An investigation into the health and tenderness benefits present within Highland cattle beef compared to a Commercial breed

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SAC

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Declaration

I declare that the work reported in this thesis was carried out by myself and has not been accepted in any previous application for a degree. All information drawn from other sources, and assistance received, have been acknowledged in the appropriate place.

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Abstract

Highland Cattle are one of the most instantly recognizable cattle breeds worldwide due to their long hair and long horns.

The purpose of this study was to analyse beef from Highland cattle from a variety of regions within the UK to achieve a good picture of the properties present within Highland Beef in the UK, then to compare the results achieved with a comparative population of beef cattle with Limousin breed sires in order to compare any possible beneficial properties within the beef from the Highland Breed.

Previous studies such as the 1997 study led by Dr Ivy Barclay of the Scottish Agricultural College have shown preferential characteristics within the highland beef when compared to published figures for all beef, this was to form the basis of this study.

The samples were analysed using chemical analysis methods to obtain information on the; moisture, fat, ash, energy, iron, protein carbohydrate and cholesterol levels within both sample populations and T-Tests and correlation tests were used to analyse the results statistically.

A Rapid Slice Shear Test was also carried out on the samples in order to gain information on the tenderness of the sample populations and again results were analysed using a T-Test to determine statistical difference in the results.

The results of the study showed that there were statistically significant benefits within the beef from the Highland breed with the Iron levels and Protein levels of the beef proving to be preferential. The tenderness also proved to be preferential when statistically analysed.

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Chapter 1: Introduction and Literature Review

1.1 Introduction

Highland cattle are generally recognised worldwide for their long hair and horns. However this is not a saleable asset for the majority of the male animals. A study performed by Dr Ivy Barclay in 1997 gave these male animals a more saleable angle by proving them to have increased health characteristics when compared to "All beef" results published by the Ministry for Agriculture Fisheries and Foods (MAFF). This has been a major marketing tool used by the Highland cattle society since it was first published. This study will try to replicate and update the results of the 1997 study using measured comparatives rather than published figures.

Beef is one of the best sources of both protein and iron, both of which are important for the functioning of a healthy body, increased levels of these characteristics within a breed sample of beef could provide an excellent marketing tool for that breed as a quality beef product. There are also negative health associations with beef, beef is thought to be a food high in saturated fatty acids and cholesterol, both of which contribute significantly to ill-health in the UK.

A well as the importance of health characteristics within beef products, eating quality is another major factor to be considered within the beef industry. The marbling fat is thought to be directly linked to the eating quality of the beef in terms of succulence and flavour. Tenderness is also an important characteristic of beef as far as eating quality is concerned.

1.2. History of the Highlander

Long before recording of cattle and the pedigrees of breeds were kept, there were many fewer breeds of cattle, the breeds were often named after the region in Scotland in which the animal was found. There were initially two differing types of highland cattle there was the Western Isle type known as the Kyloe which was a small hardy breed of cattle generally black in colour. The other type was the North Highland which was from the Sutherland area of Scotland and was shaped more like the breed originating from Orkney. These animals were usually redder in colour and were slightly larger if less well shaped than the Kyloe. There was a third breed which although not a highland animal showed the same characteristics as the highland cattle and the Kyloe, these animals were larger in size than either the West or North type and originated in Perthshire. It is a mix of the three types along with natural selection which has lead to the multicoloured type highland animals which are around today. These breed types are taken from the Agricultural Dictionary published in 1845 and give a detailed description of the types of cattle and their origins from that time period (Wilson, 1845).

1.3. Beef Industry Review and Breed Trends

1.3.1. Breed Trends

General trends in the breeds of cattle used within the UK beef industry have shown a move away from native breeds to the larger continental breeds, even the more popular native breeds are far removed from what they used to be. The fact that only one native breed sire is in the top five top terminal sire breeds within the UK, is testament to this fact (British Limousin Cattle Society, 2011).

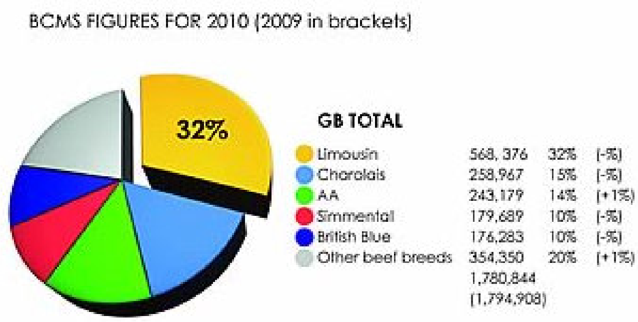

Figure 1.1, Graphical representation of the major terminal sire breeds used within the UK and the numbers of calves born to each breed in 2010.

This native breed sire being the Aberdeen Angus which is third in the list seen in figure 1.1; The Aberdeen Angus in this list is not the traditional native breed Aberdeen Angus however, as this sire breed includes large amounts of imported genetics. The traditional native Aberdeen Angus breed is one of the breeds closest to extinction within the UK cattle industry, and appears in the critical bracket within the "Rare Breeds Survival Trusts" endangered list (RBST, 2011). The beginning of this trend away from native breeds began in the late 1960's early 1970's. Until then British animals had been bred smaller due to a large export demand to Argentina, the USA, New Zealand and South Africa, for smaller native breed beef animals. As interest in these breeds began to decrease, due to their lack of size for commercial purposes, the continental breeds, such as the Charolais, Limousin and Simmental, were introduced, (Buglass, 2008). This, along with the increasing availability of artificial insemination, meaning continental sires were more easily obtained, led to a dramatic shift towards continental cattle throughout the period between the 1960's and the mid 1990's.

However, the trend, in the fifteen or so years since then, has been for an increase in native breed animals. There have been several reasons for this.

There has been an increase in the need for farms to diversify, marketing their own produce through either farmers markets or farm shops has been one form of popular diversification (Karim, 2008). Those who are marketing their own beef products tend to favour native breed beef, due to its perceived added quality aspects over continental type animals.

This perceived added quality available from native breeds has lead to premiums being paid by certain abattoirs for particular native breed cattle. Such as the premium price scheme, announced by Morrison's supermarket earlier in the year, which will pay a premium on top of market value for beef sired by Aberdeen-Angus, Shorthorn or Hereford cattle (Press and Journal, 2011).

Another reason for the market share increase of native breeds, is the publicity they have received from some of the celebrity chefs. The Highland breed is one such breed that has been given praise by celebrity chefs either on the television or in press articles; Marco Pierre White stated “I can’t remember the last time I had beef as good as this” in reference to highland beef while filming for his television programme “Marco’s Great British Feast” aired on STV on the 2nd of July 2008. “It’s Definitely the best meat to work with: its flavour, texture and marbling are unbeatable” a quote from Bruno Birkbeck, head chef at the Torridon Hotel, Scottish Hotel of the Year 2011, in reference to highland beef. (Bath, 2011)

These factors have all lead to an increase in the market share of native breeds within the beef industry in recent years.

1.3.2. Beef Market Review

Beef has the majority of the market share within the red meat industry, with just over half the red meat being eaten in the UK being Beef. In the period between 2005 and 2010 there was a small growth of 3% in total weight of beef sold. The industry has also been under pressure since 2007 due to price inflation caused by the increasing price of inputs and a decrease in the total numbers of cattle. (Mintel, 2010) The trend of growth within the industry also features in the market reports from October 2000 and November 2006. Trends within the beef industry are different in these periods with regards to types of beef being bought, the October 2000 report states a move towards ready meals and less time consuming ideas (Mintel, 2000), while the November 2006 and October 2010 reports both state an increase in people returning to cooking for themselves again and people enjoying cooking as a hobby (Mintel, 2006). The quality beef market was also one which was relatively strong during the 2005-2010 period, although more popular within certain population demographics than others (Mintel, 2010). This is the area into which the Native breed beef is aiming for, order to gain premiums for smaller carcase animals.

1.4. Previous Work

1.4.1. Native Breed Beef

Native breeds of beef cattle have been superseded in numbers by their continental counterparts within the United Kingdom, since the 1960's, however within the past two decades their numbers have began to increase again as their traditional properties regain popularity (Alderson, 2000). This information is taken from a group of studies published by the White Park Cattle Association, into the benefits of keeping native breed cattle such as the White Park, and the added value obtained from these breeds compared to the continental counterparts, with regards to their environmental adaptability. The study also mentions an important factor with regards to the beef, in that native cattle produce beef for the consumer, rather than the commercial market.

A recent study, carried out by Bristol University, into slow grown native beef compared to intensively reared Charolais type beef, also found benefits within the native breeds. A higher level of polyunsaturated fat was found within the beef from native breeds, which were reared slowly and on a bio-diverse pasture. The longer period of time taken for the animals to finish, meant that there was less deposition of fat than that occuring in the higher intensity systems, it also meant that there was a longer period of time for the long chain omega 3 type fatty acids to increase in concentration (Hunt, 2010).

1.4.2. Health Properties of Highland Beef Study

CUT	**FAT** g/100g	**CHOLESTEROL** mg/100g	**PROTEIN** g/100g	**IRON** mg/100g
Pure Highland Rump	**4.2**	**45.8**	**22.4**	**2.0**
MAFF ALL Beef (Rump)	13.5	63.0	18.9	2.3

Pure Highland Shoulder	**4.7**	**42.2**	**21.6**	**1.9**
MAFF ALL Beef (Shoulder)	10.6	63.0	20.2	2.1
Pure Highland Sirloin	**7.1**	**37.0**	**21.8**	**2.3**
MAFF ALL Beef (Sirloin)	22.8	67.0	16.6	1.6
Pure Highland ALL Cuts	**4.5**	**40.9**	**20.7**	**2.1**
MAFF ALL Cuts	15.6	64.3	18.6	2.0

Table 1.1; results of previous study

Table 1.1 above is taken from a study published in 1997 by a team of scientists led by Dr Ivy Barclay head of the Food Science & Technology Department of the Scottish Agricultural College (The Beef Site). The comparatives for the study were taken from all beef results published by McCance and Widdowson of the Ministry for Agriculture Fisheries and Foods (MAFF) (previously DEFRA) . This study is used by the majority of highland beef producers as advertisement. This is the table which formed the basis of this study. This study is also backed up by American studies which have shown that beef from highland cattle is 4% lower in cholesterol than supermarket bought beef (The Beef Site). Both of these pieces of information are used on the majority of American Highland cattle breeder websites particularly those selling highland beef to the public.

1.4.3. Other Beef Health Studies

An American study into the fat composition and cholesterol levels of different breeds of cattle using a mixture of American breed, British breed and Cross bred cattle showed that there was a negligible difference in the cholesterol levels of the different breeds used and negligible difference in cholesterol variance resulting from different slaughter ages (Byers, Schelling, Cross, Lunt, & Greene).

A study in America carried out in 2007, has shown cancer risk is increased at certain sites in the human body, by consuming an excess of red meat, with links to colorectal and lung cancer (Cross, Leitzmann, Gail, Hollenbeck, & Schatzkin, 2007). This has lead to recommendations to decrease the quantities of red meat in the human diet by different bodies including the UK Government, following advice from their own scientists (Hennessy & Donnelly, 2011). These recommendations mean that the maximum possible health benefits from beef need to be obtained from as small a quantity as possible.

Another American study into the health characteristics of beef was published in 2010, analysing the benefits of beef produced in a grass fed system compared to a grain fed system. This study found that the saturated fatty acids within grass fed beef, contained a higher proportion of cholesterol neutral stearic fatty acid and lower concentrations of cholesterol elevating fatty acids, such as myristic and palmitic fatty acids. The conclusions also state that lean beef can be interchanged with fish and skinless chicken, to reduce serum cholesterol levels in hypercholesterolemic patients (Daly, Abbott, Doyle, Nader, & Larson, 2010). Although diet was not a defining variable within this study, the general production methods of beef from the Highland animals and Commercial beef animals tend to follow different trends, with the commercial animals being more intensively reared, and highland animals more likely to be extensively reared on a pasture based diet.

1.5. Health Properties of Meat

1.5.1. Cholesterol

Cholesterol is an important molecule within the body and was first discovered in solid form in 1769 by Poulletier de la Salle, within gall stones and bile. Its presence within blood was not discovered until the early 19th century until which time scientists believed that blood contained only one protein and no fat (Olsen, 1998).

Cholesterol is a lipid, or fatty substance, which is synthesised within the body or obtained by eating food stuffs with cholesterol present. Within the body it is synthesised mainly within the liver and is vital within the body for the creation of bile acids, which are important in the breaking down of fats for absorption and digestion. Cholesterol is also important in the manufacture of hormones and is present in the cell walls of all body cells. Cholesterol however, is insoluble in water and so unable to transport itself around the body, it is therefore transported via blood and is carried by molecules known as lipoproteins. There are two major lipoprotein carriers of cholesterol within the bloodstream, one carries cholesterol to the cells and one back from the cells to the liver. The lipoprotein carrying cholesterol to the cells is known as Low-Density Lipoprotein with this cholesterol otherwise referred to as bad cholesterol as this is the cholesterol which is deposited within arteries when an excess is present. The other is High-Density Lipoprotein, carrying cholesterol from the cells back to the liver to be processed and disposed of, this is therefore known as good cholesterol. It is the build up of cholesterol within the arteries, caused by excess volumes being present in the blood, that is thought to be responsible for contributing to heart disease hence the reason for advising moderation of cholesterol levels within the diet (National Health Service, 2009).

With the average levels of cholesterol in the UK being some of the highest in the world and being above the recommended levels it is important to control the levels of cholesterol intake (National Health Service, 2009). As red meat is one of the major sources of dietary cholesterol intake, some advocate that it should be avoided (Farnworth, 2002). If it can be proven that one type of beef is lower in cholesterol, then this could be a big selling point for that type of beef.

1.5.2. Protein

Protein intake is important for the maintenance and repair of tissue, muscle and neural function and to maintain defence mechanisms. Within the protein which the body requires, there are 20 different amino acids divided into essential and nonessential amino acids. The Essential amino acids must be provided through the diet while the nonessential amino acids can be synthesised by the body hence are not an essential part of the human diet. It is therefore important to include these amino acids in the correct concentrations in the diet each day, to ensure correct function of the body. The recommended protein intake of an adult is 0.8g/kg bodyweight, this is increased in pregnant woman, athletes, young children and those recovering from burns or surgery (Boron & Boulpaep, 2005).

Beef is a known source of complete protein, meaning that it contains all nine of the essential amino acids. This type of dietary protein is important for the health of the human body (Zieve, Zuhn, & Eltz, 2009).

1.5.3. Iron

Iron is an element which is vital within the body, its major role is to assist in the transport of oxygen within the blood stream in the form of haemoglobin (Boron & Boulpaep, 2005). Iron is absorbed within the human body through the stomach where it binds with oxygen and is transported into the plasma portion of the blood. It then goes on to form haemoglobin, the transporter of oxygen within the blood stream and is stored within the liver, spleen and bone marrow for use as needed (University of Maryland Medical Centre, 2008).

The most easily absorbed form of iron is haem iron, the form of iron found in haemoglobin within animal tissues. Around 40% of the iron found in animal tissue is haem iron, which is the best form of iron for those suffering from iron shortages, as it is more easily utilised within the body (Kassel, 2010).

A lack of iron within the body can lead to Iron Deficiency anaemia, a condition occurring due to a reduced haemoglobin count due to a lack of iron to produce it. This condition makes the sufferer very lethargic and tired and can cause an irregular heartbeat (NHS 2, 2010).

1.5.4. Fat Content

Although beef is a good source of other nutrients within the diet, it is also thought to be a high source of fat within the diet. Although fat is an important part of the human diet, there are constraints on the types of fats that should be consumed, to avoid health problems associated with a high fat diet, mainly coronary problems. It is the fatty acids within the fat which can cause the problems, these can be broken down into saturated, monounsaturated and polyunsaturated fatty acids. The definitions of the different types of fatty acid arise from the presence of double bonds between the carbon atoms in the acid structures. Saturated fatty acids have no double bond within their structure as all the carbon atoms are bonded to hydrogen atoms, monounsaturated fatty acids contain one carbon to carbon double bond within their structure and the polyunsaturated fatty acids contain more than one carbon to carbon double bond. The presence of these double bonds is important in the properties of these fatty acids and the way in which they function within the body. Recommendations for the current western diet state that there should be a reduction in the consumption of saturated fats with an increase in the unsaturated fats seen as beneficial to health such as omega 3 (Moloney, 2007).

1.5.4.1. Intramuscular Fat Content and Effect on Beef Eating Quality

With regard to eating quality of beef, as far as fat is concerned, the more intramuscular fat present, the more succulent the beef will be. The intramuscular fat level is also related to the flavour of the beef. It is thought that marbling fat is gained from intensive finishing of cattle in countries such as Australia and the USA, cattle are therefore finished in feed lots to ensure a high level of marbling fat and obtain a top quality beef product. This is thought to be mainly due to the age of the animals at slaughter being younger hence more juicy and tender. The marbling fat is also thought to be lower in saturated fat content than the intermuscular, seem fat, fat or the subcutaneous fat (Food Science Australia, 2005).

Another study carried out in America looked into the effect tenderness and marbling of beef had on consumers acceptance of the meat. By performing a large scale taste test on beef samples of varying marbling score and tenderness ratings, using a Warner Bratzler sheer force test, the study showed that there was a direct relationship between customer's acceptance of the steaks, based on juiciness tenderness and flavour, and the marbling level of the meat. As shown in figure 1.2 below (Platter, Tatum, Belk, Chapman, Scanga, & Smith, 2003).

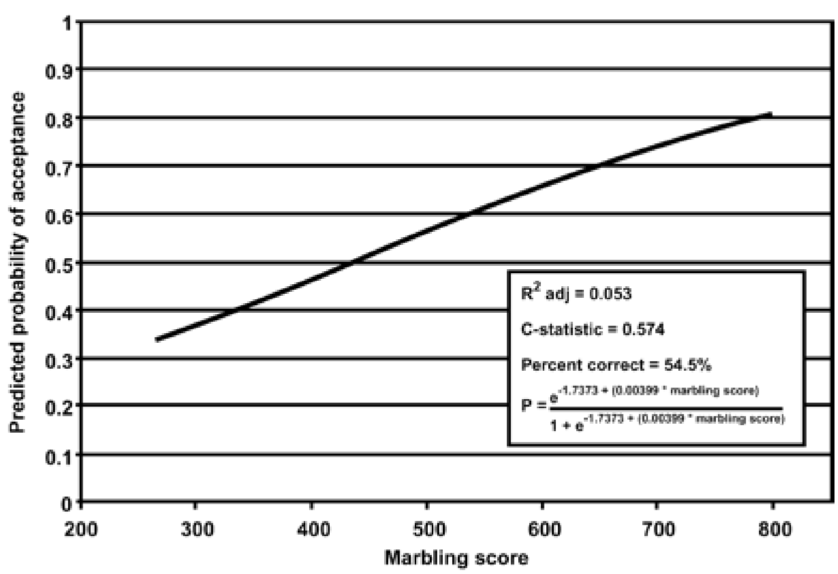

Figure 1.2; graphical results of marbling score against predicted consumer acceptance of steaks taken from the 2003 study by Platter et al.

As well as the feeding of cattle to increase the marbling of the beef there is a variety of work going into increasing marbling with the use of genetics. Several breeds are thought to be genetically better with regards to marbling of beef, these are generally the more traditional breeds such as the shorthorn, Angus and the Japanese breed Wagyu. There are however large variations within these breeds (Johnstone, 2003). This piece of information is important to this study, the majority of other studies found state that the variations in marbling are due to feeding, this study states breed can have an effect on intramuscular fat level.

A German study looked at breed influence on marbling levels, along with the age at which it develops. It used four differing beef population samples; German Angus, as an example of a typical beef breed, Galloway, as an example of a smaller more environmentally resistant beef cattle, Holstein-Friesian, as a typical dairy example and Belgian Blue, as an example of the extreme muscling within commercial beef production. This study showed that marbling begins to develop early in the animals life and increases significantly with age, it also showed that the German Angus and Galloway animals gave the best marbling scores throughout the different ages of slaughter, the dairy animal had a high number of smaller marbling flecks and the Belgian Blue was significantly lower than the others at all stages of the test (Albrecht, Teuscher, Ender, & Wegner, 2006). This study once more shows the difference between breeds with regards to marbling, showing positive results for traditional breeds such as Angus and Galloway.

Chapter 2: Aim, Objectives and Hypothesis

2.1. Aim

To establish whether there are preferential health and tenderness characteristics within beef from highland cattle when compared to a commercial control.

2.2. Objectives

1. To update results carried out by Barclay, 1997 section 1.4.2 which determined health properties of the Highland beef breed.
2. Compare the chemical analysis (cholesterol, Iron and Protein) of samples of the Highland breed and the commercial Limousin breed to determine health benefits.

3. Compare the chemical analysis (fat) and the tenderness results obtained from samples of Highland breed and commercial Limousin breed, to determine meat eating quality benefits.

2.3. Hypothesis

2.3.1 Null Hypothesis- There are no preferential health or meat eating quality benefits present within beef from the Highland breed when compared to a commercial Limousin breed beef.

2.3.2 Alternative Hypothesis- There are preferential health or meat eating quality benefits present in beef from the Highland breed when compared to commercial Limousin breed beef.

Chapter 3: Methodology

3.1. Sample Gathering

Two sample populations were chosen;

1. The Highland breed sample, to include 15 samples gathered from around the country, chosen to encompass the differing climatic conditions in which highland animals are kept within the UK, in order to gain a fuller picture of the beef characteristics within the breed.

2. The Commercial comparison sample population, the Limousin breed was chosen as the terminal sire breed for the comparison sample as it is the most common terminal sire breed within the UK beef industry, with 32% of the calves within the beef industry being born to Limousin sire in 2010 (British Limousin Cattle Society, 2011).

3.1.1 Highland Samples

Fifteen samples of Highland beef were gathered from thirteen different sources within the UK, including beef from the Western Isles, Lowland Scottish farms, Highland Scottish farms and one sample from Yorkshire, further details in figure 3.1 below. The reason for taking the samples from a variety of areas and a variety of differing climates was to obtain a fuller picture of the highland breed within the UK. Obtaining samples from these differing climatic conditions and different feeding regimes would provide a fuller picture of the highland animal and the results would be more relevant to all breeders, rather than just to those within similar type farms to the ones from which the samples were gathered. Samples were gathered from a variety of sources of Highland beef; Highland Drovers were used to collect four samples from four differing locations, R McDougall, butchers in Glasgow, were used to source another four samples from four differing locations, a highland cattle breeder, who also deals in direct sales of highland beef, provided five samples from three different location, the other two samples were provided by highland breeders, dealing in direct meat sales.

Figure 3.1, Points of origin of highland beef samples

3.1.2 Commercial Limousin Samples

The commercial samples were gathered from the Scotbeef abattoir in Stirling and were sourced from a variety of different holdings rather than just the first fifteen samples which came to hand. The points of origin of the commercial samples were; Stonehaven, Pencaitland, Stirling, Fife, Bathgate, Morpeth and Perth. With the exception of Morpeth, all these holdings are within the East of Scotland. The reason that the commercial samples did not have to be as widely spread as the highland samples is that the feeding regimes and conditions for keeping commercial cattle do not vary as widely as those for highland cattle, which can be kept on hill ground all winter.

Scotbeef abattoir was chosen as they are currently working with the Scottish Agricultural College on a similar project. The choice of samples from different holdings should again have helped to give a representative sample of commercial cattle of Limousin Sire being processed through this particular abattoir, rather than just taking the samples from one holding.

3.1.3 Choice of Sample and Quantity Required

The cut chosen for analysis was the Sirloin cut, as demonstrated in figure 3.2 below, with the exception of Minced and processed cuts, this is one of the most commonly sold cuts within the UK food market. The sirloin is also one of the better quality cuts from which a premium price can be taken. The Commercial samples were taken from the same muscle but from the Rib-Eye part of the muscle, chosen as the abattoirs preference. The cuts are identified in figure 3.2 below. One kilogram of meat was gathered from each animal tested, this was to cover the 500g sample required for the tenderness testing and the 300g requirement of the chemical analysis.

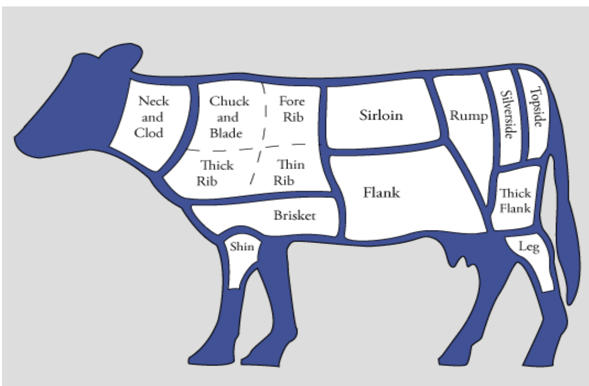

Figure 3.2; showing the cuts of the animal with the sirloin muscle running along the back of the animal, the Rib-Eye is part of the Fore-Rib section

3.1.4 Maturation of the Meat Samples

The beef maturation period differed for a specific purpose. The highland samples were all matured for a minimum of 21 days prior to freezing, the commercial samples were matured for 14 days prior to freezing, this difference represented the added value the majority of highland beef producers provide, by maturing beef for a longer period than the majority of commercial outlets, in order to give a greater quality of produce. This should have had a small effect on the Sheer Slice test, as maturation is thought to be key to the tenderness of beef, however the 14 day maturation period for the commercial beef is longer than most commercial beef is matured for. Supermarkets charge a premium for beef matured for a longer period and state this longer period on the packaging. The 14 day maturation period should have provided a balance between this longer period beef and the shorter period which the majority of beef receives within the commercial beef sector. The effect of maturation on the chemical analysis was thought to be negligible as the chemical properties of the animal would stop changing once it was dead and cooled.

3.2. Tenderness; A Rapid Slice Shear Force Test was used to determine the Tenderness of the Samples

Possible analysis methods for the tenderness experiment were either the Rapid Shear Slice Test or the Warner Bratzler Shear Force test. The Rapid Slice Shear Force Test test gives accurate results on the tenderness of meat when compared to the opinions of taste panels, it is a reasonably new method of testing for tenderness with the first results being published in 1992. The Warner Bratzler Shear Force test has been in use for a longer period of time with first published results in the 1930's, it is however thought to be less reliable than the rapid shear slice test and takes a longer period of time to complete, a variation in results could be expected, depending on the protocol used by the institute in which the experiment was done, until a standard protocol was established in 1997 leading to a much higher repeatability of results (Ross & Keeping, 2008).

The method used for the sheer slice test was as follows. The samples were aged for the stated period of time within a vacuum sealed environment and frozen once they reached the desired number of day's maturity. The samples were thawed overnight to ensure a consistent core temperature at the start of cooking. A 25mm thick steak was taken from the sample using a sharpened knife and cutting board with a measuring plate attached to ensure a uniform thickness. Any visible fat was then removed. This sample was then weighed and the weight recorded. It was then cooked using a "George Forman" grill until it reached a core temperature of 71 degrees Celsius, it was then removed from the heat and the temperature monitored for several minutes until optimum temperature was achieved and the temperature had started to fall again. This temperature was then recorded and the sample weighed and recorded once more. There was then a small section cut off each end of the steak to identify the direction of the meat's grain. The sample was then placed into a block which cut a 5 cm wide piece of the steak, muscle fibres of this piece were then lined up within another box, which had two knife holes 1 cm apart at 45 degree angles to the board, a knife was then passed through these two holes to gain a sample for testing, 5 cm long by 1 cm, wide and cut with the grain of the muscle fibres. This sample was placed into the "Single beamed Lloyds testing Machine" with a blade which measured 1.016mm wide and had an edge which was bevelled to a half round. The lid of the machine was then closed and the button pushed, the machine exerts a pressure on the blade and the pressure applied is measured. The reading is then recorded and the process repeated for the other samples.

The Rapid Slice Sheer Force Test was used ahead of the Warner Bratzler method of testing as it was the one method set up at the Bush Estate where the experiment was carried out. It is also thought to be the more reliable of the two methods requiring only one sample from each of the beef samples for testing rather than six uniform samples. It is also the quicker method as the testing can be done when the meat is still hot rather than waiting till the meat cools, with the time scale of the experiment the quicker method was more suitable.

3.3. Chemical Analysis

Chemical analysis of both sample populations was carried out by Eclipse Scientific Group in their Cambridge Laboratory. The analysis carried out included; Fat content, Moisture content, ash content, energy content in both kJ and kcal, Carbohydrate content, Protein content, Iron content and Cholesterol content.

The fat content analysis was performed on the intramuscular fat content rather than the total fat content of the samples as this negates a lot of the differences to be expected with different levels of finish achieved on the animals. This is also more relevant to a study of beef characteristics as the majority of people will trim off the subcutaneous fat when eating beef if not already trimmed by the butchers when purchased. The intramuscular fat content contributes more to the flavour and succulence of the meat in comparison to the subcutaneous fat in most cases.

To prepare the meat for this experiment any visible fat was removed from all thirty samples of beef, the samples were then weighed to ensure they contained the full 300 grams required by the laboratory and the samples were vacuum sealed and frozen. The samples were then placed in a polystyrene box and posted using recorded next day delivery.

The reason for outsourcing this work rather than trying to set it up within the Scottish Agricultural College own premises, was mainly to ensure that the experiments could be done quickly and results achieved within the time scale. By using a production laboratory, such as the Eclipse Scientific Group, there is a guaranteed turnaround time. There is also less likelihood of bias in the results by using a food standards laboratory than if the experiments were carried out by the student within the SAC. Some of the experiments were quite complex and may have been costly to set up.

The methodologies used by Eclipse Scientific group to carry out these experiments can be found in Appendix 1.

3.4. Data Analysis

The data was recorded within a table in a Microsoft Excel spreadsheet. The results were then analysed using Microsoft Excel. The statistical analysis carried out included the use of T-Test's and Correlation, to analyse for statistical differences in the results and analyse any possible correlations between the different properties analysed.

Chapter 4: Results

4.1. Chemical Results

	Protein g/100g	Fat g/100g	Iron mg/100g	Cholesterol mg/100g
Highland from This Study	21.49	10.99	2.33	51.5
Highland, 1997 study	20.7	n/a	2.1	40.9
Commercial Limousin Breed	19.99	9.38	1.96	53.7
All Beef previous study	18.6	n/a	2	64.3

Table 4.1 Average results of experiments along with the All Cuts, MAFF figures, and highland figures results from the 1997 study.

Table 4.1 above shows the average health properties picked out from the chemical analysis. The full table of results is included in appendix 2. This is taken from the results of the 15 highland samples and the 16 commercial samples. The bottom line is taken from the previous studies comparative which was stated as "all beef". The reason for omitting the fat level in the "all beef previous study" and "Highland, 1997 study" is that a different measure was used in the previous study, it used total fat as opposed to the intramuscular fat value measured within this study. This means that the figure is much higher but irrelevant to the study.

4.1.1. Protein

The analysed protein results show that the Protein level within the Highland beef samples is on average 1.5g/100g higher than in the Commercial Limousin breed samples. The averages of the two samples along with standard error bars are shown in figure 4.1 below.

As a percentage difference the Highland samples were 6.98% higher in protein than the commercial samples.

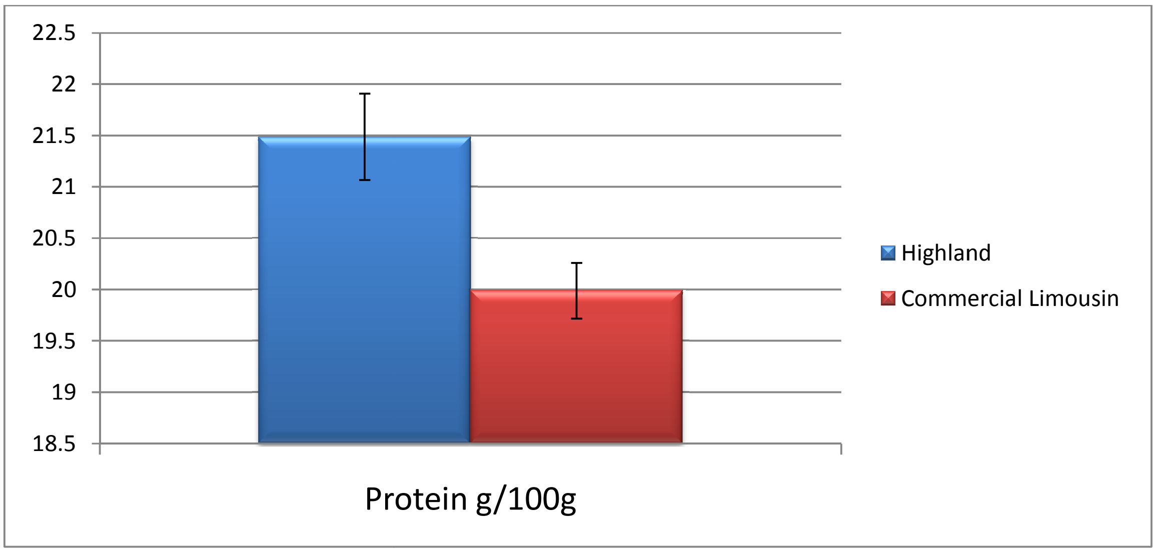

Figure 4.1; Graph of average results of the protein chemical analysis.

A two tailed T-test assuming equal variance was performed on the protein results of all samples in order to form a statistical comparison between the Highland Samples and the Commercial Samples. From results obtained for the performed t-Test it can be seen that the difference in the protein levels of the highland samples and the commercial samples are statistically significant as the t-stat figure calculated of 3.009704766 is higher than the t-critical figure of 2.048407115.

4.1.2. Iron

The analysed iron results from the study show that there is an average difference of 0.33mg/100g between the Highland breed samples and the Commercial Limousin breed samples, with the highland samples having a higher iron level on average. The average results of the Iron Analysis along with standard error are shown in figure 4.2 below.

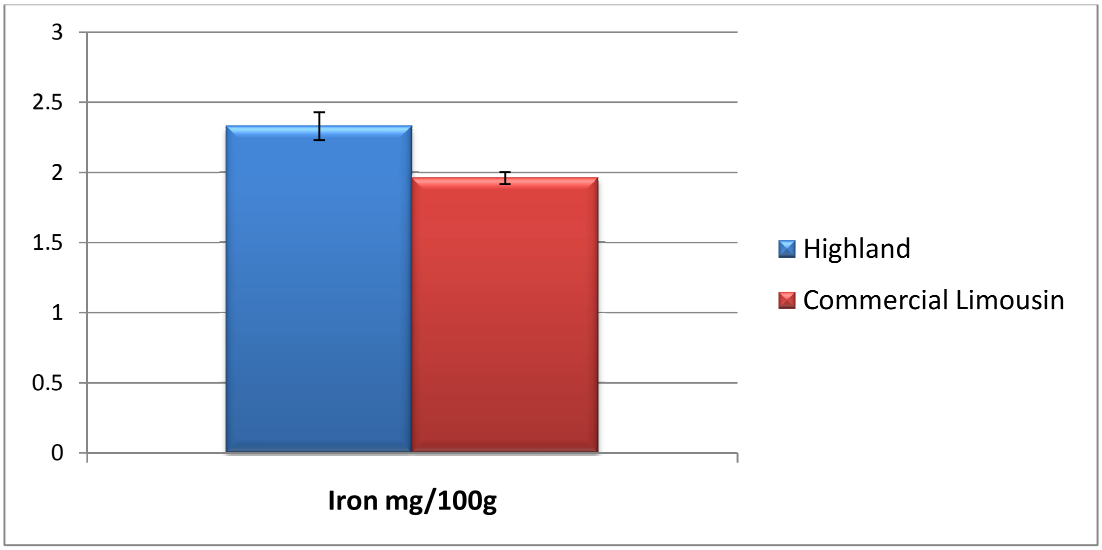

Figure 4.2; Graph of Iron content, comparing Highland and Commercial Limousin sample averages.

As a percentage difference the Highland samples were 15.88% higher than the commercial samples. A two tailed T-Test assuming equal variance was carried out on the Iron results of all samples to form a statistical comparison between the Highland and Commercial iron levels. From the T-Test the results show that the difference in iron levels between the highland samples and commercial samples is statistically significant as the calculated t-Stat figure of 3.489038065 is higher than the t-Critical figure of 2.045229611.

5.1.3. Cholesterol

The analysed cholesterol levels of the Highland breed samples and the Commercial Limousin breed samples showed that the Highland breed samples were on average 2.2 mg/100g lower in cholesterol than the commercial Limousin breed samples. The average Cholesterol levels of the two sample populations along with standard error bars are shown in figure 4.3 below.

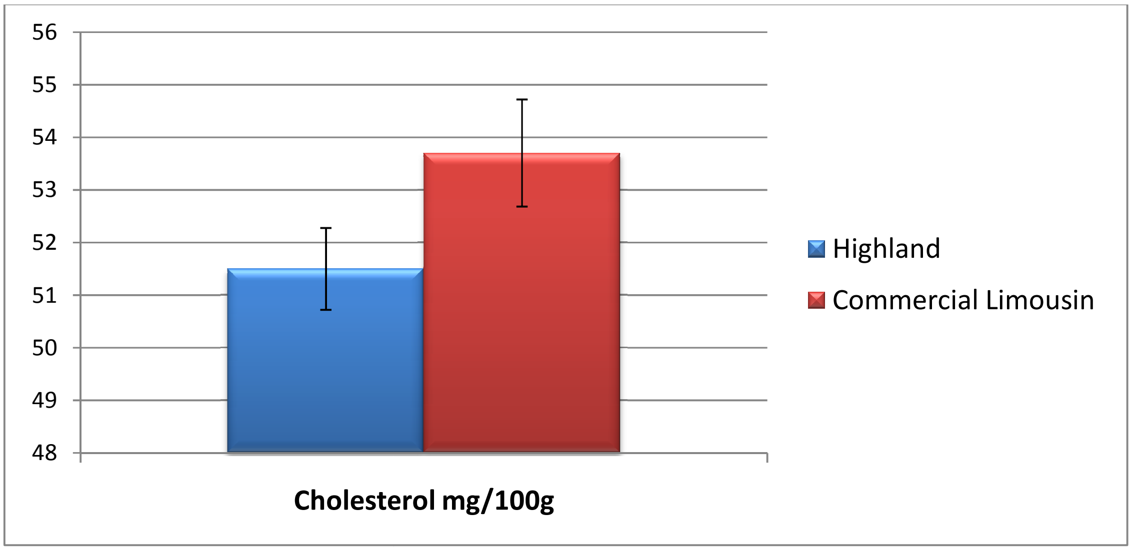

Figure 4.3; Graph detailing the difference in average cholesterol levels of the Highland beef samples and the commercial Limousin samples.

The highland samples were on average 4.1% lower than the commercial samples. A two tailed T-Test assuming equal variance was performed on the cholesterol results of all samples in order to form a statistical comparison between the Highland and the Commercial samples. The results show that the difference in cholesterol between the highland samples and the commercial samples is not statistically significant. As the calculated t Stat figure of -1.716251081 is lower than the t Critical figure of 2.048407115.

4.1.4. Intramuscular Fat Content

The analysed results for intramuscular fat content show that on average the Highland breed samples contained 1.61 g/100g more intramuscular fat than the Commercial Limousin breed samples. The average results along with the standard error bars are shown below in figure 4.4.

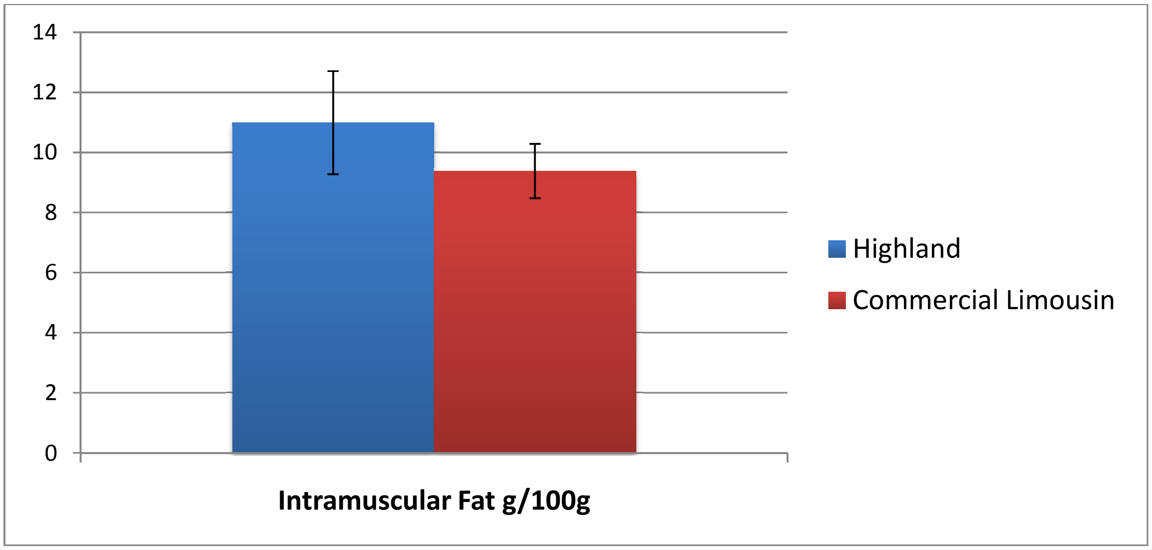

Figure 4.4; Graph of Intramuscular Fat content comparing Highland and Commercial Limousin sample averages.

As a percentage difference the Highland samples contained 14.65% more intramuscular fat than the commercial samples.

A two tailed T-Test assuming equal variance was performed on the intramuscular fat content of the samples analysed to test for statistical difference in the results. The results obtained show that the total intramuscular fat content within the highland samples is higher than the commercial samples, however the difference is not statistically significant as the calculated t-Stat of 0.864337103 is lower than the t Critical figure of 2.045229611.

This may be seen as a negative factor with the fat being higher in the highland animal, however this is a positive factor when looking at the preferential characteristics of the beef as a whole as the fat measured was the intramuscular fat and not the total fat. This intramuscular fat is also known as marbling and is what gives the beef its succulence and flavour when cooking.

4.2. Tenderness Results

	Average Lateral Peak
Highland Samples	83.27
Commercial Limousin Samples	107.84

Table 4.2; table of average lateral peak results of Highland samples and Commercial Limousin Samples.

A copy of the full table of results and the T-Test done for the tenderness analysis can be found in appendix 3. The main part of these results was the lateral peak recording which measures the tenderness of the samples.

Table 4.2 above shows the average lateral peak figures obtained from the shear slice force test, from this it can be seen that the average difference was 24.57, this figure equates to a 22.78% difference in tenderness figures between the Highland Samples and the Commercial Limousin samples. A figure below 100 is regarded as being very tender and any figure over 200 is regarded as being very tough. Hence the lower the figure the more tender the meat.

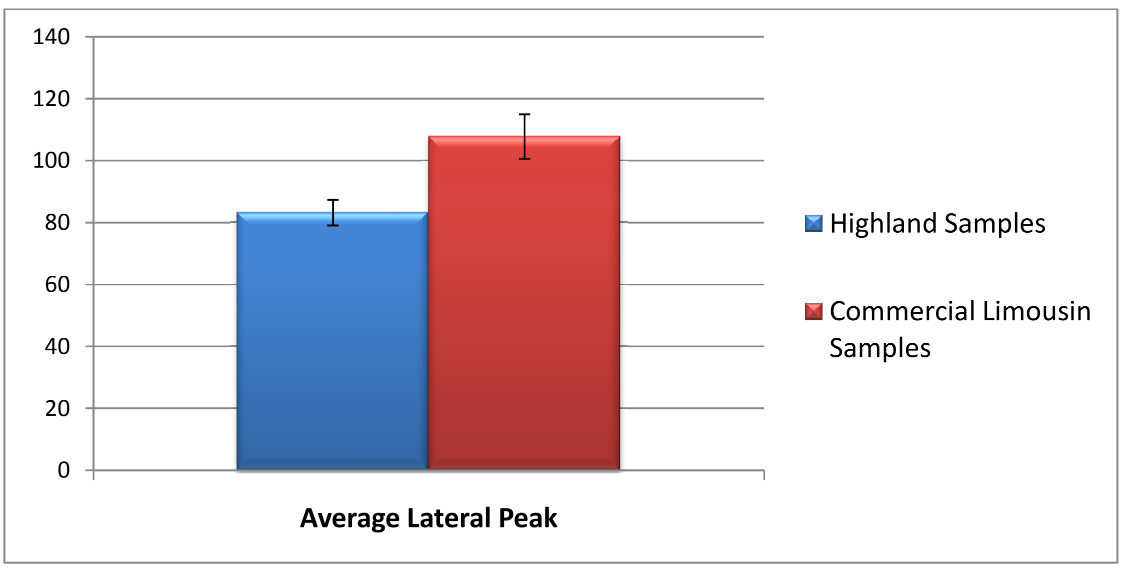

Figure 4.5; average lateral peak figures of the Highland breed samples compared to the Commercial Limousin breed samples.

A two tailed T-Test assuming equal variance was carried out on the lateral peak results obtained from the Shear Slice test to analyse whether there was a statistical difference between the two sample populations. The results of the T-Test show that the highland samples gave statistically lower results than the commercial samples as the calculated t-Stat value of -2.961001391 was higher than the t-Critical value of 2.048407115.

4.3. Correlation Results

	Protein	*Total Fat*	*Iron*	*Cholesterol*	*Lateral Peak*
Protein	1				
Total Fat	-0.6587	1			
Iron	0.294717	-0.08602577	1		
Cholesterol	0.313655	-0.403334	-0.079089	1	
Lateral Peak	-0.2192	-0.02329809	-0.244402	0.3300449	1

Figure 4.6; Correlation output

To analyse whether there was a statistical link between any of the analysed characteristics a correlation test was performed with the above output being obtained.

The above correlation shows that there are no strong correlations between any of the tested beneficial characteristics. The most surprising of these is the low figure for correlation between fat and cholesterol level as these may have been expected to be highly correlated.

Chapter 5: Discussion

5.1. Discussion of Results

The results show that there are preferential characteristics within the highland beef when compared to the commercial samples, with the iron, protein and tenderness all proving to be statistically better than the commercial samples.

The iron levels being significantly higher in the highland beef samples is in agreement with the results from the previous study by Barclay in 1997 and will be seen as a very positive result by highland cattle breeders. This is a highly saleable marketing point within beef as it gives it preference for those who suffer from iron deficiency conditions. This attaches a significant health benefit to the Highland samples compared to the commercial Limousin beef.

The protein results are another very strong marketing point for the highland breed. With the population being encouraged to eat as little red meat as possible, there is still a need to eat the daily recommended levels of protein. It is therefore important to maximise the levels of the protein from each portion.

The intramuscular fat levels of the highland beef also proved to be higher than those of the commercial samples, although not statistically significant, this is another positive aspect of the results from the point of view of the Highland animal as this shows a higher level of marbling within the meat sampled. The experiment was set up to analyse the intramuscular fat content rather than the total fat content which means that a higher figure in this case is a better figure as it improves the eating quality of the beef, the fact that this result proved to be statistically insignificant was interesting as in the previous experiment the difference between the fat content of the highland samples and the other samples was vast, however this may be down to the use of total fat content rather than the intramuscular fat content analysed in this experiment. It may have been more beneficial to gain results for both the total fat content and the intramuscular fat content of the samples, this was made more difficult to control as the samples were at different levels of finish, hence some would have proved a lot higher in total fat than others.

The higher levels of intramuscular fat within the Highland breed samples relates well to some of the studies cited in chapter 1 of this study, as the studies show that the traditional breeds show higher levels of marbling within the beef. There is also a disagreement with the other studies cited which have shown that the marbling level is attributed to intensive feeding of the animals. As the Highland animals would not have been so intensively fed as the commercial Limousin animals.

The lower cholesterol but higher fat content of the samples would tend to disagree with most opinions which say that the cholesterol levels of a beef sample are related strongly to the fat content. The lack of a correlation between the fat and cholesterol levels also goes against this theory and proved to be an interesting point of the results.

The cholesterol figures obtained, are likely to be viewed as the most disappointing by highland cattle breeders. Although still lower than the commercial samples by 4.1%, the difference proved to be insignificant. This is in contrast to the previous study in 1997 that's results proved very favourable for the highland samples with regards to cholesterol. A possible reason for this could have been the choice of comparative, the previous study used "all beef", this would have included beef finished using a number of other more intensive methods of feeding such as, feed-lots and barley beef systems. As intensive finishing of beef is thought to increase the cholesterol levels within beef due to the different Fatty acid compositions that result from predominantly grain fed beef when compared to predominantly grass fed beef, the average cholesterol level for "all beef", as found in the previous 1997 study, may have been expected to be higher. This lack of significance within the results is not solely due to the comparative changing however, as the Highland samples analysed showed a large increase from the 1997 study, the Highland and comparative were both almost half way between the Highland and "all beef" figures from 1997.

Possible reasons for the highland results to have risen so much could be that some of the samples were taken from those who are finishing highland cattle specifically for meat production, this means that they are likely to be feeding them more grain than perhaps others would, it could also just be because of the large variation which is thought to exist within each breed, this should have been avoided by the large variation in the samples collected. Without a copy of the previous 1997 study however a definitive answer on this cannot be given as there is not enough knowledge of the samples used in the previous study.

The lack of significance in the results obtained from the analysis of the cholesterol in this study, agrees with the US study which showed that there was little breed difference in cholesterol levels, and little difference in cholesterol depending on age at slaughter. The cholesterol results from the Commercial Limousin breed animals are very favourable for the commercial beef sector as they prove to be significantly lower than the "all beef" figures which were used as a comparative in the Barclay 1997 study.

The tenderness results obtained from the experiment were significantly in favour of the highland animal, the proportion of this difference resulting from the different ageing periods applied to the beef for the purposes of this study, and the proportion resulting from the breed difference is unknown. This difference in maturation time was used as a measure of the differing ways in which the highland beef from the sources used is handled prior to sale, compared with the pre sale handling of the majority of commercial beef within the country. With regards to tenderness analysis, perhaps it may have improved the quality of results had a full sensory analysis picture been built up, including possible blind tasting experiments. Full sensory analysis was avoided to limit any personal opinions being brought into the results, however it may have enhanced the profile. of the beef with regards to flavour, succulence and tenderness if these analysis techniques had been used. This would also have involved acquiring larger quantities of samples which may have proved more difficult and may have been costly.

The results show a general increase in health results, from the Barclay 1997 study, in both the Highland breed samples and the Commercial Limousin breed samples, with the exception of the Highland breed cholesterol samples. From this it could possibly be concluded that the health characteristics present within beef in the UK have improved as a whole, this could be due to the increased health and welfare measures in place following disease outbreaks in the period between the 1997 study and the present day, such as BSE and Foot and Mouth disease. Although the different samples used could be the contributing factor these different measures are likely to have had some effect on the industry, the ever increasing costs of producing cattle may lead to more the use more of the native smaller breeds, with less intensive inputs being used in future, this may again have a beneficial effect on the health properties of the beef products within the UK.

5.2. Sample Problems

The major problem with the samples was that there were too few of them, due to the financial constraints of a fourth year honours project, however there should have been enough to form a fair comparison and say with some confidence that the results are accurate. Another problem may be the fact the samples were taken from slightly different parts of the animal, with the highland samples being taken from the sirloin part of the loin muscle and the commercial samples being taken from the rib-eye part of the loin muscle and surrounding muscles. This was due to the abattoirs preference, as this is the part of the animal which they were willing to provide. The difference is very slight as both the Rib-eye and Sirloin cuts are a continuation of the loin muscle. The lack of a controlling factor for the animals used, in terms of a control over age, or finish level of the cattle, may also be an issue, as it provided a number of uncontrolled variables. The problem of different ages of cattle at finish, is one which could not have been avoided for this study, and is unlikely to be possible to avoid in any future study involving the highland animal, due to its slower maturing nature. If the comparative commercial Limousin animals had been left to grow, until the

Highland animal was at a suitable level of finish, they would have been past their best with regards to fat content and scale.

5.3. Choice of Study Methods

The initial thought process included several differing possibilities, most of which involved questionnaires to be sent to breeders of highland animals, and to non highland breeders, in order to gain information about why people keep the breed, and why people keep other breeds, so that a comparison could be formed regarding reasons for keeping Highland cattle, compared to other breeds used in the UK beef industry. This would not have provided a very useful or relevant piece of work as it would have been compromised heavily by opinions. The next thought was to do an experiment comparing the Highland animal with other major terminal sire breeds used within the UK, in order to analyse any possible difference in beef characteristics between differing breeds. Highland cross animals would have been included as a comparison within that study, to analyse if any benefits were carried through to first generation cross animals. It was felt that this idea would have given excellent data, however the cost and potential political conflicts likely to arise by directly comparing breeds, were to be avoided. There was also an idea to compare different highland animals from differing regions and differing climate and diet, this was thought to contain too many uncontrolled variables, and trying to get a large enough sample of highland carcasses form a number of differing regions may also have proved difficult, due to the low numbers being handled in general. The results from this study would tend towards this idea having negligible results, as the highland animals gave reasonably uniform results, as seen in Appendix 2. It was then thought that taking a representative sample of highland beef, from highland beef producers within the UK, and comparing this against beef from a commercial abattoir, with all samples being of the same terminal sire, would provide a good set of results to update the 1997 study. The Limousin breed was chosen as the terminal sire breed for this experiment, as it is the most commonly used terminal sire breed within the UK beef industry. This choice of sample populations provided a good comparison between the typical highland beef products sold and commercial beef available in the UK. It was then arranged that the samples would be analysed using both sensory and chemical techniques. The tenderness analysis performed would be a Rapid Slice Sheer Force test. This method was chosen as it is the most efficient method with regards to time and volume of sample required, it is also the method which was set up within the SAC's Bush Estate premises for analysis. This experiment was performed at the SAC's Bush Estate premises by the student, to lower costs. Due to the high costs of the chemical analysis it would have been impractical to outsource the tenderness analysis. The chemical analysis performed would include a “group 2” analysis (including; Protein, Fat, Moisture, Ash, Carbohydrate and Energy) and an analysis of the Cholesterol content and Iron content of the samples. This analysis would be outsourced from a food standards lab in order to limit any possible problems with the results. The laboratory used was part of the Eclipse Scientific Group laboratories at their Cambridge site.

The second of the proposed options may have been the most interesting option, however the political conflicts arising from a direct breed comparison, and the sample gathering problems which would have been likely, made this an unfeasible option for a fourth year honours project.

5.4. Limitations

The major limitations on the experiment were finance and time. This meant that the samples had more than one uncontrolled variable. In order to use samples which had only the one variable, the breed of animal, a number of years, and a substantial amount of money would have been required, in order to take young animals of different breeds and take them through in the same climate and feeding regimes to a finished product for analysis. The cost of the testing also meant that a lower number of samples were used than may have been statistically preferable. The finance which was able to be secured was vital to ensuring an experimental approach rather than the subjective approach of sending out questionnaires. The financial constraint relating to an honours project were also a limitation when choosing the final samples for experimentation, to carry on with the initial plan of using 5 different breeds would have required tens of thousands of pounds, in order to collect enough samples of each breed for a statistical comparison to be made.

Being unable to obtain a copy of the previous study was another limitation of the project, the table of results for the study was widely available on highland breeder’s websites, however the full study was unable to be sourced, due mainly to the closure of the department within the Scottish Agricultural College, where the study was performed. Although considerable time was spent trying to obtain a copy of the study it remained elusive, this meant that information about the samples was unknown with regards to the highland animals, it is therefore not possible to make relevant comparisons with the results as the; types, ages, finishing systems and area of origin are unknown.

5.5. Further Work

This study could be taken further if more finance and time were available. If these were in place then a study in which the only variables were the breeds of cattle could be set up, this would have to be done by taking young animals and rearing them in the same conditions with the same feeds and climatic condition. The initial idea of analysing different breeds of cattle, to form a comparison of beef characteristics, would also be a very interesting expansion of this study.

An expansion of this study to include analysis of the fat composition within the highland breed, when compared to other breeds, or the commercial Limousin samples analysed, would have provided added interest to the study, if it had been less expensive. This could include the proportions of saturated and unsaturated fat, and also a breakdown of the omega balance within the meat. This would certainly be interesting with the previous work done on fat composition providing favourable results for the less intensively reared native breeds, when compared to the larger more intensively finished commercial breeds. This may even have been a more relevant study for the current market, more people are becoming concerned with the types of fat they eat and are looking for foodstuffs higher in omega 3 fatty acids, and lower in unhealthy saturated fats.

The possibility of analysing levels of important vitamins and minerals present within beef, which are known to be important within the human body, would have been another beneficial expansion of the study.

Another area of work which may be of interest to the Highland breed is a study into the beneficial effects of lighter carcass animals, such as the highland, on a grass sward. In order to gain a fuller comparison any possible study would have to include out wintering of the lighter carcase animals to show the full annual impact caused by the different groups of cattle on the sward.

Full sensory analysis using blind tasting panels for the further analysis of tenderness, and the analysis of succulence and taste, would be a possible piece of further work from this study. With the preferential tenderness measured within the study being expanded further and the inclusion of other breeds, to form the basis of a very interesting piece of work for the UK beef industry, and in particular those who are marketing specific breeds from small outlets or national retailers.

Chapter 6: Conclusions

The alternative hypothesis was accepted, there were beneficial health and tenderness characteristics present in the beef samples from the Highland breed, when compared to the Commercial Limousin breed samples.

All the tested characteristics showed positively in favour of the highland breed, with the protein, iron and tenderness results proving statistically significant.

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Appendix 2; Full Results Tables for Chemical Analysis

Highland Sample Id	Moisture	Protein	Intramuscular Fat	Ash	Carbohydrate	Energy kcal	Energy kJ	Iron	Cholesterol
H1	62.1	21.9	14.4	0.8	0.8	220	918	20.1	0.051
H2	72.3	22.2	3.6	1	0.9	125	525	18.4	0.049
H3	69.2	21.6	6.9	1	1.3	154	645	30.2	0.051
H4	69.8	22.8	7	1.2	<0.1	154	647	28.4	0.056
H5	64.9	21	13	0.9	0.2	202	841	20.9	0.049
H6	50.3	17.3	31	0.7	0.7	351	1453	19	0.048
H7	65.1	21.7	11.4	0.9	0.9	193	806	23.6	0.052
H8	66.6	21.2	10.9	0.9	0.5	185	771	27.2	0.049
H9	70.3	21.7	7.2	1.1	<0.1	152	635	26	0.053
H10	62.5	19.3	17.2	0.9	0.2	233	967	24	0.05
H11	65.7	20.3	12.3	0.9	0.8	195	814	23.3	0.047
H12	70.1	22.3	7.9	0.9	<0.1	160	671	17.8	0.052
H13	70.5	21.8	7	0.9	<0.1	150	630	27.1	0.053
H14	66	23.1	9.5	1	0.4	180	751	22.3	0.054
H15	69.8	24.2	5.5	1	<0.1	146	615	21	0.058

Full Table of Results from the Chemical Analysis Carried out on the Highland Breed Samples

Commercial Limousin Sample Id	Moisture	Protein	Intramuscular Fat	Ash	Carbohydrate	Energy kcal	Energy kJ	Iron	Cholesterol
C1	69.3	19.7	10.1	0.9	0	170	709	16.2	0.055
C2	68.5	20.3	10.7	0.9	<.01	178	741	19.5	0.052
C3	70.1	19.2	9.3	0.9	0.5	163	680	17.2	0.051
C4	74.9	21.7	2.9	1	<0.1	113	476	19	0.051
C5	63.1	18.6	17.3	0.8	0.2	231	960	20.7	0.048
C6	70.6	19.1	9	0.9	0.4	159	665	22	0.055
C7	68.2	18	13	0.9	<.01	189	787	19.5	0.048
C8	67.3	18.9	12.4	0.8	0.6	189	790	21.9	0.052
C9	71.5	20.7	6.8	0.9	0.1	145	606	20.2	0.054
C10	70.4	20.3	8.7	0.9	<0.1	160	667	21.7	0.053
C11	69	20.1	10.2	0.9	<0.1	172	719	20.3	0.062
C12	73.5	21.3	4.8	1.1	<0.1	128	540	19.5	0.058
C13	72.2	20.9	6.6	0.9	<0.1	143	600	18.4	0.051
C14	71.1	20.7	7.9	1	<0.1	154	644	19.9	0.056
C15	68.4	20.3	11	0.9	<0.1	180	752	18.3	0.059

Full Table of Results from the Chemical Analysis carried out on the Commercial Limousin Breed Samples

Appendix 3; Full Tenderness Results Table and T-Test Output of Lateral Peak

Highland Sample id	Sample weight	End Cook Temp	Final Temp	Difference	Cooked Weight	Weight Lost	Lateral Peak
1	148	71	75.2	4.2	118	30	117.72
2	214	71	79.8	8.8	168	46	69.73
3	202	71.1	73.8	2.7	161	41	74.23
4	139	71	73.7	2.7	111	28	65.58
5	127	71.2	73.1	1.9	115	12	69.05
6	156	71	75.3	4.3	126	30	81.95
7	193	71	73.8	2.8	172	21	73.43
8	127	71.1	74.7	3.6	100	27	74.5
9	114	71	75	4	83	31	119.09
10	117	71.3	73.9	2.6	90	27	93.74
11	119	71	72.6	1.6	94	25	84.67
12	149	71	74.6	3.6	110	39	87.17
13	124	71	75.3	4.3	99	25	82.41
14	165	71	75.5	4.5	123	42	74.75
15	118	71.3	72.6	1.3	92	26	80.96

Highland Rapid Sheer Slice Force Test Results table

Commercial	Sample weight	End Cook Temp	Final Temp	Difference	Cooked Weight	Weight Lost	Lateral Peak
C1	64	72	77	5	50	14	105.97
C2	103	71.2	72.6	1.4	87	16	105.73
C3	122	71	82.4	11.4	108	14	84.46
C4	122	71	77.4	6.4	101	21	79.57
C5	134	71.8	76.2	4.4	106	28	95.16
C6	110	71.5	75.5	4	87	23	120.64
C7	142	71	74.2	3.2	107	35	101.23
C8	77	71.5	75.3	3.8	60	17	85.49
C9	130	71	73.7	2.7	105	25	134.39
C10	144	71	76.4	5.4	113	31	80.21
C11	108	71	75.5	4.5	89	19	132.4
C12	88	71.8	76.7	4.9	71	17	89.41
C13	124	71	71.8	0.8	101	23	174.09
C14	172	71	74.7	3.7	151	21	93.98
C15	91	71.3	78.7	7.4	70	21	94.67
C16	84	71	78.9	7.9	64	20	145.86

Commercial Limousin Rapid Sheer Slice Force Test Results table.

t-Test: Two-Sample Assuming Equal Variances	*Highland sample Lateral Peak*	*Commercial Limousin Sample Lateral Peak*
Mean	83.26533333	107.70375
Variance	259.3578695	722.1743717
Observations	15	16
Pooled Variance	498.7457155	
Hypothesized Mean Difference	0	
df	29	
t Stat	-3.044796349	
P(T<=t) one-tail	0.002458033	
t Critical one-tail	1.699126996	
P(T<=t) two-tail	0.004916066	
t Critical two-tail	2.045229611	

The T-test output for the statistical comparison of the Lateral Peak results obtained from the Shear Slice Test.

Appendix 4 T-Test Outputs from Chemical Analysis

t-Test: Two-Sample Assuming Equal Variances	*Highland Protein*	*Commercial Limousin Protein*
Mean	21.49333333	19.98666667
Variance	2.662095238	1.096952381
Observations	15	15
Pooled Variance	1.87952381	
Hypothesized Mean Difference	0	
df	28	
t Stat	3.009704766	
P(T<=t) one-tail	0.002742029	
t Critical one-tail	1.701130908	
P(T<=t) two-tail	0.005484057	
t Critical two-tail	2.048407115	

This is the T-test output from the Protein comparison analysis

t-Test: Two-Sample Assuming Equal Variances	*Highland Iron*	*Commercial Limousin Iron*
Mean	23.28666667	19.62
Variance	14.72695238	2.746
Observations	15	15
Pooled Variance	8.73647619	
Hypothesized Mean Difference	0	
df	28	
t Stat	3.397300111	
P(T<=t) one-tail	0.001028399	
t Critical one-tail	1.701130908	
P(T<=t) two-tail	0.002056798	
t Critical two-tail	2.048407115	

T-Test output from the Iron comparison analysis

t-Test: Two-Sample Assuming Equal Variances	*Highland Cholesterol*	*Commercial Limousin Cholesterol*
Mean	0.051466667	0.053666667
Variance	9.12381E-06	1.55238E-05
Observations	15	15
Pooled Variance	1.23238E-05	
Hypothesized Mean Difference	0	
df	28	
t Stat	-1.716251081	
P(T<=t) one-tail	0.048580966	
t Critical one-tail	1.701130908	
P(T<=t) two-tail	0.097161933	
t Critical two-tail	2.048407115	

T-Test output for the Cholesterol comparison analysis.

t-Test: Two-Sample Assuming Equal Variances	*Highland Total intramuscular Fat*	*Commercial Limousin Total Intramuscular Fat*
Mean	10.98666667	9.38
Variance	43.99838095	12.19028571
Observations	15	15
Pooled Variance	28.09433333	
Hypothesized Mean Difference	0	
df	28	
t Stat	0.830131798	
P(T<=t) one-tail	0.206743234	
t Critical one-tail	1.701130908	
P(T<=t) two-tail	0.413486468	
t Critical two-tail	2.048407115	

T-Test output for the intramuscular fat content analysis.