balanced dietary protein

Parameter	Breed	126	143	161	178	196	213	SEM
WHC (%)	NZW	10.47^{a}	13.62^{a}	11.11^{a}	18.59^{a}	14.41^{a}	10.06	1.129
	CAL	18.90^{a}	16.57^{a}	20.46^{a}	19.89^{a}	19.44^{a}	19.60	1.094

List of abbreviations: WHC= water holding capacity, NZW= New Zealand White, CAL= Californian, SEM standard error of means.

Table 3. 10: The effect of balanced dietary protein on the water holding capacity of meat of NZW and CAL rabbits using linear regression with groups1

Parameter	Estimate	SE	t(20)	tpr.	R^2
Water holding capacity					0.584
Constant	17.99	2.64	6.82	<.001	
Protein	0.330	0.677	0.49	0.631	
Breed NZW	-5.72	3.73	-1.53	0.140	
Protein*Breed NZW	-0.107	0.957	-0.11	0.912	

[1] Reference breed was CAL

Table 3.11 and Table 3.12 indicate that the balanced dietary protein did not have a significant effect (P > 0.0.5) on the cooking losses of meat from the two rabbit strains. The results ranged (25.23 – 31.95%) for New Zealand White and (10.78 – 15.86%) for Californian rabbits. No linear trends were found for the experimental diets and cooking losses.

Table 3. 11: Mean values for cooking loss of NZW and CAL as influenced by balanced dietary protein

Parameter	Breed	126	143	161	178	196	213	SEM
Cooking loss (%)	NZW	29.93^{a}	25.23^{a}	30.15^{a}	31.95^{a}	28.85^{a}	27.48^{a}	1.018
	CAL	12.98^{a}	11.02^{a}	10.78^{a}	10.85^{a}	15.86^{a}	12.64^{a}	0.7651

List of abbreviations; NZW= New Zealand White, CAL= Californian, SEM= standard error of means.

Table 3. 12: The effect of balanced dietary protein on the cooking loss of meat of NZW and CAL rabbits using linear regression with groups1

Parameter	Estimate	SE	t(20)	t pr.	R^2
Cooking loss					0.112
Constant	11.07	2.13	5.20	<.001	
Protein	0.368	0.547	0.67	0.509	
Breed NZW	17.82	3.01	5.92	<.001	
Protein*Breed NZW	-0.355	0.773	-0.46	0.651	

[1] Reference breed was CAL

Table 3.13 and Table 3.14 illustrated that there was no significant dietary effect on shear force values of New Zealand White and Californian rabbits. Higher shear force values were observed on Californian rabbits.

Table 3. 13: Mean values for Shear force values of NZW and CAL as influenced by balanced dietary protein

Parameter	Breed	126	143	161	178	196	213	SEM
Shear force (N)	NZW	66.82[a]	56.94[a]	41.55[a]	52.51[a]	52.02[a]	53.44[a]	3.465
	CAL	100.35[a]	93.02[a]	58.38[a]	99.01[a]	72.06[a]	73.49[a]	7.21

List of abbreviations; NZW= New Zealand White, CAL= Californian, SEM= standard error of means.

Table 3. 14: The effect of balanced dietary protein on the shear force of meat of NZW and CAL rabbits using linear regression with groups1

Parameter	Estimate	SE	t(20 df)	t pr.	R^2
Shear force					0.596
Constant	98.4	12.9	7.61	<.001	
Protein	-4.47	3.32	-1.35	0.193	
Breed NZW	-37.4	18.3	-2.05	0.054	
Protein*Breed NZW	2.45	4.70	0.52	0.607	

[1] Reference breed was CAL

There was no significant dietary effect on drip loss of NZW and CAL rabbits as shown in table 3.15 and table 3.16. The results ranged from 6.245 to 8.165%.

Table 3. 15: Mean values for drip loss of NZW and CAL as influenced by balanced dietary protein

Parameter	Breed	126	143	161	178	196	213	SEM
Drip loss (%)	NZW	7.725[a]	6.920[a]	6.245[a]	8.165[a]	6.830[a]	7.450[a]	0.3810
	CAL	8.120[a]	7.550[a]	7.560[a]	6.355[a]	7.415[a]	7.415[a]	0.2909

List of abbreviations; NZW= New Zealand White, CAL= Californian, SEM= standard error of means.

Table 3. 16: The effect of balanced dietary protein on the drip loss of meat of NZW and CAL rabbits using linear regression with groups1

Parameter	Estimate	SE	t(20)	t pr.	R^2
Drip loss					0.957
Constant	8.006	0.794	10.08	<.001	
Protein	-0.185	0.204	-0.91	0.375	
Breed NZW	-0.8	1.12	-0.72	0.479	
Protein*Breed NZW	0.19	0.88	0.67	0.511	

[1] Reference breed was CAL

3.8 Discussion

Several meat quality attributes are affected by pH, including tenderness, water-holding capacity, colour and juiciness (Mir *et al*. 2017). Husak *et al*. (2008) stated that meat with a higher pH maintains better colour and improves moisture retention. Bai *et al*. (2013), highlighted that post-mortem glycolysis reduces lactic acid in muscle, resulting in a substantial increase in meat pH.

The current study found no linear trends for pH values between the two breeds at pH 45 and pH 24. There is inadequate evidence published on the effect of balanced dietary protein on physicochemical of NZW and CAL rabbits. However, a study by Ribeioro *et al*. (2014) found that dietary protein content also had no influence on pH of breast meat in broilers. These results are in line with Sirtori *et al*. (2014), who found that dietary protein did not influence pH 45 and pH 24 on pigs. In addition, Alonso *et al*. (2010) reported no dietary protein influence on pH 24 of pork. A study by Wang *et al*. (2021) also observed non-significant levels of dietary protein in both pH 45 and pH 24 of lambs. In general, at 24 hours post slaughter pH values declined significantly. In the present study the ultimate pH fell within the normal range (5.6 and 5.85), which is accepted in rabbit meat. A pH which is below the normal range is associated with meat that is firm and dry due to the myofibrillar network shrinkage and the reduction of water holding capacity (Morshdy *et al*., 2002).

Colour of meat affects consumer acceptance of meat and is an influential factor when purchasing meat (Muchenje, 2009; Xazela, 2012). Ribarski and Genchev (2013), stated that colour of the meat is indicative of tenderness and freshness of the meat and it differs with species. However, Joo *et al*. (2013) reported that the substantial variations in the range of meat colour among various animals are primarily caused by the amount of myoglobin in muscle. Moreover, the redness and desired appeal of meat are highly correlated with the myoglobin concentration of the meat (Khliji *et al*., 2010). In the current, study there was no significant difference (P> 0.05) in the colour Lightness, redness and yellowness of meat across the dietary treatments. this could have been attributed These results correspond with the findings by Bidner *et al*., (2004) who found no differences in colour of pork. Tarasewicz *et al*. (2007) also found no effect of protein levels on colour coordinates L*, a* and b* of quail breast meat. Additionally, Wang *et al*. (2021) also reported no significant differences in colour coordinates of lambs fed levels of dietary protein. According to Piolo *et al*. (2002), when the hue angle is close to 90° the colour become yellowish. However, the results of hue angle in the current study were below 90°. Yellow meat appears to be undesirable to consumers which can affect their meat acceptance and purchasing decisions (Altmann *et al*., 2022).

In the present study the balanced dietary protein content did not influence shear force and these results agree with Teye *et al*. (2006) who reported no effect of protein content on shear force. However, this lack of effect could be due to a negative relationship between the dietary protein levels and the shear force parameter. There was no significant effect of dietary protein levels on drip loss. A study by See and Odle (2000) also revealed that balanced dietary protein had no influence on drip loss in broilers. The results of the current study are in line with the findings from other studies which found no significant effect of dietary protein on drip loss of pork (Witte *et al*., 2000). Furthermore, Alonso *et al*. (2010) also did not find a dietary effect of protein content on drip loss in pigs.

Consumers are less likely to choose meat when there are high cooking losses as stated by Aaslyng *et al*. (2003). A reduction in carcass juiciness is associated with an increase in cooking loss (Schonfeldt and Strydom, 2011). However, in the current study no differences were observed in cooking loss which corresponds with the observations by (Ribeioro *et al*., 2014) who found no significant effect of dietary protein on cooking loss of breast meat from broilers.

Although the study did not show a significant impact of a balanced dietary protein on meat quality attributes of rabbits, it does not necessarily imply that feeding such protein is detrimental to rabbits. The absence of significant results merely indicates a negative correlation between balanced dietary protein and specific measures of meat quality. Therefore, it is imperative to undertake further research to identify the dietary protein levels that can affect the meat quality of rabbits positively.

The study's findings suggest that there is a need for more comprehensive studies to establish the optimum dietary protein levels for rabbits. These studies can explore the influence of different dietary protein levels on rabbit's growth, metabolism, and ultimately, meat quality. The results of these studies would help rabbit farmers make informed decisions when selecting a dietary protein level for their rabbits. Furthermore, this information would contribute to the development of better feeding practices for rabbits, ultimately improving the quality of their meat for human consumption.

3.9 Conclusion

Results from this study showed that balanced dietary protein levels no effect on the meat quality attributes. We concluded that the balanced dietary protein has the potential to be used in rabbits diets without compromising their performance and health status. An optimum dietary protein inclusion level could not be determined suggesting a need to further investigate the effect of balanced dietary protein at higher inclusion levels.

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CHAPTER 4

Consumer sensory evaluation of New Zealand White and Californian Rabbit Meat Fed Balanced Dietary Protein

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Abstract

The objective of the current study was to determine the effect of balanced dietary protein (BDP) on sensory attributes of different sexes, breeds New Zealand (NZW) and Californian (CAL) rabbits. A total of eighty rabbits (80) NZW and CAL were used. Rabbits were grown under the same conditions, fed the same diet and slaughtered after a period of 56 days. Rabbit meat was prepared by using different thermal treatments (boiling and frying). The sensory analysis of rabbit's meat was carried out on the *Longissimus* muscle. A total of three different tribes, which include Shona, Zulu and Xhosa composed of different age groups were used to study sensory evaluation of rabbit's meat. In this study, the first bite was rated superior ($P < 0.05$) in NZW breed for cooked meat. Higher scores were observed in overall flavour intensity for fried meat in NZW breed ($P < 0.05$). Shona tribe gave higher scores ($P < 0.05$) in both cooked and fried meat for all sensory properties. Xhosa tribe gave highest scores ($P < 0.05$) in First bite, muscle fibre and overall tenderness in cooked meat. With regards to age, the highest scores ($P < 0.05$) for sustained impression of juiciness from fried meat were given by respondents in age group 26-30 years of age. High scores ($P < 0.05$) were observed in both females and males for fried meat than cooked meat for all sensory characteristics. Highest scores ($P < 0.05$) were detected in overall flavour intensity of fried meat in all tribes. It was therefore concluded that consumers prefer fried meat than cooked meat based on the scores given by the respondents.

Key words: Sensory evaluation, Rabbit meat, Cooked meat, Fried meat, Gender, Age, dietary protein.

4.1 Introduction

Globally, meat from rabbits is typically a popular food source (Abdel-Naeem *et al*., 2021). Its consumption is mainly an eating habit across European (EU) countries, North Africa, in particular Egypt and Middle East (Cullere and Dalle Zotte, 2018). The meat from rabbits is rich protein of high biological value, low levels of cholesterol (almost free) and low levels of fat (Para *et al*., 2015). Several studies revealed that meat from rabbits contain both macro and micro elements, including phosphorus, potassium and selenium (Dalle Zotte and Szendrő, 2011), thus it is regarded as an ideal healthy diet for human nutrition. Zalton (2017) denoted that rabbit meat is classified as a white meat with a tender taste.

Rabbit meat is suggested to be included amongst other meat to be in the nutritional regime of patients suffering from certain illnesses, including cardiovascular diseases (Khan *et al*., 2016). According to Rasinska *et al*. (2018), ions and hind legs are considered as the most valuable cuts, merely because of their high lean content. Meat sensory evaluation are crucial for the consumer's choice and can be made using a trained taste panel. Furthermore, (Das *et al*., 2020) revealed that sensory evaluation also has a great impact on the willingness of a consumer to reject or accept the meat. A number of studies from the literature highlighted that cooking of rabbit meat is considered as a vital process (Rasinska *et al*., 2013), which allow its consumption as it is usually not subjected for salting, as well as aging unlike other species (Crovato *et al*., 2022).

Cooking generally helps in the creation of pleasant characteristics, tenderness, flavour and taste. Furthermore, cooking also decrease production of microbial loads, thus prolonged meat shelf life (Đorđević and Đurović-Pejčev, 2015). Earlier study by Combes *et al*. (2004) found that sensory attributes differ according to the method of cooking, such as boiling or frying. Apart from this, age, sex, nutrition and breed might affect the final quality of rabbit meat, namely sensory attributes. Therefore, understanding the mechanism involved in sensory attributes as it is affected by aforementioned factors is of paramount importance. Interestingly, to our knowledge, few studies, if any, have focused on examining the balanced dietary protein in terms of sensory quality of NZW and CAL rabbit meat. Hence, the current study aimed at extending current knowledge by assessing the effect of Balanced dietary protein on sensory evaluation (sensory panel) of NZW and CAL rabbit meat.

4.2 Materials and methods

The same material and methods were used as explained in Chapter 3.

4.3 Sensory evaluation

The analysis of sensory evaluation was done randomly by a consumer panel composed of 15 students and staff from University of KwaZulu Natal based on seven descriptors, which are illustrated in Table 4.1. Two thermal treatments were used in this study, namely boiling and cooking. The meat samples were first deboned and cut into smaller pieces approximately of 2cm x 2cm boiled and fried for 30 minutes, salt was added to taste. Meat from each cooking method was randomly distributed to the tasting panel. Different ages (21-25, 26-30 and>30), gender (male and female) and tribes (Xhosa, Zulu and Shona) were used for the meat tasting. The panellist was trained on how to record the scores for each sample and were told to rinse their mouths with water prior tasting the next sample.

Table 4. 1**:** Meat sensory evaluation characteristics

Items	Description	Scores
AI	The intensity of an odour as perceived at first	1 = extremely dry and 8 = extremely juicy
IJ	The amount of liquid that drips from the cut surface when the thumb and forefinger are pressed together	1 = extremely dry and 8 = extremely juicy
FB	The impression that you form on the first bite	1 = extremely tough, and 8 = extremely tender
SJ	Sensation of juiciness you get when you begin chewing	1= extremely dry and 8 = extremely juicy
MFT	Chew the sample with a light chewing action	1 = extremely tough, and 8 = extremely tender
ACT	The chewiness of the meat	1 = extremely and 8 = none
OFI	The interaction of flavour while chewing and swallowing referring to the typical beef flavour	1 = extremely bland and 5 = slightly intense

Abbreviations: AI, Aroma intensity; IJ, Initial impression of juiciness; SJ, sustained impression of juiciness; FB, first bite; MFT, muscle fibre and overall tenderness; Amount of connective tissue (Residue), ACT; OFI, overall flavour intensity

4.4 Statistical analysis

The general analysis of variance procedure of GenStat 20th edition, VSN International (2016) was used to determine the effects of diet, genotype and thermal preparation on meat sensory characteristics of rabbits. Turkey's test was used to compare means and considered significant at $P < 0.05$.

The following model was:

$$Yijkl = \mu + Ci + Gj + Dk + (G \times D)jk + (G \times C)ij + (D \times C)ik + (G \times D \times C)ijk + Eijkl$$

Where Yijkl = response variable (aroma intensity, initial impression of juiciness, first bite, sustained impression of juiciness, fibre and overall tenderness, amount of connective tissue and overall flavour intensity)

μ = overall mean common to all observations

Ci = effect of thermal treatment (boiled, fried)

Gj = effect of genotype (NZW and CAL)

Dk = effect of diet

$(G \times D)$ jk= interaction between diet and genotype

$(G \times C)$ij = interaction between thermal treatment and genotype

$(D \times C)$ik = interaction between diet and thermal treatment

$(G \times D \times C)$ijk = interaction between diet, genotype and thermal treatment

Eijkl = random error distribution as N (0,I δ2)

A separate model was used to test for the effects of cooking method, gender, tribe and sex of panelist on the sensory scores. Turkey's test was used to compare means and considered significant at P < 0.05.

4.5 Results

Table 4.2 and Table 4.3 represent the influence of breed, diet and thermal treatment on sensory characteristics. Thermal treatment and breed had a significant influence (P <0.05) on aroma intensity. Diet, however, had no significant influence (P> 0.05) on aroma intensity. Cooked meat from New Zealand white (NZW) had a stronger aroma intensity (P <0.05). Thermal treatment, breed and diet significantly influenced (P <0.05) initial impression of juiciness. Fried meat for both breeds was juicier in protein level 178g/kg. Thermal treatment had no significant effect (P> 0.05) on first bite. However, breed or genotype had a significant influence (P<0.05) on first bite. Higher scores for first bite were observed in cooked meat of NZW. Thermal treatment and genotype had a significant influence (P <0.0.5) on sustained impression of juiciness. Diet did not influence (P> 0.0.5) sustained impression of juiciness. Sustained impression of juiciness was rated higher for fried meat from NZW.

Thermal treatment and breed had a significant influence (P <0.0.5) on muscle fibre and overall tenderness. Muscle fibre and overall tenderness scores showed that panelists regarded both cooked and fried meat tender from both breeds. Amount of connective tissue was influenced (P <0.05) by thermal treatment and breed. Diet had a significant influence on the amount of connective tissue scores. Fried meat had higher amount of connective tissue scores than cooked meat. Overall flavour intensity was influenced by (P<0.05) by thermal treatment and breed. Overall flavour intensity was observed to be higher in fried meat than cooked meat.

Tables 4.4, 4.5 and 4.6 show the influences of tribe, gender and age on sensory attributes of rabbit meat. Gender was observed to have a significant influence (P<0.0.5) across all the sensory characteristics. Both genders gave higher scores ($P<0.0.5$) in aroma intensity of fried meat. For the initial impression of juiciness, males gave high values ($P<0.0.5$) for fried meat. Higher scores have been observed from male respondents for first bite in cooked meat. In contrary, females gave higher scores for first bite in fried meat. Sustained impression of juiciness was rated superior in fried meat by males compared to females. Males gave higher scores in muscle fibre and overall tenderness in fried meat. However, higher scores were observed in amount of connective tissue and overall flavour intensity for both genders and thermal preparations ($P<0.05$). Tribe and thermal treatment had a significant effect on all the sensory characteristics except for first bite ($P<0.05$). Zulu and Shona participants rated aroma intensity superior ($P<0.0.5$) in both cooking methods. Xhosa respondents gave high scores for first bite in cooked meat. Moreover, Zulu and Shona participants gave higher values for sustained impression of juiciness for fried meat. However, all tribes gave higher values for muscle fibre and overall tenderness for both cooked and fried meat. Participants from the Zulu tribe gave highest scores in amount of connective tissue in fried meat. Highest scores were observed in overall flavour intensity of fried meat in all tribes.

Consumer age group had a significant influence ($P<0.05$) on meat sensory scores across thermal treatments. Age had a significant influence in aroma intensity. Fried meat was rated superior for aroma intensity by age group 21-25 years of age. However, age group 26-30 years of age gave higher scores for both cooking methods in aroma intensity. No differences were observed between the scores given by age group ≥30 for aroma intensity. Age group 26-30 considered fried meat juicier than cooked meat due to high values for initial impression of juiciness. Age group 21-25 rated first bite superior in both thermal treatments, however age group ≥30 gave higher values for first bite in cooked meat. Sustained impression of juiciness had higher values in fried meat from age groups 21-25 and 26-30. All age groups rated amount of connective tissue higher in fried meat. Higher scores for overall flavour intensity were observed in both thermal treatments.

Table 4. 2: Influence of breed, diet and thermal treatment on aroma intensity, initial impression of juiciness and sustained impression of juiciness

Breed		**126**	**143**	**161**	**178**	**196**	**213**
				AI			
CAL	C	4.179^{abc}	3.893^{a}	4.071^{ab}	4.714^{abcd}	4.643^{abcd}	4.393^{abcd}
NZW	C	5.036^{abcd}	5.321^{cd}	4.857^{abcd}	5.250^{bcd}	4.821^{abcd}	5.071^{abcd}
CAL	F	5.036^{abcd}	4.893^{abcd}	4.571^{abcd}	4.929^{abcd}	5.071^{abcd}	5.036^{abcd}
NZW	F	4.714^{abcd}	5.286^{cd}	4.679^{abcd}	5.250^{bcd}	5.500^{d}	5.107^{bcd}
				IJ			
CAL	C	3.321^{ab}	3.893^{abcd}	3.500^{abc}	4.000^{abcd}	3.821^{abcd}	3.036^{a}
NZW	C	3.56^{abc}	4.857^{cd}	4.500^{bcd}	4.429^{abcd}	4.571^{bcd}	4.071^{abcd}
CAL	F	4.536^{bcd}	4.679^{bcd}	4.500^{bcd}	5.036^{d}	4.786^{cd}	4.429^{abcd}
NZW	F	4.857^{cd}	4.571^{bcd}	4.714^{bcd}	5.214^{d}	5.000^{d}	4.821^{cd}
				FB			
CAL	C	4.679^{a}	4.321^{a}	4.536^{a}	4.750^{a}	5.000^{a}	4.429^{a}
NZW	C	5.250^{a}	5.556^{a}	5.357^{a}	5.179^{a}	5.250^{a}	5.071^{a}
CAL	F	4.821^{a}	4.679^{a}	4.821^{a}	5.036^{a}	4.821^{a}	4.964^{a}
NZW	F	5.286^{a}	5.286^{a}	5.286^{a}	4.857^{a}	5.286^{a}	5.000^{a}
				SJ			
CAL	C	4.607^{abcd}	3.571^{a}	4.107^{ab}	4.143^{abc}	4.143^{abc}	4.286^{abcd}
NZW	C	4.321^{abcd}	5.143^{bcd}	4.643^{abcd}	4.536^{abcd}	5.000^{bcd}	4.893^{bcd}
CAL	F	4.429^{abcd}	4.643^{abcd}	4.714^{abcd}	5.0741^{bcd}	4.714^{abcd}	4.786^{bcd}
NZW	F	5.393^{d}	5.071^{bcd}	5.071^{bcd}	4.964^{bcd}	5.250^{bcd}	5.268^{cd}

Abbreviations: CAL; Californian, NZW; New Zealand white, C =, Cooked and F =, Fried AI, Aroma intensity; IJ, Initial impression of juiciness; SJ, sustained impression of juiciness. Values within column with different superscript are significant different ($P < 0.05$).

Table 4. 3: Influence of breed, diet and thermal treatment on muscle fibre and overall tenderness, amount of connective tissue and overall flavour intensity.

Breed	Sex	126	143	161	178	196	213
				MFT			
CAL	C	4.393^{ab}	4.250^{a}	4.536^{ab}	4.714^{ab}	4.714^{ab}	4.393^{ab}
NZW	C	5.036^{ab}	5.250^{ab}	5.429^{ab}	4.893^{ab}	5.071^{ab}	5.179^{ab}
CAL	F	4.857^{ab}	4.964^{ab}	4.929^{ab}	5.143^{ab}	5.143^{ab}	5.071^{ab}
NZW	F	5.536^{b}	5.250^{ab}	5.393^{ab}	5.286^{ab}	5.250^{ab}	5.036^{ab}
				ACT			
CAL	C	4.179^{abc}	3.893^{a}	4.071^{ab}	4.174^{abcd}	4.643^{abcd}	4.393^{abcd}
NZW	C	5.036^{abcd}	5.321^{cd}	4.857^{abcd}	5.250^{bcd}	4.821^{abcd}	5.071^{abcd}
CAL	F	5.036^{abcd}	4.893^{abcd}	4.571^{abcd}	4.429^{abcd}	5.071^{abcd}	5.036^{abcd}
NZW	F	4.714^{abcd}	5.286^{cd}	4.679^{abcd}	5.250^{bcd}	5.500^{d}	5.107^{bcd}
				OFI			
CAL	C	4.321^{ab}	4.107^{a}	4.321^{ab}	4.429^{abc}	4.607^{abcde}	4.464^{abcd}
NZW	C	4.429^{abcde}	5.286^{bcde}	5.071^{abcde}	4.964^{abcde}	5.607^{de}	5.429^{bcde}
CAL	F	4.679^{abcde}	4.964^{abcde}	4.893^{abcde}	4.929^{abcde}	4.893^{abcde}	5.143^{abcde}
NZW	F	5.536^{cde}	5.393^{bcde}	5.321^{bcde}	5.429^{bcde}	5.679^{e}	5.393^{bcde}

Abbreviations: CAL; Californian, NZW; New Zealand white, C = Cooked and F = Fried. MFT, muscle fibre and overall tenderness; Amount of connective tissue (Residue), ACT; OFI, overall flavour intensity. Values within column with different superscript are significant different ($P < 0.05$).

Table 4. 4: Influence of gender and thermal treatment on sensory characteristics

Gender	Cooked	Fried
	AI	
F	4.614^{a}	5.045^{b}
M	4.873^{ab}	5.069^{b}
	IJ	
F	3.621^{a}	4.364^{b}
M	4.181^{b}	5.020^{c}
	FB	
F	4.817^{a}	5.159^{a}
M	5.029^{a}	4.917^{a}
	SJ	

F	4.205^{a}	4.826^{bc}
M	4.608^{b}	5.029^{c}
	MFT	
F	4.636^{a}	5.295^{b}
M	4.941^{ab}	5.064^{b}
	ACT	
F	4.523^{a}	5.167^{c}
M	4.794^{ab}	4.902^{bc}
	OFI	
F	4.902^{ab}	5.220^{b}
M	4.725^{a}	5.167^{b}

Abbreviations: F, female; M, male; AI, Aroma intensity; IJ, Initial impression of juiciness; SJ, sustained impression of juiciness. Values within a row with different superscript are significant different ($P < 0.05$).

Table 4. 5: Influence of tribe and thermal treatment on sensory characteristics

Thermal treatment	Xhosa	Zulu	Shona

	AI		
Cooked	4.817^{ab}	4.676^{a}	5.917^{cd}
Fried	4.892^{abc}	5.078^{bc}	6.417^{d}
	IJ		
Cooked	4.125^{ab}	3.784^{a}	5.333^{bcd}
Fried	4.558^{bc}	4.794^{c}	6.250^{d}
	FB		
Cooked	5.167^{bc}	4.709^{a}	6.750^{d}
Fried	4.975^{ab}	4.966^{ab}	6.167^{cd}
	SJ		
Cooked	4.717^{b}	4.245^{a}	5.250^{abc}
Fried	4.767^{b}	4.980^{b}	6.250^{c}
	MFT		
Cooked	5.092^{b}	4.559^{a}	6.583^{c}
Fried	4.975^{b}	5.172^{b}	6.667^{c}
	ACT		
Cooked	4.675^{a}	4.554^{a}	7.083^{c}
Fried	4.508^{a}	5.167^{b}	7.250^{c}
	OFI		
Cooked	4.992^{ab}	4.627^{a}	5.667^{bc}
Fried	5.067^{b}	5.191^{b}	6.333^{c}

Abbreviations: Values within a row with different superscript are significant different ($P < 0.05$). AI, Aroma intensity; IJ, Initial impression of juiciness; SJ, sustained impression of juiciness. MFT, muscle fibre and overall tenderness; Amount of connective tissue (Residue), ACT; OFI, overall flavour intensity. Values within a row with different superscript are significant different ($P < 0.05$).

Table 4. 6: Effect of age and thermal treatment on sensory characteristics

Sensory characteristics	**Age**					
	21-25		**26-30**		**≥30**	
	C	**F**	**C**	**F**	**C**	**F**
AI	4.590^{a}	5.090^{b}	5.038^{b}	5.174^{b}	4.625^{ab}	4.646^{ab}
IJ	3.878^{a}	4.647^{b}	4.152^{abc}	5.152^{d}	3.708^{a}	4.062^{ab}
FB	4.948^{ab}	5.218^{b}	4.947^{ab}	4.947^{ab}	4.938^{ab}	4.521^{a}
SJ	4.327^{a}	4.968^{bc}	4.664^{ab}	5.098^{c}	4.312^{a}	4.479^{ab}
MFT	4.737^{a}	5.276^{b}	4.947^{ab}	5.227^{b}	4.750^{ab}	4.563^{a}
AT	4.737^{ab}	5.058^{b}	4.773^{ab}	5.000^{b}	4.292^{a}	4.854^{ab}
OI	4.846^{a}	5.244^{bc}	4.864^{ab}	5.333^{c}	4.438^{a}	4.604^{a}

Abbreviations: AI, Aroma intensity; IJ, Initial impression of juiciness; SJ, sustained impression of juiciness. MFT, muscle fibre and overall tenderness; Amount of connective tissue (Residue), ACT; OFI, overall flavour intensity. Values within a row with different superscript are significant different ($P < 0.05$).

4.6 Discussion

In the present study an influence of genotype on sensory characteristics was observed. The results are similar to the observations by Muchenje *et al*. (2008a) and Tshabalala *et al*. (2003) who reported variations among breeds in aroma intensity and tenderness. The significant influence of thermal treatment on aroma intensity agrees with the findings by (Tornberg, 2005) that cooking usually alters the structure of animal fat and increase meat's energy level thus affecting sensory characteristics. It has been shown that aroma and flavour of meat vary depending on several factors, including species, age, fatness, type of tissue, location, gender, diet, and method of cooking (Calkins and Hodgen, 2007; Muchenje *et al*. 2009).

Irrespective of genotype, the initial and sustained impression of juiciness for the fried meat was significantly higher across the increasing protein diet levels. Webb *et al*. (2005), reported that meat juiciness is determined by intramuscular fat content, however, it is significantly influenced by animal species (Tshabalala *et al*. 2003; Muchenje *et al*. 2008). It appears, therefore, that the dietary protein was able to enhance the intramuscular fat thereby increasing the marbling of the meat. Overall flavour intensity was significantly influenced by the diet judging from the high scores across the dietary treatments given by respondents in both cooking methods and breed. Both breeds had higher scores with slight differences in flavour. According to Muchenje *et al*. (2008a), amount and composition of fat in meat has an influence on flavour such that meat with pleasant flavour is associated with higher levels of intramuscular fat and more intense marbling. Furthermore, Dzudie *et al*. (2000) reported that flavour is influenced by different cooking methods through the changes in the fat composition and level of saturation of fats.

Cooking method had a significant effect on meat sensory characteristics. According to Xazela *et al*. (2011), consumers evaluate the quality of cooked meat by its flavour, aroma, and juiciness. Different scores on sensory characteristics among the cooking methods may be attributed to consumer familiarity and experience with a particular cooking method of meat. In the current study, higher sensory scores were observed in fried meat compared to the cooked meat. Similarly, Dyubele *et al.* (2010) found a significant effect of thermal treatment on chicken sensory scores, with roasted chicken scoring higher than cooked chicken. However, this could be influenced by the cooking losses due to the different thermal treatments used. Usually in our community's meat is prepared through cooking more than frying. Thus, consumers may not recognize the differences in sensory characteristics of fried meat due to their unfamiliarity with frying meat. In addition, cooking oil used in the preparation of fried meat might have increased the flavour hence the higher scores representing higher preference for fried meat.

Consumer age, gender and thermal preparation had a significant influence on meat sensory scores. Highest scores were observed in male respondents compared to female participants for meat juiciness. However, the results are inconsistent with the findings by Simela (2005), Dyubele *et al*. (2010), and Xazela *et al.* (2011) who observed that females had higher scores in meat juiciness than males. The inconsistency between the results could be the different animal species used and that females are likely not to be familiar with rabbit meat. In most communal areas, males usually consume rabbit meat through hunting especially young boys.

Tribe and thermal treatment had a significant effect on meat sensory characteristics. In African countries, socio-cultural factors usually affect how consumers perceive meat acceptability (Xazela *et al*., 2011). In all the observed sensory attributes, significant differences were observed among different tribes. Shona and Zulu consumers gave higher scores in both cooked and fried meat in all meat sensory characteristics compared to the Xhosa tribe. Lower scores for Xhosa consumers could be attributed by unpleasant appearance of rabbit carcass and lack of familiarity by consumers to rabbit meat due to location and cultural beliefs. Rabbit carcasses are perceived by consumers as human infants or cats, thus labelled as unappealing.

4.7 Conclusion

From the scores given by consumers, it was observed that they have a high preference for fried meat than cooked meat. Cooking method had a significant influence on meat sensory characteristics. There was an interaction between thermal treatment, breed and diet in some of sensory characteristics. Dietary protein significantly improved tenderness and juiciness of rabbit meat. Gender and tribe significantly influenced meat sensory parameters where Shona respondents gave higher scores than other breeds. In conclusion, consumers from different tribes showed significant positive interest in consuming rabbit meat hence differences on the two cooking methods were observed.

CHAPTER 5

General discussion, knowledge gaps and recommendations

5.1 General discussion

The objective of the current study was to investigate the effect of balanced dietary protein on physicochemical quality and sensory attributes of rabbit meat from two commercial breeds. The effect of balanced dietary protein on physicochemical quality was determined in Chapter 3. In chapter 4, effects of two breeds and dietary protein on sensory scores of rabbit meat prepared using different cooking methods were determined.

In chapter 3, physicochemical quality of the two rabbit breeds were evaluated. Both breeds had lower muscle pH_{24} meaning the rabbits did not experience pre-slaughter stress. Higher L* values were found in NZW breed as compared to CAL in all the protein levels. Contrary, CAL had higher values for a* than NZW rabbits. No significant differences were observed for drip loss, cooking loss, water holding capacity and Warner-Bratzler shear force values.

The effects of balanced dietary protein on sensory scores of rabbit meat prepared using thermal treatment methods was evaluated in Chapter 4.

Genotype significantly affected sensory characteristics the variation between breeds on sensory attributes. Thermal treatment had a significant influence on aroma intensity. Consumers evaluate the quality of cooked meat by its flavour, aroma, and juiciness. Different scores on sensory characteristics among the cooking methods may be attributed to consumer familiarity and experience with a particular cooking method of meat. In the current study, higher sensory scores were observed in fried meat compared to the cooked meat. Consumer age, gender and thermal preparation had a significant influence on meat sensory scores. Highest scores were found in male respondents compared to female contestants for meat juiciness. Tribe and thermal treatment had a significant effect on meat sensory characteristics. Shona and Zulu consumers gave higher scores in both cooked and fried meat in all meat sensory characteristics compared to the Xhosa tribe reason for this could be the familiarity due to the type of location, preference and cultural beliefs .

5.2 Conclusion

Rabbit meat has been reported to be healthier as compared to other meat types since it contains low levels of cholesterol. However, the diet did not have a positive nor negative influence on meat quality attributes of rabbits. Fried meat was the most preferred by the sensory panellist as compared to the cooked meat. It has been observed that consumers of different tribes, gender and ages had different preferences of meat sensory attributes among the cooking methods for New Zealand white rabbits.

5.3 Recommendations

It may be recommended that the effect of balanced dietary protein can be used to assess the fatty acid composition of different rabbit strains. A study on balanced dietary protein is recommended to evaluate the haematological and serum biochemical indices of rabbits using different strains.

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Appendix 1: Meat sensory evaluation sheet of rabbit

Meat sensory evaluation form

Sensory analysis of rabbit meat

Age: 21-25------., 26-30-------., ≥ 30-----.

Tribe: Xhosa------., Zulu-------.,Shona-------., Other--------.

Gender: Male--------., Female---------.

Name:………………………………….. Date:………………

Please evaluate the following samples of rabbit meat for the designated characteristics.

Characteristics	**Rating scale**	**Sample ID**	**Fried**	**Cooked**
1.Aroma intensity Take a few short sniffs Typical rabbit meat aroma	1=Extremely bland 2= Very bland 3= Fairly bland 4= Slightly bland	P3		
		P47		
		P44		
		P42		
		P12		
		P40		
		P16		

	5=Slightly intense 6= Fairly intense 7= Very intense 8=Extremely intense	P13		
		P18		
		P31		
		P25		
		P27		
2.Initial impression of juiciness The amount of fluid exuded on the cut surface when pressed between the thumb and forefinger	1= Extremely dry 2= Very dry 3= Fairly dry 4= Slightly dry 5=Slightly juicy 6= Fairly juicy 7= Very juicy 8=Extremely juicy	P3		
		P47		
		P44		
		P42		
		P12		
		P40		
		P16		
		P13		
		P18		
		P31		
		P25		
		P27		
3.First bite The impression that you form on the first bite	1=Extremely tough 2= Very tough 3= Fairly tough 4= Slightly tough 5=Slightly tender 6= Fairly tender 7= Very tender 8=Extremely tender	P3		
		P47		
		P44		
		P42		
		P12		
		P40		
		P16		
		P13		
		P18		
		P31		
		P25		
		P27		
4.Sustained impression of juiciness The impression of juiciness that you form as you start chewing	1= Extremely dry 2= Very dry 3= Fairly dry 4= Slightly dry 5=Slightly juicy 6= Fairly juicy 7= Very juicy 8=Extremely juicy	P3		
		P47		
		P44		
		P42		
		P12		
		P40		
		P16		
		P13		
		P18		
		P31		
		P25		
		P27		
		P3		

5. Muscle fibre & overall tenderness Chew sample with a light chewing action	1=Extremely tough 2= Very tough 3= Fairly tough 4= Slightly tough 5=Slightly tender 6= Fairly tender 7= Very tender 8=Extremely tender	P47		
		P44		
		P42		
		P12		
		P40		
		P16		
		P13		
		P18		
		P31		
		P25		
		P27		
6.Amount of connective tissue (Residue) The chewiness of the meat	1=Extremely abundant 2= Very abundant 3=Excessive amount 4= Moderate 5= Slight 6= Traces 7= Practically none 8= None	P3		
		P47		
		P44		
		P42		
		P12		
		P40		
		P16		
		P13		
		P18		
		P31		
		P25		
		P27		
7.Overall flavour intensity This is the combination of taste while chewing and swallowing-referring to the typical beef flavour	1=Extremely bland 2= Very bland 3= Fairly bland 4= Slightly bland 5=Slightly intense 6= Fairly intense 7= Very intense 8=Extremely intense	P3		
		P47		
		P44		
		P42		
		P12		
		P40		
		P16		
		P13		
		P18		
		P31		
		P25		
		P27		