The Performance of Ruminant Livestock and the Quality of Their Meat Produced Under Intensive and Extensive Rearing Methods – A Review

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Abstract

A review of the literature was undertaken to assess the current state of knowledge regarding the impact of rearing method (Extensive vs. Intensive) on ruminant livestock performance, and on the resulting meat quality. The impact of breed type (Rare/Native Breeds vs. Improved Breeds) was also factored into this assessment, in order to assist in the weighing up the role of traditional/native breeds in conservation grazing. As a consequence of their ability to hold greater stock levels, intensively managed pastures produce a greater cumulative amount of meat, in comparison to those extensively managed. On the other hand, meat from livestock on extensive pastures has been shown to have a higher polyunsaturated:saturated fatty acid ratio (due to lower intramuscular fat levels) and a higher n-6:n-3 fatty acid ratio, although what causes the latter is unclear. No clear pattern or no significant difference exists in the research between intensive and extensive rearing methods for carcass weights, carcass conformation scores, carcass fatness scores, meat conjugated linoleic acid contents, meat colour, meat oxidative stability and sensory attributes. Furthermore, no major (Extensive vs. Intensive) x (Rare/Native Breeds vs. Improved/Continental Breeds) interactions were noted and the only difference between the breed types was in carcass fatness, which was greater in the rare/traditional breeds. The paucity of research covering this topic is a likely cause for this lack of understanding of certain parameters on extensive rearing systems. It is concluded that more research is needed using a cross factorial design, to ensure all factors of extensive systems are taken into account so that a clearer picture can come to light regarding the impact of such a rearing method, on livestock performance and meat quality.

Front Cover photograph by J. Noades (2009).

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Contents

1. Introduction

As highlighted by Naveh (1998), the transition of human society through the industrial fossil-fuel age and into a post-industrial global information era, has been associated with accelerating rates of biological, environmental and cultural impoverishment within in our landscapes (See Table 1). Mankind has now reached a cross roads, where it can choose to either enter into a partnership with our natural world, or continue to falsely behave as its master and pave the way to our destruction.

Table 1: A summary of 4 UK Ecosystems used in livestock production including an outline of their past alterations and the associated factors behind such change. Note that agriculture is a key factor. Ecosystem definitions and related information extracted from the UK National Ecosystem Assessment Technical Report (UK NEA, 2011).

UK Ecosystem	Associated Habitats	Examples of the Goods and Services They Provide	Past Changes	Key Reasons for Past Changes
Mountains, Moorlands and Heathlands	Heathland; Bracken; Upland Fen, Marsh and Swamp; Bog; Montane; Inland Rock.	Food and Fresh Water; Climate Regulation; Flood Regulation; Water Quality Regulation; Recreation and Tourism; Aesthetic Values.	Overall, there has been a long term decrease in the condition of such habitats. Great losses have been noted in the extent of heathland and bog habitats in the last two decades.	Afforestation, agricultural development, overgrazing and airborne pollution.
Semi-Natural Grasslands	Calcareous GL; Acid GL; Neutral GL; Lowland Fen, Marsh and Swamp.	Food and Biofuels; Climate Regulation; Air and Water Quality Regulation; Cultural Heritage; Education.	Dramatically declined in area since the end of the second world war, with around a 90% loss in UK lowlands.	Agricultural grassland improvement, conversion to arable and/or forestry, nitrogen deposition and transfer and overgrazing.
Woodlands	Broadleaved; Mixed; Yew; Coniferous.	Timber and Fuelwood; Species Diversity; Climate Regulation; Erosion Control; Soil Quality Regulation; Recreation and Tourism; Sense of Place.	Great losses over the last millennium. However, since 1945, woodland has doubled to cover 12% of the UK. Much of this increase is due to timber production, leading to a dominance of timber species.	There are many factors including pollution, change in land use, as well as global timber trade and domestic markets.
Coastal Margins	Sand Dunes; Machair; Sea Cliffs; Saltmarsh.	Food and Cooling Water (Power Plants); Biodiversity Coastal Defence; Pollution Control; Spiritual Values; Health Benefits.	Costal margin habitats have declined by an estimated 16% since 1945.	Development for industry, housing, tourism and agriculture.

Signs of a symbiotic relationship between human society and nature are already appearing through agri-environment policy, as well as scientific research covering landscape multi-functionality (Gibon, 2005). Well managed livestock grazing within semi-natural habitats like those mentioned in Table 1, is a good example of this relationship at work. Grazing is crucial to maintain the structure and composition of a number of natural habitats, upon which a variety of plants and animals are dependent for their survival (Rook et al., 2004; Tallowin et al., 2005 and English Nature, 2005). However, this extensive form of grazing is still a low key method in comparison to the more conventional methods of livestock rearing (e.g. grazing on improved pastures), owing to greater returns for farmers from the latter (Hodgson et al., 2005), as well as weaknesses in agri-environmental policies (Beaufoy & Marsden, 2010). Livestock products from extensive grazing systems can fetch premium prices as a result of the slower, less intense production methods, which are associated with the natural landscapes and cultural heritage, which consumers can become emotionally attached too (Bignal et al., 1999 (cited from Rook et al., 2004) and Kuit & Van der Meulen, 1997). Despite this, Milne (2005) and Dr Ian Richardson of the University of Bristol (Personal Communication, 17th July 2012), both highlight a lack of knowledge when it comes to the impact these grazing schemes have on livestock performance, as well as the resulting meat quality.

This review aims to outline the present understanding of extensive grazing systems, and their impact on livestock performance and meat quality, in comparison with conventional management schemes. Within this overview, a similar evaluation of rare/native livestock breeds, compared with improved varieties of livestock under the comparative management schemes, will also be offered (breed x environment interactions). The Grazing Animals Project (GAP, 2009) indicates that rare/native breeds are frequently used in conservation and extensive grazing as a consequence of their hardiness, and their ability to cope within unimproved grasslands. Rook et al. (2004) however, point out that much quantification of the various breed and rearing environment effects on animal performance and meat quality, is still required. It will therefore be appropriate to factor in the role of rare/native breeds in this review, so that more holistic conclusions can be drawn on what is required of future research regarding extensive grazing, in order to underpin the development of sustainable livestock systems.

2. Aims and Objectives

2.1 Aims

1. To review the current state of knowledge regarding the impact of rearing method (Extensive vs. Intensive) on ruminant livestock performance and the resulting meat quality.
2. To review the current state of knowledge regarding the impact of breed type (Rare/Native Breeds vs. Improved Breeds) on ruminant livestock performance and meat quality under different rearing methods ((Extensive vs. Intensive) x (Rare/Native Breeds vs. Improved/Continental Breeds)).

2.2 Objectives

The following is to be reviewed within the variables stated in the aims above:

- Animal Performance and Carcass Quality – e.g. live weight gain measurements, carcass conformation and fat scores.
- Nutritional Meat Quality – e.g. Intramuscular fat content, fatty acid composition.
- Sensory Meat Quality – e.g. Taste, texture, juiciness, meat colour and oxidative stability.

Proposals for future research will be provided throughout the review and summarised in the final section.

3. Animal Performance and Carcass Quality

3.1 Animal Performance

Livestock that reach the desired slaughter weight at a younger age (i.e. have high live weight gains) are highly desirable in meat production, as a consequence of the diminishing quality of meat in ageing livestock (Miller, 2002). As highlighted in Table 2, the live weight gain of cattle and sheep when considered cumulatively is greater under more intensive forms of livestock production. Indeed, as highlighted by much of the research, the intensive systems of rearing are able to hold a higher density of livestock, resulting in a greater overall meat output in a given amount of time.

Table 2: Effect of rearing method (Extensive vs. Intensive) on individual and cumulative live weight gain (LWG) in the studies reviewed in the current investigation. Comparisons of LWG measurements between rare/native breeds and improved breeds are also shown in *italics* where studied. N.S.D. = No Significant Difference, Int. = Intensive, Ext. = Extensive, R/N = Rare/Native Breed, I/C = Improved/Continental Breed.

Study	Experiment	Livestock	Individual LWG	Cumulative LWG	Breed x Rearing Environ. Interaction
Fraser et al. (2009)	1	Cattle	Int. > Ext. *R/N > I/C.*	Int. > Ext.	None
	2		Int. > Ext. *N.S.D.*	Int. > Ext.	None
	3		Int. > Ext. *N.S.D.*	Int. > Ext.	None
Fothergill et al. (2001)	-	Lambs	N.S.D.	Int. > Ext.	-
Barthram et al. (2002)	-	Lambs	Int. < Ext.	Int. > Ext.	-
Bjarnadóttir et al. (2006)	-	Lambs	Int. > Ext.	-	-
Steinshamn et al. (2010)	1a (2006)	Cattle	Int. > Ext.	-	-
	1b (2007)		Int. < Ext.	-	-
	2 (2008)		Int. > Ext.	-	-
Isselstein et al. (2007)	UK	Cattle	N.S.D. *R/N < I/C*	Int. > Ext.	None
	Germany	Cattle	Int. < Ext. *N.S.D.*	Int. > Ext.	None
	France	Cattle	N.S.D. *R/N < I/C*	Int. > Ext.	None
	Italy	Ewes	N.S.D. *R/N > I/C*	Int. > Ext.	None

Conversely, no clear pattern seems to emerge from the literature concerning individual live weight gain, and the reasons behind this are unclear. In their first experiment, Steinshamn et al. (2010) found the LWG for pre-weaned calves to be greater on cultivated lowland pasture than mountain pasture in 2006, and vice versa in 2007. Such findings may suggest that the effect of pasture type on LWG may also be dependent on the year. Indeed, the lower individual LWG's noted on the extensive pasture in 2006, may be down to a greater level of annual rainfall on such in comparison to 2007, resulting in the formation of more wet areas of pasture, which cattle tend to avoid grazing (Hessle et al., 2008). Fraser et al. (2009) concluded that the individual LWG of their steers was always greater on the improved pastures. Grazing behaviour measurements suggest this was a consequence of the steers on extensive pastures having to spend a greater amount of time ruminating, at the expense of grazing time, in order to digest the more fibrous flora. More research covering individual live weight gains on a range of different pasture types is required, and this should be accompanied with measurements of possible factors associated with such pastures that could impact individual live weight gains. This research is important because with little chance of gaining similar cumulative live weight gains to intensive methods of rearing, livestock producers using extensive systems will be more concerned over individual live weight gain measurements.

Methodological and geographical differences between the studies highlighted in Table 2, can also be considered factors behind the different patterns noted in individual LWG. Steinshamn et al. (2010) for example utilised pre weaned calves, where as Fraser et al. (2009) utilised weaned cattle. Fothergill et al. (2001) defined intensive and extensive through different fertiliser applications to the pasture, where as Barthram et al. (2002) and Isselstein et al. (2007) used different sward heights maintained by different grazing intensities. Fraser et al. (2009), Steinshamn et al. (2010) and Bjarnadóttir et al. (2006) on the other hand used two contrasting pasture types, an unimproved (extensive) treatment and improved (intensive) treatment. Future research should perhaps consider comparing the impacts of different grazing intensities with those of different fertiliser applications, through cross factorial studies.

It has been suggested that slower growing traditional breeds are more suited for fattening on extensive pastures, when compared with the faster growing continental breeds (Tolhurst and Oates, 2001). Much of the evidence supporting this statement however is anecdotal (Ferguson, 2012). Furthermore, despite the significant results highlighted in Table 2, Isselstein et al. (2007) and Fraser et al. (2009) concluded that choosing to use a traditional breed should be based on their ability to survive and reproduce on extensive pastures, rather than on their ability to put on fat, which was seen as unimportant. Indeed, more scientific research seems to exist for the former, in comparison to the latter. Casasús et al. (2002) also found no difference in cattle performance between two different breeds on mountain pastures. Nevertheless, breed x diet interactions on live weight gain have been noted in more conventional systems (Warren et al., 2008a) and Isselstein et al. (2007) did notice some commercial vs. traditional breed x country interactions on animal performance in their cross European study. This author agrees with the conclusion of Fraser et al. (2009), in the need for greater research to quantify the performance of different livestock breeds on a range of vegetation community types.

Fraser et al. (2009) found that despite the individual LWGs for cattle being greater on the improved pastures, the unimproved pastures still produced weight gains that were acceptable for meat production. However, Fothergill et al. (2001) and Barthram et al. (2002) question the ability of extensive pastures to sustain acceptable growth levels. Future research therefore not only needs to bring about an understanding of the impacts on individual LWG, it also needs to look into ways that allows sustainable livestock production on extensive systems.

3.2 Carcass Weight, Classification and Fatness

Carcass weight (CW) is the mass of the body of an animal which has undergone the dressing process (Blanchard et al., 1999). Although a greater carcass weight may result in a greater financial return for the abattoir/farmer, a carcass' conformation and fatness could alter this preferred outcome. Carcass conformation (CC) describes the carcass' muscularity and shape in terms of its convex/concave profiles, and provides an indication of the amount of meat in relation to the size of the bones (DEFRA et al. 2001). In Europe, most carcasses are graded for their conformation under the following system with the classes: E, U, R, O and P. E refers to a carcass of excellent conformation that is likely to contain less waste as a consequence of its greater meat to bone ratio. On the other hand, a carcass receiving a P classification would show a much lower ratio value (Warriss, 2000). Fatness (CF) refers to the degree of visible fat on the outside of the carcass and is normally categorised within the EU under numerical classes ranging from 1 to 5 for cattle, and 1 to 4 for sheep, with the last two digits further divided into low (L) and high categories (H) (Blanchard et al. 1999). With there being an increasing demand for leaner meat from consumers (Zervas and Tsiplakou, 2011), carcasses with a high fat class (e.g. 5L) are penalised against, as are those at the opposite end of the scale with too little fat. Put together, CF and CC score indicate the proportion of saleable meat (the valuable meat that's left after excess fat, bones and other trim has been removed) in the carcass, and thus determine the financial return for the abattoir/farmer (DEFRA et al. 2001).

Zervas and Tsiplakou (2011) reviewed that lambs raised under a grazing system will produce carcasses of an inferior CF and CC score, in comparison to those fed a diet of concentrates. Supporting this statement, Priolo et al. (2002) in their experiment to explore potential growth rate x nutritional environment interactions, found lambs raised in stalls and fed concentrates produced heavier and fattier carcasses with better conformation scores than those lambs free to graze on natural pasture. Similar results by Wikilund et al. (2001)

were also found for reindeer under similar dietary treatments. However, a comparable yet later study by the same primary author (Wikilund et al., 2003) produced a different pattern of

Table 3: Effect of rearing method (Extensive vs. Intensive) on livestock carcass weight, conformation and fatness in the studies reviewed in the current investigation. Comparisons of these variables between rare/native breeds and improved breeds are also shown in *italics* where studied. Studies highlighted compare these variables under extensive pasture and concentrate feeding, as opposed to extensive pasture and improved pasture. * indicates a difference that is not significant due to sample size. N.S.D. = No Significant Difference, Int. = Intensive, Ext. = Extensive, R/N = Rare/Native Breed, I/C. = Improved/Continental Breed.

Study	Experiment	Livestock	Carcass Weight	Carcass Conformation	Carcass Fatness	Breed x Rearing Environ. Interaction
Fraser et al. (2009)	2	Cattle	Int. > Ext. *R/N > I/C*	Int. > Ext. *N.S.D.*	Int. > Ext. *R/N > I/C **	None
Bjarnadóttir et al. (2006)	-	Lambs	N.S.D.	N.S.D.	Int. < Ext.	-
Steinshamn et al. (2010)	1a	Cattle	Int. > Ext.*	Int. > Ext.	Int. < Ext.	-
	1b		Int. < Ext.	Int. < Ext.	Int. < Ext.	-
	2		Int. > Ext.	N.S.D.	Int. > Ext.	-
Ådnøy et al. (2005)	-	Lambs	Int. > Ext. *	Int. < Ext.	N.S.D.	-
Richardson et al. (2008)	Objective 2	Cattle	Int. > Ext. *R/N < I/C*	N.S.D. *N.S.D.*	Int. > Ext. *R/N > I/C*	None
Priolo et al. (2001)	-	Lambs	Int. > Ext.	Int. > Ext.	Int. > Ext.	-
Wikilund et al. (2001)	-	Reindeer	Int. > Ext.	Int. > Ext.	Int. > Ext. (Trim fat, % of carcass weight)	-
Wikilund et al. (2003)	1	Reindeer	N.S.D.	Int. > Ext.	Int. > Ext. (Trim fat, % of carcass weight)	-
	2		Int. > Ext.	N.S.D.	Int. < Ext. (Trim fat, % of carcass weight)	-

results. For example, trim fat (% of carcass weight) in the first experiment of this study was greater from the carcasses of reindeer fed concentrates, in comparison to those reindeer on natural grazing, and vice versa in experiment two. The animals in experiment one however were older and as livestock grow older, the proportion of fat in their carcasses increases, since fat is the last tissue to be laid down in the growth process (Warriss, 2000; Zervas and Tsiplakou, 2011). Therefore, as a consequence of their immaturity, it could be argued that the animals in experiment 2 had not yet reached their fat storing potential, and thus the greater energy intake through the concentrates diet was not yet the major influence over fat level. Furthermore, the difference in trim fat between the carcasses of both treatment groups was greater in experiment one (2%) than in experiment two (0.4%). Priolo et al. (2002) also found that lambs raised on a low growth weight were slaughtered at the same weight as those reared on a high growth weight, but consequently at an older age with a higher CF.

Fraser et al. (2009) was the only study out of those undertaken on improved and unimproved pastures, where CF, CC and CW were significantly greater on the intensive than the extensive treatment. A key difference between this study and those of Ådnøy et al. (2005), Bjarnadnóttir et al. (2006) and Steinshamn et al. (2010), was the location of their treatments. Fraser et al. (2009) had both their improved (intensive) and unimproved (extensive) pastures situated in upland locations. The other studies however located their intensive treatments in lowland regions and their extensive treatments in upland areas. Whilst many upland pastures are utilised for extensive grazing, the differences in CF, CC and CW highlighted in Table 3 may have been down to differences between lowland and upland environments alone (e.g. the vegetation communities present, temperatures etc.), rather than differences in farming method. Furthermore, Steinshamn et al. (2010) highlight the differences between lowland and upland locations can alter according to year. During the first half of their study, the first experiment in 2006 (1a in Table 3) produced carcasses from livestock on intensive lowland pastures with greater weights (although not significantly different) and better conformation scores than those from mountain extensive pastures. However, from their second experiment in 2007 (1b in Table 3), this relationship was vice versa. They attributed this to the cooler summer experienced in 2007, which would have delayed plant maturity and prolonged the access to high quality forage in mountainous regions.

Richardson et al. (2008) and Fraser et al. (2009) found no nutritional environment x genotype interactions ((Extensive vs. Intensive) x (Rare/Native Breeds vs. Improved/Continental Breeds)). Carcass weights however were found to differ between the rare/native breed and continental/improved breed in both of these studies, with Richardson et al. (2008) also finding a greater fatness score for the rare/native breed. There was no significant difference between the breeds in Fraser et al. (2009) for fatness level, although 15 out of 24 of the Welsh Black Steers had a fat grading of 3-4L in comparison with only 8 out of 24 of the Charolais Cross. This is in line with Hinks et al. (1999) where the later maturing, faster growing improved breeds had a lower fatness level than the early maturing, slower growing native breeds.

In summary, from the few studies reviewed here, livestock fed concentrates tend to have greater carcass weights, confirmation scores and fatness levels than those on pasture. Conversely, studies on improved and unimproved pastures depict less of a clear picture. Indeed, age seems to be a confounding factor along with breed. As highlighted, differences between extensive and intensive pastures may correlate with differences in upland and lowland respectively. Future research into extensive grazing therefore needs to flesh out these confounding factors, with experiments undertaken to quantify the performance of different livestock breeds on a range of extensive pastures.

4. Nutritional Meat Quality

4.1 Fat Content, PUFA:SFA Ratio and n-3PUFA:n-6PUFA Ratio

As a consequence of lipid biohydrogenation (addition of hydrogen) within ruminant digestive systems, saturated fatty acids (SFA) become heavily incorporated into their fatty tissues, creating negative perceptions amongst consumers regarding the nutritional quality of the resulting meat products (Zervas and Tsiplakou, 2011). This viewpoint is justifiable, with fat and SFA consumption having been related to many modern diseases including atherosclerosis and various cancers, with the former increasing the chances of coronary heart disease (Wood et al., 2003; Wood et al., 2007). However, not all the components of fat have a negative value with regards to human health. Polyunsaturated Fatty Acids (PUFA) have been shown to act as an antithrombogenic and to lower cholesterol levels, resulting in a reduced risk of cardiovascular disease (Ulbricht and Southgate, 1991; Wood et al., 2007). In particular, n-3 PUFA have been implicated in reducing the risk of type-2 diabetes, as well as various cancers (Scollan et al., 2008). Therefore, there is a need for a high PUFA:SFA (P:S) ratio within meat to optimise its nutritional quality, with the UK Department of Health recommending a ratio value greater than 0.4 (Wood et al., 2003). In addition, a high n-6PUFA:n-3PUFA (n-6:n-3) ratio within the human diet has been associated with an increased risk in ascertaining some cancers, as well as coronary heart disease, prompting a recommendation for a ratio value of less than 4 in meat (Wood et al., 2003).

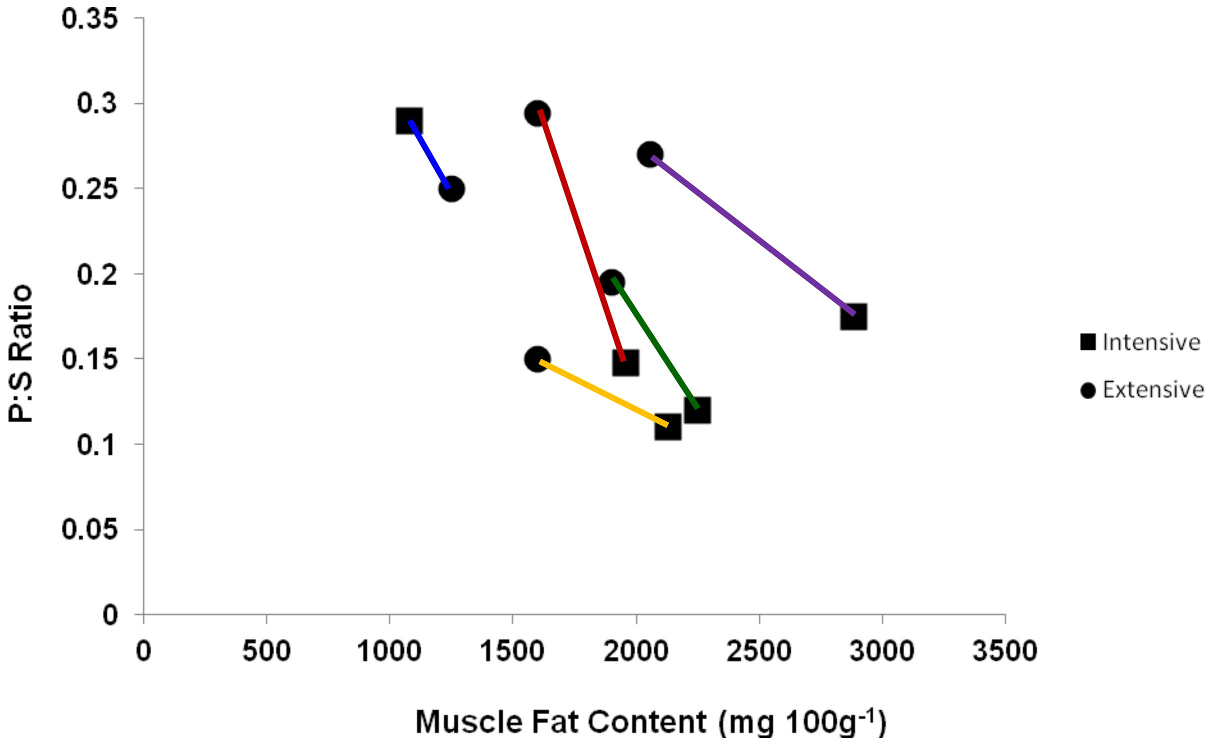
As reviewed by Nürnberg et al. (1998), Scollan et al. (2006) and Zervas and Tsiplakou (2011), many studies have shown that the energy density of the diet, coupled with the level of food intake, will alter the rate of fat deposition in a ruminant, and in turn its lipid composition. Hoehne et al. (2012) clearly demonstrated this latter alteration. Absolute values for ∑SFA and ∑PUFA in cattle meat were found to be positively related with IMF, although the slope of the regression curve for ∑SFA was more positive than that for ∑PUFA, and when considered relatively (% of total FA in *longissimus* muscle), ∑PUFA was negatively correlated with IMF. This is a consequence of the nature of the PUFA rich Phospholipid (PL) fraction of fat (see table 4) to remain more or less constant with increasing IMF. On the other hand, the PUFA poor Triacylglycerol (TG) fraction of fat (see table 4) increases with greater IMF, resulting in the % proportion of ∑PUFA being diluted by an increase in the total amount of SFA and MUFA (Monounsaturated Fatty Acids), which dominate the content of TG. Such findings also explain the sharply increasing P:S ratio at lower levels of IMF in an exponential model fitted to a number of previous studies by De Smet et al. (2004).

Table 4: The two major types of lipid and some of their associated properties (Wood et al., 2008)

Lipid Types Within IMF	Function	FA Composition	Correlation between Lipid Type and Total Lipid (IMF) (Warren et al., 2008a)
Triacylglycerol (Neutral Lipid)	An energy store in adipose tissue.	• Lower PUFA Content • More Oleic Acid (18:1cis-9) (The Major Fatty Acid in Meat) • Less or No Linoleic Acid (18:2n-6) • Less or No Linolenic Acid (18:3n-3)	Triacylglycerol is positively correlated with IMF with a high regression curve.
Phospholipid	An essential component of cell membranes.	• A Much Higher PUFA Content • Less Oleic Acid (18:1cis-9) • More Linoleic Acid (18:2n-6) • More Linolenic Acid (18:3n-3)	Phospholipid remains fairly constant with increasing IMF.

This knowledge rationalises the differences noted in P:S ratios when comparing meat from livestock reared on intensive or extensive systems, with the former having a greater IMF content and thus a lower P:S ratio and PUFA proportion, in comparison to that from the latter (Wikilund et al., 2001; Richardson et al., 2008; Ådøny et al., 2005; Lourenç o et al., 2007a; Fraser et al., 2009; Steinshamn et al., 2010). Figure 1 highlights this relationship.

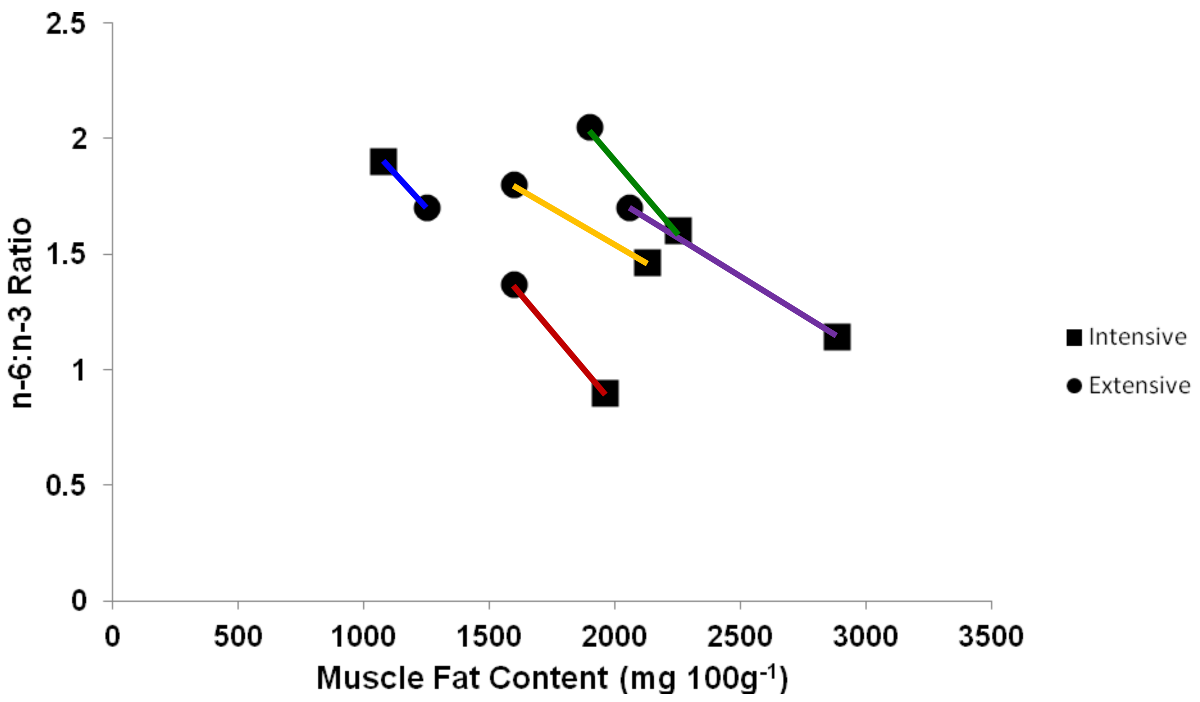
Figure 1: A scatter plot of the muscular fat content and P:S ratio of ruminant meat produced under intensive and extensive livestock systems from Lourenco et al. (2007a), Richardson et al. (2008), Fraser et al. (2009), and Steinshamn et al. (2010) experiments one and two*.



* The use of pre weaned calves in the study by Steinshamn et al. (2010) is a likely cause of the different pattern of results noted between their first and second experiment. In experiment one, the IMF from calves on extensive pastures was found to contain a greater proportion of oleic acid (C18:1n-9) (the most important FA in cow's milk), in comparison to the calves from the intensive rearing system. This suggests that the former had a greater reliance on their mothers' milk and would therefore have consumed less forage (rich in PUFA), resulting in a greater fat intake but a lower consumption of PUFA, when compared with the calves from the intensive system. Reasons behind the calves' over reliance of their mothers' milk in comparison to experiment two may be down to the difference in the quality of pasture. Indeed, the two experiments took place in different geographical locations within Norway, as well as within different years of study leading to possible differences in plant species composition and weather conditions respectively.

Similar studies suggest that the n-6:n-3 ratio is also related to IMF level, with a higher IMF content and a lower n-6:n-3 ratio noted in the meat from intensive rearing systems, in comparison to that from extensive pastures (Wikilund et al., 2001; Richardson et al., 2008; Lourenco et al., 2007a; Fraser et al., 2009; Steinshamn et al., 2010). This relationship is highlighted in Figure 2 and could be attributed to the PL fraction of meat having a greater n-6:n-3 ratio, as well as constituting a greater proportion of total lipid at lower IMF levels, resulting in the overall meat having a greater n-6:n-3 ratio when IMF content is low (De Smet et al., 2004).

Figure 2: A scatter plot of the muscular fat content and n-6:n-3 ratio of ruminant meat produced under intensive and extensive livestock systems from Lourenco et al. (2007a), Richardson et al. (2008), Fraser et al. (2009), and Steinshamn et al. (2010) experiments one and two.



However, the correlation between the n-6:n-3 ratio and muscular fat content has been shown to be weak or non-existant (De Smet et al., 2004; Hoehne et al., 2012). Indeed, Whittington et al. (2006) found no significant difference in the total lipid content between the lamb meat from the animals that grazed improved pasture, saltmarsh, heathland or moorland. The heathland treatment however had a significantly higher n-6:n-3 ratio, as well as a higher P:S ratio alongside the lamb meat from the moorland group, in comparison to the other treatments. Ådøny et al. (2005) also found no significant difference in the IMF level of lamb meat between two different geographically located improved pastures in Norway, yet the meat from one of the pastures had a significantly greater PUFA content than the other.

Much of the scientific literature suggests livestock on a grazed grass/grass silage diet, will produce meat with a greater proportion of n-3 PUFA and a lower proportion of n-6 PUFA in the IMF, corresponding with a lower n-6:n-3 ratio, in comparison to those on concentrate diets (Fisher et al., 2000; French et al., 2000; Gatellier et al., 2005; Scollan et al., 2006;

Wood et al., 2007; Warren et al., 2008a; Moloney et al., 2008). Much of this research relates this difference to the greater proportion of n-3 PUFA (in comparison to n-6) found in grass, rather than down to the impact of fat on n-3 and n-6 proportions (French et al., 2000; Warren et al., 2008a; Moloney et al., 2008). When it comes to improved and unimproved pastures however, no studies have shown a greater supply of n-3 PUFA from either, despite the studies in Figure 2 possibly suggesting otherwise (Lourenco et al., 2007b).

A different explanation could be the process of biohydrogenation in the rumen. PUFA are toxic to many bacteria in the rumen, and will therefore detoxify such through the hydrogenation of the PUFAs' double bonds (Scollan et al., 2008). Some studies have shown that forage from unimproved pastures (leguminous plants in particular) can, through a number of possible mechanisms, avoid much of this hydrogentation process, resulting in a greater outflow of PUFA from the rumen and into the tissues (Moloney et al., 2008). Indeed, Lourenco et al. (2007a) found that some inhibition of biohydrogenation had occurred in the rumen of lambs grazing biodiverse pastures when compared with that from lambs grazing intensive ryegrass pastures, as a consequence of a shift in the rumen microbial population. The resulting higher P:S ratio in the IMF of lambs from Biodiverse in comparison to intensive ryegrass pastures however, could not be distinguished from the impact that IMF level has on P:S ratios. Furthermore, there is little evidence to suggest that this inhibition of the biohydrogenation process has an impact on the n-6:n-3 ratio (Lourenco et al. (2007a). Lourenco et al. (2007a) however did discover that grazing a diverse pasture did stimulate the production of beneficial long chain fatty acids such as Docosapentaenoic acid, Eicosapentaenoic acid and Arachidonic acid in the lambs, more so than those on the other pastures. Again however, the impact of IMF level on the production of these fatty acids could not be ruled out.

There is a paucity of information regarding any (Extensive vs. Intensive) x (Rare/Native Breeds vs. Improved Breeds) interactions concerning meat P:S, and n-6:n-3 ratios. Fraser et al. (2009) found no such interactions. Richardson et al. (2008) on the other hand, noted that

Charolais Cross finished on unimproved pasture produced meat with a lower IMF level and an associated higher P:S ratio, in comparison to the Longhorn native breed. There was no apparent difference between the breeds on the improved pasture. This supports the theory that most differences in FA composition between breeds can be attributed to differences in the genetic influence on IMF levels (De Smet et al., 2004). Indeed, Fraser et al. (2009) found that meat from the Welsh Black steers had an apparent (but not significant) lower IMF content associated with a significantly higher P:S ratio. Despite this, after correction for fat level, breed differences in the MUFA:SFA ratio and in the longer chain C20 and C22 metabolism have been noted (De Smet et al., 2004; Warren et al., 2008a).

In summary, it is apparent that extensive methods of livestock rearing produce meat with a lower IMF content, and as a consequence, a higher proportion of PUFA associated with a higher P:S ratio within the meat. None of the studies reviewed however produced a P:S ratio value >0.4, as is desired for ruminant meat by the UK Department of Health (Wood et al., 2003). De Smet et al. (2004) and Scollan et al. (2006) highlight that this can only be achieved when the IMF constitutes less than 1% of the meat, a result that is only accomplished when using lean breeds (e.g. double-muscled animals). The inhibition of the biohydrogenation of PUFA in the rumen by biodiverse forage may also contribute to the high P:S ratios in the meat associated with such grazing. Such a process should therefore be explored further relative to unimproved pastures, if a P:S ratio >0.4 is to be achieved. The n-6:n-3 ratio appears to be higher in meat from extensive systems as opposed to intensive systems. What causes this relationship however is unclear, resulting in a need for future research to flesh out the role of IMF levels, dietary constituents and biohydrogenation on impacting n-3 and n-6 PUFA proportions. As reported by Scollan et al. (2008) and Moloney et al. (2008), there is lack of research that considers the impact these underpinning mechanisms have on the fatty acid composition of meat from ruminants consuming biodiverse pastures. Despite all this, achieving a recommended P:S ratio of >0.4, and a n-6:n-3 ratio of <4 at the same time under either an intensive or extensive system, may not be possible. Indeed, the lowest n-6:n-3 ratio reviewed by Scollan et al. (2006) was 0.9 in the beef of cattle fed fish oil as a part of their diet, a constituent difficult to incorporate fully into extensive systems. However, despite the extensive systems producing meat with higher n-6:n-3 ratios than intensive production methods, the former's ratios were still less than 4. Combine this with the higher P:S ratios and it can be argued that extensive systems produce meat of greater nutritional quality. A greater quantity of research however is required in order to make similar statements regarding different breeds.

4.2 Conjugated Linoleic Acid

Conjugated Linoleic Acids (CLA) have been shown to have the potential of enhancing immunity, alleviating allergies, decreasing blood cholesterol, acting as anticarcinogens, and having antiatherosclerotic effects (McGuire and McGuire, 2000; Mir et al., 2004). The amount of CLAs in meat however is relatively small when compared with the required daily intake of 3500 mg $d^{-1,}$ in order to have any appreciable health benefits (Mir et al., 2004).

CLA proportions of total lipid are usually greater in meat from livestock on grazing pastures in comparison to that from livestock fed concentrates (French et al., 2000; Mir et al., 2004; Scollan et al., 2006; Wood et al., 2007; Moloney et al., 2008). This has been attributed to the proportionally higher level of PUFA found in grass based diets, in comparison to concentrates (Scollan et al., 2006). The main pathway of CLA synthesis involves the rapid biohydrogenation of such PUFA into stearic acid (18:0) within the rumen, with Trans Vaccenic Acid (TVA) formed as an intermediate of this process. The latter is then converted into CLA within adipose tissue, by Δ9 desaturase (Scollan et al., 2006; Wood et al., 2008). Grass based diets also create a rumen environment that promotes biohydrogentation more than a concentrate diet, leading to greater TVA and CLA production within the rumen itself, with the bacterium *Butyrivibrio fibrisolvens* being key to this process (Kepler and Tove, 1967, cited from French et al., 2000).

When it comes to comparing CLA content of meat from unimproved and improved pastures however, the paucity of research on the subject depicts an unclear picture. Indeed, it is the lack of research into this area that makes any patterns difficult to decipher. The different patterns highlighted for rearing method between the studies in Table 5 are likely a cause of differences in diet. Nevertheless, how this impacts the CLA content is unclear, due to more than one mechanism having being noted above (i.e. dietary constituents, impact on rumen environment, impact on desaturase enzyme in adipose tissue). When comparing meat from different extensive grazing habitats, a significantly higher amount of CLA was found in muscle from lambs on moorland habitat compared to others (Whittington et al., 2006). There is therefore good reason for more research to be undertaken on meat from extensive pastures concerning CLA content.

Table 5: Effect of rearing method and breed on CLA proportions of total FA. * indicates a difference that is not significant due to sample size. N.S.D. = No Significant Difference, Int. = Intensive, Ext. = Extensive, R/N = Rare/Native Breed, Imp. = Improved Breed, # - Although not the major CLA isomer in meat, it is a key one.

Study	**Rearing Method or Breed**	**IMF**	**CLA cis-9, trans-11**	**CLA trans-10, cis 12 [#]**
Lourenco et al. (2007a)	Rearing Method	Int. > Ext.*	N.S.D.	N.S.D.
Richardson et al. (2008)	Rearing Method	Int. > Ext.	Int. < Ext.	-
	Breed	An apparent but not significant breed x rearing method interaction.	A significant breed x rearing method interaction.	-
Fraser et al. (2009)	Rearing Method	Int. > Ext	Int. >Ext	-
	Breed	Imp. > R/N *	Imp. < R/N	-

Richardson et al. (2008) noted a significant breed x rearing method interaction for CLA content in one part of their study. The CLA proportion of total fatty acids increased from improved to unimproved pasture for the rare/native Longhorns, and decreased for the improved Charolais breed. A similar finding was found in another part of their experiment, where the CLA proportion increased from concentrate to a grass/silage diet in the rare/native Beef Shorthorn breed, whilst such a proportion remained significantly unaltered for the improved Charolais breed, and significantly lower than the Beef Shorthorns overall. On observing the relationship between TVA and CLA, it was noted that the efficiency of conversion of TVA to CLA was lowest for the Charolais breed fed concentrates than any other group. Fraser et al. (2009) in their study found that the rare/native Welsh Black steers deposited more CLA per a unit of fat than the Charolais Cross steers. No breed x rearing method interactions were noted. However, the higher proportion of CLA in the fat of meat from steers that grazed improved pastures was a consequence of a greater substrate supply, rather than a more efficient conversion of TVA into CLA, since the ratio between these two fatty acids was similar for both treatment groups. It could therefore be suggested that diet modifies the availability of CLA precursors, whilst breed alters the processes under which these precursors are converted into CLA. Furthermore, it seems that the rare/native breeds store a higher proportion of CLA in their adipose tissue, and this is greater when reared on extensive systems. A greater amount of research however is required to justify this claim.

5. Sensory Meat Quality

5.1 Tenderness and Flavour

Meat from livestock on a forage diet has been shown to have a stronger meaty flavour in comparison to that from livestock fed concentrates (Notter et al., 1991; Fisher et al., 2000; Sanudo et al., 2000; Raes et al., 2003; Young et al., 2003; Richardson et al., 2004; Warren et al., 2008b; Richardson et al., 2008). Many test panels have also suggested a preference to the former (Sanudo et al., 2000; Warren et al., 2008b; Richardson et al., 2008) which has also been scored as having a lower abnormal flavour (Fisher et al., 2000; Richardson et al., 2004; Warren et al., 2008b). Tenderness and juiciness can be influenced by fat content (Warriss, 2000), but on reviewing the literature, there is no consistent pattern for these parameters between concentrate and grass fed animals. Even when fat content was controlled for in past studies on beef, there were still no consistent difference in juiciness or tenderness between the grass fed and concentrate fed cattle (Moloney et al., 2008).

Much work has been done to understand the differences in flavour highlighted above. The meat from concentrate fed animals has been shown to produce octanals when cooked, a group of compounds linked to “soapy” odours, where as meat from grass fed animals formed hexanals, which are associated with “green” odours (Lorenz et al., 2002). Furthermore, the meat of grass-fed animals has been shown to fabricate a greater amount of phyt-1-ene and phyte-2-ene (both derivatives of chlorophyll) when cooked, in comparison to that from concentrate fed animals. Such diterpenoids are positively correlated with a “gamey/stale” off-flavour (Maruri & Larick, 1992). Priolo *et al*. (2001) reported that branched-chain fatty acids and skatole (3-methyl-indole) were involved in the pastoral flavour in sheep, although such constituents seem to play a less important role in beef because of the lack of branched-chain fatty acids. Instead the oxidation products of linolenic acid and its derivates, which are derived substantially from pasture, played a more important role in the pastoral flavour of beef.

When it comes to comparing intensive and extensive systems, no clear pattern emerges for tenderness, juiciness or the different flavours. Furthermore, many sensory attributes have been shown not to significantly differ between improved and unimproved pastures (Ådøny et al., 2005; Steinshamn et al., 2010; Fraser et al., 2009). Ådøny et al. (2005) and Steinshamn et al. (2010) however did find that meat from livestock on extensive mountain pastures was less “greasy” than that from livestock on cultivated lowland pastures. Ådøny et al. (2005) and Whittington et al. (2006) also found that meat from lambs on improved pasture had higher rancid and abnormal flavour scores, with Whittington et al. (2006) noting a greater “lamb” flavour from moorland pastures in comparison to that from heathland, saltmarsh and improved pastures.

Consequently, there are some differences, and although these may not be consistent across the research, any sensory qualities highlighted for meat from extensive pastures could be used to promote local or regional products, as suggested by Ådøny et al. (2005). Indeed, Priolo et al. (2001) noted that different pastures with different plant compositions can alter meat flavour. Moloney et al. (2007) highlights from other studies that clover and alfalfa can create more intense flavours in meat and that too much can become undesirable. There is therefore a need for a greater amount of research to quantify sensory attributes under intensive and extensive pastures, as well as under different extensive pastures. Furthermore, relating chemical constituents to any potential differences in sensory attributes should also be key, since the use of sensory panels alone and whom are trained on other types of meat, can possibly lead to a skewing of the results (Steinshamn et al., 2010). Future research also needs to focus on creating a standardised approach for testing sensory characteristics, since the studies reviewed here utilised different sensory attributes and different methods for processing the meat. Indeed, Richardson et al. (2008) were unwilling to make any comparison between the meat from improved and unimproved pastures because different processing techniques were used in the abattoirs between the two treatment groups. This study however did find that the rare/native Longhorn breed produced more tender meat with a higher beef flavour and a greater overall liking compared with the improved Charolais breed. Also, differences in flavour (Warren et al., 2008b) and tenderness (Richardson et al., 2008) have been noted between breeds fed on either a concentrate or forage diet. With little research in this area , and with the paucity of research suggesting that breed can have a key impact on sensory attributes, research into (Extensive vs. Intensive) x (Rare/Native Breeds vs. Improved Breeds) interactions should definitely be a priority topic for future study.

5.2 Meat Colour and Oxidative Stability

As put forward by Lawrie and Ledward (2006), the colour of meat not only depends on the quantity of myoglobin present, but also on the chemical state of the myoglobin molecule. Indeed, pH has been shown to alter the physical state of myoglobin (Warriss, 2000), and consequently, it has also been shown to correlate with meat lightness, with meat from livestock fed on pasture having exhibited a higher ultimate pH, yet a darker meat colour in comparison to those fed concentrates (Priolo et al., 2001). Warris, (2000), Wikilund et al. (2003) and Priolo et al. (2001) attribute this disparity between the two rearing methods to the resulting differences in the glycogen content of the meat. As explained by Miller (2007), an animal's metabolic processes continue after it is has been slaughtered. However, without the presence of oxygen, glycogen is broken down anaerobically, resulting in a build up of lactic acid, and an associated drop in pH within the muscle. On the other hand, animals lacking in glycogen stores prior to slaughter as a result of under-nutrition, will as a consequence produce less lactic acid. This will lead to no adjustment in the already high ultimate pH, and consequently the physical state of the myglobin, along with the colour of the meat. As found in studies reviewed by Priolo et al. (2001), both Wikilund et al. (2001) and Wikilund et al. (2003) found ultimate pH was significantly lower in meat from concentrate fed reindeer as opposed to that from reindeer on natural pasture. It is difficult to relate these findings to meat lightness however, since neither study measured this factor. Nevertheless, the differences in pH were attributed to the reindeer fed concentrates having greater glycogen stores in comparison to those on natural grazing (as a result of under-nutrition).

Future studies should measure the nutritional status of the animal, along with the meat glycogen content, ultimate pH and lightness in order to establish and understand any correlations between these factors. This is paramount, since not all studies suggest there is a relationship between such (Priolo et al., 2001). Steinshamn et al. (2010) for example found in their first experiment, that the muscle from calves grazed on improved pasture was darker than that from the calves on unimproved mountain pasture. This pattern of results was found to be the same across the two years of this experiment and therefore cannot be explained by nutritional status, since the live weight gain, end live weight and carcass weight altered between the years. It cannot be explained either by pH, since this factor showed no significant difference in value between the two treatments. Richardson et al. (2008) also found that the meat from steers on improved pastures was darker, with a higher pH, but also a higher nutritional status than that in steers from unimproved pastures.

Priolo et al. (2001) suggest that with fat being lighter in colour, its presence would contribute to an increased lightness value. Indeed, this could explain such findings from the first experiment of Steinshamn et al. (2010), but in their second, no difference was found between the lightness of the meat under the intensive and extensive treatments, despite the intramuscular fat content being greater in the meat from livestock on improved pastures. The role of physical activity has also been attributed to altering glycogen content and consequently meat colour (Priolo et al., 2001; Dunne, P.G., 2011). Furthermore, Gatellier et al. (2005) suggest that myoglobin isn't always the key factor behind meat lightness. Indeed, the higher myoglobin concentration found in the muscle of cattle fed a mixed diet of forage and maize corresponded with an unexpected lighter coloured meat, and those cattle on improved pasture with a lower muscle myoglobin concentration corresponded with an unexpected darker coloured meat. Despite this, myoglobin concentrations in livestock muscle have also been shown to increase with age, along with an increase in the darkness of the resulting meat (Priolo et al., 2001).

Fraser et al. (2009) found that colour saturation was greater in meat from cattle that grazed improved pastures, as opposed to those who grazed unimproved. However it is difficult to compare this with other studies where colour saturation has not been considered. Of the few studies reviewed here, most of them have measured lightness. However, Steinsham et al. (2010) and Ådøny et al. (2005), also included red and yellow measurements in their study. Again however no clear pattern stood out between the extensive and intensive production methods. As summarised by Priolo et al. (2001), meat colour is normally measured instrumentally using L*, a* and b* values (lightness, red-blue and yellow-green respectively). Colour saturation can be calculated from these values using the formula √ a* + b* (Fraser et al., 2009). Future research should include attaining such values so that clear comparisons can be made between investigations in order to establish patterns and related theories.

Zervas and Tsiplakou (2011) state that the oxidative stability of meat is determined by the balance between anti- and pro-oxidant substances present within it. Unsaturated fatty acids within the meat, especially those with more than two double bonds (polyunsaturated fatty acids – PUFAs), are more readily oxidised, causing a deterioration in meat colour (through the oxidation of red oxymyoglobin to brown metmyoglobin) and sensory quality (i.e. meat becomes rancid). It could therefore be suggested that different PUFA proportions within the fat of the meat could alter its oxidative stability, and thus its shelf life (Wood et al., 2003). Indeed, Vatansever et al. (2000) showed that diet related concentrations of the highly oxidisable n-3 PUFA within the beef of cattle had an impact on shelf life, where higher proportions of n-3 PUFA led to greater lipid oxidation and colour deterioration within a given amount of time. Grass based diets have been shown to increase n-3 PUFA proportions in livestock meat (Wood et al., 2003). It has been shown however that beef from cattle finished on pasture had significantly lower TBARS values (lower lipid oxidation) and greater colour stability, than that from animals finished on concentrate/mixed diets (Warren et al., 2008b;

Richardson et al., 2004; Gatellier et al., 2005). Warren et al. (2008b) and Richardson et al. (2004) were able to attribute this finding to a greater concentration of vitamin E (an antioxidant) within the meat of the grass fed livestock, which would have increased its oxidative stability.

Very little research has been undertaken concerning the oxidative stability of meat from livestock under extensive or intensive rearing systems. Fraser et al. (2009) found that beef from cattle under an extensive rearing system contained a greater amount of Vitamin E, which resulted in lower TBARS values and greater shelf life, in comparison with those on improved pastures. Colour stability was also greater under the extensive treatment. However, this meat started off at a lower colour saturation level at the beginning of the retail display simulation in comparison to the intensive treatment, and therefore did not decline as dramatically. After 9-10 days, the saturation level for the beef under both treatments had more or less converged at the point where the colour is unacceptable to sell to the consumer. However, this was long after the actual shelf life of beef required by the retailer. Despite finding a greater concentration in the meat from steers on unimproved pasture in comparison to that from steers on improved pastures, Richardson et al. (2008) found no significant difference in the oxidative stability and colour shelf life between the two treatment groups.

Neither Fraser et al. (2009) or Richardson et al. (2008) found any significant differences between breed for meat colour and oxidative stability on improved and unimproved pastures. No breed x nutritional environment interactions were found either. Warren et al. (2008b) however found some breed differences and breed x diet interactions in cattle under intensive rearing methods. For example, half Aberdeen Angus cross and half Holstein-Friesian slaughtered at 24 months of age showed a significantly higher pH 48 hours after slaughter in the Holstein-Friesians. This however did not relate to any meat colour differences. On the other hand, after 4 days of simulated retail display, TBARS values were uniformly greater in steaks from the Holstein-Friesians than the Aberdeen Angus as a consequence of the latter having a significantly greater vitamin E concentration in their blood plasma. After 7 days of simulated retail display, breed x diet interactions were found, with the TBARS values for steaks from the Holstein-Friesians under the concentrate diet being significantly greater in comparison to the rest. The results from Warren et al. (2008b) therefore suggest that future research should not overlook breed and age differences.

As can be ascertained from the literature, very little has been done to clarify differences or indeed similarities in meat colour between extensive and intensive forms of meat production. As put forward by Miller (2007) and Jacob et al. (2008), meat colour strongly influences consumer purchasing decisions, with darker coloured meat being one of the leading causes for consumers rejecting a certain cut of meat. More research is therefore required and should include all possible colour measurements to make comparisons between studies easier. Such experiments should also seek to measure possible factors behind alterations in meat colour, in order to assist with the demystifying of the causes. Studies measuring impacts on colour besides age and nutritional status should slaughter their livestock at a similar age and weight so that such factors do not act as compounding variables. It is clear that Vitamin E is key to reducing the oxidation process of meat, however more research is needed to establish clear patterns of oxidative stability, if any at all, between meat from unimproved and improved pastures.

6. Conclusion

From this review, it is clear that there is a paucity of literature covering animal performance, meat sensory attributes and nutritional quality produced under extensive livestock rearing methods. Despite this, there are some evidential differences between extensive and intensive systems. As a consequence of their ability to hold greater stock levels, intensively managed pastures produce a greater cumulative amount of meat, in comparison to those extensively managed. On the other hand, as a consequence of the livestock on extensive systems having lower intramuscular fat levels (as a result of a lower energy intake), there is also a higher P:S ratio in the meat from such, in comparison to that from livestock reared intensively. The n-6:n-3 ratio overall was also found to be higher in meat from extensive systems, although what causes this is unclear.

With there being a higher P:S ratio and an n-6:n-3 ratio of less than the recommended value of 4 in the meat from extensive pastures, it could be suggested that it has a greater nutritional value. However, strict EU food labelling guidelines prevent such claims being made when being sold to the public. Indeed, for food to be labelled as high in polyunsaturated fat, “at least 45% of the fatty acids present in the product (have to) derive from polyunsaturated fat under the condition that polyunsaturated fat provides more than 20% of energy from the product” (Regulation (EC) No 1924/2006). Such an amount is hard to attain in ruminant meat (Pers. Comm. Dr Ian Richardson – University of Bristol – U.K.). Marketing meat products from extensive pastures will therefore have to involve using other attributes. For example, as discussed in section 5.1, meat from extensive pastures may have certain sensory qualities that could be used to market such. Furthermore, there is a growing preference for food products associated with regional production systems involving certain pasture types and indigenous rearing methods (Moloney et al., 2008). The extensive rearing system itself is therefore a selling point in its own right.

No clear patterns emerged from the literature with regards to individual animal live weight gain, carcass weight, conformation and fatness between extensive and intensive systems. Livestock fed concentrates however did produce carcasses with greater weights, and higher scores for conformation and fatness than those on pasture. Furthermore, some studies also suggested that although the animals' performance was lower on extensive systems, it was still at acceptable levels. The sustainability of such however was questioned. Reasons behind the different patterns noted for these parameters between the studies reviewed is unknown, although the year of study, geographical location of the pasture, as well as the vegetation communities present, have all been identified as possible causes. These should be considered as parameters for future studies, so a greater picture about animal performance under extensive and intensive rearing systems can be acquired. Indeed, with much of the research associating extensive pastures with upland locations and intensive pastures with lowland locations, there is a need for future investigations to quantify animal performance under extensive and intensive systems in upland or lowland areas alone (i.e. Fraser et al. 2009).

No clear pattern exists in the research between intensive and extensive rearing methods for meat colour. Indeed, there are many possible factors that influence such and until these are quantified in meat from unimproved systems, little understanding behind the different outcomes between studies will become available. In terms of the oxidative stability and the conjugated linoleic acid content of the meat, the lack of research covering these parameters on extensive systems means little can be concluded from such. As for sensory attributes, no clear differences are highlighted here either, although it should be remembered that such a parameter is qualitatively measured, and the perception of tasting panel participants can be warped according to their own experiences and preferences.

On consideration of breed, no major (Extensive vs. Intensive) x (Rare/Native Breeds vs. Improved/Continental Breeds) interactions have been noted. Differences between rare/native and improved/continental breeds were however noted for carcass fatness, with the early maturing, slower growing rare/native breeds producing fatter carcasses than the later maturing, faster growing improved/continental breeds. No other parameters considered in this review however showed any differences between the two breed types. Indeed, some studies suggest that the choice of breed for grazing unimproved pastures should be based on other attributes. For example, although mostly anecdotal, many traditional/native breeds have been shown to reproduce more easily and acquire less ailments in the environments associated with unimproved pastures, as well as produce grazed swards that match targets for nature conservation purposes (Rook et al., 2004; Ferguson, 2012). The paucity of information however covering different breeds on extensive pastures means there is good potential for (Extensive vs. Intensive) x (Rare/Native Breeds vs. Improved/Continental Breeds) interactions to be found in much needed future research.

In conclusion, it is clear that more research covering animal performance and meat quality on/from extensive pastures is required. In an ideal world, such investigations would quantify the parameters discussed in this review under different extensive and intensive rearing methods, using different breeds on different vegetation communities, in different geographical locations, and in different years. It is appreciated however that such a task would be colossal. As highlighted in section 3.1, the definitions of intensive and extensive rearing method on their own are vast. However, as research progresses in this area, more defined patterns may emerge. These may then be supported by the growing wealth of literature covering the causes behind changes in meat colour and other parameters.

References

Ådnøy, T., Haug, A., Sørheim, O., Thomassen, M.S., Varszegi, Z., and Eik, L.O. (2005) 'Grazing on mountain pastures – does it affect meat quality in lambs?', **Livestock Production Science**, 94, 25-31.

Barthram, G.T., Marriott, C.A., Common, T.G., and Bolton, G.R. (2002) 'The long-term effects on upland sheep production in the UK of a change to extensive management', **Grass and Forage Science**, 57, 124-136.

Beaufoy, G. and Marsden, K. (2010) **CAP Reform 2013 – last chance to stop the decline of Europe's High Nature Value Farming?** Available at: http://www.efncp.org/publications/others/2001-today/ (Accessed: 17th May 2012)

Bjarnadóttir, T., Sveinbjörnsson, J., and Ey- thórsdóttir, E. (2006) 'The effects of different grazing pasture systems and spring turn-out date on lamb growth and development of lambs', **Icelandic Agricultural Sciences**, 19, 71-80.

Blanchard, P., Warkup, C., and Matthews, K. (1999) **A Glossary of Carcase and Meat Quality Terms.** Meat and Livestock Commission, Milton Keynes – U.K.

Casasús, I., Sanz, A., Villalba, D., Ferrer, R., and Revilla, R. (2002) 'Factors affecting animal performance during the grazing season in a mountain cattle production system', **Journal of Animal Science**, 80, 1638–1651.

Carrasco, S., Ripoll, G., Sanz, A., Alvarez-Rodriquez, J., Panea, B., Revilla, R., and Joy, M. (2009) 'Effect of feeding system on growth and carcass characteristics of Churra Tensina light lambs', **Livestock Science**, 121, 56-63.

DEFRA, IGER, ADAS and the University of Bristol (2001) **Carcass Classification**, Leaflet 314. Produced under the DEFRA funded Livestock Knowledge Transfer Initiative. Available at: http://www.teagasc.ie/faol/NR/rdonlyres/0279BFE9-BCD5-49C5-A365-EF7F6B95FA96/60/CarcaseClassification.pdf (Accessed: 18th May 2012).

De Smet, S., Raes, K., and Demeyer, D. (2004) 'Meat fatty acid composition as affected by fatness and genetic factors: a review', **Animal Research**, 53, 81-98

Dunne, P.G., Monahan, F.J., and Moloney, A.P. (2011) 'Current perspectives on the darker beef often reported from extensively-managed cattle: Does physical activity play a significant role?', **Livestock Science**, 142, 1-22.

English Nature (Natural Engalnd) (2005) '**The importance of livestock grazing for wildlife conservation**', Available at: http://publications.naturalengland.org.uk/category/48011 (Accessed: 15th May 2012).

Ferguson, L. (2012) **The Role of Traditional Native Breeds in Conservation Grazing**. A Grazing Animals Project Trainee Report. GAP, Stoneleigh Park, Warickshire – U.K.

Fisher, A.V., Enser, M., Richardson, R.I., Wood, J.D., Nute, G.R., Kurt, E., Sinclair, L.A., and Wilkinson, R.G., ‘Fatty acid composition and eating quality of lamb types derived from four diverse breed x production systems’, **Meat Science**, 55, 141-147.

Fraser, M.D., Davies, D.A., Vale, J.E., Nute, G.R., Hallet, K.G., Richardson, R.I., and Wright, I.A. (2009) ‘Performance and meat quality of native and continental cross steers grazing improved upland pasture or semi-natural rough grazing’, **Livestock Science**, 123, 70-82.

French, P., Stanton, C., Lawless, F., O’Riordan, E.G., Monahan, F.J., Caffrey, P.J. and Moloney, A.P. (2000) ‘Fatty acid composition, including conjugated linoleic acid, of intramuscular fat from steers offered grazed grass, grass silage, or concentrate-based diets’, **Journal of Animal Science**, 78, 2849-2855.

Fothergill, M., Davies, D.A., and Morgan, C.T. (2001) ‘Extensification of grassland use in the welsh uplands: sheep performance in years 1-6’, **Grass and Forage Science**, 56, 105-117.

GAP (2009) **What is conservation grazing?** (Online). Available at: http://www.grazinganimalsproject.org.uk/what_is_conservation_grazing.html (Accessed: 15th May 2012).

Gatellier, P., Mercier, Y., Juin, H., and Renerre, M. (2005) ‘Effect of finishing mode (pasture- or mixed-diet) on lipid composition, colour stability and lipid oxidation in meat from Charolais cattle’, **Meat Science**, 69, 175-186.

Gibon, A. (2005) ‘Managing grassland for production, the environment and the landscape. Challenges at the farm and landscape level’, **Livestock Production Science**, 96, 11-31.

Hessle, A., Rutter, M., and Wallin, K. (2008) ‘Effect of breed, season and pasture moisture gradient on foraging behaviour in cattle on semi-natural grasslands’, **Applied Animal Behaviour Science**, 111, 108-119.

Hinks, C.E., Hunter, E.A., Lowman, B.G., and Scott, N.A. (1999) ‘Effect of breed type, sex, method of rearing, winter nutrition and subsequent grazing treatment on lifetime performance and carcass composition in a 20-month beef system: carcass characteristics’, **Animal Science**, 69, 465-472.

Hodgson, J.G., Montserrat-Martı´, G., Tallowin, J., Thompson, K., Dı´az, S., Cabido, M., Grime, J.P., Wilson, P.J., Band, S.R., Bogard, A., Cabido, R., Ca´ceres, D., Castro-D´ıez, P., Ferrer, C., Maestro-Martı´nez, M., Pe´rez-Rontome´, M.C., Charles, M., Cornelissen, J.H.C, Dabbert, S., Pe´rez-Harguindeguy, N., Krimly, T., Sijtsma, F.J., Strijker, D., Vendramini, F., Guerrero-Campo, J., Hynd., A., Jones, G., Romo-D´ıez, A., de Torres Espuny, L., Villar-Salvador, P., and Zak, M.R. (2005) ‘How much will it cost to save grassland diversity?’, **Biological Conservation**, 122, 263-273.

Hoehne, A., Nuernberg, G., Kuehn, C., and Nuernberg, K. (2012) ‘Relationships between intramuscular fat content, selected carcass traits, and fatty acid profile in bulls using a F_2-population’, **Meat Science**, 90, 629-635.

Hopkins, A. (2009) ‘Relevance and functionality of semi-natural grassland in Europe -status quo and future prospective’, **Report of the International Workshop of the SALVERE-**

Project 2009 at the Agricultural Research and Education Centre Raumberg-Gumpenstein, 9-14. Available at: http://www.salvereproject.eu/content/international-workshop-austria (Accessed: 22nd July 2012).

Isselstein, J., Griffith, B.A., Pradel, P. and Venerus, S. (2007) ‘Effects of Livestock breed and grazing intensity on biodiversity and production in grazing systems. 1. Nutritive value of herbage and livestock performance’, **Grass and Forage Science**, 62, 145-158.

Jacob, R., Warner, R., and Jose, C. (2008) **Quality Sheepmeat – Meat Colour and Shelf-life.** A leaflet by the Cooperative Research Centre for Sheep Industry Innovation (Sheep CRC) – Australia. Available at: http://www.sheepcrc.org.au/information/practical-wisdom-notes/quality-sheepmeat-series.php (Accessed: 17th September 2012).

Kuit, G. and van der Meulen, H. (1997) **Marketing beef from nature reserves in Holland** (Online). Available at: http://www.macaulay.ac.uk/livestocksystems/faunus/faunus2/kuit.htm (Accessed: 14th July 2012).

Lawrie, R.A., and Ledward, D.A, (2006) **Lawrie’s Meat Science**. Woodhead Publishing Limited, Cambridge – U.K.

Lorenz, S., Buettner, A., Ender, K., Nuernberg, G., Papstein, H.J., Schieberle, P., and Nuernberg, K. (2002) ‘Influence of keeping system on the fatty acid composition in the longissimus muscle of bulls and odorants formed after pressure cooking’, **European Food Research and Technology**, 214, 112-118.

Lourenç o, M., Van Ranst, G., De Smet, S., Raes, K., and Fievez, V. (2007a) ‘Effect of grazing pastures with different botanical composition by lambs on rumen fatty acid metabolism and fatty acid pattern of *longissimus* muscle and subcutaneous fat’, **Animal**, 1 (4), 537-545.

Lourenç o, M., Van Ranst, G., Vlaeminck, B., De Smet, S., and Fievez, V. (2007b) ‘Influence of different dietary forages on the fatty acid composition of rumen digesta as well as ruminant meat and milk’, **Animal Feed Science and Technology**, 145 (1-4), 418-437.

Maruri, J.L. and Larick, D.K. (1992) ‘Volatile concentration and flavour of beef as influenced by diet’, **Journal of Food Science**, 57 (6), 1275-1281.

McGuire, M.A., and McGuire, M.K. (2000) ‘Conjugated linoleic acid (CLA): A ruminant fatty acid with beneficial effects on human health’, **Animal Science**, 77, 1-8.

Miller, M. (2007) **Dark, Firm and Dry Beef**. A Factsheet produced by The Centre for Research & Knowledge Management in the Department of Research, Education & Innovation at the National Cattlemen’s Beef Association – Centennial, Colorado, U.S.A. Available at: http://www.beefresearch.org/factsheetsmeetingsummaries.aspx (Accessed: 17th September 2012).

Miller, R.K. (2002) ‘Factors affecting the quality of raw meat’, in Kerry, J., Kerry, J., and Ledward, D. (Eds) **Meat Processing – Improving Quality**. Woodhead Publishing Limited, Cambridge – U.K.

Milne, J.A. (2005) ‘Societal expectations of livestock farming in relation to environmental effects in Europe’, **Livestock Production Science**, 96, 3-9.

Mir, P.S., McAllister, T.A., Scott, S., Aalhus, J., Baron, V., McCartney, D., Charmley, E., Goonewardene, L., Basarab, J., Okine, E., Weselake, R.J., and Mir, Z. (2004) ‘Conjugated linoleic acid-enriched beef production’, **American Journal of Clinical Nutrition**, 79 (suppl), 1207S-1211S.

Moloney, A.P., Fievez, V., Martin, B., Nute, G.R., and Richardson, R.I. (2008) ‘Botanically diverse forage-based rations for cattle: implications for product composition, product quality and consumer health’, in Hopkins, A., Gustafsson, T., Bertilsson, J., Dalin, G., Nilsdottir-Linde, N., and Sporndly, E., (Eds) ‘Biodiversity and Animal Feed: Future Challenges for Grassland Production’, **Grassland Science in Europe**, 13, 361-374, European Grassland Federation, Uppsala, Sweden.

Naveh, Z. (1998) ‘Ecological and Cultural Landscape Restoration and the Cultural Evolution towards a Post-Industrial Symbiosis between Human Society and Nature’, **Restoration Ecology**, 6 (2), 135-143.

Nürnberg, K., Wegner, J., and Ender, K. (1998) ‘Factors influencing fat composition in muscle and adipose tissue of farm animals’, **Livestock Production Science**, 56, 145-156.

Notter, D.R., Kelly, R.F., and Berry, B.W. (1991) ‘Effects of ewe breed and management system on efficiency of lamb production: III Meat characteristics’, **Animal Science**, 69, 3523-3535

Priolo, A., Micol, D., and Agabriel, J. (2001) ‘Effects of grass feeding systems on ruminant meat colour and flavour. A Review’, **Animal Research**, 50, 185-200.

Priolo, A., Micol, D., Agabriel, J., Prache, S., and Dransfield, E. (2002) ‘Effect of grass or concentrate feeding systems on lamb carcass and meat quality’, **Meat Science**, 62, 179-185.

Raes, K., Balcaen, A., Dirinck, P., De Winne, A., Claeys, E., Demeyer, D., and De Smet, S. (2003) ‘Meat quality, fatty acid composition and flavour analysis in Belgian retail beef’, **Meat Science**, 65, 1237-1246.

Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods.

Richardson, R.I., Nute, G.R., Wood J.D., Scollan, N.D., and Warren, H.E. (2004) ‘Effect of breed, diet and age on shelf life on shelf life, muscle vitamin E and eating quality of beef’, **Proceedings of the British Society of Animal Science**, 1, p. 84.

Richardson, R.I., Scollan, N., and Wood J.D. (2008) **Healthiness and quality of beef produced from traditional and modern breeds reared in species-rich, unimproved grasslands.** A DEFRA funded research project – Reference Number LS3523. Available at:

http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=13134 (Accessed: 24th September 2012).

Rook, A.J., Dumont, B., Isselstein, J., Osoro, K., Wallis De Vries, M.F., Parente, G., and Mills, J. (2004) 'Matching type of livestock to desired biodiversity outcomes in pastures – a review', **Biological Conservation**, 119, 137-150.

Sanudo, C., Enser, M., Campo, M.M., Nute, G.N., Maria, G., Sierra, I., and Wood, J.D. (2000) 'Fatty acid composition and sensory characteristics of lamb carcasses from Britain and Spain, **Meat Science**, 54, 339-346

Scollan, N., Hocquette, J., Nuernberg, K., Dannenberger, D., Richardson, R.I., and Moloney, A. (2006) 'Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality', **Meat Science**, 74, 17-33

Scollan, N.D., Kim, E.J., Lee, M.R.F., Whittington, F., and Richardson, R.I. (2008) 'Environmental Impacts on the n-3 content of foods from ruminant animals', in Givens, I., Baxter, B., Minihane, A.M., and Shaw, E. (Eds), **Health benefits of organic foods: Effects of the environment**. Commonwealth Agricultural Bureaux International.

Steinshamn, H., Höglind, M., Havrevoll, Ø., Saarem, K., Lombnæs, I.H., Steinheim, G., and Svendsen, A. (2010) 'Performance and meat quality of suckling calves grazing cultivated pasture or free range in mountain', **Livestock Science**, 132, 87-97.

Tallowin, J.R.B., Rook., A.J. & Rutter, S.M. (2005) 'Impact of grazing management on biodiversity of grasslands', **Animal Science**, 81, 193-198.

Tolhurst, S., and Oates, M. (2001) The Breed Profiles Handbook, English Nature, Peterborough – U.K.

UK NEA (2011) **The UK National Ecosystem Assessment Technical Report**, UNEP-WCMC, Cambridge. Available at: http://uknea.unep-wcmc.org/Resources/tabid/82/Default.aspx (Accessed: 15th May 2012).

Ulbricht, T.L.V., and Southgate, D.A.T., (1991) 'Coronary Heart Disease: Seven Dietary Factors', **The Lancet**, 338, 985-992.

Vatansever, L., Kurt, E., Enser, M., Nute, G.R., Scollan, N.D., Wood, J.D. and Richardson, R.I. (2000). 'Shelf life and eating quality of beef from cattle of different breeds given diets differing in *n*-3 polyunsaturated fatty acid composition', ***Animal Science,*** 71, 471-482.

Warren, H.E., Scollan, N.D., Enser, M., Hughes, S.I., Richardson, R.I., and Wood, J.D. (2008a) 'Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. I: Animal performance, carcass quality and muscle fatty acid composition', **Meat Science**, 78, 256-269.

Warren, H.E., Scollan, N.D., Nute, G.R., Hughes, S.I., Wood, J.D., and Richardson, R.I. (2008b) ‘Effects of breed and a concentrate or grass silage diet on beef quality in cattle of 3 ages. II: Meat Stability and flavour’, **Meat Science**, 78, 270-278

Warriss, P.D. (2000) **Meat Science – An Introductory Text**. CABI Publishing, Oxon – U.K.

Whittington, F.M., Dunn, R., Nute, G.R., Richardson, R.I., and Wood, J.D. (2006) ‘Effect of pasture type on lamb product quality’, Presentation to 9th Annual Langford Food Industry Conference, ‘New Developments in sheepmeat Quality’ 24th-25th May, Bristol – U.K. **Proceedings of the British Society of Animal Science**, P. 27-31.

Wikilund, E., Johansson, L., and Malmfors, G. (2003) ‘Sensory meat quality, ultimate pH values, blood parameters and carcass characteristics in reindeer (*Rangifer tarandus tarandus* L.) grazed on natural pastures or fed a commercial feed mixture’, **Food Quality and Preference**, 14, 573-581.

Wikilund, E., Pickova, J., Sampels, S. and Lundström, K. (2001) ‘Fatty acid composition of M. longissimus lumborum, ultimate muscle pH values and carcass parameters in reindeer (Rangifer tarandus tarandus L) grazed on natural pasture or fed a commercial feed mixture’, **Meat Science**, 58, 293-298.

Wood, J.D., Enser, M., Fisher, A.V., Nute, G.R., Sheard, P.R., Richardson, R.I., Hughes, S.I. and Whittington, F.M. (2008) ‘Fat deposition, fatty acid composition and meat quality: A review’, **Meat Science**, 78, 343-358.

Wood, J.D., Richardson, R.I., Nute, G.R., Fisher, A.V., Campo, M.M., Kasapidou, E., Sheard, P.R., and Enser, M. (2003) ‘Effects of fatty acids on meat quality: a review’, **Meat Science**, 66, 21 - 32

Wood, J.D., Richardson, R.I., Scollan, N.D., Hopkins, A., Dunn, R., Buller, H., and Whittington, F.M. (2007) ‘Quality of meat from biodiverse grassland’, in Hopkins, J., Duncan, A.J., McCracken, D.I., Peel, S., and Tallowin, J.R.B. (Eds), **High Value Grassland**, 107-116, British Grassland Society, Cirencester, Gloucestershire – U.K.

Young, O. A., Lane, G.A., Priolo, A., and Fraser, K. (2003) ‘Pastoral and species flavour in lambs raised on pasture, Lucerne or maize’, **Journal of the Science of Food and Agriculture**, 83, 93-104.

Zervas, G. and Tsiplakou, E. (2011) ‘The effect of feeding systems on the characteristics of products from small ruminants’, **Small Ruminant Research**, 101, 140-149.