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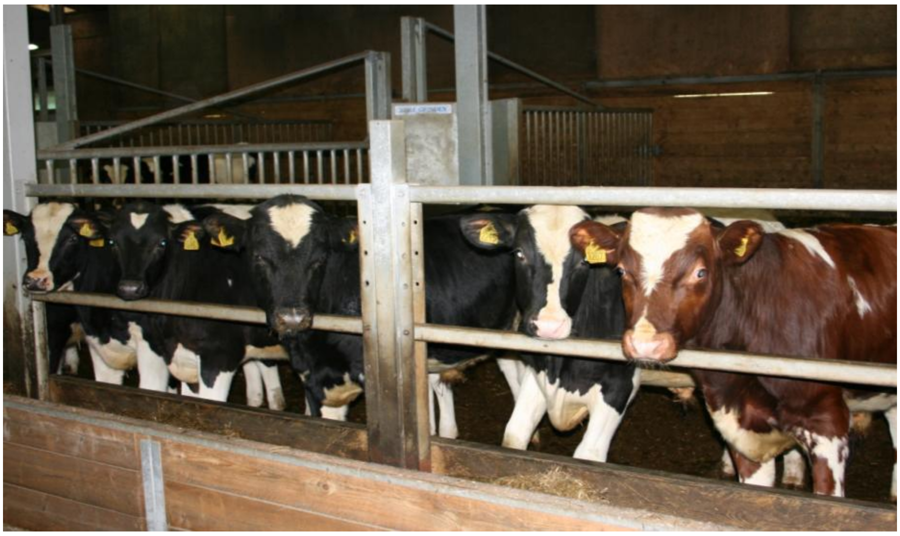
**Agricultural Science programme – Animal Science**



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# FÖRORD

Detta examensarbete omfattar 30 ECTs inom agronomprogrammet, inriktning husdjur, vid Sveriges Lantbruksuniversitet. Examensarbetet är en del i ett större projekt som undersöker olika proteinfodermedels effekt på foderintag, tillväxt och vomfunktion hos kalvar.

Tack till Stiftelsen lantbruksforskning, Agroväst, Skarborgs läns nötkreaturförsäknings bolags stiftelse och SLU som finansierat det stora projektet. Ett tack också till Agroetanol som sponsrade dranken som användes.

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Jag vill även tacka examinator Anna Hessle och opponent Kristina Holmström för utvecklande frågor och funderingar.

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## SUMMARY

The cattle production in the world has been questioned in Sweden due to its negative impacts on the environment. The use of imported soya bean meal as a protein feed for Swedish cattle results in the cutting of rainforest and an extensive use of pesticides in the countries were the soya beans are produced. As a consequence, the environmental impacts caused by cattle production increases. A production of protein feeds in Sweden would decrease the transportations and the cutting of rainforest. For organic beef producers the possibility to produce home-grown protein feeds is important since organic protein feeds can be difficult to obtain in another way. The organic beef production has increased over tha last five years in Sweden and the knowledge about what kinds of protein feeds that are possible to grow locally and use with satisfying results needs to be developed.

The purpose of the study was to compare feed intake, growth, feed utilisation and rumen function in dairy calves fed dried distiller's grains with solubles (DDGS) or Swedish grown rolled soya beans (SSB) compared to imported soya bean meal (SBM) as protein feed in a total mixed ration.

In the trial 84 dairy bull calves were used. At the start of the experiment the calves were weighed and assigned to the three different protein treatments. The experiment had a completely randomized design. For each treatment four pens were used and there were seven animals in each pen and, there were 12 pens used in total. At arrival, the calves had an average live weight of 93 (standard deviation, SD, 13) kg and at the end of the experiment the mean live weight was 271 (SD, 28) kg. Weighing of the calves was performed on two consecutive days at the start and at the end of the experiment and every 14 days between that.

The total mixed rations contained grass-clover silage, rolled barley and sufficient amounts of minerals together with either SBM, DDGS or SSB. The target gain per day was 900 g and when balancing the diets firstly the content of crude protein and amino acids absorbed in the small intestine (AAT) were considered and, secondly, the content of metabolizable energy. Because the requirements of protein in relation to energy change when calves grow the diets were rebalanced four times for the weight intervals 75-125 kg, 126-175 kg, 176-225 kg and 226-275 kg. In the diets with DDGS and SSB cold-pressed rapeseed cake was included until the calves reached a weight of 175 kg to be able to meet the requirements of crude protein and AAT according to Swedish recommendations.

Feed was offered *ad libitum* (> 5% refusals) and feeding was performed once per day. The feed was weighed every day before feeding and refusals were weighed three times per week and the amounts were thereafter used to calculate the intakes of the calves. The average daily live weight gain was calculated from the average value of the first two and the last two weighings of the calves. From the growth and feed intake during the experimental period the feed efficiency of the calves was calculated. Rumen function was estimated from the consistency of the faeces and faecal content of long (>10 mm) particles, whole and partial grains.

The calves fed the DDGS diet had higher growth rates than calves fed the SBM or SSB diets (1.34 kg vs. 1.21 kg and 1.25 kg per day, $P < 0.01$). Calves fed DDGS also had a strong tendency for higher intake of DM (4.81 kg per day vs. 4.45 kg and 4.50 kg, $P =$

0.058) and had higher intakes of crude protein (811 g per day vs. 725 g and 750 g, *P* < 0,05) than the other calves. The feed efficiency did not differ between treatments and was around 22 g $MJ^{-1}$ and 278 g $kg^{-1}$ DM. The effect of protein feed on faecal traits varied between weight intervals. Generally faeces from calves fed DDGS had a firmer consistency than faeces from calves fed SBM (*P*< 0.001). The number of long particles (>10 mm) in faeces was similar in all treatments and indicated similar retention times of the protein feeds in the rumen and a good rumen function.

In conclusion, SSB or DDGS work as well as SBM as a protein feed when cold-pressed rapeseed cake is included in the diets until the calves reach a live weight of 175 kg. The conclusion is supported by the fact that calves fed DDGS had a higher growth rate than calves fed SBM and calves fed SSB had the same growth rate as calves fed SBM. At the same time feed efficiency and rumen function did not differ between the protein feeds.

# INTRODUCTION

It has been shown that cattle production contributes to the environmental problems seen in the world today (Steinfeld *et al.*, 2006). The environmental impact of different feed rations for dairy cows was studied by Wallman *et al.* (2010). They found that one of the major factors affecting the energy needed to produce feeds is the use of commercial fertilisers. It was also found that feeds grown on the own farm needed less energy for transportation. The conclusion was that a ration with home-grown protein feeds and silage from nitrogen fixating legumes would be the best alternative for the environment if the over-fertilizing emissions could be handled.

Soya beans are widely used in the world as a protein feed of good quality but the ethics around the use are often questioned. Some reasons behind this are that production of soya beans contributes to the cutting of rainforests and that the fertilizers and pesticides used contaminate the water (Naturskyddsföreningen, 2011).

In Sweden the organic cattle production has increased over the last five years (KRAV, 2010). The feed used on organic farms has to be 100% organic, except for minerals and vitamins, and at least 50% must be grown on the farm (The Swedish Board of Agriculture, 2010a). For beef producers the main difficulty caused by these regulations is the possibility to get high quality protein feeds and to get them at a reasonable cost (The Swedish Board of Agriculture, 2010b). To avoid some of these problems the farmer can choose to grow his own protein feeds.  It might be a good solution also from an environmental perspective due to less transportation and the benefits of nitrogen fixation of the free nitrogen in the air by many of these crops resulting in less use of artificial nitrogen fertilizers.

Calves need relatively high concentrations of protein in their feed to be able to grow properly. The protein feed must be of a good quality with sufficient amounts of rumen-undegradable protein since the proteins synthesized by the rumen micro-organisms will not be enough for the fast growth of a calf (McDonald *et al.*, 2002; Phillips, 2010).

## Purpose

The purpose of this study was to compare feed intake, growth, feed utilisation and rumen function in young dairy bull calves fed either dried distiller's grains with solubles, Swedish grown rolled soya beans or imported soya bean meal in a total mixed ration. The comparison was done to investigate whether sufficient growth and feed efficiency could be obtained when using only feeds produced in Sweden.

## Hypotheses

With diets balanced for similar crude protein and energy contents the hypotheses were that:

- Similar dry matter intakes are obtained in diets containing either dried distiller's grains with solubles, Swedish grown rolled soya beans or imported soya bean meal.

- Feeding soya bean meal results in a higher daily live weight gain than feeding dried distiller's grains with solubles or Swedish grown rolled soya beans.

- Feed utilisation is higher when using soya bean meal compared to dried distiller's grains with solubles or Swedish grown rolled soya beans.

- Feeding dried distiller's grains with solubles or Swedish grown rolled soya beans results in a better rumen function compared to feeding soya bean meal.

# LITERATURE REVIEW

## Digestion and intake of feed

### Proteins

Proteins are organic compounds constructed of amino acids and they are present in all living cells where they participate in all cell activities. In the rumen, micro-organisms hydrolyse a large part of the proteins given in the feed to peptides and amino acids. Some of the proteins are degraded even further to organic acids, ammonia and carbon dioxide (McDonald *et al.*, 2002). The ability of the microbes to get in contact with the hydrolysable sites on the polypeptide chain is affected by the chemical and physical properties of the protein. Also, the presence of water-insoluble materials such as lipids may reduce the surface area of the proteins accessible to proteases and peptidases (Nolan and Dobos, 2005). The by-products produced during the protein break down are used by the rumen micro organisms to synthesize microbial protein (McDonald *et al.*, 2002). The amount of microbial protein produced is not only depending on how much protein that is supplied but also on how much energy that is available from the carbohydrate fermentation in the rumen (Olsson, 1987; McDonald *et al.*, 2002; Børsting *et al.*, 2003; Nolan and Dobos, 2005). Microbial protein and feed protein that have not been degraded in the rumen can be degraded by enzymes in the abomasum and absorbed in the small intestines (McDonald *et al.*, 2002; Nolan and Dobos, 2005).

There are about 20 commonly found amino acids and they are usually divided into essential and non-essential amino acids. Essential amino acids cannot be synthesized in the body and needs to be supplemented by the feed while non-essential amino acids can be synthesized in the body. Because of the ability of the micro organisms to produce all of the essential amino acids, ruminants are almost independent of what kind of amino acids that are provided in their feed. Supplementation of appropriate amino acids is still necessary to get a high production (McDonald *et al.*, 2002). Some feeds like soya beans are possible to heat-treat to increase the amount of rumen-undegradable protein (Harris 1990), but there is a risk that the protein will become completely unavailable to the animal (McDonald *et al.*, 2002).

### Carbohydrates

Products from the degradation of carbohydrates are primarily used as an energy source by the body and the rumen microbes. The ruminal microbes are very important in the degradation of carbohydrates, especially in the degradation of fibres. The degradation of carbohydrates is done in several steps and starts with degradation of particles with microbial enzymes to simple sugars. These sugars are immediately taken up by the microbes that metabolize them. During the carbohydrate degradation pyruvate is produced which is used to synthesize volatile fatty acids (mostly acetic, propionic and butyric acids). Absorption of the volatile fatty acids to a large extent takes place in the rumen, the reticulum and the omasum but there is also some absorption in the small intestine (McDonald *et al.*, 2002).

### Fat

Most of the fats given in the feed to ruminants are hydrolyzed in the rumen by bacterial lipases. Unsaturated fatty acids are then saturated by the bacteria, usually to stearic acid.

The rumen microbes can synthesize many different fatty acids which are later becoming incorporated in the milk and the body fat of the animal. Ruminants have a limited ability to digest fats and an intake of more than 10% $kg^{-1}$ dry matter (DM) will reduce the microbial activity which results in impaired fibre digestion and reduced feed intake. Diets for ruminants normally contain less than 5% fat $kg^{-1}$ DM (McDonald *et al.*, 2002).

## Protein requirements of growing cattle

The requirements of protein in ruminants are closely related to the energy requirements due to the microbial degradation and synthesis of protein which are dependent on energy (Kelly *et al.*, 1993; McDonald *et al.*, 2002). Requirements of both protein and energy in growing cattle are mostly dependant on animal live weight (LW) and desired average daily gain (ADG) but also breed and sex has an effect (Olsson, 1987). Requirements of metabolizable energy (ME) increase with larger animals and with higher ADG, though the need for protein per unit ME decreases when cattle grow larger (Spörndly, 2003). This is due to a larger deposition of fat per kilogram of LW gain in larger animals which need more energy compared to protein deposition. Young calves deposit more protein in muscle than older animals and they therefore have a greater need for protein in their feed. For calves younger than about five months the protein quality is of great importance since the growth potential of the calf is large in proportion to the amount of nitrogen the rumen is able to supply. Consequently calves have a need for rumen-undegradable protein to reach a high growth rate (Phillips, 2010).

To reduce the nitrogen excreted by cattle it is important to maximize their utilisation of the nitrogen (proteins etc.) offered in the feed. To be able to fulfil the microbial needs of nitrogen while offering as little protein as possible synchronized feeding of protein and energy is essential (Børsting *et al.*, 2003; Nadeau *et al.*, 2007).

### Protein supplementation and growth

Forages as well as energy feeds contain protein although usually not in as large amounts as protein feeds, such as soya bean meal or peas. There have been several studies performed to investigate if there really is a need for supplementation with a specific protein feed in the diet for cattle reared for beef production. For younger calves the studies have been more targeted on the amount of crude protein (CP) needed in the diet.

Holstein calves, with an initial age of four days, offered concentrates (starters) with different CP content was studied by Akayezu *et al.* (1994). There were four different treatments with the CP contents 15.0, 16.8, 19.6 and 22.4% of DM. From weaning until the end of the experiment (53 days in total) calves receiving the starters with the two highest CP contents had a higher ADG (0.83 kg) than calves receiving the starter containing the lowest amount of CP (0.71 kg). The amount of feed $kg^{-1}$ LW gain was not affected by the different treatments and was around 2.0 kg for the whole experimental period in all treatments.

Petit *et al.* (1994) studied performance of late maturing beef steers (>200 kg LW at the start) fed only timothy silage or silage in combination with different amounts of canola (a variety of rapeseed that contains low levels of eruic acid and glucosinulates) meal and molasses. In their study steers fed canola meal had higher ADG (1.09 kg and 1.22 kg) than steers fed molasses (0.66 kg) or only silage (0.57 kg). The nitrogen intake $day^{-1}$ of the steers fed canola meal was 205 g and 223 g while it was around 150 g for the steers fed molasses and 130 g for those on silage only. Bidner *et al.* (1981) compared early maturing steers with a start LW of >200 kg fed only forage with steers fed forage plus different amounts of supplements. Steers fed only forage had more days on feed before slaughter than the groups, who besides forage, were offered additions of maize and urea or/and a commercial protein supplement. Unfortunately there are no figures on the CP or energy content of the diets written in the report.

Huuskonen *et al.* (2008) found that growing dairy bulls, weighing >250kg, fed a total mixed ration (TMR) containing protein supplements did not have a significantly higher ADG than bulls fed a TMR without protein supplement. The protein supplements used were rapeseed meal (RSM), wet distiller's solubles (WDS) or a mixture of barley protein (BP) and WDS which are both by-products from ethanol production. The content of CP and amino acids absorbed in the small intestine (AAT) were around 160 g $kg^{-1}$ DM and 8.3 g $MJ^{-1}$ ME in the diets with protein supplements and 150 g $kg^{-1}$ DM and 8.0 g $MJ^{-1}$ in the diet with only silage and a barley based concentrate. The conclusion was that silage of good quality together with barley-based concentrates can give enough protein for growing dairy bulls. On the diet without protein supplements the ADG was around 1.2 kg which is higher than treatments without canola meal in the study made by Petit *et al.* (1994). However, the average DM intakes of the animals in the study done by Huuskonen *et al.* (2008) were higher than of the animals in the study by Petit *et al.* (1994).

Veira *et al.* (1990) showed that Shorthorn and Simmental crossbred beef steers, with an initial LW of around 250 kg, can have an ADG of 0.83kg if they are fed good quality silage. However, steers supplemented with barley or fish meal or a mixture of these had a higher ADG, 1.10 kg, 0.98 kg and 1.19 kg respectively, and a higher feed efficiency (FE) than steers fed silage only. Supplementation with soya bean meal gave an ADG of 0.95 kg that did not differ significantly from the ADG of 0.83 kg and 0.98 kg that was obtained on silage only or supplementation with fish meal. The FE of the steers supplemented with soya bean meal did not differ from any of the treatments. From the results it was concluded that both energy and protein were deficient in the steers fed silage (Veira *et al.*, 1990).

Olsson (1987) fed dairy calves (82 kg initial LW) diets with 0.5 kg hay and concentrates *ad libitum* in two experiments. The concentrate was based on oats and barley with different levels of soya bean meal when altering the CP content of the concentrate. Significantly higher ADG were only observed in experiment 1 in calves given moderate amounts of CP (15.1%) compared to low (12.9%). The ADG for the first 12 weeks of the experiment were 1.25 kg for calves given moderate amounts of CP in the concentrate and 1.17 kg for calves given concentrate with low CP content. Higher contents of CP in the concentrate (17.5 and 19.8%) gave ADGs in between the low and moderate diets. Though, the FE was similar in all treatments and close to 300 g $kg^{-1}$ DM (Olsson, 1987).

## Faecal particle size

A simple method to evaluate the rumen function in cattle is to evaluate the faeces. Faecal evaluation can in combination with other observations of e.g. animal performance and feeding management give an indication on what changes are needed in management or diet formulation. Faeces containing large fibre particles and visible grains indicate that the feed has not been retained in the rumen for a sufficient time to get degraded by rumination and by the micro-organisms (Hall, 2002; Varga, 2003). Fibres stimulating rumination is called physically effective fibre (peNDF) and sufficient intakes of peNDF give a smaller faecal particle size and less visible grains (Hall, 2002).

Kovács *et al.* (1997) studied how the distribution of particles and liquids in the rumen was affected by the dry matter intake (DMI) and the time post feeding. A higher intake of feed DM resulted in increased mean particle length of particles and an increased proportion of particles (material retained on sieves ≥ 0.063 mm) in rumen DM content. However, the particle length in faeces was not affected by DMI even though the proportion of particles in faecal DM increased with increasing DMI.

Increasing intakes gave increasing particle DM weights (retained on sieves ≥0.125mm) in faeces from four-year-old Angler-Rotvieh steers (Kovács *et al.*, 1997). Particles contained more NDF and acid detergent fibre (ADF) at a high intake (12.04 kg DM day$^{-1}$) compared to a medium intake (9.03 kg DM day$^{-1}$).

According to Mgbeahuruike (2007) increased intakes of starch in the form of concentrates or in the total diet will increase the number of long particles (>1cm) in the faeces of early lactation dairy cows. Faecal DM increases with increasing intakes of concentrates and, thus, higher forage intakes give lower faecal DM (Mgbeahuruike, 2007).

In an experiment done by Hessle *et al.* (2008) faecal traits of newly weaned dairy calves and dairy steers with an initial LW of about 350-400 kg receiving soya bean meal or cold-pressed hempseed cake as a protein feed was studied. For the calves it was found that the diet containing hempseed cake gave fewer particles (>10 mm) 100 g$^{-1}$ faeces and a lower proportion of barley kernels 100 g$^{-1}$ DM than in faeces from calves fed soya bean meal. Steers had fewer particles 100 g$^{-1}$ faeces and a lower proportion of particles in faecal DM when they had been fed cold-pressed hempseed cake instead of soya bean meal (Hessle *et al.*, 2008).

## Protein feeds

There are several protein feeds used in cattle production and they all have their advantages and disadvantages. Table 1 shows the nutrient content of some protein feeds that will be mentioned later in the text.

**Table 1.** *Approximate values on the nutrient content (kg$^{-1}$ DM) of soya bean meal, wheat dried distiller's grains with solubles, cold-pressed rapeseed cake, peas, field beans, cold-pressed hempseed cake and blue lupine*

| | DM (%) | ME (MJ) | CP (g) | NDF (g) | AAT (g) | Source |
|---|---|---|---|---|---|---|
| Soya bean meal | 87 | 14.6 | 510 | 95 | 182 | Spörndly, 2003 |
| Dried distiller's grains with solubles | 90 | 13.3 | 320 | 270 | 116 | Spörndly, 2003 |
| Cold-pressed rapeseed cake | 91 | 16.7 | 275 | 215 | 82 | Johansson and Nadeau, 2006 |
| Peas | 87 | 13.8 | 226 | 100 | 97 | Spörndly, 2003 |
| Field beans | 76 | 12.9 | 273 | - | 79 | Spörndly, 2003 |
| Cold-pressed hempseed cake | 89 | 12.1 | 385 | 449 | 77 | Eriksson, 2007 |
| Blue lupine | - | 13.5 | 332 | 239 | 127 | Eriksson *et al.* 2010 |

**Soya bean (*Glysine max*)**

Soya beans are usually fed to animals in the form of a meal which is the by-product produced when extracting the oil. Chemical extraction is however not approved in organic production (EU Council Regulation, 1999). It is also possible to feed the soya beans whole, crushed, grinded or rolled (Harris, 1990).

In Sweden there have been some experimental harvests with different varieties of soya beans. Picture 1 show a field planted with soya beans in Öland, Sweden. The yield has been around 1-3 tonnes of DM per hectare which is normal worldwide. The protein content has been as good as in imported soya beans with around 400 g CP $kg^{-1}$ DM of whole beans (F. Fogelberg, pers. comm.).

Picture 1. Field planted with soya beans in Öland, Sweden (Fogelberg, 2006).

In the future it is likely that there will be a production of soya beans in the south of Sweden. The possibility to use the same equipment as for other crops grown in Sweden increases the probability of a production in the future. However, pods placed close to the ground can make the harvest difficult (Picture 2). Soya beans do not share diseases with peas but one should be careful with including rapeseed in the crop rotation. Problems in the experimental fields have been that birds have eaten the seeds (F. Fogelberg, pers. comm.).

Picture 2. Soya bean plants with pods from a field in Öland, Sweden (Fogelberg, 2006).

### *Nutritional value*

The content of CP is higher in soya beans compared to peas, whole rapeseeds or rapeseed cake (Spörndly, 2003). Different soya bean products differ in their nutrient content and soya bean meal (SBM) contain more CP than whole soya beans. Heating of the soya beans or the SBM usually increases the content of rumen-undegradable protein (Harris, 1990; Penn State, 2011).

Raw soya beans contain several anti-nutritional substances that can cause thyroid damages or allergic reactions. Protease inhibitors can cause impaired growth if the soya bean is fed raw or as unheated meal (McDonald *et al.*, 2002). In ruminants however, anti-nutritional substances are not a big problem because the rumen micro-organisms are able to degrade them to less harmful substances and, therefore, roasting of the soya beans are not necessary (McDonald *et al.*, 2002; Penn State, 2011). However, calves younger than four months can be sensitive and should therefore not be fed raw soya beans (Penn State, 2011).

### *Effects on production*

In a study by Veira *et al.* (1990) Shorthorn and Simmental crossbred beef steers, with an initial LW of around 250 kg, obtained an ADG of 0.95 kg when the grass silage diet was supplemented with SBM. However, that did not differ significantly from the ADG of 0.83 kg and 0.98 kg that was obtained on silage only or when supplemented with fish meal.

Hilton *et al.* (1932) conducted two trials studying growth and feed intake of dairy breed calves fed either ground soya beans or linseed meal as a protein supplement in their ration. At the start of the first trial the calves had an average age of 64 days and in the second trial the average age was 89 days at the start. Up to 90 days of age the calves were fed whole milk and thereafter lucerne hay and a grain ration containing either 18,5% linseed meal or 15,7% ground soya beans. The protein content was 162 g $kg^{-1}$ DM for the linseed oilmeal ration and 164 g $kg^{-1}$ DM for the ration with ground soya beans. The average ADG was 0.58 kg, both for calves receiving ground soya beans and for calves receiving linseed meal. Also the FE was similar for both protein feeds and was around 164 g $kg^{-1}$.

Concentrate starters differing in protein sources was studied by Claypool *et al.* (1985). All starters contained the same amount of CP (16.0%) and digestible nutrients and the protein sources used were cottonseed meal, soya bean meal and canola meal. The study was conducted on 45 dayold Holstein calves which were weaned at 8 weeks of age. There were no differences in consumption of starter or ADG among the different treatments. The ADG was around 0.61 kg for the preweaning period and roughly 0.90 kg for the 8 weeks postweaning period that was studied.

A comparison of soya bean meal and canola meal as protein supplement in diets for Charolais crossbred steers was done by Nelson and Landblom (1990). The starting weight was over 300 kg for the animals and the CP content in the rations was accordning to recommendations given by the National Research Council (NRC). The feed rations contained about 80% concentrates and at the start the content of CP in the rations was 10.8% and when steers reached approx. 408 kg it was changed to 10.3%. The ADG and FE was 1.57 kg and 155g $kg^{-1}$ feed for soya bean meal fed steers and 1.66 kg and 154 g $kg^{-1}$ feed for canola meal fed steers and did not differ significantly between the treatments.

**Distiller's grains with solubles**

From the production of ethanol several co-products possible to use as animal feeds can be derived. Distiller's grains with solubles (DGS) and dried distiller's grains with solubles (DDGS) are the co-products mainly used in animal production and can be fed with similar effects on the production (Schingoethe *et al.*, 2009).

When making ethanol the raw material used is first milled into flour to which water and enzymes are added. After the enzymes have converted the starch to sugar yeast is added which ferments the sugar to alcohol and carbon dioxide. The alcohol is then separated from the mixture by distillation and the alcohol free residue is called stillage (Agroetanol, 2010). From the stillage it is possible to compose several co-products such as DGS, DDGS, thin stillage, distiller's grains and distiller's solubles (Akayezu *et al.*, 1998). Dried distiller's grains with solubles can be made either by drying of the whole stillage (Agroetanol, 2010) or by adding solubles from the thin stillage to the distiller's grains at drying (Akayezu *et al.*, 1998).

Ethanol can be produced from several different raw materials such as maize, barley and wheat (Akayezu *et al.*, 1998; Mustafa *et al.*, 2000; Lardy and Anderson, 2009; Agroetanol, 2010). In Sweden, wheat is the most commonly used raw material in ethanol production followed by triticale and barley (Agroetanol, 2010).

***Nutritional value***

The nutrient content of DDGS is influenced by the raw material used in the ethanol production due to the type of grain used (Akayezu *et al.*, 1998; Mustafa *et al.*, 2000; McKinnon and Belivaeu, 2007; Walter *et al.*, 2010) and the quality of the grains (Agroetanol, 2010; Belyea *et al.*, 2010). Differences in nutrient content of DDGS are often similar to that of the original grain used if the starch content is subtracted (McKinnon and Belivaeu, 2007; Schingoethe *et al.*, 2009). Drying method and the amount of solubles added also affect the nutritional value (Akayezu *et al.*, 1998).

Nutritional value of DDGS can vary between ethanol production plants but also within production plants (Spiehs *et al.*, 2002; Belyea *et al.*, 2010). The within production plant variation is due to variations between fermentation batches caused by dissimilarities in the processing conditions (Belyea *et al.*, 2010) and/or by different qualities of the maize (Belyea *et al.*, 2010) or grain used (Agroetanol, 2010).

A comparison of three different DDGS, containing 100%, 75% or 70% wheat and the rest maize, and canola meal was conducted by Boila and Ingalls (1994). Ruminal and post-ruminal degradation of DM, nitrogen and amino acids were studied on yearling Holstein steers. Inclusion of maize affected the ruminal degradability as did the content of acid detergent insoluble nitrogen (ADIN), which is the proportion of nitrogen in the acid detergent fibre fraction. DDGS made from a blend of 70% wheat and 30% maize with an ADIN content of 16% of the total N had the lowest ruminal digestibility followed by DDGS made from only wheat with an ADIN content of 9.7% of the total N. However, the 100% wheat DDGS had the highest disappearance of nitrogen and amino acids in the ileum while the DDGS containing highest levels of ADIN had the lowest (Boila and Ingalls, 1994). According to Nakamura *et al.* (1994) the ADIN content in non-forage protein sources is not a good indicator of the amount unavailable nitrogen. In their experiment, conducted on sheep, the ADIN content of different batches of DDG varied from 7.8-27.9% of the total N while the digestibility of the nitrogen was the same. Though, the ADIN content was higher in feeds that had been heat-damaged (Nakamura *et al.*, 1994). Phillips (2010) partly agrees with Nakamura *et al.* (1994) and declares that by-products from the distilling industry that have undergone long-lasting heating during the distilling process often contain lots of ADIN which is somewhat digestible.

***Effects on production***

Effects of DDGS on growth and performance of beef cattle have mostly been studied on feedlot animals that are around one year and weigh around 300 kg (e.g. Gibb *et al.*, 2008; Leupp *et al.*, 2009; Walter *et al.*, 2010). In these trials, growth promoters have been used so the ADG and FE obtained are not really comparable to those obtained under Swedish conditions were such substances are not allowed (Europa, 2011).

Gibb *et al.* (2008) replaced some of the steam-rolled barley with wheat-based DDGS in the diet, consisting of 85% barley, fed to finishing late maturing feedlot heifers. An inclusion of 60% of diet DM of DDGS had no effects on ADG, which was around 1.5 kg, but the FE was reduced due to increased daily DMI from 10.5 kg to 11.7 kg. The CP content was 327 g kg$^{-1}$ DM in the diet with 60% DDGS and 136 g kg$^{-1}$ in the diet without DDGS. When 20% of the diet DM consisted of DDGS the CP content was 200 g kg$^{-1}$ DM and the effects seen on performance during the finishing period (day 56-188 of the experiment) were negligible. Higher inclusions of DDGS in the diet reduced the energy content which might explain the higher DMI and lower FE. Diet digestibility was lower for the 60% DDGS diet with 69% digestibility compared to 76% in the steam-rolled barley diet. During day 1-55 of the experiment (backgrounding period) the diet contained a maximum of 40% barley and replacing all or half of the barley in the diet with DDGS had no effects on DMI, ADG or FE, which was around 6.74 kg day$^{-1}$, 0.93 kg and 135 g kg$^{-1}$ DM (Gibb *et al.*, 2008).

Ojowi *et al.* (1997) concluded that for growing and finishing cattle (feedlot) wheat-based wet distiller's grains is a good source of additional energy and protein. In their trial all experimental diets were formulated to contain the same amounts of energy and protein. Yearling beef steers were used in the experiment and their ADG was just above 1.30 kg.

Beef steers fed a diet with a DM content of maize DDGS of 30%, partially replacing dry-rolled maize, during growing or finishing period or both was studied by Leupp *et al.* (2009). All steers had a similar DMI, ADG, carcass characteristics and FE as the control animals. The control diets during the growing period contained roughly 50% dry-rolled maize and equal amounts of grass hay and maize silage and had a CP content of 128 g $kg^{-1}$ DM compared to 179 g $kg^{-1}$ DM in the experimental diet. During the finishing period the diet contained about 80% dry-rolled maize and had a CP content of 161 g $kg^{-1}$ DM while the experimental diet contained 227 g CP $kg^{-1}$ DM (Leupp *et al.*, 2009). Larson *et al.* (1993) observed an improved FE when feeding crossbred steer calves with wet maize distiller's grains and thin stillage up to 40% of diet DM. The calves had initial live weights around 274 kg and the FE was 185 g $kg^{-1}$ DM in the group receiving 40% by-products while it was 155 g $kg^{-1}$ DM in the control diet (Larson *et al.*, 1993).

Carcass characteristics and performance of crossbred beef steers, finished in a feedlot, fed wheat or maize DDGS were studied by Walter *et al.* (2010). No negative effects were seen on the carcass characteristics when dietary DM contained up to 40% wheat or maize DDGS, partially replacing rolled barley. The CP content in the diets varied between 121 and 209 g $kg^{-1}$ DM. There was however some differences in performance between steers fed wheat DDGS and steers fed maize DDGS. Increased amounts of wheat DDGS gave higher DMI while increasing amounts of maize DDGS decreased DMI compared to the control diet. The ADG, which was approximately 1.66 kg, was not affected statistically but steers fed wheat DDGS had less days on feed but a lower FE than steers fed maize DDGS. The FE of the steers receiving 40% maize DDGS was 192 g LWG $kg^{-1}$ DM and FE for the control steers was 156 g $kg^{-1}$ DM (Walter *et al.*, 2010).

### Rapeseed (*Brassica napus*)

Rapeseeds can be fed as whole seeds (crushed or grinded), as cake where the oil has been pressed out or as meal where a solvent has been used to extract the oil (McDonald *et al.*, 2002). The rapeseed meal (RSM) can be heat-treated to get more rumen-undegradable protein (Foderdirekt, 2010). Compared to soya bean meal, rapeseed meal contains more fibres and less energy, has a slightly lower digestibility but a better amino acid profile. It is possible to use rapeseed meal as the sole protein feed for ruminants (McDonald *et al.*, 2002). For dairy cows, cold-pressed rapeseed cake can be used as the main protein feed without decreasing the milk production (Johansson and Nadeau, 2006).

The use of rapeseed as an animal feed has been limited due to the content of glucosinolates and erucic acid which can damage e.g. the liver and the thyroid gland. The erucic acid is to some extent disappearing with the oil if the seeds are pressed or extracted. For ruminants the content of glucosinulates is a smaller problem than for monogastric animals. Today there are varieties of rape grown that contain much less of both erucic acid and glucosinolates than before (McDonald *et al.*, 2002). Olsson (1987) replaced soya bean meal in the concentrate with 12% RSM and fed to bull calves of the Swedish Red Breed in a diet where concentrate was fed *ad lib.* No negative effects were seen on ADG and feed conversion (FC) but the thyroid glands had a higher weight at slaughter, which was thought to be an effect of the high glucosinolate level in the RSM used (Olsson, 1987). In growing dairy breed bulls older than 6.5 months fed a TMR containing grass silage and rolled barley inclusion of rapeseed meal had no effect on animal performance (Huuskonen *et al.*, 2007).

For the farmer rapeseed is a good crop in a crop rotation because it does not share any soil bound pests or diseases with cereals. However, rape seed should not be grown more often than every fourth year because of the risk for pests and diseases of which many are common with peas, beans, linseed and sugar beets. To make sure to keep a low level of glucosinolates it is preferable to sow rape seeds in soils with low contents of sulphur. (Soffe, 2003)

### Other protein feeds possible to grow in Sweden

#### ***Peas (****Pisum sativum****)***

Peas contain less CP and crude fibre than field beans though the peas have a better amino acid profile with higher levels of lysine, methionine and cysteine. They also contain more starch than field beans, which also makes it possible to use peas as an energy crop. The quite high content of energy in peas makes it possible to include up to 40% in the diet, although that is not very common (McDonald *et al.*, 2002). Calves of Swedish Red Breed (130 kg LW) fed concentrate *ad libitum* had the same LWG and FC when soya bean meal (9% of concentrate) was replaced by peas (25%). However the thyroid glands were bigger at slaughter and the calves had a higher deposition of fat although a shorter rearing period (Olsson, 1987).

Due to the susceptibility to pests and diseases, peas should not be grown more often than every fifth year. Several legumes and *brassicas*, such as beans and rape seed, share diseases and pest with peas, which is important to consider in the crop rotation. Fertilizing with nitrogen is not necessary because peas are able to fixate air nitrogen (Soffe, 2003).

#### ***Field beans (****Vicia faba****)***

Field beans are a good source of protein for ruminants and can also be used as a source of energy, though the energy content is lower than in peas. Compared to cereals, field beans contain relatively high amounts of fibres. Already calves at early ages can be fed field beans and when the calves have passed the age of three months the amount can be increased to about 25% of feed DM, though such high amounts are not commonly fed. It is possible to feed field beans as whole seeds but usually they are crushed before feeding. (McDonald *et al.*, 2002)

#### ***Hemp (****Cannabis sativa****)***

In Sweden it has been illegal to grow hemp due to its content of the narcotic substance tetrahydrocannabiol (Svennerstedt and Svensson, 2004). Today there are varieties legal to grow with low content of the narcotic substance that are also possible to separate from the ones with higher amounts (The Swedish Board of Agriculture, 2010c). Hemp is quite easy to grow; it is a good competitor against weeds and need little input from the farmer (Soffe, 2003). Hemp can be grown either for its fibres or for the oil content of the seeds (Holstmark, 2006).

Hessle *et al.* (2008) studied the performance of weaned calves and yearling steers of dairy breed when hempseed cake was offered as a protein feed instead of SBM in diets balanced for energy and CP content. No differences in ADG or FE were found between the test animals and the control animals. The ADG and FE was around 1.31 kg and 302 g LWG $kg^{-1}$ DM for the calves and 1.22 kg and 111 g LWG $kg^{-1}$ DM for the steers.

***Lupine***

There are several varieties of lupines and a number of these should not be given as animal feed due to their content of toxic alkaloids. To avoid problems the alkaloid content should be less than 0.6 g $kg^{-1}$. Lupines are usually crushed before feeding but cannot be stored as crushed seeds for very long time because of risks for oxidation of the oil if not an antioxidant is used (McDonald *et al.*, 2002). For blue lupine grown in Sweden the CP content have been around 330 g $kg^{-1}$ DM and the energy content approximately 13.5 MJ $kg^{-1}$ DM (Eriksson *et al.* 2010).

# MATERIALS AND METHODS

## Experimental design

The experiment was carried out at Götala Beef and Sheep Research Station, Swedish University of Agricultural Sciences (SLU), Skara, Sweden, between November 25, 2009 and April 15, 2010. Dairy bull calves were used in a completely randomized design. The effects of protein feed on feed intake, live weight gain, feed utilisation and faecal traits were investigated. The three protein feeds studied were imported soya bean meal (SBM), Swedish grown rolled soya beans (SSB) and dried distiller's grains with solubles (DDGS). The feed intake, feed utilisation and faecal traits were recorded at pen level with pen as the experimental unit while live weight gain was recorded on the individuals with animal as the experimental unit. There were seven animals in each pen and four pens per treatment.

## Animals and housing

For the experiment 84 purebred (38 Swedish Red and 40 Swedish Holstein) and 6 crossbred bull calves were purchased but there was a reduction of the number of animals due to two deaths unrelated to the experimental circumstances. The calves were housed in an uninsulated barn with pens with deep straw bedding at one end and a scraped floor at the other end of the pen, where also the feeding troughs were situated. The animals had free access to water and salt in each pen.

Shortly after the arrival to Götala, calves were weighed and randomly assigned to the three different treatments with the mean initial live weights of the calves for each treatment to be approximately the same. Breed was not considered when the calves were assigned to the different treatments. For each treatment the calves were split into four pens with similar mean live weights between pens. An eight day adaption period to the experimental diets prior to the experimental start was conducted by all calves. The calves averaged 93 (standard deviation, SD, 13) kg in live weight and 2.9 (SD, 0.7) months of age at the start of the experiment. At the end the calves had reached an average weight of 271 (SD, 28) kg and an average age of 7.5 (SD, 0.7) months. Calves were weighed at two consecutive days at the start and at the end of the experiment and in between once every 14 days during the experimental period. Average daily live weight gain (ADG) of the calves was calculated using the average weight from the two consecutive days at the start and the end of the experiment.

## Feeds and diets

A total mixed ration (TMR) consisting of a grass/clover silage, rolled barley and sufficient amounts of minerals (according to Swedish recommendations) together with either SBM, SSB or DDGS was fed to the calves. The silage proportion in the diets was 56%, 47% and 48% of total DMI for the diets including SBM, DDGS and SSB (Table 4). The silage consisted of approximately 90% grass and 10% clover and was grown at Götala. Herbage was wilted to about 25% DM before ensiling and an additive containing formic acid, propionic acid, formiate and ammonia was used (Promyr NT 570®, Perstorp inc., Perstorp, Sweden). The DDGS was manufactured by Agroetanol, an ethanol plant in Norrköping (Lantmännen AB, Norrköping, Sweden) and the SSB was grown in Skåne and Öland, south Sweden. The SBM was purchased from Lantmännen Feeds, Sweden.

Feed was offered *ad libitum* and feeding was done once a day. The feed was weighed before every feeding and refusals were weighed three times a week to ensure *ad libitum* intake which was considered as >5% refusals. The diet was balanced for an average daily gain (ADG) of 900 g $dag^{-1}$ according to Swedish recommendations (Spörndly *et al.*, 2003). When balancing the diets for similar nutrient compositions firstly the contents of crude protein and amino acids absorbed in the small intestine (AAT) were considered and thereafter the energy content. During the experimental time the diets were rebalanced four times because the nutrient requirements of the calves change as they grow. The diets were balanced for the weight intervals 75-125 kg, 126-175 kg, 176-225 kg and 226-275 kg. To be able to fulfil the recommended protein requirements (Spörndly *et al.*, 2003) of calves given DDGS and SSB, cold-pressed rapeseed cake was included in the diet until the calves reached an average live weight of 175 kg.

## Sampling and analysis of feeds

Samples of the silage were taken every day and then frozen. Once a week silage samples were thawed and composited for analysis of DM. For analyses of crude protein (CP), ash, neutral detergent fibre (NDF) and *in vitro* rumen organic matter digestibility, silage samples from each month were composited and sent to a laboratory (Eurofins Food & Agro Sweden AB, Lidköpng, Sweden). Analysis of fermentation characteristics was performed on one composited silage sample from the whole experimental period. Nutrient content and parameters for hygienic quality are shown in Table 2.

**Table 2.** *Chemical composition and fermentation characteristics of the silage used in the experiment*

| | Silage | SD | n |
|---|---|---|---|
| DM[1], % | 23.5 | 1.95 | 25 |
| Metabolizable energy, MJ $kg^{-1}$ DM | 11.6 | 0.33 | 4 |
| Crude protein, g $kg^{-1}$ DM | 152 | 9.0 | 4 |
| Ash, g $kg^{-1}$ DM | 65 | 3.7 | 4 |
| NDF[2], g $kg^{-1}$ DM | 524 | 20.4 | 4 |
| AAT[3], g $kg^{-1}$ DM | 74 | 1.0 | 4 |
| PBV[4], g $kg^{-1}$ DM | 26 | 7.1 | 4 |
| Ammonium-N, % of total N | 7.5 | - | 1 |
| Lactic acid, g $kg^{-1}$ DM | 113 | - | 1 |
| Acetic acid, g $kg^{-1}$ DM | 11 | - | 1 |
| Propionic acid, g $kg^{-1}$ DM | <0 | - | 1 |
| Butyric acid, g $kg^{-1}$ DM | 2.0 | - | 1 |
| Ethanol, g $kg^{-1}$ DM | 44 | - | 1 |
| pH | 4.2 | - | 1 |

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

All the protein feeds and the barley were sampled once a week and each feed composited once a month, except the barley which was composited once every second month, and sent for analysis of nutrient content together with the silage samples. The chemical composition of the barley and protein feeds are shown in Table 3. The DDGS contained 21% ADIN of total N.

**Table 3.** *Chemical composition of barley, cold-pressed rapeseed cake (CRC), soya bean meal (SBM), dried distiller's grains with solubles (DDGS) and Swedish rolled soya bean (SSB) used in the experiment, shown as means with standard deviations in parenthesis*

| | Barley n=3 | CRC n=5 | SBM n=5 | DDGS n=5 | SSB n=4 |
|---|---|---|---|---|---|
| DM[1], % | 86 (1) | 92 (1) | 87 (1) | 90 (0.5) | 82 (7) |
| ME[2], MJ $kg^{-1}$ DM | 13.3 (0.4) | 17.4 (1.3) | 14.7 (0.2) | 13.7 (0.1) | 15.6 (0.8) |
| Crude protein, g $kg^{-1}$ DM | 118 (11) | 296 (28) | 528 (6) | 349 (5) | 400 (18) |
| Crude fat, g $kg^{-1}$ DM | 34 (3) | 253 (53) | 31 (2) | 68 (1) | 158 (72) |
| Ash, g $kg^{-1}$ DM | 24 (2) | 57 (3) | 62 (3) | 49 (8) | 54 (2) |
| NDF[3], g $kg^{-1}$ DM | 197 (53) | 276 (30) | 115 (9) | 335 (24) | 138 (16) |
| Starch, g $kg^{-1}$ DM | 628 (19) | 20 (27) | 38 (53) | 25 (35) | 63 (49) |
| AAT[4], g $kg^{-1}$ DM | 91 (4) | 81 (6) | 193 (56) | 110 (12) | 108 (27) |
| PBV[5], g $kg^{-1}$ DM | -36 (9) | 174 (19) | 243 (75) | 173 (28) | 239 (55) |

[1]Dry matter
[2]Metabolisable energy
[3]Neutral detergent fibre
[4]Amino acids absorbed in the small intestine
[5]Protein balance in the rumen

The DM concentration of silage was determined by drying of the samples in 60°C for 24 hours while the DM content of the protein feeds and the barley was determined at 103 °C for 24 hours. Ash content of all samples was determined in 550°C for 5 hours. Before all the other analyses, all samples were dried and grinded. Metabolizable energy in the silage was determined from the value of organic matter soluble in rumen liquid (VOS, Lindgren, 1983) which was analysed *in vitro* according to Lindgren (1979). The content of ME in the protein feeds and the barley was calculated according to Axelsson (1941). The analysis of crude protein in all feed ingredients was done using the Kjeldahl method where the crude protein content was calculated from the value of total nitrogen. The method described by Madsen *et al.* (1995) was used to determine the PBV and AAT values. Content of NDF in the silage was determined according to Goering and Van Soest (1970) and for the barley and the protein feeds NDF content was determined according to Van Soest *et al.* (1991). Starch content in the barley and the protein feeds was analysed according to Larsson and Bengtsson (1983) and the content of crude fat was analysed according to the EU Council Directive (1998). In the silage also pH and content of ammonium-N (Tecator Kjeltec Auto sample system 1035 Analyser, Tecator Inc., Höganäs, Sweden), alcohol and organic acids were analysed (Andersson and Hedlund, 1983).

## Faecal analyses

One fresh faecal sample was collected from each pen on two consecutive days at the end of each of the four weight intervals. Samples were collected in each pen and frozen until further analyses were performed on thawed samples. When collecting the faeces the consistency was also determined visually on a scale from 1 – 5 with 0.5 units precision where 1 means very runny and 5 dry and hard like faeces from a horse (Steen, 2004; Appendix 1). From each pen the mean consistency score from two consecutive days were used in the statistical analysis.

For determination of DM in faeces, samples from two consecutive days in the same pen were thawed, pooled and mixed thoroughly before weighing 100 g into an aluminium dish. The aluminium dish was placed in 105°C for 24 hours and then it was weighed again.

When determining the content of whole and partial grains and long particles (> 10 mm) in the faecal matter, 100 g from pooled and mixed samples of fresh faeces from two consecutive days were weighed into a sieve with the pore size 2.36 mm. The sample was thereafter rinsed carefully in running tap water until the water was clear (Picture 3). After rinsing, the number of particles longer than 10 mm and whole and partial grains were recorded while they were collected with tweezers and put into separate aluminium dishes (Picture 4). The dishes were weighed after 24 hours in 105°C.


Picture 3. A sieve containing a rinsed 100 g faecal sample.


Picture 4. Particles longer than 10 mm and whole and partial grains from faeces placed in aluminium dishes.

## Statistical analyses

To compare the effects of the three protein feeds two different procedures in SAS (2003) were used. Analyses of feed intake, feed conversion (FC) and feed efficiency (FE) were done with the GLM procedure using the model:

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

Where **y** is the analysed parameter, **μ** is the average value, **α** is the effect of protein feed and **e** is the residual effect.

The MIXED procedure (SAS, 2003) was used for analyses of faecal traits and ADG.

The faecal traits were analysed on pen level with pen nested within treatment as a random effect and protein feed as a fixed effect. In the original model, the weight interval period was included in the model. However, a significant interaction between protein feed and weight interval period was found ($P < 0.05$). Consequently, faecal traits were analysed separately for each weight interval according to the model:

$$\mathbf{y_{ijk} = \mu + \alpha_{i} + \beta_{j(i)} + e_{ijk}}$$

Where **y** is the analysed parameter, **μ** is the average value, **α** is the effect of protein feed, **β** is the effect of pen nested within treatment and **e** is the residual effect.

The ADG was recorded on each individual nested within pen. The model used was:

$$\mathbf{y_{ijk} = \mu + \alpha_{i} + \beta_{j} + e_{ijk}}$$

Where **y** is the analysed parameter, **μ** is the average value, **α** is the effect of protein feed, **β** is the effect of pen and **e** is the residual effect.

Results with a *P*-value lower than 0.05 were considered as significant and results with *P*-values between 0.05 and 0.10 were considered as tendencies to significance.

# RESULTS

## Feed intake and growth

The average daily intakes of the different feed ingredients are shown in Table 4. In Table 5 the average nutrient contents of the diets, based on the average DMI, are shown. The SBM diet had a higher content of AAT but a lower content of PBV than the diets containing DDGS and SSB. Also, the content of ME was lower but the content of NDF was higher in the SBM diet than in the SSB diet. The diets containing SSB and DDGS had higher contents of crude fat than the SBM diet.

**Table 4.** *Average intakes (kg dry matter day$^{-1}$) with standard deviations in parenthesis of the different feed ingredients for bull calves fed diets containing either soya bean meal (SBM), dried distiller's grains with solubles (DDGS) or Swedish rolled soya bean (SSB) as protein feed*

| Feed | SBM | DDGS | SSB |
|---|---|---|---|
| Silage | 2.48 (0.05) | 2.26 (0.05) | 2.16 (0.05) |
| Barley | 1.68 (0.04) | 1.78 (0.08) | 1.78 (0.09) |
| Soya bean meal | 0.29 (0.01) | | |
| Swedish rolled soya bean | | | 0.44 (0.03) |
| Dried distiller's grains with solubles | | 0.63 (0.03) | |
| Cold-pressed rapeseed cake | | 0.13 (0.01) | 0.13 (0.01) |
| Total dry matter | 4.45 (1.23) | 4.81 (1.28) | 4.50 (1.10) |

**Table 5.** *Average nutrient contents with standard deviations in parenthesis of diets containing either soya bean meal (SBM), dried distiller's grains with solubles (DDGS) or Swedish rolled soya bean (SSB) as protein feed, based on the average daily dry matter intakes*

| | SBM | DDGS | SSB |
|---|---|---|---|
| Metabolizable energy, g kg$^{-1}$ DM | 12.5 (0.1) | 12.7 (0.3) | 12.9 (0.3) |
| Crude protein, g kg$^{-1}$DM | 168 (15.1) | 173 (17.3) | 171 (16.6) |
| Crude fat, g day$^{-1}$ | 115 (32) | 182 (22) | 204 (30) |
| NDF[3], g kg$^{-1}$ DM | 373 (16) | 371 (5) | 348 (13) |
| AAT[1], g MJ$^{-1}$ | 7.1 (0.3) | 6.7 (0.1) | 6.5 (0.1) |
| PBV[2], g day$^{-1}$ | 74 (26) | 125 (45) | 117 (45) |

[1]Amino acids absorbed in the small intestine
[2]Protein balance in the rumen
[3]Neutral detergent fibre

Calves fed DDGS had a higher ADG than calves fed SBM or SSB (Table 6). Feeding DDGS also gave higher intakes in kg day$^{-1}$ of NDF and crude protein compared to feeding SBM and SSB, which did not differ. There also was a tendency to a higher DM intake in kg day$^{-1}$ for the calves fed the DDGS compared to calves fed SBM or SSB. Calves fed SSB had a lower intake of NDF as a percentage of live weight than the calves fed SBM or DDGS. The FE did not differ between treatments.

**Table 6.** *Average daily live weight gain (ADG), feed efficiency (FE) and average daily intake of dry matter (DM), neutral detergent fibre (NDF) and metabolizable energy (ME) of bull calves fed diets containing either soya bean meal (SBM), dried distiller's grains with solubles (DDGS) or Swedish rolled soya bean (SSB) as protein feed. Values are shown as least square means with standard error of the means (SEM)*

| | SBM | DDGS | SSB | SEM | $P$ - value[1] |
|---|---|---|---|---|---|
| Intake of DM (kg day$^{-1}$) | 4.45$^{b}$ | 4.81$^{a}$ | 4.50$^{ab}$ | 0.098 | 0.058 |
| Intake of DM (% of live weight) | 2.67 | 2.72 | 2.61 | 0.036 | NS |
| Intake of NDF (kg day$^{-1}$) | 1.66$^{b}$ | 1.78$^{a}$ | 1.57$^{b}$ | 0.035 | ** |
| Intake of NDF (% of live weight) | 1.00$^{a}$ | 1.01$^{a}$ | 0.91$^{b}$ | 0.013 | *** |
| Intake of ME (MJ day$^{-1}$) | 55.5$^{b}$ | 60.9$^{a}$ | 57.7$^{ab}$ | 1.24 | * |
| Intake of crude protein (g day$^{-1}$) | 725$^{b}$ | 811$^{a}$ | 750$^{b}$ | 16.8 | * |
| ADG (kg) | 1.21$^{b}$ | 1.34$^{a}$ | 1.25$^{b}$ | 0.027 | ** |
| FE (g gain kg$^{-1}$ DM) | 274 | 282 | 278 | 2.7 | NS |
| FE (g gain MJ$^{-1}$ ME) | 22.0 | 22.2 | 21.7 | 0.21 | NS |

[1]* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, NS = not significant,
Values that have a tendency to differ ($0.05 < P < 0.10$) have their $P$-values written in the table
Values on the same row that are significantly different ($P < 0.05$) or tend to differ ($0.05 < P < 0.10$) are marked with different letters (a, b)

## Faecal traits

During the first weight interval of the experiment (76-125 kg) calves fed SBM had a more runny consistency and lower DM of their faeces than calves fed DDGS or SSB (Table 7). Faeces from calves in the SBM treatment contained more grains per 100 g than faeces from calves in the SSB treatment.

**Table 7.** *Faecal traits of bull calves fed diets containing either soya bean meal (SBM), dried distiller's grains with solubles (DDGS) or Swedish rolled soya bean (SSB) as protein feed, during the weight interval 76-125 kg*

| | SBM | DDGS | SSB | SEM | $P$-value[1] |
|---|---|---|---|---|---|
| Dry matter (%) | 13.9$^{b}$ | 17.5$^{a}$ | 17.0$^{a}$ | 0.54 | ** |
| Consistency | 2.94$^{b}$ | 4.00$^{a}$ | 4.00$^{a}$ | 0.036 | *** |
| Number of particles >10 mm (100 g$^{-1}$) | 40.7 | 27.8 | 31.2 | 3.81 | 0.096 |
| Number of grains (100 g$^{-1}$) | 4.49$^{a}$ | 1.50$^{ab}$ | 0.50$^{b}$ | 0.957 | * |
| Number of partial grains (100 g$^{-1}$) | 13.2 | 10.3 | 9.0 | 1.17 | 0.077 |
| Particles (% of DM) | 0.17 | 0.11 | 0.11 | 0.028 | NS |
| Grains (% of DM) | 0.87 | 0.21 | 0.15 | 0.200 | 0.058 |
| Partial grains (% of DM) | 0.57 | 0.45 | 0.33 | 0.084 | NS |
| Particles (g DM 100 g$^{-1}$) | 0.02 | 0.02 | 0.02 | 0.005 | NS |
| Grains (g DM 100 g$^{-1}$) | 0.12 | 0.04 | 0.03 | 0.030 | 0.084 |
| Partial grains (g DM 100 g$^{-1}$) | 0.08 | 0.08 | 0.06 | 0.012 | NS |

[1]* <0.05, ** <0.01, *** <0.001, NS = not significant,
Values on the same row that are significantly different ($P$ <0.05) are marked with different letters (a, b)
Values that have a tendency to differ (0.05< $P$ <0.10) have their $P$-values written in the table

There were no significant differences in faecal traits between the treatments during the second (126-175 kg) and third (176-225 kg) weight intervals of the experiment (Tables 8 and 9). There was, however, a tendency during the second weight interval that calves fed the DDGS had a higher grain dry weight per 100 g faeces and as percentage of faecal DM than calves fed the SSB (Table 8). When weighing between 126 and 175 kg calves offered DDGS tended to have a firmer consistency of their faeces than calves offered SBM.

**Table 8.** *Faecal traits of bull calves fed diets containing either soya bean meal (SBM), dried distiller's grains with solubles (DDGS) or Swedish rolled soya bean (SSB) as protein feed, during the weight interval 126-175 kg*

| | SBM | DDGS | SSB | SEM | *P*-value[1] |
|---|---|---|---|---|---|
| Dry matter (%) | 15.2 | 16.3 | 16.0 | 0.44 | NS |
| Consistency | 2.69 | 3.19 | 3.00 | 0.141 | 0.089 |
| Number of particles >10 mm (100 $g^{-1}$) | 54.2 | 50.9 | 50.4 | 7.46 | NS |
| Number of grains (100 $g^{-1}$) | 5.99 | 6.49 | 3.50 | 1.025 | NS |
| Number of partial grains (100 $g^{-1}$) | 9.2 | 10.5 | 12.7 | 1.94 | NS |
| Particles (% of DM) | 0.31 | 0.32 | 0.36 | 0.076 | NS |
| Grains (% of DM) | 1.08 | 1.47 | 0.73 | 0.200 | 0.078 |
| Partial grains (% of DM) | 0.41 | 0.50 | 0.58 | 0.138 | NS |
| Particles (g DM 100 $g^{-1}$) | 0.05 | 0.05 | 0.06 | 0.011 | NS |
| Grains (g DM 100 $g^{-1}$) | 0.16 | 0.24 | 0.12 | 0.031 | 0.067 |
| Partial grains (g DM 100 $g^{-1}$) | 0.06 | 0.08 | 0.09 | 0.020 | NS |

[1] NS = not significant,

Values that have a tendency to differ ($0.05< P <0.10$) have their *P*-values written in the table

**Table 9.** *Faecal traits of bull calves fed diets containing either soya bean meal (SBM), dried distiller's grains with solubles (DDGS) or Swedish rolled soya bean (SSB) as protein feed, during the weight interval 176-225 kg*

| | SBM | DDGS | SSB | SEM | *P*-value[1] |
|---|---|---|---|---|---|
| Dry matter (%) | 15.4 | 16.2 | 15.4 | 0.33 | NS |
| Consistency | 3.06 | 2.94 | 2.75 | 0.114 | NS |
| Number of particles >10 mm (100 $g^{-1}$) | 51.2 | 58.6 | 53.9 | 4.71 | NS |
| Number of grains (100 $g^{-1}$) | 4.00 | 8.48 | 6.74 | 1.595 | NS |
| Number of partial grains (100 $g^{-1}$) | 11.5 | 17.0 | 18.2 | 2.26 | NS |
| Particles (% of DM) | 0.30 | 0.37 | 0.39 | 0.051 | NS |
| Grains (% of DM) | 0.68 | 1.55 | 1.37 | 0.307 | NS |
| Partial grains (% of DM) | 0.43 | 0.67 | 0.72 | 0.121 | NS |
| Particles (g DM 100 $g^{-1}$) | 0.05 | 0.06 | 0.06 | 0.008 | NS |
| Grains (g DM 100 $g^{-1}$) | 0.10 | 0.25 | 0.21 | 0.047 | NS |
| Partial grains (g DM 100 $g^{-1}$) | 0.07 | 0.11 | 0.11 | 0.018 | NS |

[1] NS = not significant

During the weight interval of 226-275 kg, calves on the DDGS diet had a firmer consistency, a higher DM of faeces and a higher number of grains per 100 g than in faeces from the other calves (Table 10). There was also a tendency that feeding DDGS gave higher dry weight of grains per 100 g faeces than feeding SBM or SSB.

**Table 10.** *Faecal traits of bull calves fed diets containing either soya bean meal (SBM), dried distiller's grains with solubles (DDGS) or Swedish rolled soya bean (SSB) as protein feed, during the weight interval 226-275 kg*

| | SBM | DDGS | SSB | SEM | *P*-value[1] |
|---|---|---|---|---|---|
| Dry matter (%) | $14.4^{b}$ | $16.0^{a}$ | $15.0^{b}$ | 0.26 | ** |
| Consistency | $2.88^{b}$ | $3.19^{a}$ | $2.75^{b}$ | 0.055 | *** |
| Number of particles >10 mm (100 $g^{-1}$) | 38.0 | 60.6 | 43.7 | 8.63 | NS |
| Number of grains (100 $g^{-1}$) | $5.75^{b}$ | $9.73^{a}$ | $5.74^{b}$ | 0.887 | * |
| Number of partial grains (100 $g^{-1}$) | 9.5 | 13.2 | 11.2 | 1.87 | NS |
| Particles (% of DM) | 0.30 | 0.38 | 0.31 | 0.080 | NS |
| Grains (% of DM) | 1.13 | 1.54 | 1.00 | 0.171 | NS |
| Partial grains (% of DM) | 0.48 | 0.51 | 0.49 | 0.103 | NS |
| Particles (g DM 100 $g^{-1}$) | 0.04 | 0.06 | 0.05 | 0.012 | NS |
| Grains (g DM 100 $g^{-1}$) | 0.16 | 0.25 | 0.15 | 0.026 | 0.053 |
| Partial grains (g DM 100 $g^{-1}$) | 0.07 | 0.08 | 0.07 | 0.015 | NS |

[1]* <0.05, ** <0.01, *** <0.001, NS = not significant,
Values on the same row that are significantly different (*P* <0.05) are marked with different letters (a, b)
Values that have a tendency to differ (0.05< *P* <0.10) have their *P*-values written in the table

# DISCUSSION

## Feed intake and growth

All calves had a higher ADG than expected from the diet formulation; however, the intakes of ME and CP were in accordance with Swedish recommendations for the ADG obtained (Spörndly, 2003). A probable reason for the higher ADG than the diet was balanced for is that the calves were fed *ad libitum* and had a higher than expected intake capacity. The ME concentration in the diets were higher than the lowest level that was used when balancing the diets which can explain the higher intake capacity.

Feeding DDGS gave the highest ADG but the FE was similar in all treatments. The similar FE is explained by the fact that calves fed the DDGS had higher intakes of CP and ME and a strong tendency for higher DM intake at the same time as they had a higher ADG than calves fed SBM. A higher DMI when feeding wheat DDGS has been observed by others (Gibb *et al.*, 2008; Walter *et al.*, 2010), but in those studies the DDGS was used as a replacement for barley. Also, the studies were performed on older animals fed rations containing 85% concentrates and with up to 40% DDGS in the diets, which is very different from the diets in the present experiment. The effect on FE is contradictory between studies: Gibb *et al.* (2008) observed that the FE was impaired when feeding DDGS compared to the 85% barley control diet while Walter *et al.* (2010) did not find any difference. However, in one of the studies heifers were used (Gibb *et al.*, 2008) and in the other steers (Walter *et al.*, 2010) and the feed rations contained more CP on average in the study done by Gibb *et al.* (2008). The diets in the trials performed by Gibb *et al.* (2008) and Walter *et al.* (2010) were not balanced to contain the same amounts of CP as was the case in the present experiment.

Even though the calves fed SBM had a higher content of AAT in their diet the calves on the other diets grew at similar or higher rates which were not expected. Since calves fed DDGS had higher intakes of energy and CP, of which more was rumen degradable, than SBM calves it is possible that the rumen microbes produced more microbial protein that can be enzymatically degraded and absorbed in the small intestine, resulting in a higher growth rate. Also, the higher intake in calves fed DDGS resulted in similar intakes of AAT between the SBM and DDGS fed calves. A higher production of microbial protein would support a higher growth rate since the main reason for the need of rumen-undegradable protein in young cattle is that the rumen microbes cannot synthesize sufficient amounts of protein (Phillips, 2010). This might also be the cause of the similar growth rates between calves fed SSB and SBM. Feeding energy and protein at the same time has been identified as a way to optimize the protein utilisation (Børsting *et al.*, 2003; Nadeau *et al.*, 2007). In the present study TMR feeding was used and thus energy and protein was offered simultaneously, which improved the utilisation of rumen degradable protein for synthesis of microbial protein, especially in the DDGS and SSB diets. The high ADIN concentration of DDGS should decrease the availability of important amino acids needed for optimizing growth rates of the calves fed the DDGS diet. However, this was apparently not the case in this study and leads us to discuss the possibilities that part of the ADIN in DDGS is digested and can be used by the calves as supported by results on sheep by Nakamuura *et al.* (1994).

Calves fed DDGS had the highest intakes of NDF per day and the intake of NDF as percentage of LW was higher for calves fed DDGS and SBM than for calves fed SSB. This is probably due to the higher content of NDF in the DDGS and SBM diets. It is not likely that NDF has limited the feed intake in this trial since calves fed DDGS had a higher NDF content in their diet than SSB calves and they still tended to consume more DM and they did consume more NDF. It has been proposed that NDF from e.g. DDGS is less limiting on feed intake than forage NDF (Allen, 2009) and since SBM calves had the highest content of silage in their diet that might have limited their feed intake.

## Faecal traits

Overall the faecal traits showed little or no differences between the treatments except for the consistency, DM content and number of grains $100g^{-1}$ and those differences were only observed in the weight intervals 76-125 kg and 226-275 kg, although tendencies for significance were found for the weight interval of 126-175 kg. The firmer consistency of the faeces from calves fed DDGS and SSB compared to calves fed SBM in the first weight interval and in faeces from calves fed DDGS compared to SBM calves in the second and fourth weight interval can partly be explained by a higher NDF intake, at least by the DDGS calves (Mgbeahuruike, 2006; Hessle *et al*., 2008;). In this experiment differences in consistency was accompanied by differences in faecal DM content, which has been observed before (Hessle *et al.,* 2008; Bligaard *et al.,* 2010).  A lose or runny consistency can indicate a disturbed rumen function with too high passage rates of the feed and therefore the rather firm consistency observed in all treatments in the present experiment indicated that the rumen functioned normally.

There were no significant differences between treatments in the number and dry weight of long particles (>10mm) in faeces. This can partly be explained by the fact that all calves where fed diets that resulted in similar long enough retention time of the digested feed in the rumen before the feed was passed through the intestinal tract (Hall, 2002). Number of grains in faeces differed between the treatments in the first (76-125kg) and in the last (226-275kg) weight interval but there is no clear explanation for this. In the first weight interval the highest number of grains was observed in the SBM treatment which also had the lowest DM and consistency points. On the contrary, the highest number of grains found in the last weight interval was found in the DDGS treatment with the highest DM and consistency points. In general, no obvious advantage or disadvantage of the treatments on faecal traits and, hence, rumen function could be observed.

## Future possibilities

The results show that it is possible to rear calves with DDGS or SSB as protein feed instead of SBM without negative effects on ADG, FE and rumen function. Which of the feeds that will be the most profitable to use will change with the market prices and might also be influenced by regulations and subsidies that deal with environmental issues. For Swedish organic beef producers, however, the use of DDGS is not an option as there is only one large scale producer of ethanol in Sweden (Agroetanol, 2010) and they do not produce organic DDGS.

It is probable that the production of soya beans in Sweden will increase, since experimental harvests have shown good results. However, in the northern parts of the country production will most likely not be possible and in the central part of Sweden production results may vary a lot (F. Fogelberg, pers. comm.). From an environmental view producing own soya beans or using DDGS as protein feed instead of imported SBM will reduce the use of energy for transportation (Wallmann *et al.*, 2010) and the deforestation of the rainforest. If a farm can reduce the use of commercial fertilizers and have an efficient utilisation of nitrogen, home-grown feeds are a good option for the environment and probably also for the economy. At animal level, efficient use of nitrogen can be obtained by synchronizing the feeding of proteins and energy and in that way optimize the efficiency of the rumen microbes (Børsting *et al.*, 2003).

As it has been shown in this experiment that a higher or similar ADG and similar FE can be obtained on diets containing locally produced DDGS or SSB compared to diets containing imported SBM it would be interesting to investigate how the nitrogen utilisation is affected. Then a similar experimental design could be used but instead of only measuring inputs of nutrients also the outputs in faeces and urine could be investigated. Another question that needs to be answered is if the results would be the same if the growth rates are higher or lower. There is a possibility that the differences between the treatments would be larger than in this experiment or that they would disappear. It would also be interesting to study nitrogen utilisation at a farm level with growing animals fed different protein feeds at different growth rates of the animals in a similar way that Wallmann *et al.* (2010) did on dairy cows.

## CONCLUSIONS

- Dairy bull calves can be fed DDGS and rolled soya bean grown in Sweden as protein feeds instead of imported soya bean meal without impairing ADG when cold-pressed rapeseed cake is included in the diet until the calves reach a LW of 175 kg. The DDGS can even improve the ADG, which can be related to higher intakes of DM, ME and crude protein.

- Calves fed DDGS had a higher growth rate than calves fed SBM at similar AAT intakes. This was probably caused by a higher intake of ME of calves fed DDGS resulting in a better utilisation of the higher content of rumen degradable proteins in the DDGS diet compared to the soya bean meal diet.

- Similar FE was obtained when feeding DDGS, Swedish rolled soya beans and soya bean meal.

- The diet with DDGS generally gave a firmer consistency than the diet with soya bean meal. However, the number of long (>10 mm) particles in faeces was similar for all diets which demonstrates that all protein feeds had similar retention times in the rumen with at good rumen function.

# SAMMANFATTNING

Nötköttsproduktionen i världen har ifrågasatts i Sverige på grund av sin negativa miljöpåverkan. Användningen av importerat sojamjöl som proteinfodermedel till svenska nötkreatur medför nedhuggning av regnskog och omfattande användning av bekämpningsmedel i de länder där sojabönorna odlas. Detta medför en ökning den negativa påverkan som nötköttsproduktionen har på miljön. Produktion av proteinfoder i Sverige skulle minska transporterna och nedhuggningen av regnskog. För ekologiska nötköttsproducenter är möjligheten att producera eget proteinfoder viktig då det kan vara svårt att få tag på ekologiskt proteinfoder på annat sätt. Den ekologiska produktionen av nötkött har under de senaste fem åren ökat i Sverige och kunskaperna om vilka proteinfodermedel som är möjliga att producera lokalt och använda med tillfredsställande resultat i ungdjursuppfödningen behöver utvecklas.

Syftet med studien var att jämföra foderintag, tillväxt, foderutnyttjande och vomfunktion hos mjölkraskalvar som utfodrats med agrodrank eller svenskodlad soja jämfört med importerat sojamjöl, som proteinfodermedel i en fullfoderblandning.

I försöket användes 84 tjurkalvar av mjölkras som efter en vägning vid försöksstart delades mellan de tre olika proteinbehandlingarna. Uppläggningen var ett fullständigt randomiserat försök. För varje behandling användes 4 boxar med 7 djur i varje box och totalt ingick 12 boxar i studien. Vid ankomst var medelvikten för kalvarna 93 (standardavvikelse, SD,13) kg och vid försökets slut 271 (SD, 28) kg. Vägning av kalvarna utfördes under två på varandra följande dagar i början och i slutet av försöket och däremellan var fjortonde dag.

Fullfoderblandningarna innehöll blandvallsensilage, krossat korn och tillräckliga mängder mineraler tillsammans med antingen importerat sojamjöl, agrodrank eller krossad svenskodlad sojaböna. Målsättningen var en tillväxt på 900 g per dag och när foderstaterna balanserades för liknande näringsinnehåll beaktades i första hand innehållet av råprotein och aminosyror absorberade i tunntarmen (AAT) och i andra hand innehållet av omsättbar energi. Eftersom behovet av protein i förhållande till energi ändras när kalvar växer balanserades foderstaterna om fyra gånger för viktintervallen 75-125 kg, 126-175 kg, 176-225 kg och 226-275 kg. I foderstaterna med agrodrank och krossad svenskodlad sojaböna tillsattes även kallpressad rapskaka upp till 175 kg vikt för att uppfylla behovet av råprotein och AAT enligt svenska rekommendationer.

Utfodring skedde en gång om dagen och i sådan mängd att fri tillgång uppnåddes (>5% rester). Fodret vägdes varje dag före utfodring och rester vägdes tre gånger per vecka och mängderna användes sedan för att beräkna kalvarnas konsumtion. Tillväxten per dag räknades fram utifrån medelvärdet av vikterna från de två första och de två sista vägningarna av kalvarna. Utifrån tillväxt och foderkonsumtion över hela försöksperioden beräknades kalvarnas fodereffektivitet. Vomfunktionen bedömdes utifrån träckens konsistens och innehåll av långa (>10 mm) partiklar, hela kärnor och delar av kärnor.

Den dagliga tillväxten var högre för kalvar utfodrade med agrodrank än för kalvar utfodrade med sojamjöl eller krossad sojaböna (1,34 kg jämfört med 1,21 kg och 1,25 kg per dag, $P < 0{,}01$). Kalvar som fått agrodrank tenderade också starkt att ha ett högre dagligt intag av torrsubstans (4,81 kg jämfört med 4,45 och 4,50 kg, $P = 0{,}058$) och de hade ett högre intag av råprotein än de andra kalvarna (811 g per dag jämfört med 725 g och 750 g,

*P* < 0,05). Fodereffektiviteten var lika för alla behandlingarna och låg runt 22 g $MJ^{-1}$ och 278 g $kg^{-1}$ torrsubstans. Effekten av proteinfodermedel på träckparametrarna varierade beroende på viktintervall men generellt hade kalvar utfodrade med agrodrank en fastare konsistens på sin träck än kalvar utfodrade med sojamjöl (*P*< 0,001). Antalet långa partiklar (>10 mm) i träcken var lika för alla behandlingar och visade på att retentionstiden i vommen var lika med en väl fungerande vom.

Utifrån resultaten drogs slutsatsen att svenskodlad krossad sojaböna eller agrodrank fungerar lika bra som proteinfodermedel som sojamjöl när kallpressad rapskaka inkluderas i foderstaten upp till 175 kg levande vikt. Slutsatsen stöds av det faktum att med agrodrank uppnåddes en högre tillväxt än med sojamjöl och med svenskodlad krossad sojaböna upnåddes samma tillväxt som med sojamjöl. Samtidigt var foderutnyttjande och vomfunktion lika mellan de olika proteinfodermedlen.

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## Personal communication

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**Appendix 1.** Scedule of 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. |

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