# Hempseed cake as a protein feed for growing cattle

*Hampfrökaka som proteinfodermedel till växande ungnöt*

**Maria Eriksson**

**Sveriges Lantbruksuniversitet** **Skara 2007** **Studentarbete 128**
**Institutionen för husdjurens miljö och hälsa**
**Avdelningen för produktionssystem**

***Swedish University of Agricultural Sciences*** ***Student report 128***
***Department of Animal Environment and Health***
**Section of Production Systems**

**ISSN 1652-280X**

# Hempseed cake as a protein feed for growing cattle

*Hampfrökaka som proteinfodermedel till växande ungnöt*

**Maria Eriksson**

**Examensarbete, 20 poäng, Husdjursagronomprogrammet**

Handledare: Anna Hessle, Biträdande handledare: Birgitta Johansson och Elisabet Nadeau, Inst. för husdjurens miljö och hälsa (Dept. of Animal Environment and Health)
Box 234
532 23 SKARA

## FÖRORD

Detta är ett examensarbete omfattande 20 poäng inom agronomprogrammets husdjursinriktning. Syftet var att jämföra foderintag, tillväxt, slaktkroppsegenskaper och träckegenskaper hos växande ungnöt som tilldelats två olika proteinfodermedel; hampfrökaka eller sojamjöl. Projektet har finansierats av Agroväst och Sveriges lantbruksuniversitet. Min del av arbetet har bestått av att analysera foderdata och slaktkroppsdata samt att göra analyser av träckprover som samlats in för både stutar och kavar.

Jag vill rikta ett stort tack till alla som hjälpt mig genom hela arbetet. Främst vill jag tacka min huvudhandledare Anna Hessle som under hela arbetes gång visat stort engagemang och tålamod och snabb respons med goda idéer samt Birgitta Johansson och Elisabet Nadeau för gott stöd och vägledning genom hela projektet. Jag vill även tacka Karin Wallin för all hjälp med insamling av data på slakteriet och ett tack till Tyler Turner för hjälpen med rättning av arbetet med avseende på det engelska språket. Jag vill även rikta ett tack till min examinator Sölve Johnsson och opponent Anna Jamieson för kompletterande kommentarer på arbetet och även ett varmt tack till Jonas Dahl och David Johansson på Götala försöksgård i Skara för god hand med stutar och kalvar samt med hjälp av träckinsamling.

Juni 2007
Maria Eriksson

# SUMMARY

Protein feeds used by Swedish animal producer's origin from different parts of the world. Protein feeds produced in Sweden are among all rape seed cake, peas and field bean. In addition soybean meal is imported and used as a high quality protein feed. Since 2003 there is also a new protein feed available on the market produced from hemp, *Cannabis sativa*, which can be grown in arable regions throughout Sweden. Hempseed cake, a by-product of the oil processing industry, provides a rich source of protein for the animal feed sector. Nutritionally, hempseed cake is equivalent to rape seed cake, potentially making it a viable alternative to imported soybean meal.

This master thesis included two different trials with the aim to investigate hempseed cake as a protein feed for growing dairy cattle in comparison to feeding soybean meal. In one of the trials, there were 55 bull calves while the other trial consisted of 51 steers. The calves weighted 96 kg at the start of the experiment and were used in the trial until an average weight of 237 kg, whereas the steers initially weighed 366 kg (Swedish Holstein) and 400 kg (Swedish Red Cattle) and were studied until they had reached targeted live weights for slaughter. In both of the trials the animals were divided into two groups where one group was provided hempseed cake and the other group soybean meal as a protein supplement. The steers were also divided in two groups according to their live weights at slaughter, 600 and 650 kg, and in two groups according to breed, Swedish Holstein and Swedish Red Cattle. In both trials the effects on feed intake, daily weight gain and faecal traits were investigated. In the steers also the effects on carcass traits were studied. A basal diet consisting of barley and grass silage at a 60:40 ratio was fed *ad libitum*. Basal diet was supplemented by top dressing with either hempseed cake or a soybean/barley concentrate. Supplements were balanced to provide equivalent crude protein content.

Animal daily feed intakes were calculated weekly and animal daily weight gain was calculated based on by-weekly weights. In faecal matter, number of long particles (>1 cm), number of kernels, consistency, pH and dry matter content were analyzed. At slaughter of the steers, carcass weights, conformation and fatness scores were recorded. Trim fat, bones and retail cuts from the right hind quarter were also weighed from every steer.

The content of neutral detergent fibre (NDF) was 434 g $kg^{-1}$ of dry matter in hempseed cake and 160g $kg^{-1}$ of dry matter in the mixture of soybean meal and barley. This resulted in both trials of a higher NDF intake in animals fed hempseed cake compared to animals fed soybean meal. In the trial with the calves the dry matter intake and concurrent gross energy intake were higher in those animals given hempseed cake but there was no difference in feed consumption in the trial with the steers. No effect of protein feed on daily weight gain was found. The daily gain was on average 1310 g for the calves and 1220 g for the steers. Calves fed hempseed cake had, in comparison with animals fed soybean meal, higher feed intakes in combination with similar growth resulting in worse feed conversions.

The faecal matter from steers fed hempseed cake was of a higher dry matter content and a firmer texture in comparison with faecal matter from steers fed soybean meal. In addition, in both trials, the faecal matter contained fewer long particles (>1 cm) when the animals were given hempseed cake in comparison to animals given soybean meal. The number of long particles (>1 cm) and the percentage of kernels in faeces, on a dry weight basis, were less for calves fed hempseed cake than for calves fed soybean meal.

The group of steers given soybean meal and had a target slaughter weight at 650 kg live weight required a longer finishing period to reach the targeted weight compared to steers fed hempseed cake. However, dressing percentage was higher for steers fed soybean meal than for steers fed hempseed cake. Carcasses from steers slaughtered at a live weight of 650 kg had a higher fatness score than steers slaughtered at a live weight of 600 kg. The conformation score of Swedish Red Cattle was on average 0.8 classes better than the conformation score for Swedish Holstein. No further effects of breed or live weight at slaughter were found in the study.

The higher NDF intakes in animals fed hempseed cake compared to animals fed soybean meal in combination with the lower numbers of long particles, higher dry matter content and firmer consistency in faeces indicates that feeding hempseed cake resulted in a better rumen function. The loose consistency and high numbers of particles from steers fed soybean meal indicates the feed is passing through the rumen too fast and resulting in a decreased degradation of the feed particles and more long particles remained in the faecal matter. A too fast rate of passage also results in a lower dry matter which could be seen in the faecal matter from the steers fed soybean meal.

The conclusion from the two trials is that hempseed cake as a protein feed instead of soybean meal to intensively fed growing cattle, results in similar weight gain and carcass traits as well as an improved rumen function, due to the higher content of fibres in hempseed cake in comparison to soybean meal.

# CONTENTS

# INTRODUCTION

The supply of locally grown protein feeds in Sweden is rape, peas and beans. The supply is also composed of soybean meal that is imported and additionally used as a protein feed. Soybean meal consists of high quality protein and is relatively cheap. There is an ongoing debate with the issue of the environmental disturbations, as emission of carbon dioxide and devastation of rainforests, that are caused by the transportation respectively production of the soybean meal. Another downside of using soybean meal as a protein feed to animals in Sweden is that it is beginning to get difficult to find soybean meal that is not gene modified, which is required in organic production.

An alternative to the imported soybean meal is the relatively new plant, Hemp, *Cannabis sativa.* This plant is also of importance within the group of organic producers that are required to grow and cultivate a large proportion of their own feed who's issue might be resolved with hemp (Fällman, 2006). Hemp is also applicable in the organic concept because the plant does not require large amounts of pesticides (Personal communication, Norberg, 2006). Another advantage of the hemp plant is that it is able to be grown in the northern parts of Sweden which is a problem with other protein feeds produced in Sweden (Finell et al., 2006).

Hemp plants have been used for cultivation for 3000 years (Lund, 2000) with the origin of Central Asia. In Sweden there is evidence since the Iron Age (Ivarsson, 2004) and during the Second World War the cultivation of hemp expanded (Svennerstedt and Svensson, 2006). The cultivation of hemp plant ended in 1965 when it was forbidden to cultivate because of the content of the narcotic substances tetra-hydro-cannabinol (THC; Holstmark, 2006). In 2003, The Swedish Board of Agriculture decided that the plant once again was allowed to cultivate with restrictions that the amount of THC did not exceed the level of 0.2% of dry matter (Ivarsson, 2004).

Hemp is present in two types, fibre hemp and oil hemp. The hemp type often grown in Sweden is fibre hemp with the aim as an energy source. The oil hemp is used for the seed production. The seeds contain high quality oil with large amounts of polyunsaturated fatty acids as omega-3 and omega-6 suitable for food and cosmetics (Landström, 2000; Holstmark 2006).

When pressing the oil out of the hemp seed there is a by-product produced; hempseed cake (Landström, 2000) which is considered to be nutritionally equal to other protein sources (Gibb et al, 2005.). Hemp seed protein has a favourable set of amino acids and the protein resists degradation in the rumen and yet is very digestible in the total gastrointestinal tract (Mustafa et al., 1998).

The market for different products from hemp is expected to increase during years to come (Landström, 2000). In the animal feed industry, as in the provision industry, the by-product from pressed oil hemp is of great interest because of the fat and the protein content (Landström, 2000). The current price of hemp is relatively high compared to other protein feeds but if there is going to be an increased usage of the hemp as an energy crop as well as a feed crop the price might be reduced and the hemp are able to be compared to other protein feeds according to the market price.

Hemp is a relatively new plant which is of a great interest as a high quality protein feed. There is limited research done on hemp as a protein feed for ruminants and therefore there is a large need to investigate the roll of hempseed cake as a protein feed for growing cattle why this study has been performed.

## *OBJECTIVE*

The objective of this study was to compare feed intake, weight gain, faecal traits and carcass traits in growing dairy cattle using different protein feeds; hempseed cake or soybean meal.

# LITERATURE REVIEW

## *PROTEINS*

Proteins are organic compounds that consist of carbon, hydrogen, oxygen, nitrogen and sulphur. Proteins are compounds of all living cells and their function is to interact with all activities that constitute a living cell. Proteins are constituted from combinations of the 20 amino acids, which are characterized by having a carbon and a hydrogen atom, a basic nitrogenous group, an acidic carboxyl unit and a side chain that varies in different amino acids (Figure 1). The amino acids in feed are present as two different kinds, indispensable (essential) and dispensable (non-essential). Some animals are not able to synthesise indispensable amino acids. To be able to build up body proteins, they must have a dietary source of these amino acids. Ruminants can synthesise indispensable amino acids in the rumen by the micro organisms, and they are less dependent on dietary amino acids. However, to achieve a maximum rate of growth or milk production they need a supply of dietary amino acids (McDonald et al., 2002). The dispensable amino acids are also required by the ruminants even though they can be produced from other amino acids or amine groups within the animal body, because they are not synthesized at a sufficient rate to satisfy the needs of the body (McDonald et al., 2002; Perry et al., 1999).

$NH_2$
|
R-C-H
|
COOH

Figure 1. The general formula of amino acids where $NH_2$ represents the nitrogen group, COOH the carboxyl unit and R represent the side chain of the amino acid (McDonald et al., 2002).

## *PHYSIOLOGY*

### Rumen fermentation and environment

The pH in the rumen has a value between 6 and 7 and is regulated by the saliva production via the chewing mechanism (Nørgaard, 2003). Chewing, in turn, is regulated by the physically effective fibre, which is the feed fraction that stimulates chewing (Allen, 1997; Mertens, 1997). About 100-200 litres basic saliva is produced daily to establish an optimal rumen environment. Feed particles are mechanically broken down during chewing. An optimal daily chewing time is 8-16 hours. Feed particles are broken down biochemically by microorganisms in the rumen (Nørgaard, 2003). The carbohydrates in the forage cell wall are degraded and fermented by the microbes and released as volatile fatty acids which are available to the host animal (Varga and Kolver, 1997).

Animals that are consuming roughages have a pH of the fluid of the rumen around 6.0 to 6.2. Animals that are provided additional cereals have a wider range of pH that varies between 6.0 and 7.0 and can, if the pH falls below 6.0, result in metabolic acidosis which is a disturbance in the balance between acids and bases within the body (Pehrson, 1987; Björnhag, 2000). Lower pH can occur in the rumen and can during extreme conditions go below 5.0 (Steen, 2004), but it should be prevented because of the digestible disruptions it might cause (Björnhag, 2000). If the concentrate proportion is too large in comparison to the roughage portion the results can be a loose texture of the faecal matter and diarrhoea can appear (Pehrson, 1987). Too much concentrate feed also results in less chewing and rumen contractions, and more long particles remains in the faeces (Personal communication; Nadeau, 2007)

## Particle size in feed, rumen and faecal matter

Feed intake is dependent on the particle size of the feed that animals are provided. There is an observed increased feed intake when the average particle size is reduced to 5 mm and intake is further increased in proportion to further reduction in particle size. Maximal intake is achieved when the average particle size is 1 mm or less (NRC, 1996). Pelleting and grinding feeds are examples of reduction of the particle size of feedstuff (NRC, 1996). Particles in the faeces have an average length of 1-3 mm and a width of 0.2-0.4 mm with a tendency of larger particle size at high feed intakes, which occurs when the diet contains feed with small particles. This means that digestibility is reduced in proportion with the increase in feed intake by grinding (NRC, 1996; Nørgaard, 2003). A faster rate of passage of the feed throughout the animal body results in longer particles in the faeces because of reduced microbial fermentation (NRC, 1996; Hall, 2002). Longer particles remained in faeces can be due to that the feeds are not broken down by the chewing mechanisms (Nørgaard, 2003). There is a resistance against particles leaving rumen and this resistance increases with increasing particle size. Particles that are remaining on a sieve of 1 mm are able to leave the rumen and constitute 3% of the DM that are passing out from the rumen. There is no sharp limit of how small particles have to be to be able to pass through rumen but there is evidence that there is a reduction of particles leaving rumen at a particle size over 1.18 mm. According to Nørgaard (2003) the critical particle size is 5 mm.

In a study done by Poppi and Norton (1980) it is shown that there were differences in the number of particles in the abomasum between sheep fed different diets, but there was no difference between grass and legume or between old and young herbage samples (Poppi and Norton, 1980).

Cows with a diet of a well mixed total mixed ration (TMR) shows a tendency for proper rumen fermentation and better nutrient utilization compared to cows fed forage and concentrates separately. The particle size as well as the consistency of the faecal matter is affected by the feeding sequence (NRC, 2001). It has been shown that there is an increase of the ruminal pH when the number of feedings was increased from two to five times per day (Robinson and McQueen, 1994). In a study done by Mgbeahurike (2007) it has been shown that increased amounts of starch from concentrate and increased dietary starch concentration increased the number of long particles in faeces from dairy cows. An increase of forage intake decreased faecal DM concentration whereas an increased intake of concentrates, total intake of CP, AAT, metabolized energy and dietary CP concentration increased faecal DM concentration (Mgbeahurike, 2007).

The consistency of the faecal matter is a function of feed moisture content and mean retention time of the feed in the digestive tract of the animal (Varga, 2003). Loose manure might be due to the content of protein in the diet. An excess of protein or high levels of rumen degradable protein might result in a loose texture of the faecal matter (Varga, 2003). An excess of protein in the diet might trigger increased water consumption in attempt to excrete excess nitrogen through the urine. The cause of diarrhoea might be extensive hindgut fermentation of carbohydrates and increased acid production. Other possible causes can be stress, poisoning or bacterial and parasitic infection (Hall, 2002).

## Feed intake

Feed intake, expressed as dry matter intake (DMI), is affected by various factors which are influenced by low or high digestibility of the feed. If the feed has low digestibility and contains a low level of energy (often high fibre) the feed intake is affected by physical factors such as ruminal fill and digesta passage. Highly digestible diets that contains a high level of energy (often diets with a low level of fibre and contains a high level of concentrates) is affected by the animal's energy demands and by metabolic factors (NRC; 1996). The relationship between organic matter digestibility (OMD) and organic matter intake (OMI) have been investigated by using data from voluntary intake and digestibility of 831 roughages. The results showed that if highly digestible feed is regulated by the energy demand, digestible OMI would be expected to plateau with an increasing OMD (NRC, 1996).

Voluntary intake is negatively related to cell-wall concentration of ruminants consuming high forage diets. Cell-walls affect intake by contributing to ruminal fill which is a critical determinant of animal performance. To decrease the ruminal fill and increase digestibility there has to be a reduction of the indigestible cell-wall fraction. The indigestible cell-wall fraction often consists of lignin, which is the key element that limits the cell-wall digestibility (Jung and Allen, 1995).

The quality of the structure in the feed is also of great importance because a good quality stimulates chewing and a secretion of saliva which contains buffering substances that stabilizes disturbances of pH in rumen during fermentation of carbohydrates. To increase the chewing time there has to be a larger proportion of NDF that originates from roughages than from grain and concentrates. This is because NDF that origin from roughages have a better structure on the fibre fraction (Karlsson, 2001). There is no single chemical component of silage that can be used for determining silage intake (Dawson and Steen, 2000) but NDF is considered to be the best single chemical predictor of voluntary dry matter intake (VDMI) since it has characteristics of fermenting and leaving the reticulorumen more slowly than other dietary elements (Allen, 1996). A reduction in NDF content of forage will result in a higher VMDI in ruminants even though this results in a reduced total intake of NDF (Jung and Allen, 1995). In a study by

Dawson and Steen (2000) it was shown that degradability characteristics of DM and nitrogen (N) were negatively correlated with the fibre fraction of silage while these characteristics were positively correlated with OMD. This result suggests that silage with lower fibre content is degraded at a faster rate in the rumen (Dawson and Steen, 2000).

Rumination will also have an effect on feed intake. Since rumination creates a retention time, this will result in a reduction of feed intake. There is a larger difference in feed intake of feed with a high proportion of fibres or in feed with bad quality because coarser ingesta require a longer retention time to achieve efficient extraction of energy (Van Soest et al., 1988). Time required for diet processing is in addition to the amount of large particles in the feed dependent on efficiency of the size reduction, the chemical composition and the three-dimensional anatomy of the plant particles (Kennedy, 2005).

One physiological factor that affects feed intake is body composition, especially percentage of adipose tissue, which can have a feedback role controlling feed intake during the time when the animal is about to mature. With an increase of one percentage of body fat there will be a reduction of 2.7 percentage of DMI when the body fat percentage range between 21.3 and 31.5. The gender of the animal does not seem to influence feed intake much, but in some cases it has been shown that heifers have a greater feed intake capacity than steers and bulls (NRC, 1996). The age of the animal can also affect feed intake. Younger animals, e.g. calves consume less feed per unit body weight (BW) than older animals, e.g. yearlings. Another factor that affects the feed intake is the animal’s physiological state. If the animal is lactating the feed intake increases by 35-50% compared to a non-lactating animal at the same BW and diet. Pregnancy has a reversible effect to the previous example. There was a study done which showed that the feed intake decrease by 1.5% per week during the last 14 weeks of pregnancy in Danish Black and White heifers (NRC, 1996).

The breed of the cattle influence feed intake. In a study done by Danish Institute of Animal Sciences (DIAS) it was found that there are large breed effects on feed capacity in descending order; Simmental, Danish black and White cattle, Hereford and Limousin (13.4; 12.9; 11.6 and 11.5 respectively; Olesen et al., 2004).

Beef cattle consume less feed compared with dairy cattle or crossbreeds between beef and dairy cattle, relatively to BW. Feed intake can further be affected by genetics and selection for feed efficiency. Genetically modified animals would be produced for increased feed intake potential, suggesting that genetic potential for growth may affect feed intake (NRC, 1996).

To maximize the forage intake and to balance grain proportions for a maximum growth rate, it is useful to optimize feeding rations. Since cell-walls are a limiting factor of intake it is important to analyse the fraction of cell walls in the feed which is done by the NDF method. The NDF fraction that is extracted by this method is defined as the total amount of fibre content of the plant (Danielsson, 1990; Emanuelsson and Salomonsson, 2003).

## Fibre digestion

Ruminal fibre digestion is dependent on; composition and structure of the plant, the nature of population densities of the fibre digesting microorganisms present in the rumen and microbial factors that control adhesion and hydrolysis by complexes of hydrolytic enzymes of the adherent microbial population and animal factors that increase the availability of nutrients through mastication, salivation and digesta kinetics (Cheng et al., 1991).

Rumination is a mechanism for reducing the size of the fibres because there is a limitation to the length of the fibre particles that are passing the stomachs of the ruminant (Van Soest et al., 1991). The digestibility of the fibres are also affected by the amount of indigestible fibres, the rate of digestion of the potentially digestible fibres and the passage rate of the feed through the rumen (Jung & Allen, 1995).

The fermentation of fibres in rumen is generally a slower process than fermentation of starch which results in a reduction of the fluctuation of the acid production and thereby fluctuations of the pH in the rumen. Most of the potentially digestible fibres in grass and legume (85-96%) are broken down after 36 hours (Nadeau et al., 1996).

Supplementation of fibres leads to an increase of the retention time of the feed in the rumen which is of a positive characteristic. A too short retention time of the feed in the rumen will cause a too fast passage of the feed which results in an increased transfer of volatile fatty acids and gas to the abomasum which can lead to displaced abomasum (Pehrson, 1987).

The nutritive availability of the fibrous fraction is dependent on the degree of lignification where lignin appears to hinder the breakdown of the cellulose (Van Soest, 1987; McDonald et al., 2002). Cellulose fermentation is dependent on whether the forage is harvested early or late and how great the lignin content is. An early harvested forage that contains 50 g lignin/ kg DM are digested to 80% whereas a forage harvested later that contains 100 g lignin/ kg DM only are degraded to 60% (McDonald et al., 2002). Lignification of the plant is greatly affected by environmental factors such as temperature, day length, light, plant stress, which means that the lignin contents in feed can be highly variable (Van Soest, 1987).

In a study, it has been shown that there was a reduction of digestibility of feed when a larger proportion of NDF, ADF and CF originate from concentrates compared to roughages. The digestibility of the fibre fractions were also affected by the fat content in the grain where a larger proportion of fat content resulted in a lower digestibility (Engstedt, 1987).

The quality of fibres are defined by the ability to exchange nutrient value and promote efficient rumen fermentation and for these properties legume fibres are superior in the rate of fermentation compared to an average grass (Van Soest, 1987).

Fibre digestion can be reduced by a reduction in pH in the rumen due to an excess of volatile fatty acids (Mould et al., 1983). This phenomenon is probably due to the defaunating effect of the ruminal acids (Bonhomme, 1990; Yang and Varga, 1993). The fibre digestion is interrupted because the ruminal acids kill or destroy the fibre digestion mechanisms (Hall, 2002).

## Digestion and absorption of proteins

Proteins that are supplied to the animals by the feed are mainly degraded in the rumen into peptides, amino acids and ammonia. The remaining part of the protein, the undegraded part, is available to the animal when it arrives to the small intestine. The proteins that are degraded into nitrogen in the rumen are used by the microbes to synthesize new protein. This protein is available to the animal when it leaves the reticulo-rumen. Microbial synthesis is dependent on two factors, nitrogen available and the energy required by the microbes for the synthesis. In growing cattle the microbial protein is the major part of the amino acids that flows to the duodenum (Olsson, 1987; Van der Honing et al., 1988). The composition of the microbial protein is favourable for the animals' needs of amino acids. The ability to synthesize microbial protein gives ruminants the property to utilize feed resources that have a lower content of proteins and still produce high quality proteins such as milk and meat that non-ruminant animals are not able to do (Olsson, 1987; Van der Honing et al., 1988).

Different proteins are broken down at different rates depending on the protein structure, irrespective of the type of microbial population present in the rumen (Wallace, 1988).

Methods for manipulation of protein degradation that are available today include; heat, aldehydes, alkali, and coating with fat, blood, or fish hydrolysate, which are responsible for altering the degradability of protein supplements (Wallace, 1988).

## Requirements of proteins

The proteins that ought to be given to growing cattle can be divided in two categories, those required for maintenance and those required for growth. The proteins required for maintenance are derived from inevitable losses of nitrogen that occurs with urination, faecal matter, hair and scurf. The protein requirement for growth derives from the amino acids deposited in the new tissues. The protein requirements are also dependent on factors such as breed, gender, weight, age and growth rate of the animal. If the animals have the same breed and gender the protein deposition is mainly dependent of live weight (LW) and live weight gain (LWG). If the LW will increase in animals that have the same LWG, there will be a reduction of daily protein deposition and proportion of protein in LWG (Olsson, 1987).

There is a difference in protein requirement dependent on the size of the animal for obtaining similar fat end points. Large-framed cattle require longer feeding periods compared to cattle of smaller maturity size. The metabolizable protein requirements are also different according to the age of the animal, where the requirements are greater of large-framed finishing calves compared to traditional yearling finishing cattle. This statement is based on the fact that younger cattle have greater rates of protein deposition (Sindt et al., 1993).

The nitrogen that is required by the animal is foremost used for protein synthesis. The nitrogen that is present in feed are stated as proteins and is determined by a modification of the Kjeldahl technique. This technique is based on two assumptions; that all nitrogen in the feed is present as proteins and that all proteins within the feed contains 160 g N/kg. The results that are presented are expressed in terms of crude protein (CP; McDonald et al., 2002). The following equation shows calculations of crude protein in feedstuffs:

$$CP\ (g/kg) = gN/kg \times 6.25$$

The factor 6.25 is based on that the nitrogen amount in proteins is relatively constant and has a value of 16 percent. Crude protein is defined as proteins together with Non-Protein-Nitrogen (NPN). NPN consists of nitrogen compounds such as free amino acids, amides, ammonium salts and nitrates. The level of NPN in crude protein in grain is 6-7% and 20-30% in silage (Andersson et al., 1991).

Protein requirements are expressed in various ways, but in Sweden the protein requirements are mainly expressed in relationship with the energy intake of the feed. This method is based on the amount digestible crude protein per mega joule (MJ) metabolizable energy (ME) present in the feed. The protein requirements are high at the beginning of rearing and decrease with an increasing live weight (Table 1; Andersson et al., 1991).

*Table 1. Recommended amounts crude protein (CP) and amino acids absorbed from the intestines (AAT) in feeding plans for growing cattle (Olsson et al., 1998)*

| Live weight, kg | Digestible CP, g/MJ | CP, g/MJ | AAT, g/MJ |
|---|---|---|---|
| 40-75 | 13.0 | 16.1 | 7.5 |
| 76-125 | 11.5 | 14.6 | 7.5 |
| 126-175 | 10.0 | 13.1 | 7.3 |
| 176-225 | 9.3 | 12.4 | 7.0 |
| 226-275 | 8.6 | 11.6 | 6.8 |
| 276-325 | 8.1 | 11.2 | 6.5 |
| 326-375 | 7.9 | 11.1 | 6.5 |
| 376-425 | 7.6 | 10.8 | 6.5 |
| 426-475 | 7.4 | 10.6 | 6.5 |
| 476-525 | 7.2 | 10.4 | 6.5 |
| 526-575 | 6.9 | 10.1 | 6.5 |
| 576-625 | 6.9 | 10.1 | 6.5 |

Protein requirement can also be expressed according to the AAT-system (amino acids absorbed from the intestines) and PBV (protein balance in the rumen) that was introduced in Sweden 1991. There is no relationship between the content of crude protein in the feed and the content of AAT and PBV. When there is a reduction of PBV, AAT will increase where there is a given amount of crude protein. Because of this it is of importance to know the exact values of crude protein, AAT and PBV (Olsson et al., 1998). Crude protein and AAT are used for growing cattle and AAT and digestible crude protein are used for sheep and goats (Spörndly, 2003). The nutritive value of some protein feeds are shown in Table 2.

*Table 2. The nutrient value of protein feeds for ruminants; linseed, lupin seed, distillers waste (DW), rape seed, soy bean (SB), field bean (FB), peas and hempseed cake (*Spörndly, 2003; #Analycen, 2006)*

| | *Lin[1]** | *Lupin[1]** | *DW[2]** | *Rape[1]** | *SB[3]** | *FB** | *Peas[4]** | *Hemp#* |
|---|---|---|---|---|---|---|---|---|
| DM% | 93 | 87 | 6 | 93 | 87 | 76 | 87 | 89 |
| **Per kg DM** | | | | | | | | |
| ME, MJ | 20.1 | 13.6 | 11.4 | 22.1 | 16.4 | 12.9 | 13.8 | 13.0 |
| AAT, g | 51 | 139 | 94 | 56 | 69 | 79 | 97 | 119 |
| PBV, g | 154 | 265 | 52 | 111 | 273 | 124 | 69 | 193 |
| CP, g | 240 | 453 | 200 | 210 | 400 | 273 | 226 | 369 |
| CF, g | 380 | 49 | 7 | 460 | 180 | 15 | 17 | 104 |
| Starch, g | 54 | 220 | - | 10 | 150 | 420 | 550 | 15 |
| NDF, g | 140 | 263 | - | 120 | 101 | | 100 | 434 |
| Ca, g | 2.8 | 3.6 | 2.8 | 4.3 | 2.6 | 4.0 | 0.9 | 2.0 |
| P, g | 5.7 | 7.5 | 7.3 | 8.6 | 6.3 | 4.8 | 4.3 | 14.0 |
| Mg, g | 3.9 | 3.1 | 0.0 | 2.4 | 2.8 | 1.5 | 1.3 | - |
| K, g | 9.0 | 14.0 | 55.0 | 8.2 | 19.0 | 12.3 | 11.1 | - |
| Na, g | 0.4 | 0.2 | 0.6 | 0.1 | 0.3 | 0.1 | 0.3 | - |
| **DC[5], %** | | | | | | | | |
| CP | 86 | 86 | 80 | 81 | 90 | 88 | 88 | - |
| CF | 90 | 75 | 65 | 95 | 90 | 80 | 70 | - |
| EFD[6] | | | | 45 | | 50 | 55 | - |
| EPD[7] | 82 | 72 | 74 | 68 | 79 | 80 | 80 | 72/62 |

[1] Seed
[2] Distiller´s waste (potatoe)
[3] Meal
[4] Kernel, food and feed peas
[5] Digestion coefficient
[6] Effective fibre degradation
[7] Effective protein degradation

Norfor is a new system for evaluation for feedstuff for cattle that will be practiced in Sweden, Norway, Denmark and Iceland beginning fall 2006. Norfor will be used for planning and optimizing of feeding plans. The system is based on an AAT model produced in Norway which is a follow-up from the Nordic AAT/PBV-system. Norfor is based on knowledge about the chemical composition of the feed, feed intake of the animal, digestive process in the gastrointestinal canal, microbial synthesis of organic substances in rumen and in colon and the efficiency of the intermediate metabolism (metabolism within the body exclusive of abdomen and intestines; Rygh et al., 2004).

EPD, effective protein degradation, is a measurement of the proportion of NDF in the feed that is broken down in the rumen. The EPD value should be somewhere between 50-60% for a forage with a good quality. This value is further used for calculations of AAT and PBV (Emanuelsson and Salomonsson, 2003).

## Amino acids requirement and nitrogen surplus

At some locations within the European Union there are problems with high ammonia emission and high nitrogen (N) surplus, often due to high stocking rates. This phenomenon causes N-leaching into the (aquatic) environment. To prevent N-leaching a systematic approach is essential and can be done by lowering the concentrations of nitrogen in the feed and improved energy conversion (Børsting et al., 2003).

When feeding ruminants it is important to cover the requirement of amino acids and nitrogen for the microbes in the rumen, in addition to the amino acid requirement of the ruminant. This is achieved by usage of the Nordic protein evaluation system, PBV. To obtain a minimal excretion of nitrogen from the ruminant there has to be a synchronization of the supply of nitrogen and energy. This will result in optimal rumen fermentation. Also, when the nitrogen supply in the feed is low ruminants are able to absorb higher amounts of nitrogen in the kidneys and thereby there is improved nitrogen utilization (Børsting et al., 2003; Nadeau et al., 2006).

## Fat metabolism

Most of the fat given to ruminants in feed consists of long-chain fatty acids, in free form or as triglycerides, and are hydrolyzed in the rumen (Gibb et al., 2005; Sjaastad et al., 2003). Unsaturated fatty acid that arrives to the rumen are hydrogenated in the rumen to glycerol and free fatty acids prior to the absorption and incorporation into meat and milk fats, but the deposited fat in ruminants can be affected by diets with high values of unsaturated fatty acids (Gibb et al., 2005).

Long chained polyunsaturated fatty acids (PUFA) can be toxic to ruminal microbes as protozoa and cellulolytic bacteria which results in a reduction of microbial activity which has an effect on digestibility (Gibb et al, 2005). The dietary lipids in ruminant diets are derived from forage crops and cereal grains. The lipids that are present in roughages are foremost glycolipids and phospholipids and the composition of these lipids are mainly unsaturated linolenic and linoleic fatty acids. The seed oils that are used in concentrates are rich in linoleic acid and oleic acid (Harfoot and Hazlewood, 1997).

## Growth

The objective of a study was to evaluate the effects of replacing soy bean with urea on performance, carcass traits and intake and digestibility of nutrients of steers. The diets were isonitrogenous (12% of CP) and consisted of soybean meal or urea. Except for ether extract (EE) the protein sources did not affect the intake and digestibility of nutrients. Replacing soybean meal with urea did not change the average daily gain, with expected body weight gain from 1.1-1.2 kg/day (Paixao et al., 2006).

Intake, apparent tract digestibility of nutrients, passage rate, average daily gain, carcass yield and feed conversion were investigated in beef cattle fed diets containing four levels of crude protein (9, 11, 13 and 15%). Intake and passage rate was not affected by increased levels of CP in the diet. However, intakes of both CP and EE increased linearly when the diet varied from 9-15%. CP digestibility increased linearly with the incremental levels of CP in the diet. By increasing dietary CP it was shown that quadratic effects were found for the average daily gain and feed conversion, but there was no effect on carcass yield found between the two diets (Obeid et al., 2006).

## Classification of carcasses and carcass traits

The classification of cattle is based on regulations done by The Swedish Board of Agriculture and the object for this procedure is to gather information on the composition and traits of the carcasses. The traits that are primarily observed at the classification are the distribution of tissues as meat, fat and bone. The classification is a foundation of the payments to the animal producers (SJVFS 1998:127). The fat that mainly is classified is the subcutaneous fat whish is defined as the fat just underneath the skin, and is the largest portion of fat on the carcass. Another type of fat tissues is the intermuscular fat that is deposited between the muscles and this fat is separated from the carcass at an anatomic cutting. Retail cuts that consist of several muscles contain intramuscular fat which is defined as fat within the muscles. Within the fillet (*m. psoas major*), strip loin (*m. longissimus dorsi*), outside round (*m. biceps femoris* and rump steak (*m. gluteus medius*) the intramuscular fat has a percentage of 1-3 percent (Hansson, 1989).

Since 1992, Sweden applies a classification model named EUROP that was established by The European Union (EU). The classification separates species and estimates the amount of fat (percentage of trimfat) and a classification of form and the degree of meatiness. This model consists of five form classes; E, U, R, O and P which are complemented with a plus or a minus which results in a total of 15 classes (SJVFS 1998:127).In young cattle and in cows there is a content of meat of 60-70%, trim fat 5-20% and bones and tendons 16-20%. However, these numbers are dependent on contribution of beef breeds and maturity of the animals which results in a variation of the percentage of meat, fat and bone (Hansson, 1989; SJVFS 1998:127). The grouping of animals is based on species which are further divided into categories based on the gender and age of the animal at slaughter. The ruminant categories are; immature calf, fattening calf, fattened calf, young bull, bull, steer, heifer, young cow and cow. Different carcass measurements are shown in Table 3 where some of the categories of animals are represented (SJVFS 1998:127).

*Table 3. Content of meat, fat and bone expressed in percentage in different types of cattle. Average (x) and standard derivation (S.D.; SJVFS 1998:127)*

| | Young Bulls | | Steers | | Heifers | | Young Cows | | Cows | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. | Mean | S.D. |
| Number | 2.136 | | 174 | | 643 | | 265 | | 341 | |
| Meat% | 68.8 | 3.0 | 66.2 | 2.2 | 65.7 | 3.2 | 66.3 | 3.0 | 64.5 | 4.1 |
| Fat% | 12.1 | 3.0 | 13.3 | 2.9 | 14.9 | 4.1 | 13.2 | 4.2 | 15.9 | 5.5 |
| Bone | 16.8 | 1.7 | 17.9 | 1.5 | 17.1 | 1.7 | 18.1 | 1.9 | 17.2 | 2.2 |

In a study done by Keane and Allen (1998) there was a comparison between two live weights at slaughter (640 and 720 kg respectively) and the results were that with an increasing slaughter weight, there was an increase of all measures of carcass and muscle fatness (Keane and Allen, 1998).

In a study by Steen and Kilpatrick (2000) it was shown that an increased slaughter weight results in increased carcass fat content by 39 g/kg per 100 kg increase in slaughter weight (Steen, 2000). This statement agrees to earlier studies done that says that an increased slaughter weight exhibits greater carcass fatness in all adipose tissues depots (Dunne, 2004). To reduce fat content on the carcass it is more likely successful to reduce slaughter weight than reducing energy intake during finishing period. Reducing the feed dry matter intake to 21% results in a reduced carcass, lean and fat gains (Steen and Kilpatrick, 2000).

Another study was done to compare carcass traits from bulls and steers. Bulls had higher slaughter and carcass weights per day and had a higher proportion of muscles and a lower proportion of fat at in the ribs joint compared to the steers (Keane, 2003; Dunne, 2004).

Numerous studies has shown that steers of 17 to 20 months of age gives light carcasses of less than 300 kg while steers of 24-40 months of age produces heavy carcasses from 320kg to more than 450 kg (Thénard et al., 2006).

Fatty acid composition in ruminants can be manipulated by the diet of the animal, but the presence of the rumen makes it more difficult to manipulate the fatty acid composition in comparison with pigs. PUFA are present in relatively high levels in ruminant meat but further increases can be achieved by including whole linseed or linseed oil to the diet of ruminants. Docosahexaenoic acid (DHA) can be increased by feeding sources as fish oil (Wood et al., 2002). The effect of feeding diets containing n-3 fatty acids on muscle long-chain n-3 fatty acids were investigated in lambs. The results were that the fatty acid composition of meat of lambs fed low or medium-quality pasture or roughage diet can be altered by feeding supplements such as fish meal or soy meal for 6 to 7 weeks before slaughter. Fish meal increased longissimus thoracis (LT) muscle long-chain n–3 fatty acid content while soy meal diets increased LT muscle n-6 fatty acid content but did not affect long-chain n-3 fatty acid content (Ponnampalam et al., 2001).

Feed that is aimed to be given to fattening calf often consists of grain that is supplemented with protein feed, which often is soybean meal. The aim with a trial performed in Sweden was to study the effect of an inclusion of 10% respectively 15% of soybean meal to the concentrates that where given to fattening calf. The parameters that were studied were growth, feed conversion and carcass traits. The result was that there were no or only small differences in the three parameters between the two groups of animals (Hansson and Brulin, 1981).

There was a trial done with different urea levels on a dry matter basis (0.0, 0.65, 1.30 and 1.65%) which replaced soybean meal to a total content of crude protein of 22, 37, 50 and 63%. The aim of this study was to see if there were any effects of the different levels of crude protein on carcass traits, feed intake and digestibility. The urea level did affect rumen degradable protein and total digestible nutrients which increased with urea level but there were no effects on carcass traits observed. The conclusion of the study was that urea can totally replace soybean meal in diets for confined crossed dairy steers allowing gains of 1 kg/day. Using urea in the diet also resulted in improvement of nutrient digestibility (Magalhaes et al., 2006).

Holstein and crossbred beef steers have been individual fed one of four isonitrogenous diets to evaluate effects of forage source and protein source (soybean meal and fish meal) on feedlot performance. The results were that there was no difference on daily gain or most carcass traits between the two treatments with different protein feed (Comerford et al., 1992).

# PROTEIN FEEDS

## Current status

There are only a small number of protein feeds that are suitable to grow in the Swedish climate and environment and together with government regulations that says that a greater proportion of the feed given to animals at the farm should be home-grown feed, makes a challenge for animal producers in Sweden (Boström, 2004).

According to EU Council Directive (2005) protein feeds that are used in organic production systems for ruminants must be based entirely on organic grown feeds as of January 2008. Thereby a demand is created to formulate diets from locally grown crops. This regulation implies that many of the imported protein feeds that are used today are going to decrease in usage. To replace these protein feeds there is alternative protein feeds as peas, field beans or cold-pressed organic rape seed cake (CORC) that is available on today’s market (Johansson and Nadeau, 2006).

There has been much focus on protein sources in ruminant feedings because of reducing costs of ruminant production and required reductions of leakage of nitrogen into the environment. There is also a need for alternative protein feeds as a substitute for the proteins that origin from animal by-products that are prohibited and for the reduction of the usage of gene modified products that are prohibited in organic production, e.g. soybean meal (Wilkins and Jones, 2000).

## Antinutritional factors

Trypsin-inhibitors are chemical compounds that reduce the bio-availability of trypsin, an enzyme which is essential to nutrition of many animals. Trypsin-inhibitors are present in leguminous plants, e.g. soy beans and peas. Lectines are another group of antinutritional factors which become bound in the epithelia cells of intestines and reduce the absorption of nutritional substances. Trypsin-inhibitors and lectines are able to be inactivated by heat treatment (Boisen, 2002). Tannins are a group of antinutritional factors which form a complex with proteins and carbohydrates and form an enzyme resistant complex which results in a reduction of digestibility. Tannins also cause injury of the intestinal mucosa as well as a reduction of iron absorption (McDonald et al., 2002). Alkaloids are typically from lupines and are absorbed in the intestines and partly broken down in the liver. This substance is toxic for the organism and reduces the absorption of nutrient substances. Glycosinulates are present in rapes among other feeds. This substance has no negative effect on absorption but gives the feed a bitter taste (Boisen, 2002). By-products cause damage in liver and in kidneys and are able to inhibit the absorption of iodine in pancreas which results in reduced production of thyroxin (Boisen, 2002). Glycosinulates can be reduced by plant breeding which results in a lower value of the substance in the plant (Personal communication; Johansson, 2006).

## *HEMP*

### Origin and current status

Hemp, Cannabis sativa L., is one of the oldest plants that have been used for cultivation. The origin of the plant is Central Asia where it has been cultivated for 3000 years (Lund, 2000). In the southern of Sweden (Skåne) there are archaeological findings from the Iron Age (550 BC-1150 AD) of hemp (Ivarsson, 2004). During Second World War the cultivation of hemp expanded very rapidly and in 1942, 2000 hectare was cultivated including 1000 hectare on the island of Gotland (Svennerstedt and Svensson, 2006). In the late 1950’s the hemp plant was cultivated on 1000 hectare (2.471 acres) in Sweden with a harvest of 1000 kg per hectare or more. At that time the hemp plant was cultivable in the whole country of Sweden but the cultivation ended in the late 1950’s at the same time as cultivation of flax ended (Lund, 2000). In 1965 the hemp plant was forbidden to cultivate because of its content of narcotic substances (Holstmark, 2006). Since 2003 the Swedish Board of Agriculture has decided that it is allowed to cultivate particular strains of industry hemp that contains smaller amounts than 0.2% of the narcotic substance tetra-hydro-cannabinol (THC), Figure 2 (Ivarsson, 2004). In 2005 there were 126 farmers who cultivated hemp plant in Sweden on 368 hectares (Sundberg and Westlin, 2005). The total world production of hemp fibres were 66300 metric tons and the total production of hemp seeds were 30200 metric tons in 2004 (Svennerstedt and Svensson, 2004). Today the amount from the harvest of biomass is somewhere between 8 and 14 metric ton dry matter (DM) and the fibre yield somewhere between 2 and 3.5 metric ton DM per hectare (Svennerstedt and Svensson, 2004).

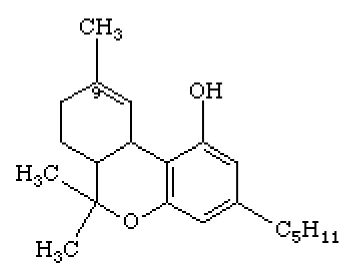


Figure 2. Tetra-hydro-cannabinol (BioTech Resources, 2007)

## Hemp cultivation within the European Union (EU)

The amount of cultivation of hemp plants were between 10 000 and 12 300 hectares in the years 2001 until 2003. The average hemp straw yields in these years amounted to between 5.3 and 6.2 t/ha (Figure 3; Karus, 2005).

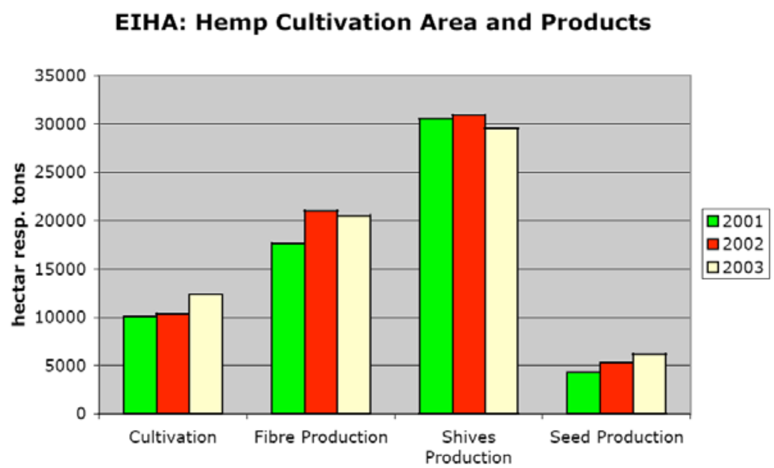


Figure 3. Amount of hemp plants cultivated in 2001 until 2003 in the EU, and the products from the hemp plant according to EIHA, European Industrial Hemp Association (Karus, 2005).

The total area for cultivation of hemp that was used for fibre production in EU was during 2004-2005 approximately 15900 hectares (Jordbruksdepartementet 2004; Finell et al., 2006). The years before that, 2003-2004 there were 18000 hectare cultivated. The leading country 2004/2005 in the production of fibre hemp was France with 800 hectare where after Germany was the second leading country with 1700 hectare production and United Kingdom with 1400 hectare. Remaining countries that cultivated hemp for fibre purposes were Czechoslovakia (150 ha), Denmark (40 ha), Spain (657 ha), Italy (950 ha), Hungary (500 ha), Holland (100 ha), Austria (399 ha), Polen (1000 ha), Finland (7 ha) and Sweden (140 ha; Jordbruksdepartementet, 2004).

Outside EU, in the rest of the world the leading producer of hemp seeds are China and in Canada the most common field of application for hemp in those countries is also the seed production (Svennerstedt and Svensson, 2006).

## Botanical

The hemp plant is an annual herbaceous plant which belongs to the family Cannabinaceous (Mustafa et al., 1998). Botanically the hemp fibre plant is able to grow as tall as four meters high whereas the drug plant only grows to a height of two meters. The leafs of the plant are big, serrated and are composed of three to nine leaflets, have a colour of dark green and a rough surface (Figure 4; Lund, 2000). Hemp stems contains three types of fibres; primary bast fibres which are long and contains a low level of lignin, libriform fibres which are short and has a high level of lignin and secondary bast fibres that has an intermediate length and content of lignin (Van der Werf, 1991).

Figure 4. Leaf of the hemp plant consisting of three to nine leaflets (Naturhistoriska riksmuseet, 2007).

## Types and yield

The species of hemp plant that are allowed to cultivate today within the European Union (EU) are called industry hemp and contains low levels of narcotic substances in comparison to the origin of the industry hemp; Indian hemp (Cannabis indica).
Within the industry hemp species there are two different types of hemp plants. These are the fibre hemp and the oil hemp (Holstmark, 2006).

The oil hemp is foremost intended to be used for production of seeds (Figure 5). The oil content in the seeds is high (30%) and the share of unsaturated fatty acids is significantly higher compared to the linseed oil. At cold pressing there is an amount of approximately 20% oil that is extracted whereby the remaining product is used for animal feed. As animal feed the hempseed cake has a nutritionally value equal to rape seed as a protein feed. The oil hemp plant is able to grow to a length of 1.5-2 meters and the seed yield at harvest amount to 1-3 metric ton per hectare (Holstmark, 2006). The biomass yield at harvest is not that high as compared to the fibre hemp (Finell et al., 2006).

Figure 5. The left picture shows hemp seeds and right picture shows barley seeds (Finell et al., 2006).

Typically harvest yields for hemp seed are (Personal communication; Finell, 2006):

- Canada: 750 kg/ha
- Finland: 1000 kg/ha
- Sweden, Umeå (Röbäcksdalen): 1000-1500 kg/ha.

The fibre hemp is able to grown to a length over 3 meters, which is considerably higher than oil hemp plants (Figure 6). About 70-75% of the fibre plant consists of woody materials whereby the rest of the plant is fibres. The fibres are approximately 50 mm (millimeter) long (Fällman, 2006). This kind of hemp does not give many seeds but it gives a higher biomass yield at harvest compared to the oil hemp (Jonas Ivarsson, 2004; Holstmark, 2006). Pure fibre strains do not produce seeds in the Swedish climate (Personal communication; Finell, 2006). According to Svennerstedt and Svensson (2006) the biomass that are achieved from harvest are 10 metric tons per hectare, bast fibres 2.5-3 metric tons per hectare, woody materials 7.0-7.7 metric tons per hectare and seeds 1.0-1.5 metric tons per hectare (Personal communication; Svennerstedt, 2006).

Figure 6. Hemp strain of Finola (oil hemp strain) in the middle of the picture and fibre hemp strains at the sides of it (Finell et al., 2006).

There are also strains that are a mixture of the fibre and seed strains. These strains produce seeds and give a relatively high biomass yield at harvest (Finell et al., 2006).

## Strains

There is several strains of industry hemp and among those who are approved by EU there is three French strains which are rich in fibres; Fedora 17, Felina 34 and Futura 75. There is also one additional French strain, Santhica 27 which is refined and has a value of THC of nearly zero. On the list of approved hemp strains there are also German, Polish, and Hungarian strains. The Polish strain Beniko has been successfully used in Sweden in experiments. There is in addition a Finish strain, Finnola, which gives a higher yield of seed harvest (Figure 7; Svennerstedt and Svensson, 2004).


.
Figure 7. Hemp plant of the Finola strain (Finell et al., 2006).

During the years of 1999-2001 there have been a number of experiments performed in the southern of Sweden with the aim to study three monoecious varieties; Felina, Fedora and Futura which are fibre hemp strains (Finell et al. 2006, Svennerstedt and Svensson, 2006). The results were that Futura had the highest fibre yield and showed best results in development while Fedora showed the lowest fibre yield. Further, results showed that a good biomass and fibre yield could be achieved with an appropriate high summer temperature during the summer months in Sweden as well as sufficient nitrogen fertilization. In the same experiment the seed rate was tested and the results showed that there was not any difference in biomass and fibre yield at a seed rate at 30 and 60 kg/hectare, but the stem diameter showed best results at the seed rate at 30 kg/hectare (Svennerstedt and Svensson, 2006).

There was a trial in Röbäcksdalen, Sweden 2003, where the strain Finola was studied during northern growing conditions. Finola which is a seed strain of the hemp plant was compared to three other fibre strains; Beniko, Fedora and Futura. The results showed that the total biomass yield in the fall was approximately 10 metric tons per hectare for the fibre hemp strains and almost 6 metric tons per hectare for the oil hemp strain. Only stem yield were almost 8 metric tons for the fibre hemp strains and 2.5 metric tons per hectare for the oil hemp strain. Fractions of leaves and seeds were approximately 2 metric tons for the fibre hemp strains and 2.5 metric tons per hectare for the oil hemp strain (Figure 8; Finell et al., 2006).

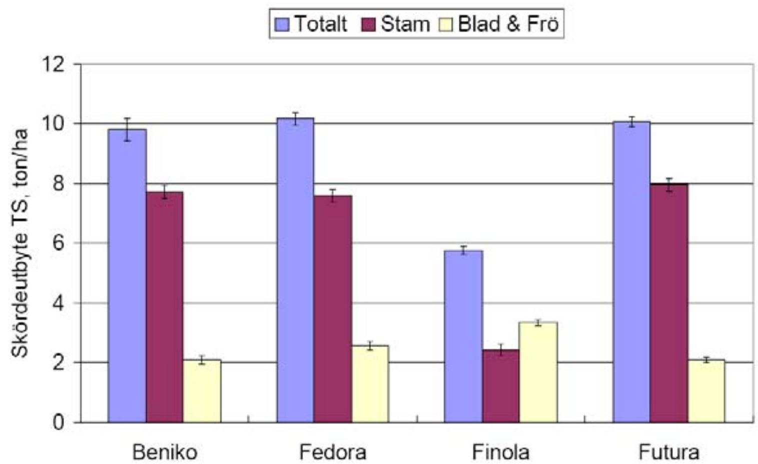


Figure 8. Yield at harvest for different fractions for all of the hemp strains in the trial performed in Röbäcksdalen, Sweden. Numbers shown in the picture is a mean value and SD for samples taken from three repetitions (Finell et al., 2006).

## Cultivation

The planting season for hemp in the southern part of Sweden reaches from April until October, preferably in soils containing 6-12% organic matter but can also be planted on clay- and sandy soils. The hemp plant germinate at low temperatures but the temperature at sowing should be around 8-10ºC which means that the hemp plant should not be sowed in an early time period of the year (Svennerstedt and Svensson, 2004).

Depending on the harvest time for hemp the adequate uses of the plant will vary and the stem yield will be significantly reduced with time. When harvested in the fall, August – October, the fibre quality will be high and it is worth while to separate the fibres from the core. Roughly 25% of the stem weight consists of bast fibre the rest is a wood-like material called shives or hurds. From the bast fibres both long (for clothing) and short (industrial) fibres may be produced. The woody material is used as animal bedding and particle boards. The total stem losses are estimated at about 10 % when harvested in the early fall. If the hemp is harvested later in the fall or early winter, November-December, the stem is more suitable for short fibre applications, e.g. for insulation purposes, and the shives may be used as energy preferably after palletizing or briketting. The loss of stem material is estimated at 20% compared to the original stem biomass available. The harvest can also be performed in late winter and spring, January – May and with the purpose to produce primarily energy. However, the stem losses are considerable and amount to approximately 40%. The quality of the fibres is reduced with later harvesting time and it is of importance to know the aim of the hemp plantation before it is planted. Hemp fibres from an early harvest are preferably used for textiles whereas hemp fibres from a late harvest may be good enough to be used as insulation materials (Svennerstedt, 2006).

In a hemp study with experiments in Europe it has been showed that it is favourable with long day conditions for fibre plant production and therefore the long days during the summers in Sweden could be of interest for hemp production (Svennerstedt and

Svensson, 2006). The spacing between the plants should be 12-24 centimetres (cm) and the depth of the bed should be somewhere between 3-4 cm. In the Nordic climate the industry hemp blooms approximately 80-100 days after the sowing and the incipient ripeness of the seed occur after 120-140 days. According to the rules of the Swedish Board of Agriculture, the hemp plant should be planted in pure stand and be cultivated when the seeds are produced or 10 days after flowering (Svennerstedt and Svensson, 2004). The roots of the plant reach a long distance into the soil and are, because of this property, easily broken down after harvest which makes the soil porous. For ecological organic farming there is an advantage to let the plant putrefact on the field after harvest because one third of the material will then stay on the field. Concerning rotation of crops, the hemp has an important advantage according to diseases. This is because it has no congener in the rotation of crops (Svennerstedt and Svensson., 2004)

The aim with planting and cultivating hemp plants the first two years is to reduce weeds which are reduced because of the considerable height and density of the plants (Personal communication; Norberg, 2006). In a trial done in England and Denmark hemp was used to control couch grass and other weeds in a natural manner (Svennerstedt and Svensson, 2004). The weeds are present in different extents depending on what strain that are used (Personal communication; Norberg, 2006). Finell et al (2006) showed that the fibre hemp strains were growing more tightly together compared to the oil hemp strains which resulted in a reduced amount of weeds in the fields of fibre hemp (Figure 9).

Figure 9. Oil hemp strain in the left picture and fibre hemp strain in the right picture shows that there were more weeds present together with oil hemp strain compared to fibre hemp strain (Finell et al., 2006).

The handling of the plant requires hard work because the fibres are closely attached to the stem which is a disadvantage for the hemp plant. The extraction procedure of the fibres is equal to the procedure for extracting flax, but the handling of hemp plants require more powerful agricultural machines since the hemp plant is a heavier plant than the flax plant (Lund, 2000). Yield received from harvest can vary a lot depending on different factors.

Among those factors are;

- Soil type. The most suitable ground for hemp plant is a comparable damp but well drained ground. The hemp plant is sensitive for water, both in too small amounts as well as in too large amount during the early phases of growth.
- Strain. Most of the strains that are allowed to cultivate in EU are refined for the usage of fibre. The aim with the refinement has been to increase the yield of fibres, but also the quality of the fibres.
- Seed rate (plant spacing). The seed rate that often are used for fibre production are 50-140 kg/ha and one can generally state that the plant spacing is increasing with an increasing number of fibre together with that the quality of the fibres increases (Sundberg and Westlin and Westlin, 2005).
- Fertilizing. The hemp plant is considered to have a great need of nutrients especially concerning the amount of nitrogen, potassium and calcium.
- Frost is another factor that can affect the yield of the harvest. If this occurs, the bast fibres will come off the wood and there will be a reduction of the DM and the water content will only be 10-20% (Sundberg and Westlin, 2005).

The expenses for production of hemp are approximately 5000 SEK per hectare. A large share of these expenses consists of seed and fertilizer (Sundberg and Westlin, 2005).

## Usage

The most common field of application of hemp within EU is for production of fibres, (Figure 10) and these fibres are often used for production of ropes (Landström, 2000) but hemp is also used for animal feed because of the high levels of oils that are present in the seed (Landström, 2000; Lund, 2000; Svennerstedt, 2006).

Figure 10. Hemp stem fibres (Wikimedia Commons, 2007).

The bast fibres are often used to ropes, sailcloth and clothing. The production of these kinds of products is expensive and therefore the production often is moved to eastern countries. To make this process profitable in Sweden there is a need for new processing techniques and machineries. The short fibres are often used for industry purposes which are papers and cartons. The remaining product from hemp fibres are woody materials which are used for particle boards, animal bedding materials and energy (Personal communication; Norberg, 2006).

Other fields of application for the hemp plant is textiles, non-conducting material, car details (Figure 11) and fuel (Ivarsson, 2004).

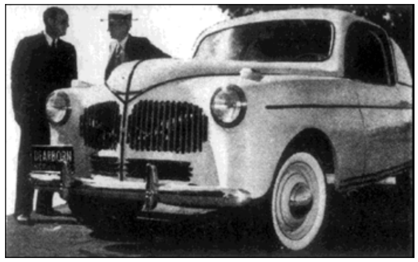

Figure 11. Car made from hemp materials (Wikimedia Commons, 2007).

The market for different products of hemp is expected to increase during years to come. This is foremost because the replacement for products of petroleum with natural crude material. In the animal feed industry as well as in the provision industry the by-product from pressed oil hemp is of great interest because of the fat and the protein content. Hemp is also important because of the high value of PUFA (Landström, 2000). The nutritional properties of hemp have long been recognized and valued as food for both humans and domestic animals (Callaway, 2004).

The oil that is pressed from the seed is abounding in polyunsaturated essential fatty acids PUFA and also contains gamma-linolenic acid that also can be found in mothers' breast milk, seeds from black currant and cod-liver oil (Ivarsson, 2004). The oil is further used for production of margarine, treatment of wood, production of paint as well as soap (Lund, 2000).

## Nutritional value

Hemp seed contains over 30% oil and 25% protein and has a high value of dietary fibres, vitamins and minerals (Table 4 and Table 5). About 80% of the hemp seed oil is PUFA which are rich in two essential fatty acids (EFAs), linoleic acid (18:2 omega-6) and alpha-linolenic acid (18:3 omega-3). The ratio between the two EFAs (omega-6 to omega-3) is normally from 2:1 to 3:1 which is optimal for human health (Callaway, 2004).

*Table 4. Nutritional content of hemp seed, shown as % of DM unless stated otherwise (Callaway, 2004, Chi Hemp Industries Incorporated, 2007)*

| | Whole seed | Seed meal | Hemp seed cake |
|---|---|---|---|
| Oil (%) | 35.5 | 11.1 | mv |
| Protein | 24.8 | 33.5 | 32.7 |
| Carbohydrates | 27.6 | 42.6 | 44.0 |
| Moisture | 6.5 | 5.6 | 9.9 |
| Ash | 5.6 | 7.2 | 6.4 |
| Energy (kJ/100 g) | 2200 | 1700 | mv |
| Total dietary fibre (%) | 27.6 | 42.6 | mv |
| Digestable fibre | 5.4 | 16.4 | mv |
| Non-digestable fibre | 22.2 | 26.2 | mv |

*Table 5. Content (mg/100 g) of vitamins and minerals in hemp seed (Callaway, 2004)*

| | |
|---|---|
| Vitamin E | 90.0 |
| Thiamine (B1) | 0.4 |
| Riboflavin (B2) | 0.1 |
| Phosphorous (P) | 1160 |
| Potassium (K) | 859 |
| Magnesium (Mg) | 483 |
| Calcium (Ca) | 145 |
| Iron (Fe) | 14 |
| Sodium (Na) | 12 |
| Manganese (Mn) | 7 |
| Zinc (Zn) | 7 |
| Copper (Cu) | 2 |

A human diet that contains sufficient levels of PUFA can lower arterial levels of LDL-cholesterol and blood pressure, reduce the risk of heart diseases, inhibits the growth of prostate and breast cancer, delays the loss of immunological functions, and are required for normal foetal brain and visual development (Lewis et al., 2000; Callaway, 2004). The protein content in hemp seed is mainly composed of edestin and albumin. These proteins are high-quality storage proteins are easily digested and contain the sufficient amounts of all amino acids for humans. One amino acid that is found in extraordinary amounts in hemp seed is arginine and there are sufficient amounts of the two sulphur containing amino acids methionine and cystine (Table 6). Because of the high nutritionally value hemp seed has been compared with other high quality proteins such as egg white and soy bean which is considered equal according to the nutritionally value. Hemp has been considered valuable as human food because of its nutritional properties throughout Asia, India, Russia, and in Eastern Europe. In China the hemp seed is still sold as a snack by street vender´s and in Russia “black” oil has been pressed from hemp seed and used as a dietary fat source. A comparison of the fatty acid profile in hemp seed oil and olive oil has been done because of the high nutritional value, Table 7 (Callaway, 2004).

*Table 6. Amino acid content in hempseed cake and comparable protein feeds (Karlsson, 2006)*

| | Field bean | Peas | Rape seed cake | Hemp seed cake |
|---|---|---|---|---|
| Cystine | 1.3 | 1.4 | 2.3 | 2.0 |
| Histidine | 2.5 | 2.4 | 2.4 | 2.5 |
| Lysine | 6.0 | 7.0 | 5.1 | 5.5 |
| Methionine | 0.8 | 1.0 | 2.0 | 1.8 |

*Table 7. A comparison of the fatty acid profile in hemp seed oil and olive oil (Callaway et al., 2005)*

| Fatty acid | Hemp seed oil (%) | Olive oil (%) | Class |
|---|---|---|---|
| Palmitic oil | 6 | 15 | Saturated |
| Stearic oil | 2 | 0 | Saturated |
| Oleic oil | 9 | 75 | MUFA omega-9 |
| Linoleic oil | 54 | 7 | PUFA omega-6 |
| Alpha-linolenic acid | 22 | <1 | PUFA omega-3 |
| GLA | 4 | 0 | PUFA omega-6 |
| SDA | 2 | 0 | PUFA omega-3 |
| % of PUFA | 82 % | 7 % | omega-6 + omega-3 |
| n6/n3 ratio | 2.2:1 | >7:1 | omega-6/omega-3 |

In a study done by the University of Saskatchewan it was shown that hemp meal had a higher value of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) compared with other protein sources as borage meal (BM), canola meal (CM) and heated canola meal (HCM). There was an equal amount of CP found in hemp meal as in BM and a lower value of CP than that found in CM and HCM. Concerning the soluble CP levels HM had a comparable amount with HCM but lower than that of BM and CM. The neutral detergent insoluble CP was highest in CM and HCM but HM had a higher value than that of BM. The four protein sources had a comparatively equal amount of total CP associated with ADF. The results conclusions of the above mentioned study was that hemp meal is an excellent natural source of rumen undegradable CP which is a good alternative to heat treated canola meal (Mustafa et al., 1998).

## Hemp as animal feed

A study by Mustafa et al. (1998) was done with the aim to determine ruminal nutrient degradability of hemp meal in comparison to common protein sources. The total-tract nutrient digestibility of hemp meal was also determined in the same study. In situ studies were done by using two non-lactating Holstein cows fitted with flexible rumen fistulae. The results for the digestibility showed that the in situ soluble DM fraction was lower for hemp meal compared to canola meal, heated canola meal and borage meal. Hemp meal as well as the heated canola meal had the lowest soluble CP fractions relative to the other two feeds. Hemp meal is according to previous study similar to heated canola meal in rumen degradability characteristics, which is highly undegraded in the rumen compared to canola meal and borage meal. The rumen degraded protein was higher in hemp seed meal that in canola meal and borage meal. The lower rumen degradability results in a higher amount of crude protein available for post-ruminal digestion (Mustafa et al., 1998). The conclusion of the study was that hemp seed meal is a good natural source of rumen undegraded protein that is equivalent to heat treated canola meal since there is a high amount of crude protein (Mustafa et al., 1998).

Another trial was performed of Gibb et al. (2005) studying effects of full-fat hemp seed on performance and tissue fatty acids of feedlot cattle. Sixty individual penned steers were fed barley-based finishing diets and were placed in three group with different amounts of full-fat hemp seed (HS); 0% (control group), 9% and 14%. Feeding HS did not have any effects on DMI, ADG or carcass traits. However, fat deposits can be positively affected by feeding with hemp seed. The carcass fat had increased levels of conjugated linoleic acid (CLA) as well as omega-3 acids without negatively affecting performance. There was no negative effect of feed conversion by feeding of hempseed cake with 14% of the total DM content of the feeding plan (Gibb et al., 2005).

In Sweden there has recently been an experiment performed with hemp as a protein feed for dairy cows done by Swedish University of Agricultural Science (SLU) in Uppsala. The experiment lasted during two months and included three dairy farmers with dairy cows. Two of them had an organic production and one of them had a conventional production. The breed of the cows was all of Swedish Holstein and Swedish Red Cattle. The aim of this study were to measure if there was any differences in milk production if the current protein feed were replaced with an inclusion in the diet up to 3 kg hempseed cake. The hempseed cake was compared to the commercial concentrate Akleia (organic) or Solid (conventional). There were not any significant differences in milk production when using hemp as a protein feed. However, the animals in the experiment needed some days to get use to the new protein feed they were provided because of the taste (Personal communication; Gustavsson, 2006).

In a Canadian study the effect of feeding hemp seed meal to laying hens was investigated. The effect of feeding hemp seed meal to laying hens it was shown that egg production, feed consumption, feed efficiency and body weight were not affected by increasing amounts of hemp seed meal in the diet. The conclusions were that hemp seed meal can be given to laying hens with no adverse effects and that hemp seed meal is a valuable source of protein, energy and long chain fatty acids. There were lower concentrations of palmitic acid and higher concentrations of linoleic and linolenic acids in the hemp seed meal produced eggs (Silversides et al., 2002).

In a trial done with cows and sheep it is shown that hemp seed was a good source of rumen undegraded protein (RUP; Callaway, 2004). Another study that was performed in Finland with hemp seed as a feed for farmed fish showed that hemp seed was as good as soy meal according to growth (Callaway, 2004).

## Hemp as human feed

Hemp seed oil has been used as human food and medicine in China for at least 3000 years and is today available in food shops in Europe and North America. A medical study compared hemp seed oil with olive oil given patients suffering from Atopic dermatitis, more commonly known as eczema. The aim was to study the effects on plasma lipid profiles, transepidermal water loss, skin quality and dermal medication usage. Hemp seed oil improved clinical symptoms of atopic dermatitis by change plasma fatty acid profiles. These results are suggested to be due to the content of PUFA in hemp seed oil (Callaway et al., 2005).

Hemp seeds are able to be used as human food (Figure 12) because of advantages that comes with the seeds. The proteins the seeds are composed of are easily broken down and consists of 65% globulin, edestin and albumin, essential fatty acids, gamma-linolenic acid (GLA), vitamins and minerals, omega 3 and omega 6 and the seeds are free from cholesterol. The hemp seeds can also be consumed hulled or shelled while a nutty flavour is distinguished, but the content of carbohydrates and fibres are reduced with the peeling procedure (Personal communication; Norberg, 2006).

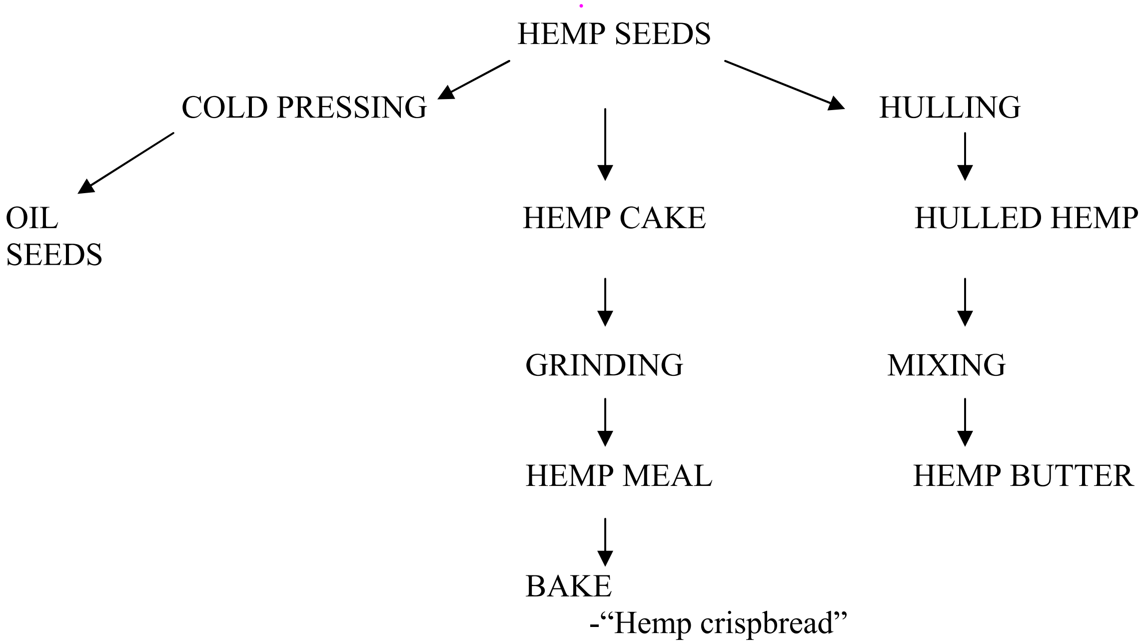


Figure 12. Fields of applications and procedures at production of different products (Personal communication; Norberg, 2006).

The largest numbers of hemp products that are used for human consumption in Sweden are imported from Canada, USA, Germany and Great Britain (Personal communication; Norberg, 2006). Hemp products that origin from hemp seeds and are imported from Canada are snacks, meal, and oils (Personal communication; Finell, 2006).

## SOY BEAN

Soy beans (Glycine max; Figure 13) have during the last decades been an important agricultural commodity which has increased in annual production. The major producing countries are USA, Brazil, China and Argentina and in the USA most of the soy beans are being crushed to extract oil which are used for human consumption and the remaining product which is a defatted meal, is being used for animal feed (Kiers, 2001).

In 1999 soybean meal was one of the best sources and mostly used protein feed to animals. The bean contains 160 to 210 g/kg of oil and the residual meal has a content of 10g/kg. The amino acid content is succicient beside the content of cysteine and methionine which are suboptimal. There are a number of toxic, stimulatory and inhibitory substances present in soybean meal. Among these, the protease inhibitors are of most importance according to nutrition. Protease inhibitors acts as a growth-retarding factor and affects protein digestion but also results in hyperactivity of the pancreas which causes an increased production of trypsin as well as chymotrypsin. These problems arise often in a connection with raw soy bean or unheated soybean meal (McDonald et al., 2002).

A study with the aim to determine the effects of feeding Charolais steers was done with diets rich in either n-6 or n-3 polyunsaturated fatty acids (PUFA) and time on feed (TOF) on muscle fatty acid composition and content. Two concentrates varying in the source of fat; soy (high in C18:2 n-6) and whole linseed (high in C18:3 n-3). These concentrates were fed approximately 0.73% of total DM intake. The results showed that the diet did not affect total fatty acid content of neutral lipid in m. longissimus thoracis but feeding linseed increased total phospholipid fatty acid by approximately 15%. Linseed increased the amount and proportion of C18:3 n-3 and the proportion of CLA, while soy increased the content and proportion of C18:2 n-6 in muscle neutral lipid (Choi et al., 2006).

Figure 13. Soy beans (Whole foods market, 2007)

## *RAPE SEED*

Compared to soybean meal, rape seed meal contains more NDF (243g/kg DM; Spörndly, 2003) and the lysine and methionine content are more favourable in rape seed meal compared to soybean meal, but the amino acid availabilities are lower than for soybean meal. The oil residue that is a result from extraction contains about 400 gram protein per kg DM (Boucqué and Fiems, 1988; McDonald et al., 2002). The crude protein content in rape seed is 210g/kg DM and is lower than that in soy bean (Spörndly, 2003). One advantage is though that the rape seed has a higher level of the amino acid methionine than the value of methionine in the soybean oil. The ratio between calcium and phosphorous is sufficient and this protein concentrate contains more phosphorous compared to other oilseed residues (Boucqué and Fiems, 1988; McDonald et al., 2002).

Rape seed meal contains glycosinolates such as tannins and sinapine which might results in reduced voluntary feed intake (Olsson, 1987) and reduced palatability. In a study it was shown that feeding rape seed meal to ruminants did not impair carcass quality traits but increased unsaturated fatty acids ($C_{22:2}$ and *trans* $C_{18:1}$) content in carcasses (Tripathi, 2007). To reduce or remove glycosinulates, various treatment methods are tried. Most of these methodologies included hydrolysis or decomposition of glucosinolates before feeding. Chemical treatment and or supplementation were also tried to overcome glucosinolate related toxicity in animals (Tripathi and Michra, 2007).

The results of a study done by Olsson (1987) showed that feeding growing cattle with high glucosinulate rape seed meal (sort used in the eighties) results in an enlarged thyroid gland at slaughter. The interpretation to this result is that the increased thyroid gland is a compensatory growth in response to glucosinulates or glucosinulate split products of the rape seed meal (Olsson, 1987).

Different species have different physiological responces to the variety of rape seed used today. Ruminants are not affected negatively according to growth and production, and can be given rape seed meal as a whole source of daily protein. The growth of chickens can be negatively affected if the inclusion rate is too large, exceeding 50g/kg. The taint of brown shelled eggs can also be affected by rape seed meal in the diet and get a flavour taint of fish. The reason for this phenomenon is that these birds have an inability to oxidize trimethylamine which is produced from the polyphenolic choline ester sinapine (McDonald et al., 2002).

One recent Swedish study showed that milk yield could be maintained when dairy cows were fed high inclusions of cold-pressed rape seed cake, but fat and protein contents in milk were reduced (Johansson and Nadeau, 2006).

## *LINSEED*

Linseed meal consists of 60% of hull but the amount of crude fibres in the meal is relatively low, which is due to the fact that the hull does not only contain fibres. The proteins that are present in the seed are relatively easily soluble and are broken down to a great extent in the rumen of ruminants. Trials have been done to lower the digestibility in rumen of the proteins which is of great importance in dairy cows (Olsson et al., 1988).

Linseed meal, which is a residue from linseed oil (Figure 14) is unique from other oilseed residues because it contains 3-10% of mucilage. This mucilage is indigestible for non-ruminants but ruminants are able to digest this substance by the microbes that are present in the rumen. The mucilage has a property to absorb a large amount of water which results in an increase in the bulk of the meal. The increase in the bulk of the meal has an advantage because it increases the retention time in the rumen, which is favourable for microbial digestion. The mucilage might also have an advantage since it can protect the gut wall against mechanical damage and together with the bulkiness regulates excretion through and prevents constipation without causing loosness. The statements mentioned above are not scientifically tested (Boucqué and Fiems, 1988; McDonald et al., 2002).

Figure 14. Linseed (Punjab national bank and agriculture credit, 2007)

The proteins in linseed consists of low levels of the amino acids methionine and lysine which causes problems in feeding plans for porcine and poultry (Olsson et al., 1988) but not for ruminants and horses. The result of a study done by SLU shows that milk yield can be lowered when cows are given linseed cake as an only source of protein, which can be due to a too low AAT-level in the feed. At a ration up to 2-2.5 kg per cow and day this feedstuff has to be complemented with another protein source with lower rumen degradability (higher AAT-content) to get the same results as when only heat-treated rape seed cake was fed. The study also shows that the ratio between the fatty acids omega-3 and omega-6 are significantly higher in the milk from cows given linseed as a protein source compared with rape seed as a single protein source (Bertilsson et al., 1994).

The content of calcium is moderate in linseed meal while it is rich in phosphorous. This protein concentrate is also a good source of thiamin, riboflavin, nicotinamide, pantothenic acid and choline (McDonald et al., 2002).

Immature linseed contains cyanogenic glycosides which produces hydrogen cyanide together with the enzyme limaras. Linamaras and the other glycosided are destroyed by the oil extraction and thereby is the risk for the animals being poisoned eliminated (Olsson et al., 1988).

Before feeding animals with linseed the seeds should be crushed or soaked well otherwise the feed will pass through the body of the animal unaffected (Olsson et al., 1988).

The linseed meal is given with advantage to fattening animals because these animals have a potential to gain a higher weight faster than those animals given other protein supplements (McDonald et al., 2002). The aim of a study by Burris et al (1974) was to compare carcass traits between animals feed with either soybean meal, fish meal or linseed meal. There were no significant differences between the three protein supplement according to carcass traits. Fattening animals given linseed meal obtained faster gains compared to other vegetable protein supplements and attained a very good sleek appearance though with a soft body fat. Cows given the same supplement produced a soft milk fat which is susceptible to the development of oxidative rancidity (McDonald et al., 2002).

There have been two feeding experiments performed by SLU at Kungsängen Research Station, Sweden in order to evaluate the feeding value of linseed expeller to high yield milking cows. The result showed that cows fed with linseed expeller as a dominant protein and fat source had a significantly lower milk and protein yields and that this feed should be considered as an energy- and fat-rich feedstuff (Bertilsson et al, 1994).

## BEANS

Beans, as well as lupines, are currently important in Sweden where they are suitable to grow as an organic feed. The reason for this is the early ripe phase and that these species contains lower levels of noxious harmful substances compared to the older strains (Boström, 2004).

The beans that are used for human and animal consumption are mainly Vicieae and Phaseoleae. The most well known and used bean within the group of Vicieae is Vicia faba also known as the broad bean, horse bean or Windsor bean (McDonald et al., 2002). The protein content of the horse bean is 23-27% depending on winter or spring varieties. The crude fibre content is about 7-8% and the oil content is about 1-1.5% (Todorov 1988). Within the group of Phaseoleae, the Phaseolus genus is the most numerous and the P. vulgaris the best known with varieties as garden, field, kidney and haricot beans. Beans are good sources of proteins with high quality with a high level of the amino acid lysine, but the content of cysteine, methionine and tryptophan are lower than in similar animal and vegetable proteins. Beans also have a high amount of energy (McDonald et al., 2002) with metabolizable energy content of 12.9 MJ/kg DM for ruminants (Spörndly, 2003). Concerning the amount of vitamins present in beans there is little or no amount of carotene (vitamin C) but the amounts of thiamin (vitamin B1), nicotinamide and riboflavin (vitamin B2) are good. The mineral content of beans is similar to the composition of cereals and oilseed residues, i.e. high phosphorous and low calcium content. Beans contain a low level or none of sodium, chlorine or manganese (McDonald et al., 2002).

Horse beans are successfully used for all classes of animals, and for animals like dairy and beef cattle and sheep, horse bean can be used as a single source of protein. In non-ruminant animals it is important to consider the low level of methionine and the content of tannins that are present in horse beans. The tannins can be reduced in horse beans by moisture and temperature treatment as well as genetic selection of strains that have a lower level of tannins (Todorov, 1988).

It is mainly in organic dairy farm productions the horse field beans are suitable. In the south west region of Sweden, Västra Götaland, there are a number of organic producers that are using diets with 100% organic feeds for the animals on the farm, where 20% of the feeding diet consists of horse bean (Pettersson, 2004).

## PEAS

The composition of peas is similar to that of beans with a high content of proteins according to the content of metabolized energy, CP and CF (Spördly, 2003). The oil content is higher in peas than beans but the degree of saturation is similar in the two protein concentrates. There is a limitation of the amino acid methionine in peas but in a comparison with beans, this protein concentrate has higher values of methionine, lysine and cysteine (Todorov, 1988; McDonald et al., 2002). The metabolizable energy content for ruminants is 13.8 MJ/kg DM (Spörndly, 2003) which is a large contribution to the energy intake of the animal.

It has been suggested that peas have a high patability because of a high daily concentrate and DM intake compared to soybean meal and rape seed meal. It has also been showed that animals fed peas had larger amounts of subcutaneous and internal fat deposits (Olsson, 1987).

Field pea is contributing with high amounts of proteins, carbohydrates and amino acids to beef animals. Maximum recommendations are 13.5 to 14% crude protein in the diet. Therefore, peas fed of more than 25% of the total diet will probably result in excess crude protein, but in a trial where peas were included at 50% or more of the concentrates the result were that there was a slightly improved performance (Anderson et al., 2002)

Both starch and protein from field peas degrade slowly but relatively thoroughly in the rumen, with only modest levels of escape protein (<25% of crude protein). Slow starch fermentation makes peas a potentially desirable complement for stabilizing ruminal pH and prevents acidosis when more rapidly fermented feeds like wheat and barley are fed (Anderson et al., 2002; Flatt and Stanton, 2002).

There is a study done to evaluate growth performance and carcass characteristics of cattle fed four levels of field peas (0, 5, 10 and 20%) in a finishing diet. The results were that feed intake increased linearly as the level of peas increased in the ration. Average daily gain did not differ between the different diets. Feed efficiency improved linearly for animals fed an increasing level of peas (Flatt and Stanton, 2002)

Carcass characteristics such as: dressing percent, hot carcass weight, marbling score, percent grading choice, and yield grade scores were not improved when comparing cattle on the control ration verses those on the pea supplemented rations (Flatt and Stanton, 2002)

In a trial where the influence of field pea supplementation were studied according to intake and digestive characteristics in beef steers fed medium concentrate diets the results were that organic matter intake (% of LW) decreased with increasing field pea level. However, organic digestibility was not affected by the level of field peas in the diet. Intake of NDF and ADF decreased linearly with increasing field pea level as a result of the deceased dry matter intake even though the NDF digestibility were not affected (Soto-Navarro et al., 2003).

## *LUPINES*

Lupine seeds are rich in proteins (Moss et al, 2001) with a content of 453g/kg DM (Spörndly, 2003). The lupine species exist as annual as well as perennial. Among the annual lupines there are blue (Lupinus Angustifolius), white (Lupinus Albus) and yellow (Lupinus Luteus) flowers. In Sweden the perennial lupine is called flower lupine (Lupinus Polyphyllus) (Mejnertsen, 2002). Yellow lupines are characterized by high protein content (40-45%) and a low fat content (4-5%) in the seed while the white lupines have a high fat content (8-11%) and relatively low protein content (35%). However, the blue lupines have a low fat content (5-6%) and low protein content (30-35%) (Flengmark, 2002).

There are two different varieties, sweet and bitter within each species and the bitter one should not be given to animals since they contain toxic alkaloids. The sweet variety can also contain these toxic substances but in those cases the inclusion limitation have to be less than 0.6g/kg compared with the levels of 10-20g/kg that are present in the bitter flowers. The metabolizable energy in the lupine seed meal is 13.2 MJ/kg for ruminants. Lupine seed meal has not a sufficient amount of amino acids present so if a lot of lupine seed meal are included in the diet there should be a complementation of amino acids, foremost methionine, of which there is a deficiency (Flengmark, 2002). There is also a deficiency of the amino acid cysteine, but lupines are a good source of the amino acid lysine (Flengmark, 2002). The chemical composition of lupines are considerable different to peas and horse beans where the lupines have a higher value of proteins, fats and crude fibre and a low level of starch (Stensig and Strudsholm, 2003; Mejnertsen, 2002). Lupines are able to use uncrushed for ewes and lambs because lupines have a softer seed coat than peas. Because of the low level of starch in lupines, the feed makes it a good supplementary feed for cattle as well as for sheep (Mejnertsen, 2002).

Lupine is an important feed for ruminants because it contains a high value of AAT which is the highest value of leguminous plants that are able to be cultivated in the Swedish climate and environment. It is also of great importance in the feeding plan because of the high level of crude protein. In an analysis of the degradation of the proteins done at SLU it was shown that a special strain of lupine (Bora) had an EPD-value of 63% which is equal to a content of AAT of 139 g/kg DM. Danish analysis on the strains Prima and Borweta showed values of 80% which is equal to a content of 110g/kg DM according to the Danish measurements. If the Swedish measurements were used the EDP-value of 80% would be equal to an AAT-value of 95 g/kg DM (Stensig et al., 1993; Möller and Pedersen, 2003). There have been studies that have shown that lupines have considerable potential as a protein source for productive ruminants. One of the species that have good agronomic characteristics, high protein content and lower protein solubility is the dwarf determinate type (Lunivers; Moss et al., 2001).

Heat treatment of lupine seeds has been shown to reduce rumen degradability and increase post-ruminal availability (Moss et al., 2001).

## DISTILLER´S WASTE

Distiller’s waste is a by-product made from the industry of alcohol. Alcohol is mainly made from grains which contains a high level of carbohydrates. The process of alcohol starts with fermentation by enzymes of the starch of the grain into sugar and later into alcohol, which is distilled away. The remaining product is wet distiller’s waste with a DM of approximately 6-9%. This product is often dried because the wet product is difficult to store (NJF, 1984). From the production of ethanol from grain the proportions are; 1/3 ethanol, 1/3 distiller’s waste and 1/3 gas (Personal communication; Hellberg, 2007).

The chemical composition of distiller's waste is similar to the grain with exception to the levels of starch and sugar which was the main products for producing alcohol and carbon hydroxide. The levels of crude protein, fibre and fat are about two to three times higher than in the original material because of the decomposition of the starch. The energy amount is lower though and this is because of the removal of the starch (Larson et al., 1993).

Larson et al. (1993) investigated the feeding value of wet distiller's by-products for finishing ruminants. The conclusion from this study were that wet distillers by-products are efficiently utilized in ruminant finishing diets as a protein and energy source due to that wet distiller´s by-product contributed more net energy for gain than corn (Larson et al., 1993).

About 5-10% meal has been used in feeding plans for pigs. The degree of the utilization of the feed decreased with a given amount of distiller's grain and this is due to a lower digestibility of the feed and also because of the lack of lysine and a high level of fibres. Distiller's grain has also been compared to soy with the result that the pigs fed with distiller's grain had reduced production results. This result was due to poorer protein quality in the distiller's grain and again the poor amount of lysine (NJF, 1984).

The recommended amount provided to cattle is less than 2 kg per day per animal and should be given together with roughage with a moderate amount of CP and a high fibre quality. Wet distiller's grains are complimentary to the feeding characteristics of corn (Personal communication; Hellberg, 2007).

## *ANIMAL PROTEIN CONCENTRATES*

### Legislation

Already in 1988 there was a prohibition for using meat meal as a feed for dairy cows in Sweden. In 1991 there was a decision made by Swedish Board of Agriculture that meat- and bone meal from ruminants should be prohibited for usage to ruminants. In 1994 a law was established about that proteins from mammals were not allowed to be used for countries within EU (Swedish Board of Agriculture, 2007).

The laws mentioned above are based on the risk of the infection of the disease bovin spongiform encephalopati (BSE). This disease is caused by an infectious substance called prions which are proteins that lack nucleic acid. The substance transforms the proteins of the brain of the animal into a pathological state (Swedish Board of Agriculture, 2007).

### Meat by-products

There are still areas in Europe where animal protein concentrates are used because of the high quality of the protein within it. The lysine content is also favourable for this concentrate while it is a poor source of the amino acids methionine and tryptophan. Because of the poor supply of the last mentioned amino acids there is a need for giving this protein feed in a combination with other vegetable protein feeds. This protein feed are better fitted to non-ruminants because of the need of dietary supply of high quality protein but if given to ruminants it should be introduced into their diets gradually because these products are not readily accepted by the animals (McDonald et al., 2002).

## Fishmeal

In UK the definition of fishmeal is "…the product obtained by processing whole or parts of fish from which parts of the oil may have been removed and to which fish soluble may have been re-added". The fish that are going to be processed to fishmeal is first cooked for further pressing the cooked mass and removal of the oil and water. The oil and water is later concentrated and brought back to the mass where the parts are mixed and dried. The last drying step is critical concerning the quality of the end product because if the becoming fishmeal are over dried there will be a lower quality of the fishmeal (McDonald et al., 2002).

The protein content of fishmeal can vary over a range between 500-750g/kg. The amino acid content of fishmeal is good where lysine, cystein, methionine and tryptophan are present at high levels. The mineral content in fishmeal are also good (100-220g/kg) where levels of calcium and phosphorous are high as well as trace elements such as manganese, iron and iodine. What concerns the vitamins is that there is a high level of vitamin B complex, particularly choline, B12 and riboflavin. The typical metabolizable energy content in fishmeal for ruminants is 14 MJ/kg which is dependent on the oil content in the product. The fat that is present in fishmeal contains to a high level of PUFA and the ratio of omega-3 to the more abundant omega-6 is desirable (McDonald et al., 2002).

Fishmeal is a prohibited product for usage for ruminants in Sweden since 2001 (Swedish Board of Agriculture, 2007).

## Blood meal

Blood meal consists of dried blood that comes from warm-blooded animals. This protein concentrate is only of importance because of its content of proteins. The amino acid content according to the content of lysine, arginine, methionine, cysteine and leucine is good while the content of isoleucine and glycine is poor. The protein concentrate has a low digestibility and very low rumen degradability (McDonald et al., 2002).

# MATERIALS AND METHODS

## *Experimental design*

The study consisted of two experiments and was conducted at Götala Research Station. Experiment 1 and 2 were carried out during the periods March 31 to September 12, 2006 and November 2, 2005 to July 11, 2006, respectively. Experiment 2 was finished during the period from April 4 until July 11 as animals had reached their slaughter weight and were slaughtered.

Experiment 1 constituted of calves and had a 2 factorial design. Two levels of protein feeds (hempseed cake *vs.* soybean meal) were used to investigate the effects of protein feed on feed intake and live weight gain in the animals.

Experiment 2 constituted of finishing steers and had a 2 × 2 × 2 factorial design. Two levels of protein feeds (hempseed cake *vs.* soybean meal), two levels of breeds (Swedish Holstein *vs.* Swedish Red Cattle), and two levels of live weight at slaughter (600 kg *vs.* 650 kg) were used. In the study, the effects of protein source breed and live weight at slaughter on feed intake, live weight gain and carcass traits in the animals were investigated.

## *Animals*

Prior to the experimental starts, the cattle in the two experiments had an adaptation period with increasing grain feeding for two weeks. During the experiments, the weights of the animals were recorded once every second week and on two consecutive days at the start and at the end of the experiment, respectively. The average daily live weight gains of the animals were calculated from the start and end weights.

### Experiment 1

In the experiment, young calves were raised from weaning until 250 kg live weight. Initially, there were 56 bull calves of the breeds Swedish Holstein (n=33) and Swedish Red Cattle (n=23), but there was a reduction of animals to 55 animals because of a death. The calves were bought from commercial farms at an age of six to eight weeks. At the start of the experiment, when the average weight of the calves was 96 (SD 1.28) kg, the calves were randomly allocated into one of two levels of protein feed, regardless of breed. The calves were kept in an non-insulated barn with four pens per treatment and with seven animals in each pen.

### Experiment 2

Fifty-one steers of the dairy breeds Swedish Holstein (n=28) and Swedish Red Cattle (n=23), initially bought from commercial farms, and were used in the study. Prior to the experiment, the steers had been grazing semi-natural grasslands during the summer and they were housed for a finishing period on October 14, 2005, when they were 13-15 months of age. At the start of the experiment, the average live weights of the Swedish Holstein steers was 366 (SD 4.09) kg and Swedish Red Cattle steers was 400 (SD 7.45).

Within the two breeds, the steers were allocated randomly into one of two levels of protein feed and one of two levels of live weight at slaughter. Per treatment combination, there were two pens with two to four individuals in each pen. The animals were housed in an insulated barn with slatted floor pens with, in total, 16 pens.

### *Feeding*

The animals in the two experiments were provided feed once a day. All animals were fed a total mixed ration *ad libitum*, which was defined as the intake at >5% orts. Orts were weighed and disposed three times a week. On a dry matter (DM) basis, the total mixed rations composed in experiment 1 of 40% grass/clover silage and 60% barley and in experiment 2 of 45% grass/clover silage and 55% barley. The silage in the total mixed rations consisted of approximately 90% grass (*Lolium perenne* L.*, Festuca pratensis* L.*,* and *Phleum pratense* L.) and approximately 10% clover (*Trifolium repens* L. and *Trifolium pratense* L.). Herbage was wilted to 25% of DM and an acidic additive containing formic acid, propionic acid, and ammonia was used (Promyr™, Perstorp Inc., Perstorp, Sweden). Silage samples were taken daily and composited to one sample per week for analysis of DM and to one sample per month for analysis of nutrient content, whereas silage samples for fermentation quality were taken weekly and composited to one sample per silo (Table 6). Samples of barley were collected weekly and composited to one sample every second month for analysis of nutrient content (Table 6). In addition to the total mixed rations, two different protein feeds were fed in the experiments. One group of animals in each experiment was fed hempseed cake as a protein feed and one group of animals was fed a mixture of 50% soybean meal and 50% barley as a protein feed. The rations of protein feeds that were provided to the animals were isonitronic, formulated to fulfil Swedish protein recommendations (Olsson, 1998) and based on the crude protein (CP) contents in the total mixed rations.

In experiment 1, the calves were fed 1.0 kg of protein feed (i.e. 1.0 kg of hempseed cake *vs.* 0.5 kg of soybean meal and 0.5 kg of barley) per animal per day all through the experiment. In experiment 2, two different amounts of protein feed were fed according to varying crude protein content in the silages. When silage from the first silo was fed (November 2 to December 20) the rations of protein feed were 0.2 kg per animal per day, but when the following silos were fed (from December 20 until slaughter), the rations were 1.4 kg per animal and day. Hempseed cake from two different batches was used in the study. Both batches were pressed by a Keller press (KEK Egon Keller GmBH & Co). Batch no. 1 were used during the period from November 2, 2005 until November 25, 2005 and hempseed cake from batch no. 2, were used from November 26, 2005 until July 28, 2006.

Samples of the hempseed cake and the soybean meal were collected weekly and composited to one sample every second month for analysis of nutrient content (Table 6). To fulfil requirements of minerals and vitamins, mineral supplement containing vitamins was fed in adequate amounts.

## *Chemical analysis of the feed*

Silage, barley, soybean meal and hempseed cake samples were analysed for DM, ash, CP (Tecator Kjeltec Auto sample system 1035 Analyzer, Tecator Inc., Höganäs, Sweden), and neutral detergent fibre (NDF). The DM concentration of silage was determined at 60º C for 24 h whereas ash was determined at 550º C for 5 h. Metabolisable energy (ME) concentration of silage was calculated from *in vitro* organic matter digestibility (Lindgren, 1979), whereas the ME of barley, hempseed cake and soybean meal were calculated according to Axelsson (1941). Concentration of NDF in silage was determined according to Goering and Van Soest (1970) and NDF in barley, hempseed cake and soybean meal were determined according to Van Soest et al (1991). Concentrations of starch and crude fat were determined in barley, soybean meal and hempseed cake (Åman and Hesselman, 1984). In addition, silage samples were analysed for pH, $NH_4$-N (Tecator Kjeltec Auto sample system 1035 Analyzer, Tecator Inc., Höganäs, Sweden) and concentrations of reducing sugars (Ekelund, 1966), organic acids and ethanol (Andersson and Hedlund, 1983; Table 6). Effective protein degradation (EPD) values were determined for the two batches of hempseed cake used in the study. Samples from these two batches were placed in fistulated cows at the Kungsängen Research Station, Uppsala, for determination of the EPD-values of the hempseed cake batches. The feed samples were taken out after 2, 4, 8, 16 24 and 48 hours, respectively, and determinations of the CP contents were done in each individual sample. Calculations of the EPD-values were based on the remaining CP contents in the samples taken out from the fistulated cows (Table 6b).

*Table 6a. Chemical analysis of the grass-clover silage used in the experiments*

| | *Calves* | | Steers | |
|---|---|---|---|---|
| **Chemical composition** | **Mean (SD)** | ***n*** | **Mean (SD)** | **n** |
| Grass-clover silage | | | | |
| DM[1], g $kg^{-1}$ | 246 (10) | 15 | 267 (35) | 36 |
| Metabolisable energy, MJ | 9.9 (0.4) | 4 | 10.2 (0.9) | 10 |
| AAT[2], g | 68 (1) | 4 | 69 (3) | 10 |
| PBV[3], g | 45 (13) | 4 | -0.1 (30) | 10 |
| Crude protein, g | 174 (-) | 1 | 119 (28) | 10 |
| NDF[4], g | 512 (59) | 4 | 554 (46) | 10 |
| Ash, g | 72.1 (6.2) | 4 | 76.0 (12.0) | 10 |
| $NH_4$ | 16.5 (-) | 1 | 14.0 (4.0) | 4 |
| Sugar, g | - (-) | - | 21.0 (-) | 1 |
| Lactic acid, g | 76.4 (-) | 1 | 90.5 (27.0) | 4 |
| Acetic acid, g | 29.2 (-) | 1 | 17.3 (3.3) | 4 |
| Butyric acid, g | 1.6 (-) | 1 | 0.6 (0.3) | 4 |
| Propionic acid, g | 4.4 (-) | 1 | 1.9 (0.7) | 4 |
| Ethanol, g | 6.8 (-) | 1 | 9.6 (5.2) | 4 |
| Ca, g | 6.3 (0.6) | 4 | 6.1 (0.6) | 10 |
| P, g | 2.6 (0.4) | 4 | 3.0 (0.4) | 10 |
| pH | 4.1 (-) | 1 | 4.0 (0.3) | 4 |

[1] Dry matter
[2]Aminoacids absorbed in the intestine
[3]Protein balance in the rumen
[4]Neutral detergent fibre

*Table 6b. Chemical analysis of barley, soybean meal and hempseed cake used in the experiments*

| | *Calves* | | Steers | |
|---|---|---|---|---|
| **Chemical composition** | **Mean (SD)** | ***n*** | **Mean (SD)** | **n** |
| Barley | | | | |
| Dry matter, g $kg^{-1}$ | 854 (9) | 2 | 850 (11) | 5 |
| Metabolisable energy, MJ | 12.8 (0.6) | 2 | 13.0 (0.4) | 5 |
| AAT[2], g | 88 (3) | 2 | 91 (3) | 5 |
| PBV[3], g | -43 (7) | 2 | -42 (8) | 5 |
| Crude protein, g | 101 (1) | 2 | 107 (9) | 5 |
| NDF[4], g | 223 (10) | 2 | 196 (21) | 5 |
| Crude fat, g | 33.2 (0.2) | 2 | 30.0 (30.0) | 5 |
| Starch, g | 630 (21) | 2 | 629 (23) | 5 |
| Ash, g | 24.0 (0.1) | 2 | 23.0 (2.0) | 5 |
| Ca, g | 0.6 (0.1) | 2 | 1.0 (0.1) | 5 |
| P, g | 4.0 (0.6) | 2 | 4.0 (0.3) | 5 |
| Soy | | | | |
| Dry matter, g $kg^{-1}$ | 875 (9) | 2 | 867 (2) | 4 |
| Metabolisable energy, MJ | 13.3 (0.0) | 2 | 14.4 (0.7) | 4 |
| AAT[2], g | 141 (53) | 2 | 169 (6) | 4 |
| PBV[3], g | 322 (67) | 2 | 269 (20) | 4 |
| Crude protein, g | 530 (9) | 2 | 520 (26) | 4 |
| NDF[4], g | 142 (18) | 2 | 124 (5) | 4 |
| Crude fat, g | 20.6 (1.7) | 2 | 23.4 (3) | 4 |
| Starch, g | 88 (5) | 2 | 84 (-) | 1 |
| Ash, g | 64.8 (0.2) | 2 | 62.6 (3) | 4 |
| Ca, g | 3.2 (0.1) | 2 | 3.1 (0.2) | 4 |
| P, g | 6.4 (0.3) | 2 | 6.6 (0.3) | 4 |
| Hemp | | | | |
| Dry matter, g $kg^{-1}$ | 893 (0.0) | 2 | 890 (2) | 5 |
| Metabolisable energy, MJ | 12.1 (0.1) | 2 | 13.0 (1) | 5 |
| AAT[2], g | 77 (6) | 2 | 119 (16) | 5 |
| PBV[3], g | 271 (50) | 2 | 193 (9) | 5 |
| Crude protein, g | 385 (6) | 2 | 369 (19) | 5 |
| NDF[4], g | 449 (9) | 2 | 434 (13) | 5 |
| Crude fat, g | 88.9 (0.3) | 2 | 104.0 (32) | 5 |
| Starch, g | 15.0 (0.0) | 2 | 15.0 (-) | 1 |
| EDP (batch 1) | - | - | 72.0 | 1 |
| EDP (batch 2) | 62.0 | 1 | 62.0 | 1 |
| Ash, g | 64.3 (2.5) | 2 | 66.0 (4) | 5 |
| Ca, g | 2.0 (0.0) | 2 | 2.0 (0.2) | 5 |
| P, g | 13.8 (0.8) | 2 | 14.0 (1) | 5 |

[1] Dry matter
[2]Aminoacids absorbed in the intestine
[3]Protein balance in the rumen
[4]Neutral detergent fibre

## *Faecal Analyses*

In both experiments, analyses were conducted on faecal samples collected at a pen level for four consecutive weeks. In experiment 1, samples from eight pens were collected from June 28 to July 18 and in experiment 2, samples from 16 pens were collected from March 14 to April 7.

*Consistency, pH and dry matter analyses*

Consistency, pH and dry matter content were determined on each individual faecal sample. The consistency was judged visually according to a table with a scale from 1-5 with the definitions: 1: runny; 2: loose; 3: mushy; 4: firm and 5: hard and dry like faecal matter from horse (Steen, 2004; Appendix 1). The consistency was estimated with 0.5 unit precision.

The pH was checked using litmus paper. A piece of the pH paper was applied on the faecal sample for about one minute. Thereafter, the colour of the paper was compared to a colour scale with a pH range from 6.4 to 8 to be able to estimate the pH of the faeces (MERCK pH-indikatorpapier, Merck KgaA, Darmstadt, Germany).

Dry matter content of the feacel material was determined by weighing 100 g of faecal matter into an aluminium dish. The dry matter content was determined by drying the sample at 105°C for 24 hours.

*Wet sieving*

Wet sieving was conducted on a composite faecal sample from the four samples taken from a pen during four consecutive weeks. This method was used to be able to sort long particles in the faeces. A 100-gram faecal sample was put on a 2.36 mm screen.  The sample was washed with running tap water until the tap water was clear. The analysis was conducted on duplicated samples.

All particles that remained on the wet sieve after washing were weighed and recorded and thereafter, the number of particles longer than 1 cm and the number of kernels were recorded. Long particles (> 1 cm) and kernels were weighed and dried at 105°C for 24 hours. The particles and kernels were weighed after drying for determination of the dry weight of long particles and kernels. The percentages of long particles and kernels in the faeces were calculated by dividing the dry weights of the long particles and the kernels with the dry weight of the faeces.

## *Carcass measurements*

In experiment 2, the steers were slaughtered in a commercial abattoir, four kilometres from the Götala Research Station. The steers were graded according to the conformation and fatness scores described by the European Union Carcass Classification Schemes (EUROP) modified to the Swedish system in which 15 classes are used (SJVFS, 1998). The EUROP classes were transformed to numerical figures for conformation score (1 = P-, poorest, and 15 = E+, best) and fatness (1 = 1-, leanest, and 15 = 5+, fattest). Cold carcass weight (0.98 × hot carcass weight) was registered. At the commercial cutting up procedure, fore and hind quarters were separated between the $10^{th}$ and $11^{th}$ rib. The right hind quarter from each steer was weighed, as well as parts from right hind quarter. These parts were trim fat, bones and retail cuts. The trim fat was defined as subcutaneous and intermuscular fat deposits separable with a knife in a standardized cutting up procedure. The bones were weighed together with closely bound connective tissue capsules and without extra cleaning of the bones. The seven most valuable retail cuts were weighed together and consisted of strip loin (*m. longissimus dorsi*), fillet (*m. psoas major*), topside (*m. semimembranosus*), outside round (*m. biceps femoris*), eye of round (*m. semitendinosus*), top rump (*m. quadriceps femoris*), and rump steak (*m. gluteus medius*). Remaining parts of the hind quarter consisted of a mixture of lean meat and fat and were not weighed.

## Statistical analysis

In each of the two experiments, two different statistical models were used for investigating the treatments; one for feed intake, feed conversion, and faecal traits and one for weight gain data.

*Feed intake and feed conversion*

Feed intake and feed conversion were investigated by using in the GLM procedure in SAS (2001). For experiment 1, young calves, the statistical model was:

$$\mathbf{y_{ij} = \mu + \alpha_i + e_{ij}}$$

and for experiment 2, finishing steers, the model was:

$$\mathbf{y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + e_{ijkl}}$$

In the models, $\boldsymbol{\alpha}$ is effect of protein feed, $\boldsymbol{\beta}$ is effect of breed, $\boldsymbol{\gamma}$ is effect of level of finishing weight, and $\mathbf{e_{ij}}$ and $\mathbf{e_{ijkl}}$ are the error terms.

*Faecal traits*

Faecal traits also were investigated by the GLM procedure in SAS (2001). For experiment 1 the statistical model was:

$$\mathbf{y_{ij} = \mu + \alpha_i + e_{ij}}$$

and for experiment 2 the model was:

$$\mathbf{y_{ijkl} = \mu + \alpha_i + \beta_j + \alpha\beta_{ij} + e_{ijk}}$$

In the models, $\boldsymbol{\alpha}$ is effect of protein feed, $\boldsymbol{\beta}$ is effect of breed; $\mathbf{e_{ij}}$ and $\mathbf{e_{ijk}}$ are the error terms.

The original model for analysis of consistency, pH and dry matter content also included the effect of week and its interactions with feed and breed. Because no significant interactions with week were found, week was excluded from the final models.

*Weight gain and carcass traits*
Live weight gain and carcass traits (experiment 2 only) were recorded on each individual animal nested within pen and analysed by using the Mixed procedure of SAS (2001). For experiment 1, young calves, the model was:

$$\mathbf{y_{ijklm} = \mu + \alpha_i + c_{ij} + e_{ijk}}$$

For experiment 2, finishing steers, the model was:

$$\mathbf{y_{ijklm} = \mu + \alpha_i + \beta_j + \gamma_k + \alpha\beta_{ij} + \alpha\gamma_{ik} + \beta\gamma_{jk} + \alpha\beta\gamma_{ijk} + c_{ijkl} + e_{ijklm}}$$

In the models, $\boldsymbol{\alpha}$ is effect of protein feed, $\boldsymbol{\beta}$ is effect of breed, $\boldsymbol{\gamma}$ is effect of level of finishing weight, **c** is effect of pen and $\mathbf{e_{ijk}}$ and $\mathbf{e_{ijklm}}$ are the error terms.
Differences among treatment means were analysed by using $LSD_{0.05}$-tests and denoted as significant at $P<0.05$ and as a tendency to significance at $0.05<P<0.10$.

# RESULTS

## Feed intake, weight gain and feed conversion

Daily NDF intakes, expressed as amount as well as proportion of LW, were higher in calves and steers fed hempseed cake than those fed soybean meal (Table 7). For calves, also daily feed intakes, expressed as amount and proportion of LW, as well as energy intake were higher in calves provided hempseed cake (Table 7). However, feed conversion was better in calves fed soybean meal than in calves fed hempseed cake. For the steers, no main effects of breed, live weight at slaughter or interactions among protein feed, breed and live weight at slaughter on feed intake, weight gain or feed conversion could be found (Table 7).

*Table 7. Effects of protein feed (hempseed cake vs. soybean meal) on average daily feed intake (DM is dry matter, NDF is neutral detergent fibre, ME is metabolizable energy, LW is live weight), average daily live weight gain (ADG) and feed conversion (FC) in 55 dairy calves and 51 dairy steers; least square means, SEM is standard error of means*

| | Calves | | | | Steers | | | |
|---|---|---|---|---|---|---|---|---|
| | Hemp seed | Soy bean | SEM | Sign. | Hemp seed | Soy bean | SEM | Sign. |
| Feed intake (kg of DM) | 5.00 | 4.55 | 0.11 | 0.025 | 11.12 | 10.57 | 0.25 | ns |
| NDF intake (kg) | 1.68 | 1.28 | 0.02 | <0.001 | 4.17 | 3.70 | 0.09 | 0.005 |
| ME intake (MJ) | 58.57 | 53.66 | 1.25 | 0.032 | 133.83 | 127.32 | 3.11 | ns |
| DM intake (% of LW) | 3.12 | 2.80 | 0.04 | <0.001 | 2.21 | 2.11 | 0.05 | ns |
| NDF intake ($kg^{-1}$ LW) | 1.07 | 0.80 | <0.01 | <0.001 | 0.83 | 0.74 | 0.02 | 0.029 |
| NDF (% of ration) | 35.8 | 30.5 | <0.01 | <0.001 | 37.5 | 35.1 | <0.01 | <0.001 |
| Starch (% of ration) | 30.4 | 36.8 | <0.01 | <0.001 | 30.2 | 32.9 | <0.01 | <0.001 |
| ADG (kg) | 1.34 | 1.28 | 0.04 | ns | 1.22 | 1.22 | 0.05 | ns |
| FC (MJ ME $kg^{-1}$ gain) | 43.25 | 40.64 | 0.76 | 0.053 | 112.00 | 106.00 | 3.04 | ns |
| FC (kg of DM $kg^{-1}$ gain) | 3.69 | 3.45 | 0.06 | 0.038 | 9.33 | 8.78 | 0.26 | ns |

## Faecal traits

The DM of the faeces was higher for the steers fed hempseed cake than for those fed soybean meal as a protein feed (Table 8). The higher DM in faeces from steers fed hempseed cake was accompanied by a firmer faecal texture than the faeces from steers fed soybean meal (Figure 15). Furthermore, for calves and steers, the number of long particles (> 1 cm) was less in faeces from the animals fed hempseed cake than in faeces from those fed soybean meal (Table 8). Calves fed hempseed cake had a lower percentage of kernels in faeces whereas steers fed hempseed cake had a lower percentage of long particles in faeces compared to animals fed soybean meal (Table 8).

*Table 8. Faecal traits of 55 dairy calves and 51 dairy steers fed two different protein feeds (hempseed cake vs. soybean meal); least square means, SEM is standard error of means*

| *Faecal traits* | *Calves* | | | | *Steers* | | | |
|---|---|---|---|---|---|---|---|---|
| | Hemp | Soy | SEM | Sign. | Hemp | Soy | SEM | Sign. |
| DM (%) | 19.1 | 16.1 | 1.12 | ns | 16.6 | 14.7 | 0.38 | 0.005 |
| Consistency[a] | 2.63 | 2.50 | 0.17 | ns | 2.94 | 2.63 | 0.09 | 0.025 |
| pH | 7.68 | 7.55 | 0.36 | ns | 7.02 | 7.16 | 0.15 | ns |
| No. of long particles (/100 g) | 46.6 | 65.0 | 4.06 | 0.019 | 45.3 | 88.7 | 4.61 | <0.001 |
| No. of kernels (/100 g) | 7.3 | 10.5 | 1.36 | ns | 8.40 | 9.4 | 0.67 | ns |
| Dry weight of particles (g/100 g) | 0.05 | 0.09 | 0.02 | ns | 0.16 | 0.21 | 0.02 | ns |
| Dry weight of kernels (g/100 g) | 0.18 | 0.33 | 0.04 | 0.023 | 0.29 | 0.29 | 0.03 | ns |
| Particles (%) | 0.26 | 0.59 | 0.14 | ns | 0.97 | 1.44 | 0.14 | 0.035 |
| Kernels (%) | 0.93 | 2.08 | 0.24 | 0.014 | 1.75 | 1.99 | 0.23 | ns |

[a]Consistency was estimated on a scale from 1-5 with 0.5-unit precision.

There was a significant main effect of week on faecal pH (<0.0001) in the experiment with the steers.

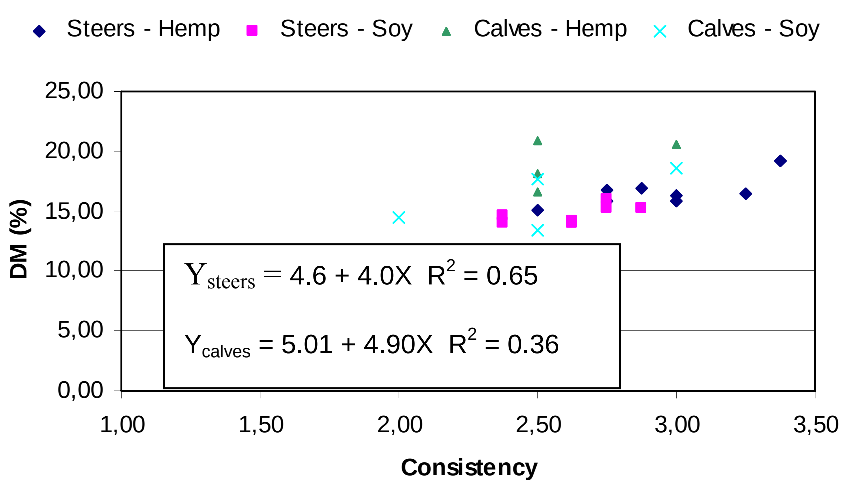


Figure 15. The relationship between consistency and dry matter (DM) of the faeces from calves and steers.

The R-square of 0.65 for the steers describes that 65% of the total variation in faecal DM can be explained by a variation in faecal consistency. The slope of the curve in figure 15 shows that if the consistency increases by 1.0 unit, the DM percentage will increase by 4.0 and 4.9 units for the steers and the calves respectively.

## Carcass measurements

Animals with a target weight of 600 kg had an average live weight at slaughter of 604 kg and animals with a target weight of 650 kg had an average live weight at slaughter of 647 kg. There were no main effects of protein feed on live weight at slaughter or days of finishing (Table 9). However, at the target live weight at slaughter of 650 kg, steers fed soybean meal required a longer finishing period than steers fed hempseed cake ($P$=0.002). There was also a difference in length of finishing period between the two breeds, where the average length of the finishing period was 225 days for Swedish Holstein steers and 194 days for Swedish Red Cattle steers ($P$=0.0002).

Dressing percentage for steers slaughtered at 650 kg live weight were higher for steers fed soybean meal than for steers fed hempseed cake, whereas no effect of protein feed could be found at slaughter at 600 kg live weight (Table 9). Carcasses from steers slaughtered at 650 kg live weight were fatter than steers slaughtered at 600 kg live weight (Table 9). There was an effect of breed on the conformation of the carcasses ($P$<0.0001), where average conformation score was 3.8 for Swedish Holstein steers and 4.6 for Swedish Red Cattle steers. No further main effects or interactions of protein feed, live weight at slaughter or breed on carcass measurements was found.

Hind quarters composed on average 49.0% of carcass weights. The hind quarters composed on average of 34.7% valuable retail cuts, 9.4% trim fat and 21.7% bones. There were no main effects or interactions of protein feed, live weight at slaughter or breed on weight or composition of hind quarters.

The price per kg for steers fed soybean meal was on average 0.35 SEK/kg higher when slaughtered at 650 kg than when slaughtered at 600 kg (Table 9). However, the total price of the carcasses was 6940 SEK for steers slaughtered at 600 kg and 7480 SEK for steers slaughtered at 650 kg live weight.

*Table 9. Effects of protein feed (hempseed cake vs. soybean meal) and live weight, LW at slaughter (600 kg vs. 650 kg) on carcass traits of 51 dairy steers; least square means, SEM is standard error of means*

| | *Protein feed* | | | | | *Significance* | | |
|---|---|---|---|---|---|---|---|---|
| | Hemp | | Soy | | | Main effects | | Interact. |
| | 600 | 650 | 600 | 650 | SEM | P | W | PxW |
| LW (kg) | 601 | 643 | 606 | 651 | 12.18 | ns | 0.001 | ns |
| CW[c] (kg) | 310 | 328 | 309 | 339 | 12.21 | ns | 0.002 | ns |
| Days | 203 [b] | 209 [b] | 186 [b] | 238[a] | 7.02 | ns | <0.001 | 0.005 |
| Dressing (%) | 51.7[ab] | 51.0[b] | 51.0 [b] | 52.1 [a] | 0.34 | ns | ns | 0.022 |
| Conform[d] | 4.3 | 4.1 | 4.0 | 4.3 | 0.18 | <0.001 | ns | ns |
| Fatness[e] | 8.4 | 8.5 | 7.7 | 8.6 | 0.20 | ns | 0.010 | ns |
| Price $kg^{-1}$ (SEK) | 22.47[ab] | 22.10 [ab] | 22.16 [b] | 22.51[a] | 0.15 | ns | ns | 0.023 |
| Total price (SEK) | 6,996 | 7,324 | 6,884 | 7,637 | 158 | ns | 0.002 | ns |

ns = non-significance at *P*>0.10
[a, b] Means in a row with different superscripts differ significantly (P<0.05) according to $LSD_{0.05}$-test
[c] Carcass weight
[d] EUROP system: 4 = $O^-$, 5 = O
[e]EUROP system: 7 = $3^-$, 8 = 3, 9 = $3^+$

# DISCUSSION

*Feed intake, weight gain and feed conversion*
Calves fed hempseed cake had a higher DM intake (11%) than calves fed soybean meal. There are indications that feeding hemp meal at levels up to 20% of the dietary DM will not depress DM intake in sheep (Mustafa et al., 1998). The higher DM intake in our study resulted in a higher NDF intake of the calves fed hempseed cake. The higher NDF intake was accompanied by a lower number of long particles in the faeces, which indicates that the digestive system is working in a more efficiently when the feed diet consists of hempseed cake instead of soybean meal. The higher DM intake might also be due to the higher content of crude fat in the diet with hempseed cake compared to the diet with soybean meal. Animals fed hempseed cake had 2.3% (steers) and 3.3% (calves) crude fat in the diet (crude fat from silage excluded) and animals fed soybean meal had a content of 1.7% (steers) and 2.1% (calves) of crude fat in the diet (crude fat from silage excluded). Also in another study of feedlot cattle (Gibb et al., 2005) the fat content of the diet increased when increasing the inclusion of cracked whole hemp seed in the diet. The addition of fat or oil may have positive effects on DM intake in diets with grains containing less oil, e.g. diets based on barley or wheat (Gibb et al., 2004). However, in the hemp seed study of Gibb et al. (2005) no effect of increasing the inclusion of hempseed cake on DM intake was found, which agree with the results from the steers where there were no differences in DM intake between the two groups given hempseed cake or soybean meal.

Calves fed hempseed cake had higher DM, energy and NDF intakes than the calves fed soybean meal, but no differences in the live weight gain between the two groups of animals could be found. The higher DM intake in combination with similar live weight gain resulted in a worse feed conversion in calves fed hempseed cake than calves fed soybean meal. For the steers, no effects of protein feed on live weight gain or feed conversion could be found. Comerford et al.(1992) evaluated the effects of forage source (corn silage and alfalfa haylage) and protein source (soybean meal and fish meal) in finishing steers. There was an interaction found for crossbred steers fed corn silage and fish meal, for which there was significantly greater feed conversion with lower energy intake above maintenance, possibly due to better fibre digestion and/or amino acid flow to the lower tract (Comerford et al., 1992).

In our study, live weight gain and carcass traits were unaffected by protein feed source. Similar results have been obtained in previous studies on hempseed cake (Gibb, 2005) and other protein feeds (Comerford, 1992) to feedlot cattle. Also in other livestock, such as laying hens, using hemp seed meal as a protein feed resulted in similar production results as feeding soybean meal (Silversides et al., 2002).

Steers given hempseed cake had an 8% higher NDF intake than steers given soybean meal, and calves given hempseed cake had an 18% higher NDF intake than calves fed soybean meal. These results were due to the NDF content of the diet of hempseed cake which was higher for the animals than the NDF content of diet of soybean meal (Table 7). A progressive inclusion of hemp meal (0, 25, 50, 75 and 100%) increased NDF, ADF and acid detergent lignin (ADL) in the diets according to a study by Mustafa et al (1998) which agrees to this study with steers and calves given hempseed cake regarding to the NDF content.

*Faecal analysis*
There were not exactly the same effects of protein feed on faecal parameters for calves and steers. The differences in results might be due to differences in amounts of NDF and CP in the feed rations for the different animals. The differences might also be due to the fact that the animals had different ages in the experiment. The steers were on the experimental diet for four months prior to the time when the first faecal samples were collected for analysis, whereas the calves were in the experiment for only one month before the first faecal sampling. Another possible cause of the different results according to the DM content and the consistency of the faecal matter might be that the calves at the sampling period of the faeces was in an adaptation period to the new environment and to the new feeding ration which might have stressed the animals and could have lead to less accurate results.

The looser texture of the faecal matter from the steers fed soybean meal in combination with a larger number of long particles in the faecal matter might indicate that the feed passed through the digestible system too fast in those animals. The feed was not degraded in sufficient amounts and the particles were not reduced in size by microbial fermentation, which resulted in longer particles in the faeces (NRC, 1996; Hall, 2002). The rate of the passage of the feed through the digestive tract depends also on feeding plan, feed intake, how often feed is provided and the temperature in the environment. If the feed intake increases there will be a higher rate of the passage of the feed through the animal, which will result in fewer particles broken down in the rumen and the digestibility of the feed will be reduced (Steen and Kilpatrick, 2000; Nordqvist, 2006).

The starch content of the diet containing hempseed cake was lower than the diet with soybean meal (Table 7). Starch is broken down in the rumen faster than NDF, which results in a larger production of short chain fatty acids in rumen and a reduced pH (Sniffen et al., 1992). An acidic rumen environment is contributing to a decreased fibre digestion because ruminal acids kills or destroys the fibre digesting micro organisms and thereby interrupting the mechanism involved in fibre digestion. Reduced fibre digestion results further in an increased number of long particles in faeces (Mould et al., 1983; Hall, 2002). Increased starch intake from concentrate and diet increased the number of long particles in faecal matter in a study by Mgbeahurike (2007) which agrees with the animals given soybean meal that had a higher amount of starch in the diet and a higher number of particles remained in the faecal matter. The steers given hempseed cake had a firmer texture to the faecal matter than the faecal matter from the steers fed soybean meal. The consistency of the faecal matter is more or less dependent on its dry matter. This is illustrated in figure 15 which shows that 65% of the total variation in faecal DM can be explained by a variation in faecal consistency. The figure shows also that if the consistency increases by 1.0 unit, the DM percentage will increase by 4.0 and 4.9 units for the steers and calves, respectively. The faecal consistency was shown to be strongly negative correlated to the number of particles remaining in faeces from the steers; the more loose texture of the faecal matter the more long particles remained in the faecal matter, which agrees with results by Nordqvist (2006).

In both of the trials (steers and calves) it was shown that there was a higher NDF intake, expressed as kg NDF per day as well as in g NDF per kg of LW, by those animals fed hempseed cake compared to animals fed soybean meal. These results can be accompanied with the results that animals fed hempseed cake also had a higher DM in the faeces (steers), a firmer consistency (steers) and a lower number of long particles in faecal matter. This indicated that a higher NDF content in the diet results in a firmer texture of the faecal matter, that was shown from the trial with steers, and the number of long particles (>1 cm) that remained in the faecal matter was reduced (both trials).

Faecal matter should have a low level of nutrients and a low number of particles and kernels which shows that the ruminant has used the feed effectively (Steen and Kilpatrick, 2000). Faecal matter that has a loose texture can indicate that the ruminants are provided a too small inclusion of structural roughages in the feed ratio and a faecal matter that has a too firm texture is an indication of a too high level of structural roughages or that the animals drink too small amounts of water (Steen and Kilpatrick, 2000). Calves in the experiment fed hempseed cake had a smaller percentage of kernels in the faecal matter and the steers fed hempseed cake had a smaller percentage of long particles in the faecal matter than animals fed soybean meal. Steers fed hempseed cake had a higher faecal DM concentration and a lower number of long particles compared to the steers provided soybean meal. These results agree with results by Mgbeahurike (2007), who found that increased faecal DM concentration decreased the number of long particles in the faeces

Hempseed cake is a protein feed that is relatively expensive today in comparison to other protein feeds that are used in Sweden, but a higher demand of organic grown feeds might further lead to a lower price of the product. As there is an ongoing debate about energy production and as hemp is used for an energy purpose there is a chance the market for hemp is going to increase and thereby also increase the market for animal feed products based on the hemp plant.

Hempseed cake is a good alternative to other protein feeds that are used in Sweden today regarding to the high value of AAT, CP and NDF (Table 2). Hempseed cake has also a relatively low value of EDP (67) in comparison to e.g. peas (80) and field beans (80) which is favorable for the protein absorption within the animal body. Hempseed cake has also a relatively low level of starch which is favorable in diets according to the fibre digestion in animals. The oil of hempseed cake also contains high values of omega-3 and omega-6 which might lead to a higher value of the fatty acids in meat which can improve the human health. Hempseed cake has also the advantage against other protein feeds as soybean meal because hemp is possible to grow in the whole country of Sweden. Growing hemp plants requires a large share of fertilizer but contrary a small amount of pesticides because weeds occurs in only small amounts around the hemp plant because of the considerable height and density of the plants. This makes the plant a good alternative for organic producers.

# CONCLUSIONS

- Hempseed cake is a suitable alternative to soybean meal as a protein feed for growing cattle because hempseed cake gives similar growth and carcass traits as soybean meal.
- From the results with calves, there is an indication that hempseed cake gives a higher feed intake, similar growth and lower feed conversion compared to calves given soybean meal.
- The digestive system works in a more balanced manner when feeding hempseed cake compared to soybean meal which is shown by a higher faecal consistency and DM concentration and a smaller number of long particles in the faecal matter from the experiment with the steers.

# SAMMANFATTNING

I Sverige används idag proteinfodermedel som har sitt ursprung från olika delar av världen. De mest vanliga inhemska proteinfodermedel som används är rapskaka, ärtor åkerböna. Dessutom så importeras soja som används som ett högkvalitativt proteinfodermedel. Sedan 2003 finns det även ett nytt proteinfodermedel på marknaden producerat från hampa, *Cannabis sativa,* vilken är möjlig att odla även i de norra delarna av Sverige. Man processar fröna och använder restprodukten hampfrökaka som proteinfodermedel till nötkreatur eller andra husdjur. Hampfrökaka är näringsmässigt jämförbar med rapskaka med ett stort innehåll av protein och kan vara ett gott alternativ till importerat sojamjöl.

I detta examensarbete har två försök har utförts med syftet att utreda hampfrökaka som proteinfodermedel till växande ungnöt av mjölkras i jämförelse med sojamjöl. I ett av försöken användes 55 tjurkalvar och i det andra försöket användes 51 stutar. Kalvarna vägde 96 kg vid insättning och följdes till 237 kg levandevikt medan stutarna följdes från 366 kg (SLB) och 400 kg (SRB) levandevikt till slakt. I båda försöken var djuren uppdelade på två grupper där den ena gruppen fick hampfrökaka och den andra gruppen sojamjöl som proteinfodermedel. Stutarna som dessutom var uppdelade i två grupper efter slutvikt, 600 respektive 650 kg, samt i två grupper efter ras, SLB och SRB. I båda försöken undersöktes effekter av proteinfodermedel på foderintag, tillväxt och träckegenskaper. För stutarna studerades även slaktkroppsegenskaper. Djuren i de båda försöken hade fri tillgång till fullfoder bestående av gräs/klöverensilage och korn. Detta kompletterades med antingen hampfrökaka eller en blandning av sojamjöl och korn, där blandningen hade samma råproteinkoncentration som hampfrökakan.

Djurens foderkonsumtion beräknades veckovis och djurens tillväxt beräknades utifrån vägningar varannan vecka. Dessutom analyserades träcken med avseende på antal långa foderpartiklar, antal kärnor, konsistens, pH och torrsubstans. Vid slakt av stutarna registrerades slaktvikt, formklass och fettklass. Dessutom vägdes putsfett, ben och styckningsdetaljer på slaktkroppens bakparter.

Innehållet av neutral detergent fibre (NDF) var 434 g/kg torrsubstans i hampfrökakan medan det var 160 g/kg torrsubstans i sojamjöl/kornblandningen. Detta resulterade i de båda försöken i ett större dagligt NDF -intag hos djur utfodrade med hampfrökaka än djur utfodrade med sojamjöl. Hos kalvarna var även foderkonsumtionen och energiintaget större hos djur utfodrade med hampfrökaka, medan ingen effekt av proteinfodermedel på foderkonsumtionen kunde påvisas hos stutarna. Den dagliga levandeviktstillväxten var 1310 g/dag för kalvarna och 1220 g/dag för stutarna, men ingen effekt av proteinfodermedlena på tillväxt kunde påvisas. Hos kalvar utfodrade med hampfrökaka resulterade den, i jämförelse med kalvar som fick sojamjöl, högre foderkonsumtion i kombination med samma tillväxt i en sämre foderomvandlingsförmåga hos kalvar som fått hampfrökaka.

Träcken från stutar utfodrade med hampfrökaka hade en högre torrsubstanshalt och en fastare konsistens än träck från stutar som hade utfodrats med sojamjöl. Dessutom innehöll träcken i de båda försöken ett färre antal partiklar då djuren hade utfodrats med

hampfrökaka än då de utfodrats med sojamjöl. Torrsubstansvikten på träcken från kalvar utfodrade med hampfrökaka bestod till en mindre procentandel av kärnor än vad träck från kalvar som hade utfodrats med sojamjöl gjorde. Vidare bestod en mindre procentandel av träckvikten hos stutar utfodrade med hampfrökaka av långa partiklar än vad träck från djur utfodrade med sojamjöl gjorde.

Inom gruppen med stutar med en slutvikt på 650 kg krävde de stutar som utfodrats med sojamjöl en längre slutgödningsperiod för att uppnå slutvikten än vad stutar som fått hampfrökaka gjorde samtidigt som slaktutbytet var högre hos stutar som fått sojamjöl än de som fått hampfrökaka. Slaktkroppar från stutar slaktade vid 650 kg hade en högre fettklass än de som slaktats vid en vikt på 600 kg. Formklassen hos stutar av SRB-ras var i medeltal 0,8 klasser bättre än hos SLB-stutar. I övrigt kunde inga effekter av ras eller slutvikt påvisas i studien.

Det större intaget av NDF hos djur utfodrade med hampfrökaka än hos djur utfodrade med sojamjöl i kombination med träckens egenskaper med avseende på antal långa partiklar, torrsubstanshalt och konsistens indikerar att det högre NDF-intaget resulterade i en bättre funktion i digestionskanalen. Den lösare träcken med fler långa partiklar hos stutar utfodrade med sojamjöl indikerar att fodret passerade med en för hög hastighet genom djurets kropp där det skedde en minskad reduktion av partikelstorleken genom mikrobiell fermentation, vilket resulterade i att fler antal partiklar återfanns i träcken. En för hög hastighet av fodret genom kroppen leder även till att torrsubstanshalten och konsistensen i träcken kommer att bli lägre, vilket kunde ses hos stutarna utfodrade med sojamjöl.

Slutsatserna från försöken är att hampfrökaka som proteinfodermedel istället för sojamjöl till växande nötkreatur med intensiv utfodring ger samma tillväxt och slaktkroppsegenskaper samt bättre magar på grund av det högre fiberinnehållet i hampfrökaka i jämförelse med sojamjöl.

# REFERENCES


Allen, M.S. 1996. Physical constraints on voluntary intake of forages by ruminants. J. Anim. Sci., 74: 3063-3075.

Allen, M.S. 1997. Relationship between fermentation acid production in the rumen and the requirement for physically effective fibre. J. Dairy. Sci., 80 (7), 1447-1462.

Andersson, A., Christensen, S., Eriksson, J.Å., Gustavsson, B., Hökås, G., Johnsson, S., Karlsson, R., Lindell, L., Martinsson, K., Norrman, E., Swennson, T., Törnquist, M. 1991. Nötkött- Avel och uppfödning. LTs förlag, Stockholm, pp 80 and 90. (In Swedish).

Andersson, R. and Hedlund, B., 1983. HPLC analysis of organic acids in lactic acid fermented vegetables. Zeitschrift für Lebensmittel-Untersuchung und Forschung 176, 440–443.

Anderson, V., Harrold, R., Landblom, D., Lardy, G., Schatz, B. and Schroeder, J.W. 2002. A guide to feeding field peas to livestock. Nutrient content and feeding recommendations for beef, dairy, sheep, swine and poultry. North Dakota State University , AS-1224, 8pp.

Bertilsson, J., Emanuelsson, M. and Murphy, M. 1994. Linseed products for dairy cows. Report 229. Department of Animal Nutrition and Management. Swedish University of Agricultural Science, Uppsala, 24 pp. (In Swedish with English summary).

Björnhag, G. 1996. Växtätarna. Kompendium i fodersmältningsorganens funktion hos de växtätande djuren. 5 ed. Uppsala, SLU, 31 pp. (In Swedish).

Boisen, S. 2002. Dyrefysiologiske aspekter-Protein, antinutritionelle faktorer og det nye fodervurderingssystem. In: DJF Rapport, no 74. Wollenweber, B., Flengmark, P.K., Knudsen, K.E.B., Boisen, S., Olesen, J.E. and Pedersen, J.B. Danmarks jordbruksforskning, Tjele, 133-149. (In Danish).

Bonhomme, A. 1990. Rumen ciliates: their metabolism and relationships with bacteria and their hosts. Anim. Feed Sci. Tech., 30: 203-266.

Boström, U. 2004. Åkerböna eller lupin ett alternativ till ärtor. Forskningsnytt, Nr 4. Institutionen för ekologi och växtproduktionslära, Sveriges Lantbruksuniversitet, Uppsala, 2 pp. (In Swedish).

Boucqué, CH.V.and Fiems, L.O. 1988. Vegetable by-products of agro-industrial origin. In: Livestock feed resources and feed evaluation in Europe. De Boer, F. and Bickel, H. Elseiver, Amsterdam, Oxford, New York, Tokyo, 97-135.

Burris, W.R., Boling, J.A, Bradley, N.W. and Ludwick, R.L. 1974. Preformed protein sources in steer finishing rations. J. Anim. Sci: 39, 742-746.

Børsting, C.F., Kristensen, T., Misciattelli, L., Hvelplund, T. and Weisbjerg, M.R. 2003. Reducing nitrogen surplus from dairy farms. Effects of feeding and management. Livest. Prod. Sci., 83, 165-178.

Callaway, J.C. 2004. Hemp seed as a nutritional resource: An overview. Euphytica 140. Department of Pharmaceutical Chemistry, University of Kuopio, Finland. Kluwer Academic Publishers, Netherlands, 65-72.

Callaway, J., Schwab, U., Harvima, I., Halonen, P., Mykkänen, P. and Järvinen, T. 2005. Efficacy of dietary hemp seed oil in patients with atopic dermatitis. J. Derm. Treatm., 16: 87-94.

Cheng, K.J., Forsberg, C.W., Minato, H. and Costerton, J.W. 1991. Microbial ecology and physiology of feed degradation within the rumen. In: Physiological aspects of digestion and metabolism in ruminants (Tsuda, T., Sasaki, Y. and Kawashima, R. eds). Academic press, Toronto, ON: 595-624.

Chi Hemp Industries Incorporated. Homepage [online] (2007-03-30). Available from: http://www.chii.ca/organic-hemp-flour/cake.html.

Choi, N. J., Kang, S. W., Kwon, E. G., Cho, W. M., Jeon, B. S. and Park, B. K. 2006. Effects of diet and time on feed on fatty acid composition in muscle of Charolais steers. J. Anim. Sci. Tech. 48 (6): 847-860.

Comerford, J. W., House, R. B., Harpster, H. W., Henning, W. R. and Cooper, J. B. 1992. Effects of Forage and Protein Source on Feedlot Performance and Carcass Traits of Holstein and Crossbred Beef Steers. J. Anim. Sci., 70:1022-1031.

Danielsson, D.A. 1990. Assessment of the feed intake of beef cattle by means of neutral detergent fibre (DF). In: Grovfoder, Forskning-Tillämpning. Grass and forage reports, no 2. Swedish University of Agricultural Science, Uppsala, 5-11. (In Swedish with English summary).

Dawson, L.E.R and Steen, R.W.J. 2000. Relationship between dry matter, fibre and nitrogen degradation characteristics of silage and silage intake of steers. J. Anim. Sci., 70: 537-546.

Dunne, P.G., Keane, M.G., O´Mara, F.P., Monahan, F.J. and Moloney, A.P. 2004. Colour of subcutaneous adipose tissue and *M. longissimus dorsi* of high index dairy and beef × dairy cattle slaughtered at two live weights as bulls and steers. Meat Sci., 68 (1): 97–106.

Ekelund, S. 1966. Socker in redos (Reduced sugar). Report no. 28, app. 8, National Laboratory for Agricultural Chemistry, Uppsala, pp, 67-71. (In Swedish).

Emanuelsson, M. and Salomonsson, M. 2003. Vallfoder inte bara fibrer. Husdjur 8: 24-26. (In Swedish).

Engstedt, M. 1987. Samband mellan kraftfodrets fiberhalt och smältbarhet hos idisslare. In: Fibre i utfodringen, 3-5 november. Institutionen för husdjurens utfodring och vård, Sveriges lantbruksuniversitet: 30-33. (In Swedish).

EU, Council Directive no. 1294/2005. 2005. Off. J. Eur. Communities 205:16-17.

Finell, M., Xiong, S. and Olsson, R. 2006. Mutifunktionell industrihampa för norra Sverige. BTK rapport 2006:13. Sveriges lantbruksuniversitet, Enheten för biomassateknologi och kemi, Umeå, 41 pp. (In Swedish).

Flatt, W.R. and Stanton T.L. 2002. Effects of Profi peas, *Pisum arvense*, on growth performance and carcass characteristics of feedlot cattle. Anim. Sci. Research Report. Department of Animal Sciences, Colorado State University, Ft. Collins, CO 80523, 5 pp.

Flengmark, P. 2002. Kvalitetsaspekter i raps och baelgsaed till foderbrug. In: DJF Rapport, no 74. Wollenweber, B., Flengmark, P.K., Knudsen, K.E.B., Boisen, S., Olesen, J.E. and Pedersen, J.B. Danmarks jordbruksforskning, Slagelse, 93-115. (In Danish).

Fällman, A. 2006. Grödan som kan bli Sveriges sockerrör. Särtryck ur Lantmännen, jan 2006. (In Swedish).

Gibb, D.J., Owens, F.N., Mir, P.S., Mir, Z., Ivan, M. and McAllister, T.A. 2004. Value of sunflower seed in finishing diets of feedlot cattle. J. Anim. Sci., 82: 2679-2692.

Gibb, D.J., Shah, M.A., Mir, P.S. and McAllister, T.A. 2005. Effect of full-fat hemp seed on performance and tissue fatty acids of feedlot cattle. Can. J. Anim. Sci., 85:2, 223-230.

Hall, M.B. 2002 Characteristics of manure - what do they mean? Proc. Tri-State Dairy Nutrition Conference, April 16-17, Ft. Wayne, IN., USA: 141-147.

Hansson, I. and Brulin, S. 1981. Försök med mellankalvar av SKB-ras. Olika inblandningar av soja i kraftfodret samt studier av slaktkropparnas egenskaper. Röbäcksdalen meddelar, Rapport från Norrlands lantbruksanstalt Röbäcksdalen, Umeå, No 8, 11 pp. (In Swedish).

Hansson, I. 1989. Nötslaktkroppar sammansättning och egenskaper. Report 89. Department of animal breeding and genetics. Swedish University of Agricultural Science, Uppsala: 1-5, 10-11. (In Swedish).

Harfoot, C.G. and G.P. Hazlewood. 1997. LIPID METABOLISM IN THE RUMEN. In: Hobson, P.N. and Stewart, C.S (Eds.) Lipid metabolism in the rumen. Blackie academic & Professional, London, UK: 382-426.

Holstmark, K. 2006. Hampa i ekologisk odling (Råd i praktiken). Jordbruksinformation-5, Jordbruksverket, Skara. 3 pp. (In Swedish).

Ivarsson, J. 2004. Ta ogräset i hampan-odla hampa! Skånskt lantbruk nr 6. Kristianstads läns hushållningssällskap, 2 pp. (In Swedish).

Johansson, B. & Nadeau, E. 2006. Performance of dairy cows fed an entirely organic diet containing cold-pressed rapeseed cake. Acta Agric. Scand., Sect. A., Animal Sci. 56: 128-136.

Jordbruksdepartementet. 2004. Rapport om förutsättningarna för odling av hampa I Sverige samt EU: s stödsystem. Regeringskansliet. Rapport.

Jung, H.G and Allen, M.S. 1995. Characteristics of cell walls affecting intake and digestibility of forage by ruminants. J. Anim. Sci., 73: 2774-2790.

Karlsson, L. 2001. NDF från grovfoder-stommen i kons foderstat. Husdjur 8:32-35 (In Swedish).

Karlsson, S. and Arnesson, A. 2004. 100 % organic feed stuffs and feed management on dairy farms in Götaland district of Sweden. Swedish University of Agricultural Science, Department of animal environment and health section of production systems. Report 3, 29 pp. (In Swedish with English summary)

Karus, M. 2005. European hemp industry 2001 till 2004: Cultivation, raw materials, products and trends. European Industrial Hemp Association (EIHA), Germany, 11 pp.

Keane, M.G and Allen, P. 1998. Effects of production system intensity on performance, carcasscomposition and meat quality of beef cattle. Livest. Prod. Sci. 56: 203–214.

Keane, M.G. 2003. Beef production from Holstein-Friesian bulls and steers of New Zealand and European/American descent, and Belgian Blue × Holstein-Friesians, slaughtered at two weights. Livest. Prod. Sci., 84 (3): 207–218.

Kennedy, P.M. 2005. Particle dynamics. In: Quantitative aspects of ruminant digestion and metabolism. Dijkstra, J., Forbes, J.M. and France, J. CABI publishing.Oxfordshire, UK and Cambridge, USA: 123-156.

Kiers, J.L. 2001. GENERAL INTRODUCTION. In: Effects of fermented soy bean on digestion, absorption and diarrhoea. PhD Thesis Wageningen University, Wageningen, The Netherlands: 2-12.

Landström, S. 2000. Hampa - en växt i ny form. Rödäcksdalen meddelar, Nr 1. Sveriges lantbruksuniversitet, Institutionen för norrländsk jordbruksvetenskap, Umeå, 2 pp. (In Swedish).

Larson, E.M., Stock, R.A., Klopfeinstein, T.J., Sindt, M.H. and Huffman, R.P. 1993. Feeding value of wet distiller's byproducts for finishing ruminants. J. Anim. Sci. 71: 2228-2236.

Lewis, N.M., Seburg, S. and Flanagan, N.L. 2000. Enriched eggs as a source of N-3 polyunsaturated fatty acids for humans. Poultry Science 79: 971-974.

Lindgren, E. 1979. The nutritional value of roughages determined in vivo and by laboratory methods. Report No 45, Dept. Anim. Nutr. Manage., Swedish Univ. Agric. Sci., Uppsala, 61 pp. (In Swedish with English summary)

Lund, A. 2000. Hampa-tåget Sveriges odlare missar. Odlaren, Nr 2. Förbundet organisk biologisk odling, 5 pp. (In Swedish).

Magalhaes, K. A., Valadares Filho, S. C., Paulino, P. V. R., Paulino, M. F., Valadares, R. F. D. 2006. Performance, digestibility and carcass characteristics of feedlot dairy steers fed diets with different urea levels. Arquivo Brasileiro de Medicina Veterinaria e Zootecnia 58 (5): 860-867.

Mejnertsen, P. 2002. Ekologisk dyrkning af proteingröder. Grovfoderseminar. (In Danish).

Mertens, D.R. 1997. Creating a system for meeting the fibre requirement of dairy cows. J. Dairy. Sci., 80: 1463-1481.

McDonald, P., Edwards, R.A., Greenhalgh, J.F.D. and Morgan, C.A (Eds.) Animal Nutrition. Ashford Colour Press Ltd. Gosport, UK: 55-72, 199-244, 583-614.

Mgbeahurike, A.C. 2007. Faecal characteristics and production of cows in early lactation. Report no 62. Department of Animal Environment and Health, Swedish University of Agricultural  Science.

Moss, A.R., Deaville, E.R. and Givens, D.I. 2001. The nutritive value for ruminants of lupin seeds from determinate and dwarf determinate plants. Anim. Feed Sci. Tech., 94 (3-4): 187-198.

Mould, F.L., Orskov, E.R. and Mann, S.O. 1983. Associative effects of mixed feeds .I. Effects of type and level of supplementation and the influence of the ruminal fluid pH on cellolysis in-vivo and dry matter digestion of various roughages. Anim. Feed Sci. Tech., 10: 15-30.

Mustafa, A.F., McKinnon, J.J. and Christensen, D.A. 1998. The nutritive value of hemp meal for ruminants. Canadian J. Anim. Sci. , 79 (1). Department of Animal and Poulty Science, University of Saskatchewan, Saskatoon, Canada: 91-95.

Möller, J. & Pedersen S.S. 2003. Fodervärdi af lupiner til kväg. www.lr.dk den 15 april.

Nadeau, E.M.G., Buxton, D.R., Lindgren, E., and Lingvall, P. 1996. Kinetics of cell-wall digestion of orchard grass and alfalfa silages treated with cellulase and formic acid. J. Dairy Sci., 79: 2207-2216.

Nadeau, E., Englund, J.E., Gustafsson, A.H. 2007. Nitrogen efficiency of dairy cows as affected by diet and milk yield. Livest. Sci., In Press, Corrected Proof, 15 pp.

National Research Council. 1996. Nutrient Requirements of Beef Cattle. 7th rev. ed. National Academy Press, Washington D.C.

National research council. 2001. Nutrient Requirements of dairy cattle. 7th rev. ed. National Academy Press, Washington D.C.

NJF (Nordiska jordbruksforskares förening). 1984. Fodrets koncentrationsgrad till svin ur foder- och avelssynpunkt. Seminarium Nr 57, 29-30 mars på Sånga-Säby kursgård Stenhamra, Sektion V-Husdjur, Uppsala, 15:1-15:7.

Nordqvist, 2006. Manure evaluation as a method to evaluate rumen function and feed utilization by dairy cows. Studentarbete 59. Swedish University of Agricultural Science, 75 pp.

Nørgaard, P. 2003. Tyggetid som mål for foderets fysiske struktur. DJF rappport Husdyrbruk nr 53, Danmarks jordbrugsforskning: 489-510.

Obeid, J. A., Pereira, O. G., Pereira, D. H., Valadares Filho, S. de C., Carvalho, I. P. C. de and Martins, J. M. 2006. Crude protein levels in beef cattle diets: intake, digestibility and performance. Revista Brasileira de Zootecnia 35 (6): 2434-2442.

Olesen, M., Madsen, P., Andersen, B.B., Madsen, N.T. and Refsgaard Andersen, H. 1994. Feed intake and production of different biological types of beef breeds. DJF rapport Husdyrbrug nr 59. Tjele, Denmark: 10-12.

Olsson, A.C., Emanuelsson, M., Wiktorsson, W. 1988. Linfröets egenskaper och användbarhet som foder. Report 173. Department of Animal Nutrition and Management. Swedish University of Agricultural Science, Uppsala: 1, 6 and 17-18. (In Swedish with English summary).

Olsson, I. 1987. Effect of protein supply on the performance of intensively reared bulls. Report 164. Department of Animal Nutrition and Management. Swedish University of Agricultural Science, Uppsala, 1-17, 1-25 (experiment C).

Olsson, I., Ciszuk, P., Hellberg, S. and Widebeck, L. 1998. AAT/PBV-systemet till växande ungnöt – förslag till utfodringsrekommendationer baserade på råprotein och AAT. Report 246. Department of Animal Nutrition and Management, Swedish University of Agricultural Sciences, Uppsala, 2-4 (In Swedish with English summary)

Paixao, M. L., Valadares Filho, S. de C., Leao, M. I., Valadares, R. F. D., Paulino, M. F., Marcondes, M. I., Fonseca, M. A., Silva, P. A. and Pina, D. dos S. 2006. Urea in diets of steers: intake, digestibility, performance, carcass traits and microbial yield. Revista Brasileira de Zootecnia 35 (6): 2451-2460.

Pehrson, B. 1987. Veterinärmedicinska synpunkter på en ur fibersynpunkt obalanserad foderstat till nötkreatur. Fodersymposium. Fiber i utfodringen 3-5 november, Malmö, pp. 11-14.

Perry, T.W., Cullison, A.E. and Lowrey, R.S. 1999. Feeds & Feeding. Prentice hall, Inc, New Jersey: 71-84.

Pettersson, B. 2004. Åkerböna till nötkreatur. Ekobruk Norr, Nr 3. Lantbruksenheten Uddevalla, 1 p.

Ponnampalam, E. N., Sinclair, A. J., Egan, A. R., Blakeley, S. J., and Leury, B. J. 2001. Effect of diets containing *n*–3 fatty acids on muscle long-chain *n*–3 fatty acid content in lambs fed low- and medium-quality roughage diets. J. Anim. Sci. 2001. 79: 698–706.

Poppi, D.P. and Norton, B.W. 1980. The validity of the critical size theory for particles leaving the rumen. J. Agr. Sci., 94: 275-280.

Robinson, P.H and McQueen, R.E. 1994. Influence of supplemental protein source and feeding frequency on rumen fermentation and performance in dairy cows. J. Dairy. Sci., 77: 1340-1353.

Rygh, A.J., Mehlqvist, M., Liljeholm, M., Larsen, M., Gustavsson, A.H., Volden, H., Aaes, O., Bævre, L., Thøgersen, R. and Gudmundsson, G. 2004. NorFor Plan, en översiktlig besktivning. Norfor Feed Evaluation System, 8 pp. (In Swedish).

Silversides, F.G., Budgell, K.L. and Lerancois, M.R. 2002. Effect of feeding hemp seed meal to laying hens. Atlantic poultry research institute, Factsheet #16. Nova Scotia Agricultural College, Canada, 2 pp.

Sindt, M.H., Stock, R.A., Klopfenstein, T.J. and Shain, D.H. 1993. Effect of protein source and grain type on finishing calf performance and ruminal metabolism. Department of Animal Science, University of Nebraska, Lincoln, USA: 1047.

Sjaastad, Ø.V., Hove, K. and Sand, O. 2003. Physiology of domestic animals. Scandinavian Veterinary Press, Oslo, 489-581.

SJVFS 127. 1998. Directions of classifications of carcasses from the Swedish Board of Agriculture. The Swedish Board of Agriculture, Jönköping. (In Swedish).

Steen, K. 2004. Träckdiagnostik hos mjölkkor. Examensarbete 205. Institutionen för husdjurens utfodring och vård, Sveriges Lantbruksuniversitet, Uppsala. (In Swedish).

Sniffen, C.J., O´Connor, J.D., Van Soest, P.J., Fox, D.G. and Russel, J.B. 1992. A net carbohydrate and protein system for evaluating cattle diets: II. Carbohydrate and protein availability. J. Anim. Sci., 70: 3562-3577.

Soto-Navarro, S.A., Williams, G.J., Bauer, M.L., Lardy, G.P., Landblom, D. and Caton J.S. 2003. Effects of field pea inclusion on intake and digestion in beef steers fed medium concentrate diets. Annual Report 5 pp.

Spörndly, R (red). 2003. Fodermedelstabell för idisslare. Swedish University of Agricultural Science, Uppsala, pages 26-43. (In Swedish).

Steen, R.W.J. and Kilpatrick, D.J., 2000. The effects of the ratio of grass silage to concentrates in the diet and restricted dry matter intake on the performance and carcass composition of beef cattle. Livest. Prod. Sci., 62 (2): 181–192.

Stensig, T., Strudsholm F., Nielsen E.S. 1993. Beskrivelse af fodermidler. Karekterisktiska og anvendelse til kväg. Rapport nr.26. Landsudvalget for kväg. 260pp. (In Danish).

Sundberg and Westlin, M. and Westlin, H. 2005. Hemp as a biomass fuel-preliminary study. JTI-rapport Lantbruk & Industri 341. Institutet för jordbruks- och miljöteknik, Uppsala: 10-11, 16-17, 26 (In Swedish with English summary).

Svennerstedt, B. and Svensson, G. 2004. Industrihampa-odling, skörd, beredning och marknad. Fakta Jordbruk, Nr 7. Sveriges lantbruksuniversitet, 4 pp. (In Swedish).

Svennerstedt, B. and Svensson G. 2006. Hemp (*Cannabis sativa L.*) trials in southern Sweden 1991-2001. Journal of industry hemp, Vol. 11 (1). The Harworth Press, Inc, 17-25.

Swedish board of agriculture. 2007. Homepage [online] (2007-03-21). Available from: http://www.sjv.se/webdav/files/SJV/pressmeddelanden/arkiv/001215.htm.

Thénard V., Dumont R., Grosse M., Trommenschlager J.M., Fiorelli J.L. and Roux M. 2006. Grass steer production system to improve carcass and meat quality. Livest. Sci., 105: 185-197.

Todorov, N.A, 1988. Cerals, Pulses and oilseeds. In: Livestock feed resources and feed evaluation in Europe. De Boer, F. and Bickel, H. Elsevier, Amsterdam, Oxford, New York, Tokyo: 47-95.

Tripathi, M.K. and Mishra, A.S. 2007. Glucosinolates in animal nutrition: A review. Anim. Feed Sci. Tech., 132: 1-27.

Van der Honing, Y. and Alderman, G. 1988. Ruminants. In: Livestock feed resources and feed evaluation in Europe. De Boer, F. and Bickel, H. Elsevier, Amsterdam, Oxford, New York, Tokyo, 217-278.

Van der Werf, H.M.G. 1991. Agronomy and crop physiology of fibre hemp. CABO Report 142. Center for Agrobiological Research, The Netherlands: 3-14.

Van Sjoest, P.J. 1987. Fibre to ruminants-Implications on nutrition and digestion. In: Fodersymposium; Fibrer i utfodringen. Sockerbolaget, SSA foder: 87-91.

Van Soest, P.J., Robertsson, J.B. and Lewis, B.A., 1991. Methods for dietary fibre, neutral detergent fibre and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583–3597.

Varga, G.A. and Kolver, E.S. 1997. Microbial and animal limitations to fibre digestion and utilization. J. Nutr., 127: 819S-823S.

Varga, G.A. 2003. Can manure evaluation diagnose areas for improvement in ration formulation, management and health? Djurhälso- & utfodringskonferens, 21 augusti. Svensk Mjölk, Eskilstuna: 33-36. (In Swedish).

Wallace, R.J. 1988. Ecology of rumen. Microorganisms: Protein use. In: Aspects of digestive physiology in ruminants. Proceedings of a satellite symposium of the 30th international congress of the international union of physiological science. Dobson, A. and Dobson, M.J (Editors). New York state college of veterinary medicine Cornell University. Comstock publishing associates, Ithaca and London: 99-122.

Wilkins, R.J. and Jones, R. 2000. Alternative home-grown protein sources for ruminants in the United Kingdom. Animal Feed Science and Technology, Volume 85, Issues 1-2. Aberystwyth, Elsevier Science B.V., UK: 23-32.

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 Sci., 66: 21-32.

Yang, C.J.M. and Varga, G.A. 1993. The effect of continuous ruminal dosing with diotyl sodiumsulphosuccinate on ruminal and metabolic characteristics of lactation cows. Brit. J. Nutr., 69: 397-408.

Åman, P. and Hesselman, K. 1984. Analysis of starch and other main constituents of cereal grains. Swedish J. Agric. Res., 14, 135–139.

**PERSONAL COMMUNICATION**

Bengt Svennerstedt, Temagrupp Biofibreteknologi, Inst. för jordbrukets biosystem och teknologi (JBT), Alnarp. Hemp seminar 2006-10-24.

Birgitta Johansson. Inst. för husdjurens miljö och hälsa, Sveriges lantbruksuniversitet, Skara, VT 2007.

Gunnela Gustavsson, Inst. för husdjurens utfodring och vård, Sveriges lantbrukuniversitet, Uppsala. Telefonsamtal, HT 2006.

Sven Hellberg, Produktchef, Lantmännen. Taurus Nötköttsseminarium, 2007-01-25.

Linda Karlsson, Grovfodercentrum, inst. för norrländsk jordbruksvetenskap, Sveriges lantbruksuniversitet, Umeå. Hemp seminar 2006-10-24

Michael Finell. Enheten för biomassteknologi, Sveriges lantbruksuniversitet, Umeå. Hemp seminar 2006-10-24

Elisabet Nadeau. Inst. för husdjurens miljö och hälsa, Sveriges lantbruksuniversitet, Skara, VT 2007.

Peter Norberg, Högskolan Gävle samt HampeKraft. Hemp seminar 2006-10-24.

**PICTURES**

Figure 2; BioTech Resources. Homepage: [online] (2007-03-22). Available from: http://biotech.icmb.utexas.edu/botany/thc.html

Figure 4; Naturhistoriska riksmuseet. Homepage: [online] (2007-03-22). Available from: http://linnaeus.nrm.se/flora/di/cannaba/canna/cannsat.html

Figure 10 and 11; Wikimedia Commons. Homepage: [online] (2007-03-21). Available from: http://commons.wikimedia.org/wiki/Cannabis_sativa?uselang=sv

Figure 13; Whole foods market. Homepage: [online] (2007-03-22). Available from: http://www.wholefoodsmarket.com/products/beans/soy.html

Figure 14; Punjab national bank and agriculture credit. Homepage: [online] (2007-03-22). Available from: http://www.pnbkrishi.com/linseedtech.htm

# APPENDIX

## Appendix 1. Schedule of the faecal consistency (Steen, 2004)

KONSISTENS-BEDÖMNINGS-SCHEMA

| Konsistens-poäng | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Träckens utseende när den lämnar kon:** | Sprutar ut | Rinner ut | Trycks ut, som kaviar | Trycks ut, kommer i klumpar | Kommer i bollar |
| **Detta händer när träcken träffar golvet:** | Stänker, flyter ut | Stänker, flyter ut | Kan stänka lite, flyter ut en del. Ger ifrån sig ett plopp-ljud när mockan fylls på. | Behåller originalformen. Ger ifrån sig ett dovt plopp-ljud när mockan fylls på. | Behåller originalformen |
| **Träckens konsistens:** | Mycket lös, som ärtsoppa | Lös | Lagom, kladdig, som havregrynsgröt | Fast | Hård och torr |
| **Träckens utseende när den ligger på golvet:** | Ingen komocka, mer likt vatten. Rinner igenom galler. | Mycket platt, har ingen höjd och inte någon topp. Rinner igenom galler. | Som en basker/kanelbulle, med några höjdkurvor. Kladdar på galler. | Bygger på höjden. Stannar på galler. | Som hästskit, flera bollar med många höjdkurvor på. Stannar på galler. |
| **Djur som har denna träck-konsistens:** | Sjuka kor, kor som får för lite struktur/ för mycket protein/ för mycket stärkelse i foderstaten. | Kor som får lite struktur/ mycket protein/ mycket stärkelse i foderstaten. Kor i tidig och mellan laktation. | Ko med väl fungerande foderstat, kor i tidig och mellan laktation. | Kor i sen laktation, sinkor. Mycket grovfoder i foderstaten. | Sinkor, ungdjur. Mycket grovt grovfoder i foderstaten. |

Vid **Institutionen för husdjurens miljö och hälsa** finns tre publikationsserier:

* **Avhandlingar:** Här publiceras masters- och licentiatavhandlingar

* **Rapporter:** Här publiceras olika typer av vetenskapliga rapporter från institutionen.

* **Studentarbeten:** Här publiceras olika typer av studentarbeten, bl.a. examensarbeten, vanligtvis omfattande 5-20 poäng. Studentarbeten ingår som en obligatorisk del i olika program och syftar till att under handledning ge den studerande träning i att självständigt och på ett vetenskapligt sätt lösa en uppgift. Arbetenas innehåll, resultat och slutsatser bör således bedömas mot denna bakgrund.

Vill du veta mer om institutionens publikationer kan du hitta det här: www.hmh.slu.se

**DISTRIBUTION:**

| Sveriges lantbruksuniversitet | *Swedish University of Agricultural Sciences* |
|---|---|
| Fakulteten för veterinärmedicin och Husdjursvetenskap | *Faculty of Veterinary Medicine and Science Animal* |
| Institutionen för husdjurens miljö och hälsa | *Department of Animal Environment and Health* |
| Box 234 | *P.O.B. 234* |
| 532 23 Skara | *SE-532 23 Skara, Sweden* |
| Tel 0511–67000 | *Phone: +46 (0)511 67000* |
| **E-post: hmh@slu.se** | ***E-mail: hmh@slu.se*** |
| **Hemsida: www.hmh.slu.se** | **Homepage: www.hmh.slu.se** |