Lönsam produktion och användning av proteinfoder till mjölkkor i norra Sverige

Profitable production and use of protein feeds for dairy cows in Northern Sweden

Authors: (alphabetical order)

Helena Gidlund, Anne-Maj Gustavsson, Pekka Huhtanen, Sophie Krizsan, Emma Olsson, David Parsons, Johanna Wallsten.

Contributions of Authors

Helena Gidlund – Conducting the interview study for WP1. Modelling and writing for WP3.

Anne-Maj Gustavsson – Providing feedback on WP1 and WP2.

Pekka Huhtanen – Research approach and editing for WP3.

Sophie Krizsan – Research approach and editing for WP3.

Emma Olsson – Economic analysis of protein feeds, and writing for WP2.

David Parsons – Writing WP4. Compiling and editing the whole report.

Johanna Wallsten – Summarizing the interview study for WP1.

1 CONTENTS

Introduction 5
2 Potential protein feed crops in Northern Sweden (WP1) 6
2.1 WP1 Objective 6
2.2 Forage crops for protein 6
2.3 Threshed crops for protein 6
2.4 Interview study 7
3 Economic analysis of protein feeds (WP2) 10
3.1 WP2 Objective 10
3.2 Methods 10
3.3 Results 11
3.4 Concluding comments 13
4 Production responses of dairy cows fed with different protein feeds (WP3) 14
4.1 WP3 Objective 14
4.2 Introduction 14
4.3 Materials and Methods 14
4.4 Results 15
4.5 Discussion 18
5 WP4 A framework for a decision support tool for growing and feeding of protein crops at the farm level 20
5.1 WP4 Objective 20
5.2 Decision Support Tools 20
5.3 A decision support tool for growing and feeding of protein crops 21
5.4 Developing a whole-farm model 22
5.5 Adapting the Lypsikki model 23
5.6 Feasibility of developing a whole-farm DST 24
5.7 Conclusions 24
6 General concluding comments 26
6.1 Key conclusions 26
6.2 Recommendations for further research 26
6.3 Project Outputs 26
6.4 Acknowledgements 26
7 References 27
8 Appendices 29
8.1 Appendix 1. Economic Analysis of Protein Crops 29

8.2 Appendix 2. Feed data extracted from the CNCPS 6.5 database. 36
8.3 Appendix 3. Feed data extracted from the NorFor feed database............................. 38
8.4 Appendix 4. Replicating the WP3 analysis with NorFor 39

INTRODUCTION

Protein is the most expensive component in the diet of dairy cows. Protein supplements have consistently increased milk yield of dairy cows fed diets consisting of grass silage and grain. The prices of protein supplements are already high in organic milk production, and are predicted to increase in the future in conventional production. At some point, this would mean that the savings in feed costs is likely to be greater than the loss of milk income if protein supplement is excluded from diets. With increasing prices of protein feed, it makes it more interesting to look at the possibility of producing protein feed on the farm.

The goal of this project was to 1) compile available information about practical cultivation of protein crops in northern Sweden, 2) conduct an economic evaluation of the various protein crops and feeds, 3) compile information on the production response of cows fed with different protein sources, and 4) examine the possibility of developing a tool that can help researchers and advisors to find economic and environmentally sound solutions for protein production and feeding at the farm level.

2 Potential protein feed crops in Northern Sweden (WP1)

Protein in the diets of dairy cows can be divided into 2 categories; the basal protein components and the supplemental protein components. The majority of the basal protein comes from the forage part of the diet, and a smaller part from grain. Normally the supplemental protein comes from high protein yielding crops, such as beans or from by-products from oil seeds like rape seed or soy beans.

2.1 WP1 Objective

Compile available information about practical cultivation of protein crops in northern Sweden.

2.2 Forage crops for protein

The most important protein resource is the ley, as silage and pasture. The protein content in this feed varies with fertilisation level, mineralisation from soil, species composition and maturity at harvest. However, there are other forages that may provide protein to the diet as well. The most common of these include whole-crop forage of peas or faba beans. Other possibilities are whole-crops from lupins and vetch. Most of these crops are co-cultivated with different cereal species, which will reduce the protein content in the final forage, since the highest levels of protein are in the legumes. For example, compare crude protein (CP) levels from whole-crop oat silages in Wallsten (2005) and whole-crop pea/oat silages in Rondahl and Martinsson (2005).

Whole-crop forages should be allowed to mature quite late in the season in order to produce the best feed and highest yields (Rondahl and Martinsson 2005; Haag et al, 2008). However, this type of crop is often used when establishing new leys, and the farmers want to harvest early to give the leys more space and light by the end of the season. The resulting silage is often more of a green crop (grönfoder), without pods or grain than an actual whole-crop (with grain/peas/beans containing starch), and consequently has a feed value more similar to a ley. As an example, Ericson (2010) showed that faba beans should be harvested already around end of flowering to avoid lower production of the undersown leys the following year in Öjebyn, Umeå and Ås.

2.3 Threshed crops for protein

Northern Sweden is a big area, encompassing mountain regions, inland regions and coastal regions with different climates and variations in the seasons. However, in most cases the vegetation period for the whole region is still too short to successfully produce threshed spring sown protein crops, and the winter survival for winter crops is questionable in most places. With different cultivars and different managements there may be future possibilities for increased production of these crops. The more possible crops include turnip rape, peas, and in some places winter rape/turnip rape. Crops less likely to grow to full maturity are faba beans and lupins.

2.3.1 Turnip rape (rybs)

Turnip rape (*Brassica rapa*) is a spring sown oil seed, where some cultivars mature at a similar time to two-rowed barley in northern Sweden. It is therefore possible to grow to full maturity in many places, and the crop is already produced as far north as Norrbotten. The major problem with turnip rape (and rape seed) is the potential for diseases (klumprotsjukan) and for damage by insects (kålmal, rapsbagge). It should therefore not be cultivated on the same land more than 1 year in 6 (Bernes & Gustavsson, 2016; Fogelfors, 2015).

2.3.2 Peas

Peas (*Pisum sativum*) are most common as a whole-crop in combination with a cereal. In organic farming its nitrogen fixing abilities is extra valuable. Peas have a much higher starch content than many other protein feeds, which makes it a bit more of a challenge when composing the diets for cows. The peas are very susceptible to root diseases such as root rot (ärtrotröta), which can stay in the ground for a long time. Therefore, pea crops need to be rotated and not sown in pure stands more often than 1 every 7 years (Fogelfors, 2015).

2.3.3 Faba Beans

Faba beans (*Vicia faba*) have a higher protein concentration than peas, but the currently available cultivars mature too slowly to be threshed in northern Sweden. While peas are sensitive to lodging, faba beans are a more secure crop to grow. Faba beans may be more resistant to the root rot that affects peas, but they may still act as a host plant and help the fungus to persist (Fogelfors, 2015; Gustafsson et al 2013).

2.3.4 Lupins

Lupins include narrow-leafed lupins (*Lupinus angustifolius*), white lupins (*Lupinus albus*) and yellow lupins (*Lupinus luteus*). Narrow-leafed is the most commonly sown in Sweden, and has been bred for disease resistance, low alkaloid levels, and high harvest index (meaning lower levels of non-grain biomass). Lupins have a high protein content, and is an interesting crop for both humans and livestock; however, the current cultivars are too slow to reach full maturity in northern Sweden. Lupins might still be an option for whole-crops, but their lower biomass production is a limitation. In addition, because they are late maturing they are not well suited for under-sowing leys, at least not if the intention is to let the crop mature until there are pods (Gustafsson et al, 2013).

2.3.5 Hemp

Hempseed (*Cannabis sativa*) cake has previously been a potential feed that could be locally produced in northern Sweden. In a thesis from 2010, Linda Karlsson investigated the feed quality of hemp seed cake for ruminants. The protein content was found to be relatively high, but the NDF content was high, and it was to a large extent indigestible. Since the most promising cultivar was taken out of commission, the production of hemp is not currently a viable option. However, if new cultivars are permitted it will be an interesting crop for the future (Karlsson 2010).

2.4 Interview Study

2.4.1 Methods

An interview study was performed in autumn 2017, with the aim to investigate current and potential protein crops among active farmers and others involved in the agricultural industry. A total of 14 farmers and extentionists from Norrbotten, Västerbotten, Västernorrland, Jämtland, and Gävleborg counties participated, and the farms included both conventional and organic farms and both dairy and beef cattle farms. The interviews were done either in person or by phone. The participants were asked about the crops they grew, the crops they no longer grew, about the yield levels of their crops bad/normal/good years, how often a crop failed for its intended purpose and about their thoughts on future locally grown protein crops.

2.4.2 Farmer and extensionist opinions on protein crops

A full report in Swedish on the interview study can be found at the project website (www.slu.se/njv/protein-i-norr), but below is a summary of the most important results.

Some farmers said that they needed more land before they could think of starting to produce more crops (either threshed or whole-crop). Availability of land in relation to the number of livestock varies between farms, and it is this type of situation that a decision support tool could address (WP4).

2.4.3 Threshed crops

Turnip rape had a similar perceived risk for failure as barley grain, 1 year in 10 compared to barley's 0.7 years in 10. Peas on the other hand had an estimated average risk of failure of 5.2 of 10 years, with greater estimations of risk from northern areas. Only one person answered about the risk for threshed faba beans, classifying the risk of failure as 10 years out of 10.

Among the farmers that were interviewed, the most commonly cultivated protein crop was spring turnip rape. It was considered to be an interesting crop financially and not everyone who grows it feeds it to their own livestock, but prefer to sell it as a cash crop. The extra work of pressing the oil and storing it at the farm makes some producers hesitant to cultivate it. Some farmers feed it to cows as whole, crushed seeds with a good result, but mentioned that it limits how much can be fed, due to the high oil content, and it therefore reduces the amount of protein able to be added to the diet.

The generally accepted recommendation is to cultivate turnip rape no more frequently than every 7th year on the same land. Insects present a risk for turnip rape cultivation, and this is especially problematic for organic farmers. Farmers mentioned the concern of increased occurrence of insects if the area of cultivation increases, and the study done by Bernes and Gustavsson (2016) also found that some farmers already had experience of this.

Threshed peas are a crop that some farmers mentioned and some had tried, but the general consensus was that the security of cultivation was low, and the risk of crop failure high. Cultivating peas as a pure crop (rather than in a mixture with a cereal) increases the risk for lodging. One person mentioned that crimped ensiled peas would be interesting, but that better cultivars that focus less on high yield and more on reduced risk are needed. Pea is susceptibility to diseases, especially root rot, and farmers acknowledge the recommendation to cultivate it no more that every 7th year as pure stands on the same land. There is also a great risk with regard to migrating birds that eat the seeds in the spring, and both peas and the young pea shoots are attractive food.

No farmers that we interviewed cultivate threshed faba beans or lupins. Farmers and extensionists have experienced that these crops stand very little chance of maturing with current cultivars. This observation is supported by unofficial trials at Röbäcksdalen. One farmer mentioned an interest in cultivating hemp seed, however there are currently no cultivars that are both suited to Northern Sweden and are permitted to be grown.

2.4.4 Whole-crop silages

The most common forage beside leys was pea/cereal mixtures. They are often used when establishing new leys, and in this study there was no information added on forage quality or harvest maturity. Because of the importance of leys we can assume that many whole-crop silages were harvested earlier than recommended (as green forage/grönfoder). The protein level in whole-crop silages also depends on the proportion of legumes. This is hard to control or predict, and is affected by factors such as fertilisation rates, sowing rates, soil characteristics and weather conditions. Using high seeding rates for the legume can help, but is not a guarantee for high legume contents in the final crop. It is therefore debatable whether the whole-crop silages in this study should be considered a protein crop or not.

Some people chose not to cultivate peas, lupins or faba beans (for whole-crops) because they thought the price for the seeds didn't compensate for the (protein) quality of the silage. How this would change if the crop would be threshed is hard to say. It also depends on how the system with subsidies would be affected.

Growing whole-crop in pure stands (without an undersown ley) would allow the farmer to wait until a better maturity stage has been reached and the yield of the crops is higher. Rondahl and Martinsson (2005) found that the CP concentration of the pea/oat crop did not change much during pod maturity. However, there is also the limiting factor of land availability.

2.4.5 Yield of protein crops

The average estimated yields from the interviews were used together with other sources to provide the economic analysis (WP2) with a table of possible yields for a bad, good or average year (Table 1). We acknowledge the huge variation among farms in this large area, and thus the yields are approximations rather than exact figures.

Table 1 Estimated low, average, and high yields for protein crops in Northern Sweden.

Feed type	Yield (t dry matter/ha)		
	Low	Typical	High
Threshed			
Spring turnip rape	0.8	1.5	2.5
Peas	1	3	4.5
Whole-crop Silage			
Pea/cereal	3	4.5	6
Faba bean/cereal	3	4.5	6
Vetch/cereal	3	4.5	6
Narrow leafed lupin/cereal	2	3	4

3 ECONOMIC ANALYSIS OF PROTEIN FEEDS (WP2)

3.1 WP2 OBJECTIVE

Conduct an economic evaluation of the various protein crops and feeds.

3.2 METHODS

3.2.1 Data sources

Data on income and costs were collected from relevant production calculations and crop production advisors.

Agronomic and production data were collected from crop production advisors, compilations of productions costs for crop farming (such as “Produktionsgrenskalkyler för växtodling” and “Maskinkostnader”) and from research literature in the area. Research literature were used for the crops not so common in farming in northern Sweden and where market data were scarce or unavailable.

Incomes were based on market prices and figures for the threshed crops were collected from similar calculations or advisors. Calculations for threshed crops were only made for peas and turnip rape (rybs) because these are currently the only realistic threshed protein crops in Northern Sweden. The income price for the whole crop silage was based on the nutritive value and the energy content, in relation to grass silage. The prices are approximate and vary due to market fluctuations depending on demand and should therefore be considered with caution.

The concentration of CP in the crops was identified from research, feed analysis and crop information found in similar calculations. The level of CP varies depending on the growing season and the figure used is an estimation based on previous values. In whole crop silage, the CP also varies depending on the proportions of protein crop and cereal in the field at harvest.

The three levels of yield, low, medium and high, for each crop were identified from WP1.

3.2.2 Calculations

The cost of production was calculated for each crop at three yield levels. These figures can be compared with other protein sources used on farm, to determine whether farm production costs are higher than buying the protein supplement. Calculations were also made for the production cost per kg of dry matter and per kg of CP, enabling comparison between crops.

A comparison was made between the production cost of the crops and common protein feeds purchased in the region of northern Sweden: *Soya* and *Expro-00 (rapeseed meal)*. The prices for purchased feedstuffs were calculated from mean values from different feed companies and included appropriate transport costs.

A calculation tool was prepared for each crop to make it possible for farmers to insert their own values for growing the crops and make changes due to specific farm conditions. With this tool it is possible to change estimated yields, use of manure and price levels, and other inputs. The tool is based on the same assumptions and calculations already described. This tool will be updated on the project website (www.slu.se/njv/protein-i-norr).

3.2.3 Assumptions

The calculations were based on inputs and outputs for conventional growing of protein crops. The inputs (seed, weed control etc.) used in the calculations for each crop were estimated for the highest of the three presented yields. The variation in yields is then an effect of the growing conditions, such as weather, and the three different levels represent different possible outcomes in a growing season.

The whole crop silage needs > 70% of the protein crop in the mixture to be considered a protein feed. The seeding rates of the protein crop and cereal were based on pure stands and calculated as 70% of the seeds from the protein crop and 30% from the cereal crop. The botanical composition of the crop however, will vary at harvest.

The figures used for the machinery costs are assumed to be contracted and include fuel and driver. Thus, the costs for labour were included in the calculations. The machinery was calculated to be comparable between the crops, except when comparing the threshed crops with the whole crop silages.

The fertilizer levels were based on recommendations from the Swedish Agricultural Agency (Jordbruksverket) and were based on soil classification 3, with regarding phosphorus (P AL-klass) and potassium (K AL-klass). In the calculations no manure was included, due to the nutrient variation between farms and the fact that protein crops do not have a requirement for nitrogen from manure.

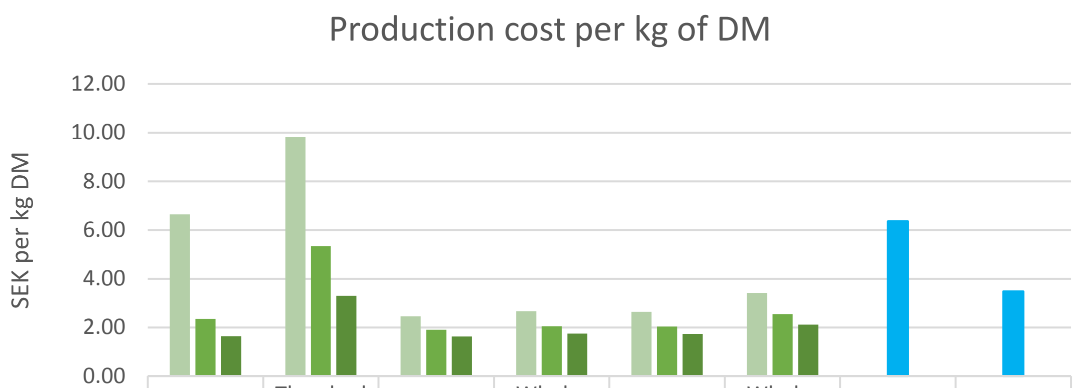
The whole crop silage was assumed to be ensilaged in round bales, as this was the most common way of storing the whole crops at the time when performing the calculations. For the threshed crops, a drying cost was calculated which assumes that the crop was harvested with a higher than optimal moisture content.

Costs for land or subsidies are not included in the calculations. The calculations were made per hectare and on a dry matter basis. Interest rate on working capital was set at 3% (reasonable at the time) calculated on 40% of the year, which is the estimated time of a year for a growing season.

Costs for storage or feeding (feeding preparation) were not included in the calculations due to variations on farm. This could be added in the extra spaces in the "farmer calculations".

3.3 Results

The full economic results for the protein crops are summarised in Appendix 1. Interactive versions of these spreadsheets are available from the project website (www.slu.se/njv/protein-i-norr).



Yield level	Threshed peas	Threshed turnip rape	Whole-crop peas	Whole-crop faba beans	Whole-crop vetch	Whole-crop lupins	Soya beans	Expro 00
Low	6.64	9.82	2.45	2.67	2.64	3.42		
Medium	2.35	5.34	1.90	2.05	2.03	2.55	6.36	3.48
High	1.64	3.29	1.63	1.74	1.73	2.11		

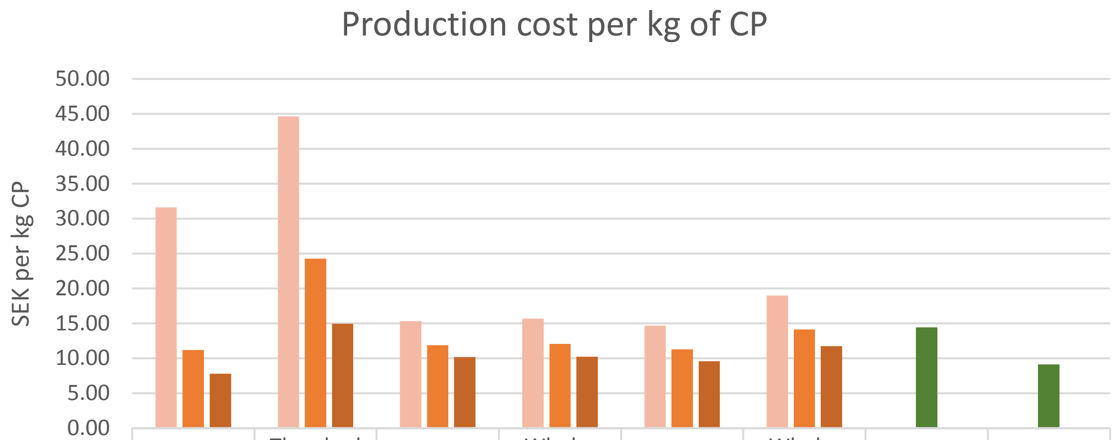
Figure 1 Production cost per kg of dry matter (DM) for protein crops

3.3.1 Threshed peas and threshed turnip rape

Threshed peas and turnip rape have high productions costs if the yields are low, due to high inputs and fixed costs (Figure 1). These crops need to reach the medium yield level to reach similar costs as for the whole-crop silages.

Threshed turnip rape has a higher cost level than threshed peas, due to its lower yield and similar costs of production; however, some costs may be lower such as transport and drying. The threshed turnip rape also differs from the other protein crops as it requires applied nitrogen. However, the income of the oil was not included in the calculations, and the economics of the crop would be more profitable if it had been included.

If the threshed crops reach medium yield levels, then they may be considered as potential protein crops when compared to conventional alternatives such as soybean and Expro-00. When the crops and protein feeds are compared on a cost per CP basis, both peas and turnip rape could be more profitable to grow if a medium yield is achieved for peas and a high yield is achieved for turnip rape (Figure 2). Again, the results for turnip rape do not include the value of the oil.



Yield level	Threshed peas	Threshed turnip rape	Whole-crop peas	Whole-crop faba beans	Whole-crop vetch	Whole-crop lupins	Soya beans	Expro 00
Low	31.61	44.63	15.31	15.70	14.69	18.98		
Medium	11.20	24.27	11.89	12.06	11.30	14.15	14.45	9.10
High	7.80	14.96	10.19	10.23	9.60	11.74		

Figure 2 Production cost per kg of crude protein (CP) for protein crops

3.3.2 Whole crop silage

Four different whole-crop silages were calculated and compared. In these calculations the whole crops have similar outcomes. However, there are small variations between the crops in total costs and when analysing the price per kg of CP.

Peas/oats has the lowest level of protein concentration of the whole-crop silages (16 %) which increases the costs for producing protein. It has a low variation in costs and yields, and is thus a relatively stable crop. Vetch/oats is similar to peas/oats with regards to low variability in yields and costs. It has the lowest production costs in terms of produced CP compared with the other whole crops, due its comparatively high level of crude protein. The 'level 1' costs (see Appendix 1) are slightly higher as the seeds are more expensive. Faba bean/spring wheat is similar to vetch/oats. It also has a higher cost for seeds, and is overall comparable to the other whole crops. Lupins/barley has a comparatively lower yield which make it costlier to produce per kg of dry matter. It typically has a high protein content, similar to vetch/oats, but as the yields are lower the costs per kg produced is higher than the other whole-crop silages. The ‘level 2’ costs are lower, due to lower yields and consequently lower costs for baling and transport.

Whole-crop silages compare favourably to purchased soya beans on a CP basis, even when yields are low. However, comparing on a CP basis is limited as it does not take into consideration the protein fractions or other characteristics of the feeds, which will be explored further in Chapter 4 (WP3). Expro-00 was generally cheaper on a CP basis than the whole-crop silage, regardless of yield; however, the cost of high yielding vetch/oats was similar to the cost of Expro-00.

For soybean to be replaced by a home-grown protein feed, the home-grown crop yield is important. When considering production per kg produced protein, it is in some cases more profitable to use whole crop protein. If the yields of the crops reach medium or high levels the costs for protein are higher when buying soybean than in the home-grown feed. If the yields are low in the whole crops it is a lower cost to buy soybean.

3.4 Concluding comments

- Comparing feeds on the basis of crude protein content does not consider the different protein fractions or their value for producing milk. This is addressed in Chapter 4 (WP3).
- The whole-crop silage combinations are common examples; however, they could feasibly be grown with other combinations of cereals. This would likely not have any large effect on productions costs (if commonly grown cereals are used).
- On farm variation should always be considered when calculating costs and yields levels.
- Purchased protein feed used is the most common bought in the region and the price and protein content is a mean value to reflect the region, these should be considered as a value for comparing in these calculations.
- Threshed peas and turnip rape appear to be costlier to produce in terms of CP; however, they are more easily sold than whole-crop silages.

4 PRODUCTION RESPONSES OF DAIRY COWS FED WITH DIFFERENT PROTEIN FEEDS (WP3)

4.1 WP3 OBJECTIVE

Compile information on the production response of cows fed with different protein sources.

4.2 INTRODUCTION

Feeding protein supplements accounts for a significant cost to the dairy farm, but is still advantageous because of the positive response in milk production. Production of protein feed on the farm can reduce the need for purchased feed. For Swedish farms, these protein feeds mainly include rapeseed, turnip rape, pea, faba beans, and lupins. However, in many parts of Sweden these crops are risky due to the threat of insect pests and the cooler climate reducing the likelihood of achieving maturity.

The main aim with work package 3 was to compile information how protein feeds of current interest for northern Sweden can increase milk production, and also to consider what knowledge we lack. The information how different protein feeds compare to each other in a feed ration should be used in the development of the protein tool comprised in work package 4. This was achieved by examining existing data from production studies and by estimating production responses with a feed evaluation program.

4.3 MATERIALS AND METHODS

4.3.1 Data collection from existing studies

Data from production studies, where rapeseed feeds, pea, faba bean, or no protein feed were compared at similar levels of dietary CP concentration, was collected and investigated. The studies were performed at our SLU-NJV and by scientists in Finland. Feed quality data was collected and compiled (see Appendix 2 and Appendix 3).

4.3.2 Estimation of production responses with Nordic feed evaluation systems

The potential milk production response of rapeseed meal, soybean, meal, pea, faba bean, and lupin were calculated using the Finnish feed evaluation system Lypsikki (Nousiainen et al. 2011). The most widely used feed evaluation system in Sweden is NorFor, and therefore we have made a comparison between NorFor and Lypsikki regarding milk production response to protein supplementation. To avoid any confounding effects between protein evaluation and other differences in the feed evaluation systems the comparison was performed using Lypsikki, but with NorFor values of AAT20 (table values) and efficient protein degradation (EPD; calculated from equations according to NorFor).The estimations were on the basis of a dairy cow of 650 kg of body weight, yielding 35 kg milk/day. The diet was based on silage and barley with metabolizable energy of 11,2 MJ/kg DM and 155 g of CP/kg DM. The protein feeds rapeseed meal, soybean meal, pea, faba bean, and lupin replaced barley in the diet. To test the effect of feeding more protein in the diet, low, medium and high levels of CP of 150, 170 and 190 g/kg DM were applied. A control diet without protein supplementation was also used in the predictions with a dietary CP concentration of 130 g/kg DM.

4.3.3 Economic evaluation of cost of alternative protein feeds

We also conducted an economic evaluation by using the optimization tool in Lypsikki. By successively lower the price of rapeseed meal it was investigated at what feed cost the feed evaluation program would stop choosing rapeseed meal in the diet and rather add pea, faba bean, lupin or soybean meal, respectively. Prices of rapeseed meal were set to between 2.60 and 5.00 SEK per kg DM. The program was set to estimate maximum value of milk income minus feed cost.

4.4 Results

4.4.1 Existing data from a few milk production studies

It is well established that an increase of CP from concentrate feed in the diet to dairy cows increase milk yield (Figure 3). In the figure the markers above the line (y=x) indicates the benefit of feeding protein feeds (y-axis) to dairy cows for increased production response, compared to feeding no protein feed (x-axis). Figure 4 indicates that rapeseed feed increases milk yield compared to pea and faba bean. The markers below the line (y=x) indicate the more efficient use of rapeseed feed into kg of energy corrected milk compared to pea or faba bean in the diet to dairy cows.

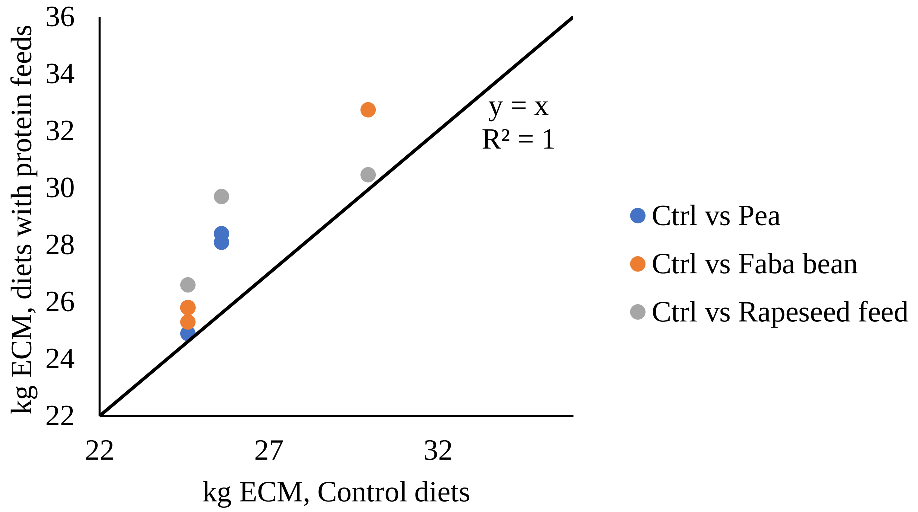


Figure 3 Production responses in kg of energy corrected milk (ECM) between inclusion of protein feeds or not in diets to dairy cows. Data comes from 3 different production trials (Ramin & Höjer, unpublished; Vanhatalo et al., 2004; 1 unpublished trial with courtesy of colleagues from Finland).

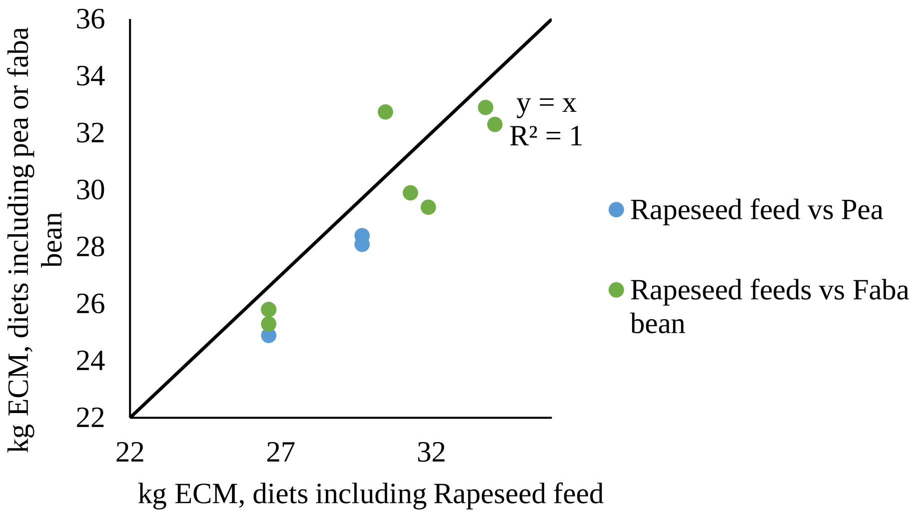


Figure 4 Production response in kg of energy corrected milk (ECM) compared on CP-basis between diets including rapeseed feeds or pea/faba bean in diets to dairy cows. Data comes from 4 different production trials (Ramin & Höjer, unpublished; Puhakka et al., 2016; Vanhatalo et al., 2004; 2 unpublished trials with courtesy of colleagues in Finland).

4.4.2 Estimation of production responses with Nordic feed evaluation systems

The comparison between estimation of production response between Lypsikki and NorFor shows that both programs follow the same linear estimation of production response (Figure 5), and that Lypsikki estimates a slightly greater response. Although the differences in response are slight between feeds and programs (Figure 6 and Figure 7), rapeseed meal comes out as the best protein feed, except with the highest CP concentration with NorFor estimation. NorFor estimates soybean meal to be the best protein feed at the highest level of CP. Lupin, pea, and faba bean are found similar at low and medium CP level, while the estimated production response are split a bit at the high CP level, especially with NorFor, and lupin a slightly higher estimation of ECM and pea slightly lower.

With both programs the increase in CP from the concentrate fraction of the diet decreases the marginal increase in ECM.

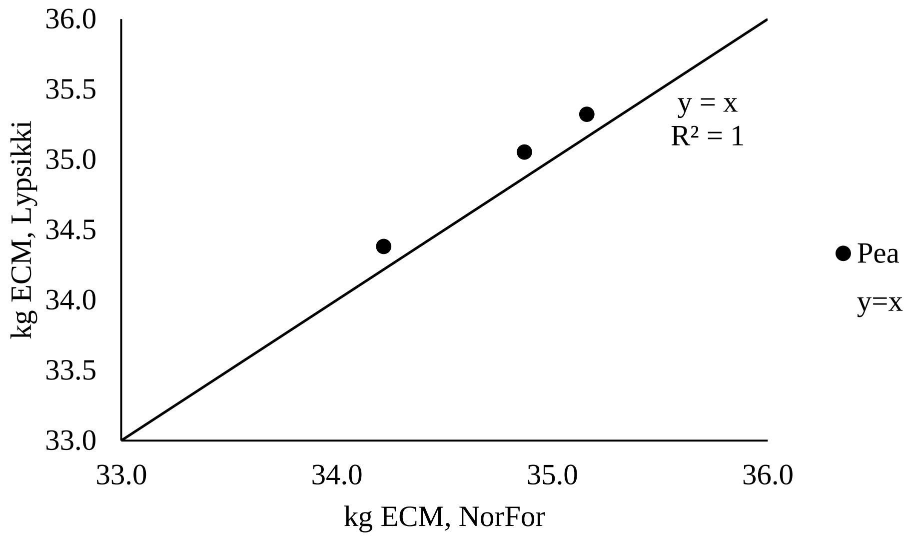


Figure 5 Comparison between the two feed evaluation programs Lypsikki and NorFor, and how they estimate yield in kg of energy corrected milk with the same diets containing pea as protein feed. The markers represent diets with linear increase in crude protein from including more peas as protein feed in the diet.

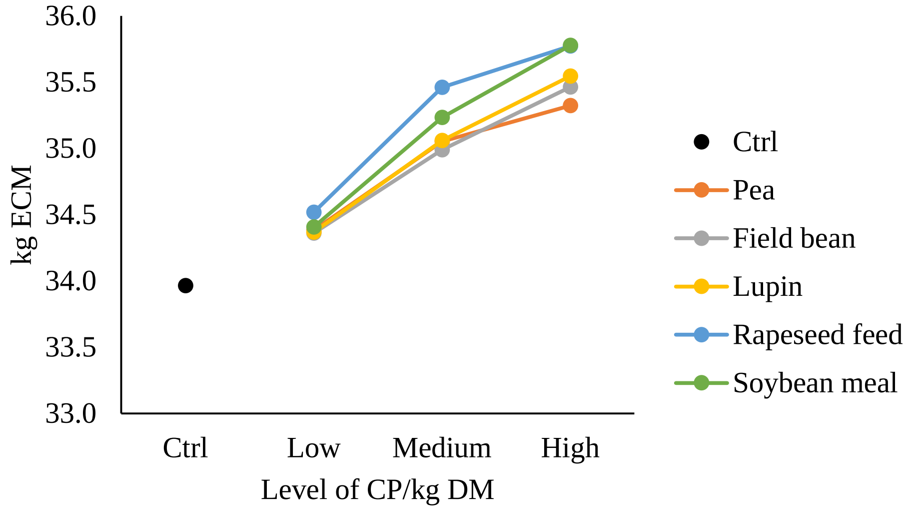


Figure 6 Lypsikki production response by dairy cows fed no protein supplement (Ctrl) or different protein feeds at three levels (low, medium and high of 150, 170 and 190 g CP/kg DM, respectively).

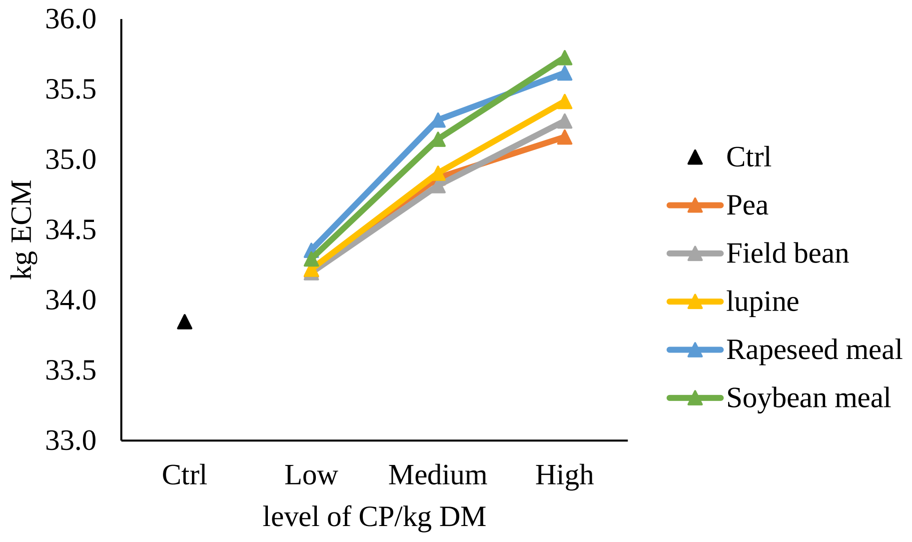


Figure 7 NorFor production response by dairy cows fed no protein supplement (Ctrl) or different protein feeds at three levels (low, medium and high of 150, 170 and 190 g CP/kg DM, respectively).

4.4.3 Economic evaluation of cost of alternative protein feeds

By giving rapeseed meal a range of costs (between 2,60 and 5,00 SEK/kg DM) in the Lypsikki feed evaluation program we get an estimation at what cost pea, faba beans, lupin and soybean meal would be an economic replacement. The production or purchase cost for pea, faba bean and lupin always needs to be lower than for rapeseed meal (Table 2). Even when the price of rapeseed meal nearly doubles, the alternative protein feeds still need to be very low for the program to include them in the feed ration to reach maximum value of milk minus feed.

Table 2 Cost (in SEK) of rapeseed meal and at what replacement cost of pea, faba bean, lupin and soybean meal the feed evaluation program Lypsikki calculates maximum value of milk minus feed.

SEK				
Rapeseed meal	**2,60**	**3,13**	**3,75**	**5,00**
Pea	2,08	2,19	2,19	2,29
Faba bean	2,19	2,19	2,19	2,40
Lupin	2,29	2,29	2,29	2,40
Soybean meal	3,23	4,38	5,63	7,92

4.5 Discussion

Rapeseed meal was clearly ranked highest in all comparisons, but with a declining response curve at the highest level of supplementation in the Nordic feed evaluation systems. These results were in agreement with the literature data. Also, the price estimation of alternative protein supplementation to dairy cows using the optimisation tool in Lypsikki indicated that it is not recommended to replace rapeseed meal with pea, faba bean or lupin in the diet of dairy cows.

We would like to know more about feeding of whole crop in different combinations with grass silage and how this can affect protein feeding of dairy cows with a whole farm perspective. For example, what mixes of crops should be used and how are they most efficiently combined with 1st, 2nd and 3rd cuts of grass and red clover silages of different quality?

Inclusion of whole crops in the crop rotation can improve the conditions for ley cultivation and handling of manure on farms. Whole crops can also be beneficial to include in the feed ration to dairy cows. Rondahl et al. (2007) showed that including pea-oat-silage in the feed ration based on grass silage reduced the need for concentrate by up to 3 kg/cow per day while maintaining milk yield. Mixing of cereal-silage with grass silage gave positive synergy effects and increases the consumption of forage by dairy cows (Huhtanen et al., 2007; Jaakkola et al., 2009). It is likely that this is also the case with mixing of legumes such as pea, faba bean and lupin, but this needs further investigation.

For more optimised protein feeding of dairy cows we should learn how to better optimize the flow of microbial protein to the small intestine, instead of buying more feed protein. An increased feed consumption increases the flow of microbial protein, optimises the actual production of microbes in the pre-stomachs, and thereby increases the amount of microbial protein. The microbes can maximise their production of new microbes if their access to energy and protein are synchronised. That kind of synchronisation is likely when grass and whole crop silage are mixed at feeding, since grass silage contains soluble nitrogen compounds and whole crop contains starch (quickly digested to energy) via cereal kernels.

5 WP4 A FRAMEWORK FOR A DECISION SUPPORT TOOL FOR GROWING AND FEEDING OF PROTEIN CROPS AT THE FARM LEVEL

5.1 WP4 OBJECTIVE

Examine the possibility of developing a tool that can help researchers and advisors to find economic and environmentally sound solutions for protein production and feeding at the farm level.

5.2 DECISION SUPPORT TOOLS

5.2.1 Models and decision support tools

We make a distinction between a model, which is a simplified, usually mathematical simulation of the real world, and a DST tool which is an application of the model, with an interface that allows the user to address real-world questions (Figure 8 The distinction between the model which performs the calculations and the decision support system with which the user interacts.Figure 8).

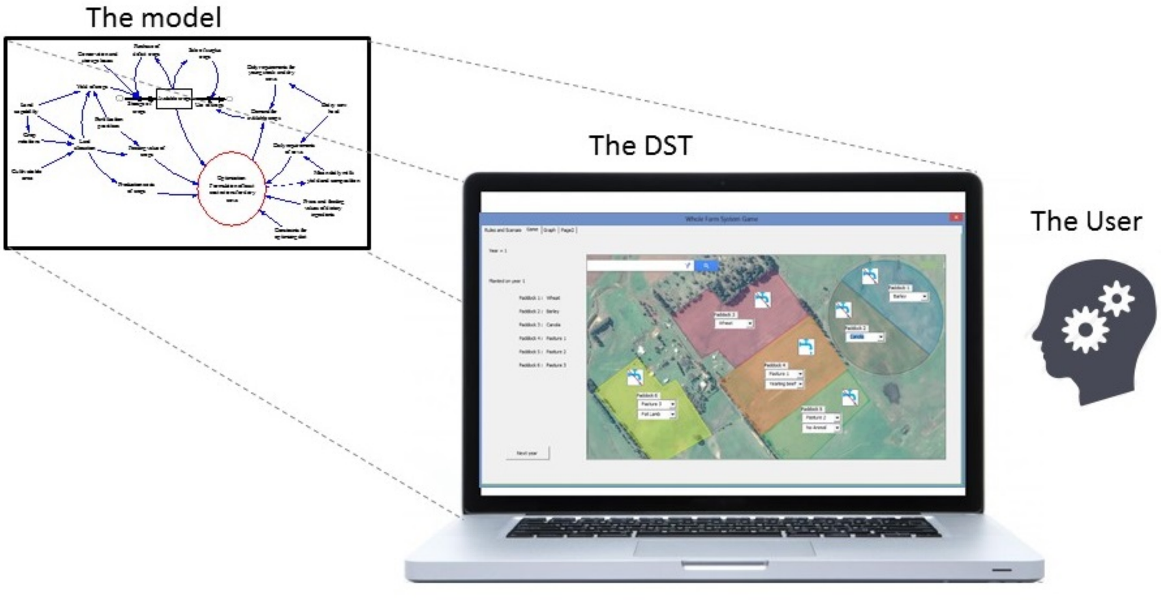


Figure 8 The distinction between the model which performs the calculations and the decision support system with which the user interacts.

Examples of whole-farm modelling tools have been developed to address questions at the farm scale (e.g. Rodriguez et al. 2006, Parsons et al. 2011, van Wijk et al. 2009). Such models have typically been developed by researchers, for researchers. They can be used, for example, to simulate productivity and natural resource management outcomes, or to evaluate trade-offs between cropping and farming system options that affect profitability and productivity in the short and longer term. Typically, they have not been developed for use by farmers, or even farm advisors, as they are complex to use and require considerable data for them to function realistically. In short, many whole farm models are not able to be used beyond the experts that created them.

5.2.2 Successful decision support tools

Decision support tools (DSTs) are designed to help the user make decisions, given a variety of options. The use of DST in agriculture is often discussed, and researchers and policy makers have good intentions to provide useful tools. However, the instances of successful decision support tools in agriculture are limited, and there are many potential reasons for this which are detailed in Rose et al., (2016).

The nature of a successful DST depends on the issue that it addresses. If the DST has a narrow scope and there is strong evidence of the accuracy of the decision, then a DST which gives *The Answer* can be effective. For example, the Vallprognos DST (http://www.vallprognos.se/) is effective because it focuses on a clearly defined question: 'When is it time to take the first ley harvest'. The answer is simple and quite accurate. In contrast, other DST address questions that are more complex and where there is less certainty in the information. In such cases, giving the answer is less useful. This may seem counter-intuitive because surely it is more important that we get the answer to complex questions. The problem is that often it is too difficult to know whether the answer is correct or understand why the answer is what it is. For this reason, Hochman & Carberry (2011) argue that DSTs should aim at developing farmers' intuition rather than replacing it with optimized recommendations. In this way, decision support tools essentially become learning tools, where the user can explore the implications of different options and in the process gain a better understanding of the problem and the potential implications of different management options. Decision Support Tools can also support joint learning among stakeholders (farmers, consultants, scientists, policy makers). An additional strategy for complex and uncertain systems is to focus on the direction and approximate magnitude of change between different scenarios, rather than focus on the absolute level.

Successful DSTs are also usually relatively simple to use. A computer-based DST where a lot of time is needed to parameterise it, or just to learn how to use the interface, presents a barrier to users. The simpler a DST is, the more likely it is to be used. This presents a problem for a DST that attempts to address the crop cultivation and feeding system for a whole farm.

5.3 A DECISION SUPPORT TOOL FOR GROWING AND FEEDING OF PROTEIN CROPS

Given the nature of decision support tools and whole farm models, we offer the following questions and responses in relation to a decision support tool for growing and feeding of protein crops. We make a distinction between the model that performs the calculations and the DST which uses the model and interfaces with the user.

What capability should the model have?

- The ability to specify crop rotations for different parts of the farm, and produce realistic yield and quality estimates. The model should also have capability to modify expected crop yields depending on their sequence in the rotation.
- Realistic animal production results resulting from feeding options.
- The crop production side of the model cannot focus only on producing crude protein, which by itself is a poor indicator of feeding value. This means that a useful model must include other determinants of forage quality.
- Feeds derived from on-farm crop production need to be assessed using a robust animal production model.
- The decision to produce protein crops is not just related to animal production. There are other benefits related to having more diverse cropping rotations, such as nitrogen fixation, improved soil structure, bio-fumigation, and risk reduction. These other factors are not easily enumerated.

- The model should assess the environmental and economic responses of different scenarios.
- Optimisation of diets according to milk income minus feed cost. This is important with increased volatility of milk and feed prices.
- The model may include the possibility for renting land to expand production.
- The ability to consider the variability in yields and prices, and thus the inherent riskiness of different scenarios. For example, grain legume and rapeseed production is inherently riskier than growing leys or cereals crops. It is possible in some modelling software packages to define a parameter not only by a mean value, but also by a distribution.

What characteristics should the DST have?

- The DST should be able to compare different management options specified by the user. The DST should not only give *The Answer*, although this is a useful option. The user should have the flexibility to specify and compare several different scenarios, thus exploring possibilities outside of the optimal solution.
- The DST should still have the capability for optimization.
- It should be simple enough that an average person with knowledge of typical farming practices could use it.
- The user should not by default have to enter too much information to get the DST to run. However, behind the main decision-making page should be other accessible pages where the user can change parameter values, e.g. crop yields, feed values, prices.
- The DST should find a balance between realism and complexity of detail.

5.4 Developing a whole-farm model

5.4.1 Existing animal production models

The NorFor model (Volden, 2011) is a semi-mechanistic animal production model that is used by advisors in Sweden and other Nordic countries. The Cornell Net Carbohydrate and Protein System (CNCPS) model (Higgs et al. 2015) has also been applied in the Nordic countries and has similar characteristics. NorFor is a static model, i.e. it does not simulate the effects of continued feeding of a diet over time. It also focuses on a single animal, or multiple animals of the same class and weight. It does not focus on crop production, or any details at the farm level. Despite these limitations, it is a capable model for what it was designed for, and can simulate the production responses with changes in detailed feed characteristics. The discussion below regarding a whole-farm model is not intended to supersede the need for or value of a ruminant nutrition model. NorFor has value as a 'tactical' model, predicting animal production responses in the short term, given available feeds and their prices. The proposed whole-farm model is 'strategic', focusing on longer-term decisions and farm structure.

5.4.2 Existing whole-farm models

Modelling offers a way to understand complex situations and practices, and how many factors interact at the farm level. It is at the farm level that the implications of interactions of farm components become evident in terms of economics and environmental effects. A number of whole-farm models have been developed to simulate crop-livestock systems. For example, The IAT model (Lisson et al., 2010) was developed to be used in a participatory way with smallholder crop-livestock farmers in developing countries. It is easily adapted to simulate different situations, and includes outputs of economics, feed sufficiency and labour demands. The IAT model is currently being updated into a new model named 'CLEM' (Crop Livestock Enterprise Model) which is integrated with the APSIM framework. The animal production models within IAT/CLEM are probably too simplified for the needs of a whole-farm model for Sweden, particularly if protein quality needs to be considered; however, there is the potential to add other livestock models to CLEM, and other needed functionality.

Orfee is a bioeconomic model (Mosnier et al. 2017) developed to simulate crop-livestock systems in France. In addition to crop and livestock production, farm management, and capital costs it includes useful measures of system performance such as economics, energy flows, greenhouse gas emissions, and system integration. The livestock production module system is simplified, and includes very little linkage between feed quality and production.

There are other available whole-farm models, however most have limitations of i) not being closely related to Nordic or European agriculture, or ii) focusing too little on animal nutrition.

5.4.3 The Lypsikki whole farm model

The Lypsikki whole farm model (Nousiainen et al. 2011) is a potentially useful model, as it combines a whole-farm perspective with a robust animal nutrition model. It has been used, for example, to evaluate different feeding management strategies to reduce the loss of P into surface water (Huhtanen et al. 2011).

A stylized overview of the whole-farm version of Lypsikki is shown in Figure 9. We developed this figure to demonstrate how Lypsikki's characteristics compare with the desired model capability as described above. The figure is simplified to indicate the major processes, and the interactions relating to phosphorus flows are not shown. A complete description of the model is described in Nousiainen et al. (2011)

On the crop production side, the areas of different types of land are specified, and the crop rotations are selected. The yield and nutritive value of crops depends on the type of soil and fertilization practices. Crop products are temporarily stored and used for animal production. Grass silage from different cuts is accounted for separately. Crop products are purchased when there is a deficit, whereas crops are sold at the end of the year if there is a surplus.

A dairy herd replacement model predicts the number of young stock required to maintain the desired number of dairy cows. The model includes modifiable replacement rates and calving intervals. Young stock and dry cows are fed according to set feeding recommendations, taking into account metabolizable protein (MP) and phosphorus (P) requirements.

Ration balancing for cows assumes a mean daily milk yield and composition during the whole lactation. Feeding is balanced to meet the daily requirements of ME, MP, Ca, P, N and Mg according to the Finnish feeding requirements (MTT, 2006). Available dietary ingredients are specified according to their chemical composition, feeding values, and prices. Least cost rations are optimised to meet daily requirements within certain physical constraints. The performance of cows fed optimised rations is predicted from regression equations derived from a large data set from milk production experiments.

The model also calculates the effect of feeding on manure composition, the nutrient flow implications of manure management, and the inflows/outflows of milk, manure, livestock, feeds, crop products, fertilisers and seeds.

5.5 Adapting the Lypsikki model as a DST

Lypsikki already has many of the features that a model would need to simulate growing and feeding of protein crops on a whole-farm level. However, to form the basis of a DST, suggested additional functionality would be needed:

- Functionality to design new rotations, and change the yield of crops based on their position in the crop rotation sequence.
- Parameterization based on available data for Sweden.

- Comparison of farmer-selected feeding options. The current version of the model emphasises a comparison of the current system and the optimised system. The DST could keep this functionality, but add the possibility to compare other balanced but non-optimal diets, allowing the user to explore different options, in keeping with the DST as a learning tool.
- Introduce distributions for key parameters, to be able to assess less or more risky options, rather than only modelling based on mean values.
- More comprehensive environmental indicators, e.g. estimated nitrogen fixation, fertiliser usage, farm self-sufficiency in feed, carbon sequestration and balance, greenhouse gas emissions based on life cycle analysis calculations, etc.

5.6 FEASIBILITY OF DEVELOPING A WHOLE-FARM DST

Our conclusions about the practicality of developing a whole-farm DST are as follows:

- A tool that could help researchers and advisors to find economic and environmentally sound solutions for protein production and feeding at the farm level would have various characteristics that make it potentially less practical as a DST for farmers. These include i) The questions that it attempts to address are complex and have a wide scope, ii) Because of the many interacting variables, the accuracy of the results would be less certain, iii) The DST itself would likely be quite complex to set up and use, providing a barrier for users.
- If a whole-farm DST is to be developed, it should be done using a co-design process, where farmers, researchers and other stakeholders work through the process in a collaborative way.
- A whole-farm DST would most likely be useful as a learning tool, rather than as a tool intended to provide *The Answer*. This does not negate the value of the process of developing such a DST, as it can stimulate learning for all involved.
- Given the nature of the DST required, developing a whole-farm tool that would be embraced by farmers would be challenging. However, we fully recommend that whole-farm models are used as a research tool. The questions and scenarios that could be assessed with such models might best be undertaken by researchers, and shared with stakeholders in various ways.

5.7 CONCLUSIONS

- Ruminant nutrition models such as NorFor are useful tools for making a static assessment of the effects of different feeding options on animal production. The discussion of the characteristics of a whole-farm DST is not motivated by a desire to replace animal-level or herd-level models.
- The structure that we used for the process of outlining the framework for a whole-farm DST comprised i) identifying characteristics of successful DSTs, ii) identifying the model capability needed, iii) identifying the DST functionality needed in addition to the model capability, and iv) detailing the most appropriate models to potentially use as a base for the DST.
- Successful decision support tools are more likely to be successful if they are simple to use and accurately address a clearly defined research question. Where DSTs attempt to address more complex or ‘high-uncertainty’ systems, the focus should shift from providing the answer to providing an environment for learning.
- The likelihood is low that a DST would be actively used by a high proportion of farmers.
- However, we emphasize that whole-farm models are an important and under-used research tool.

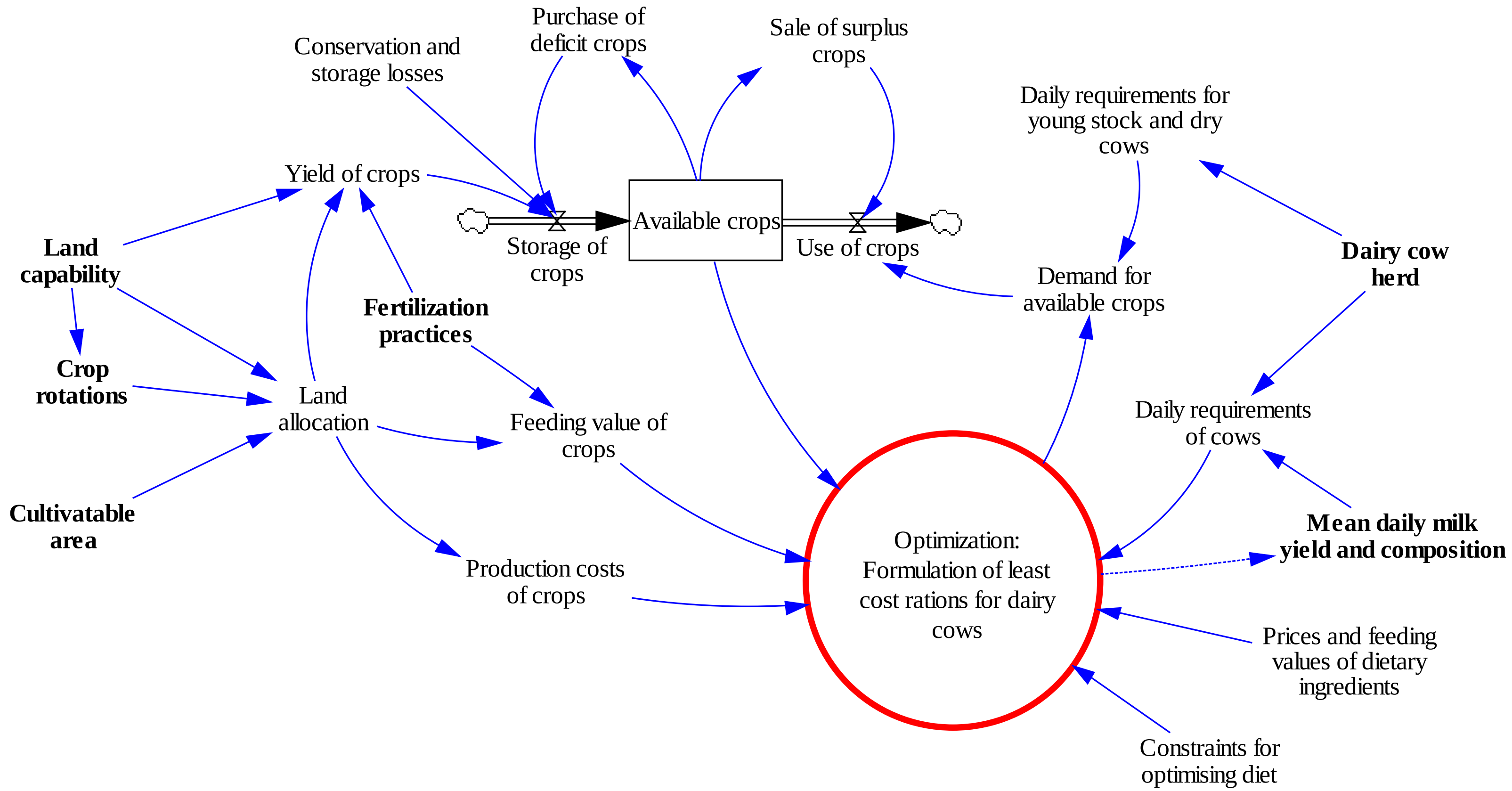


Figure 9 A stylized overview of the whole-farm version of Lypsikki developed for the purpose of detailing the types of interactions needed to simulate a whole-farm. The model is described in Nousiainen et al. (2011). Blue lines show the effect of variables on other variables. Bolded variables represent characteristics of the farm and farm practices. Boxes represent a physical 'stock'. The red circle represents the optimization process.

6 General concluding comments

6.1 Key conclusions

- Turnip rape is the lowest risk protein concentrate crop able to be grown in northern Sweden. It requires careful management but can potentially be sold or used on-farm. Threshed legumes are either higher risk (peas) or have little chance of reaching maturity (faba beans and lupins).
- Whole-crop legume/cereal silages are potentially useful additions to a cropping system; however, they are unpredictable in terms of legume proportion. They also appear to be cost effective as a home-grown feed on a crude protein basis.
- Threshed peas and turnip rape have high production costs if the yields are low, due to high inputs and fixed costs.
- The production or purchase cost for pea, faba bean and lupin always needs to be lower than for rapeseed meal. Even when the price of rapeseed meal nearly doubles, the price of the alternative protein feeds still need to be very low for the Lypsikki program to include them in the feed ration.
- The Lypsikki model has the functionality to compare protein cultivation and feeding options at the farm level. However, it may not be effective to develop it into a 'user-friendly' decision support system for farmers.

6.2 Recommendations for further research

- Investigate the quantity and location of by-products such as brewer's grain and assess their potential as protein concentrates for ruminants.
- Explore lupin cultivars from other countries to see whether there are any exceptionally early maturing varieties.
- Whole-crop legume/cereal silages can be mixed with grass/clover silage to give beneficial results. Further work could explore what mixes of whole crops should be used and how they can be efficiently combined with different cuts of grass and red clover silages.
- Explore the cost/benefit of reducing protein concentrates in rations, with different milk prices.
- Further development of a model for protein at the whole farm level, combining realistic animal nutrition responses with capability for exploring different crop rotations.

6.3 Project Outputs

- The final project workshop with the reference group was not held in December 2018, due to the unavailability of reference group members.
- Pekka Huhtanen presented results from this project to researchers and farmers at Lövsta on November 28th 2018. The title of the talk was "Grovfoder och lokala proteinfoder".
- The project website is www.slu.se/njv/protein-i-norr. It includes brief reports for all work packages, and other downloadable files.
- A draft 'Nytt Blad' will be available on the project website, and a published version will be published in early 2019.
- Downloadable tools for economic assessment of protein crops.

6.4 Acknowledgements

The authors acknowledge funding from Regional jordbruksforskning för norra Sverige (RJN) and Stiftelsen Lantbruksforskning (SLF). The authors thank the farmers, extensionists and members of the reference group who contributed time and knowledge to the project.

7 REFERENCES

Bernes, G & Gustavsson, A-M. 2016. Vårrybs - en intressant gröda i norr. Nytt från norrländsk jordbruksvetenskap, nr 1.

Ericson, L. 2010. Åkerböna som insåningsgröda vid vallinsådd. Nytt från norrländsk jordbruksvetenskap, nr 1 (ekologisk odling).

Fogelfors, H (ed). 2015. Vår mat – odling av åker- och trädgårdgrödor.1st ed. Studentlitteratur AB (printed in Poland).

Gustafsson, A. H., Bergsten C., Bertilsson, J., Kronqvist, C., Lindmark Månsson, H., Lovang, M., Lovang, U. & Swensson, C. 2013. Närproducerat foder fullt ut till mjölkkor - en kunskapsgenomgång. Forskningsr apport 1, Växa Sverige.

Haag, T., Martinsson, K. & Ericson, L. 2008. Åkerböna i samodling med vårvete som helgrödesensilage till kor. Nytt från norrländsk jordbruksvetenskap, nr 1 (ekologisk odling).

Higgs, R.J., Chase, L.E., Ross, D.A., and Van Amburgh, V.E. 2015. Updating the Cornell Net Carbohydrate and Protein System feed library and analyzing model sensitivity to feed inputs. *J. Dairy Sci*., **98**, 6340-6360.

Hochman, Z. and Carberry, P.S. 2011. Emerging consensus on desirable characteristics of tools to support farmers' management of climate risk in Australia. *Agricultural Systems* **104**, 441–450.

Huhtanen, P., Nousiainen, J., Turtola, E., 2011. Dairy farm nutrient management model. 2. Evaluation of different strategies to mitigate phosphorus surplus. *Agricultural Systems* **104**, 383–391.

Huhtanen, P., and Hristov, P. N. 2009. A meta-analysis of the effects of dietry protein concentration and degradability on milk protein yield and milk N efficiency in dairy cows. *Journal of Dairy Science*, **92**, 3222-3232.

Huhtanen, P., Rinne, M., Nousiainen., J. 2007. Evaluation of the factor affecting silage intake of dairy cows: a revision of the relative silage dry-matter intake index. *Animal*, **1**, 158-1770.

Jaakkola, S., Saarisalo, E., Heikkilä, T. 2009. Formic acid treated whole crop barley and wheat silages in dairy cow diets: effects of crop maturity, proportion in the diet, and level and type of concentrate supplementation. Agricultural and food science, **18**, 234-256.

Karlsson, L. 2010. Hempseed Cake as a Protein Feed for Ruminants. Doctoral thesis, Acta Universitatis agriculturae Sueciae 2010:86. Arkitektkopia AB, Umeå.

Lisson, S., MacLeod, N., McDonald, C., Corfield, J., Pengelly, B., Wirajaswadi, L., Rahman, R., Bahar, S., Padjung, R., Razak, N., Puspadi, K., Dahlanuddin, Sutaryono, Y., Saenong, S., Panjaitan, T., Hadiawati, L., Ash, A., Brennan, L. 2010. A participatory, farming systems research approach to improving Bali cattle production in the smallholder crop-livestock systems of Eastern Indonesia. *Agricultural Systems* **103**, 486–497.

Mosnier, C., Duclos, A., Agabriel, J., Gac, A. 2017. Orfee: a bioeconomic mixed crop-livestock farm model to simulate French farming systems ranging from intensive to organic. *Agricultural Systems* **157**, 202-215.

MTT, 2006. Rehutaulukot ja ruokintasuositukset (Feed Tables and Feeding Recommendations). Agrifood Research Finland. <http://www.agronet.fi/rehutaulukot>.

Nousiainen, J., Tuori, M., Turtola, E., Huhtanen, P., 2011. Dairy farm nutrient management model. 1. Model description and validation. *Agricultural Systems* **104**, 371–382.

Parsons, D., Nicholson, C.F., Blake, R.W., Ketterings, Q.M., Ramírez-Aviles, L., Fox, D.G., Tedeschi, L.O., & Cherney, J.H. (2011). Development and evaluation of an integrated simulation model for assessing smallholder crop–livestock production in Yucatán, Mexico. *Agricultural Systems*, **104**(1), 1-12.

Puhakka, L., Jaakkola, S., Simpura, I., Kokkonen, T., and Vanhatalo, A. 2016. Effects of replacing rapeseed meal with fava bean at 2 concentrate crude protein levels on feed intake, nutrient digestion, and milk production in cos fed grass silage-based diets. *Journal of Dairy Science*, **99**, 7993-8003.

Ramin, M., Höjer, A., Hetta, M. 2017. The effects of legume seeds on the lactation performance of dairy cows fed grass silage-based diets. *Agricultural and Food Science.* **26**(3), 129-137.

Rondahl, T., Bertilsson, J., Martinsson, K. 2007. Mixing whole-crop pea-oat silage and grass-cover silage: positive effects on intake and milk production of dairy cows. *Grass and Forage Science*, **62**, 459-469.

Rose D.C., Sutherland, W.J., Parker C., Lobley, M., Winter, M., Morris, C., Twining, S., Ffoulkes, C., Amano, T. and Dicks, L.V. 2016. Decision support tools for agriculture: Towards effective design and delivery. *Agricultural Systems* **149**, 165–174.

Rodriguez, D., DeVoil, P., Cox, H., Chudleigh, F., Conway, M., & Routley, R. (2006). APSFARM: a whole farm systems analysis of economic and environmental indicators of contrasting farm business strategies in Central Queensland. In *Proceedings 13th of the Australian Agronomy Conference*.

Vanhatalo, A., Ahvenjärvi, A., Jaakkola, S. 2004. Metabolic and production responses in dairy cows fed peas or rapeseed meal on grass silage based diet. *Journal of animal and feed Science*, **13**, suppl. 1., 231-234.

Volden, H., 2011. NorFor-The Nordic feed evaluation system, European Association for Animal Production.

Wallsten, J. 2005. Helsäd till kvigor **-** effekt av gröda och skördetid på konsumtionen. Nytt från norrländsk jordbruksvetenskap, nr 1 (husdjur).

van Wijk, M.T., Tittonell, P., Rufino, M.C., Herrero, M., Pacini, C., de Ridder, N., & Giller, K.E. (2009). Identifying key entry-points for strategic management of smallholder farming systems in sub-Saharan Africa using the dynamic farm-scale simulation model NUANCES-FARMSIM. *Agricultural Systems*, **102**(1), 89-101.

8 APPENDICES

8.1 APPENDIX 1. ECONOMIC ANALYSIS OF PROTEIN CROPS

8.1.1 Machinery and Operation Details

Maskinlista med uppgifter hämtade fr. "Maskinkostnader 2017" utg av Maskinkalkylgruppen & HIR Skåne.

Plog - Vxlplog, 6 skär, buren. Effektbehov: 130 kW, kapacitet: 1,2 ha/tim. + Traktor, effekt: 176kW, hkr: 176.

Harv - 8m, bogserad, effektbehov: 110, 5 ha/tim. + Traktor, hkr: 148.

Vält - 50 cm diameter, 9m, kapacitet: 4,5 ha/tim, effektbehov: 70. + Traktor, hkr: 95.

Kombisåmaskin - bredd: 4m, kapacitet: 1,5 ha/tim, effektbehov: 90 kW. + Traktor - 90 kW, hkr: 121.

Gödningsspridare buren - ca 1500l, bredd: 12m, kapacitet: 4 ha/tim, effektbehov 50kW. + Traktor: 50 kW, hkr: 68.

Traktor + tunna + bränsle + förare

Spruta buren - volym: 1200 l, bredd: 24m, kapacitet: 5,5 ha/tim, effektbehov 50kW. + Traktor: 50 kW, hkr: 68.

Skördetröska - bredd: 6,3 m, effekt: 220kW, kapacitet: 2 ha/tim, anskfv: 2,3 milj

Lastbil

Torkning - har en vattenhalt på 15-20 % vid trösning och ska ner till 8 % för att vara lagringsduglig (Från: faktablad Vårrybs). I kalkylen från 20 % till 8 %.

Tröskvagnar - körningar till och från fält. Vagn: 12 ton, effektbehov: 90. + Traktor, hkr: 121. (Schablontid 30 min körtid och lass med 12 ton).

Analyser - kostnad för att skicka in och analysera skörden till Lantmännen.

Ränta - på alla utgifter som görs i samband med grödan och beräknat på att utgiften täcker 40 % av året.

8.1.2 Tröska ärt (Threshed peas)

Schablonkalkyl									
ÄRT TRÖSKAD		rp	**21%**						
Norra Sverige									
Produktionskalkyl Växtodling									
Förväntad skörd: 4500 kg/ha									
Intäkter	Pris	Enhet		Kvant.	**Summa**	Kvant.	**Summa**	Kvant.	**Summa**
Foderärt	1.7 kr	kg		1000	**1,700 kr**	3000	**5,100 kr**	4500	**7,650 kr**
Halm	0 kr	kg		0	**0 kr**	0	**0 kr**	0	**0 kr**
Miljöstöd	0 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Summa intäkter:					**1,700 kr**		**5,100 kr**		**7,650 kr**
Mängd producerat råprotein:				*210*	*kg*	*630*	*kg*	*945*	*kg*
Kostnadsnivå 1									
Utsäde Foderärt	5 kr	kg		200	**1,000 kr**	200	**1,000 kr**	200	**1,000 kr**
Flytgödsel	0 kr	ton		0	**0 kr**	0	**0 kr**	0	**0 kr**
Gödning N	10 kr	kg		0	**0 kr**	0	**0 kr**	0	**0 kr**
Gödning P	18 kr	kg		18	**324 kr**	18	**324 kr**	18	**324 kr**
Gödning K	7 kr	kg		30	**210 kr**	30	**210 kr**	30	**210 kr**
Gödning S		kg							
Växtskydd ogräs	650 kr	ha		1	**650 kr**	1	**650 kr**	1	**650 kr**
Växtskydd insekt	0 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Växtskydd svamp	0 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Summa kostnadsnivå 1:					**2,184 kr**		**2,184 kr**		**2,184 kr**
Resultatnivå 1					**-484 kr**		**2,916 kr**		**5,466 kr**
Kostnadsnivå 2									
Lejd									
Plöjning	992 kr	tim		0.8	**827 kr**	0.8	**827 kr**	0.8	**827 kr**
Harvning	990 kr	tim		0.2	**198 kr**	0.2	**198 kr**	0.2	**198 kr**
Vältning	874 kr	tim		0.2	**194 kr**	0.2	**194 kr**	0.2	**194 kr**
Sådd	1,041 kr	tim		0.7	**694 kr**	0.7	**694 kr**	0.7	**694 kr**
Gödningsspridning	595 kr	tim		0.3	**149 kr**	0.3	**149 kr**	0.3	**149 kr**
Flytgödselkörning	18 kr	ton		0.0	**0 kr**	0.0	**0 kr**	0.0	**0 kr**
Bekämpning	886 kr	tim		0.2	**161 kr**	0.2	**161 kr**	0.2	**161 kr**
Tröskning	2,000 kr	tim		0.5	**1,000 kr**	0.5	**1,000 kr**	0.5	**1,000 kr**
Transport	45 kr	ton		1.1	**49 kr**	3.3	**147 kr**	4.9	**221 kr**
Torkning	120 kr	22%		1.1	**131 kr**	3.3	**392 kr**	4.9	**588 kr**
Fälttransport	650 kr	tim		0.04	**27 kr**	0.125	**81 kr**	0.2	**122 kr**
Övrigt arbete	0 kr	tim		0.0	**0 kr**	0.0	**0 kr**	0.0	**0 kr**
Foderanalys	945 kr	st		1.0	**945 kr**	1.0	**945 kr**	1.0	**945 kr**
Ränta rörelsekapital	3.0%	0.4		6559	**79 kr**	6972	**84 kr**	7283	**87 kr**
Summa kostnadsnivå 2:					**4,453 kr**		**4,872 kr**		**5,186 kr**
Resultatnivå 2	*Inklusive arbete*				**-4,937 kr**		**-1,956 kr**		**280 kr**
Produktionskostnad per kg gröda:					**6.64 kr**		**2.35 kr**		**1.64 kr**
Produktionskostnad per kg producerat råprotein:					***31.61 kr***		***11.20 kr***		***7.80 kr***

8.1.3 Tröska vårrybs (Threshed turnip rape)

Schablonkalkyl									
VÅRRYBS TRÖSKAD		rp	**22%**						
Norra Sverige									
Produktionskalkyl Växtodling									
Förväntad skörd: 2500 kg/ha									
Intäkter	Pris	Enhet		Kvant.	**Summa**	Kvant.	**Summa**	Kvant.	**Summa**
Vårrybs hela frön	3.5 kr	kg		800	**2,800 kr**	1500	**5,250 kr**	2500	**8,750 kr**
Olja									
Kaka									
Halm	0.0 kr	kg		0	**0 kr**	0	**0 kr**	0	**0 kr**
Miljöstöd	0.0 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Summa intäkter:					**2,800 kr**		**5,250 kr**		**8,750 kr**
Mängd producerat råprotein:				*176*	*kg*	*330*	*kg*	*550*	*kg*
Kostnadsnivå 1									
Utsäde Vårrybs	60 kr	kg		13	**780 kr**	13	**780 kr**	13	**780 kr**
Flytgödsel	0 kr	ton		0	**0 kr**	0	**0 kr**	0	**0 kr**
Gödning N	10 kr	kg		125	**1,250 kr**	125	**1,250 kr**	125	**1,250 kr**
Gödning P	18 kr	kg		17.5	**315 kr**	17.5	**315 kr**	17.5	**315 kr**
Gödning K	7 kr	kg		15	**105 kr**	15	**105 kr**	15	**105 kr**
Gödning S	10 kr	kg		25	**250 kr**	25	**250 kr**	25	**250 kr**
Växtskydd ogräs	380 kr	ha		1	**380 kr**	1	**380 kr**	1	**380 kr**
Växtskydd insekt	325 kr	ha		1	**325 kr**	1	**325 kr**	1	**325 kr**
Växtskydd svamp	0 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Summa kostnadsnivå 1					**3,405 kr**		**3,405 kr**		**3,405 kr**
Resultatnivå 1					**-605 kr**		**1,845 kr**		**5,345 kr**
Kostnadsnivå 2									
Lejd									
Plöjning	992 kr	tim		0.8	**827 kr**	0.8	**827 kr**	0.8	**827 kr**
Harvning	990 kr	tim		0.2	**198 kr**	0.2	**198 kr**	0.2	**198 kr**
Vältning	874 kr	tim		0.2	**194 kr**	0.2	**194 kr**	0.2	**194 kr**
Sådd	1,041 kr	tim		0.7	**694 kr**	0.7	**694 kr**	0.7	**694 kr**
Gödningsspridning	595 kr	tim		0.3	**149 kr**	0.3	**149 kr**	0.3	**149 kr**
Flytgödselkörning	18 kr	ton		0.0	**0 kr**	0.0	**0 kr**	0.0	**0 kr**
Bekämpning	886 kr	tim		0.2	**177 kr**	0.2	**177 kr**	0.2	**177 kr**
Tröskning	2,000 kr	tim		0.5	**1,000 kr**	0.5	**1,000 kr**	0.5	**1,000 kr**
Transport	45 kr	ton		0.9	**41 kr**	1.7	**78 kr**	2.9	**129 kr**
Torkning	120 kr	20%		0.9	**110 kr**	1.7	**207 kr**	2.9	**345 kr**
Fälttransport	650 kr	tim		0.03	**22 kr**	0.0625	**41 kr**	0.1	**68 kr**
Övrigt arbete	0 kr	tim		0.0	**0 kr**	0.0	**0 kr**	0.0	**0 kr**
Analyser	945 kr	st		1	**945 kr**	1	**945 kr**	1	**945 kr**
Processering		ton		0.8	**0 kr**	1.5	**0 kr**	2.5	**0 kr**
Ränta rörelsekapital	3.0%	0.4		7762	**93 kr**	7914	**95 kr**	8131	**98 kr**
Summa kostnadsnivå 2					**4,450 kr**		**4,604 kr**		**4,823 kr**
Resultatnivå 2	*Inklusive arbete*				**-5,055 kr**		**-2,759 kr**		**522 kr**
Produktionskostnad per kg:					**9.82 kr**		**5.34 kr**		**3.29 kr**
Produktionskostnad per kg producerat protein:					***44.63 kr***		***24.27 kr***		***14.96 kr***

8.1.4 Helsädesens ärt (Whole crop peas)

Schablonkalkyl									
ÄRT HELSÄDESENS									
Norra Sverige			rp	**16%**					
Produktionskalkyl Växtodling									
Förväntad skörd: 6000 kg ts/ha									
Andelen baljväxt: > 70 %									
Intäkter	Pris	Enhet		Kvant.	**Summa**	Kvant.	**Summa**	Kvant.	**Summa**
Helsädesensilage	1.3 kr	kg ts		3000	**3,900 kr**	4500	**5,850 kr**	6000	**7,800 kr**
Miljöstöd	0 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Summa intäkter:					**3,900 kr**		**5,850 kr**		**7,800 kr**
Mängd producerat råprotein:				*480*	*kg*	*720*	*kg*	*960*	*kg*
Kostnadsnivå 1									
Utsäde Ärt	5 kr	kg		140	**700 kr**	140	**700 kr**	140	**700 kr**
Utsäde Havre	4 kr	kg		50	**200 kr**	50	**200 kr**	50	**200 kr**
Flytgödsel	0 kr	ton		0	**0 kr**	0	**0 kr**	0	**0 kr**
Gödning N	10 kr	kg		0	**0 kr**	0	**0 kr**	0	**0 kr**
Gödning P	18 kr	kg		22.5	**405 kr**	22.5	**405 kr**	22.5	**405 kr**
Gödning K	7 kr	kg		45	**315 kr**	45	**315 kr**	45	**315 kr**
Gödning S		kg							
Växtskydd ogräs	195 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Växtskydd insekt	0 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Växtskydd svamp	0 kr	ha		0	**0 kr**	0	**0 kr**	0	**0 kr**
Ensileringsmedel	8.5 kr	L		0	**0.0 kr**	0	**0.0 kr**	0	**0.0 kr**
Summa kostnadsnivå 1					**1,620 kr**		**1,620 kr**		**1,620 kr**
Resultatnivå 1					**2,280 kr**		**4,230 kr**		**6,180 kr**
Kostnadsnivå 2									
Lejd									
Plöjning	992 kr	tim		0.8	**827 kr**	0.8	**827 kr**	0.8	**827 kr**
Harvning	990 kr	tim		0.2	**198 kr**	0.2	**198 kr**	0.2	**198 kr**
Vältning	874 kr	tim		0.2	**194 kr**	0.2	**194 kr**	0.2	**194 kr**
Sådd	1,041 kr	tim		0.7	**694 kr**	0.7	**694 kr**	0.7	**694 kr**
Gödningsspridning	595 kr	tim		0.3	**149 kr**	0.3	**149 kr**	0.3	**149 kr**
Flytgödselspridning	18 kr	ton		0.0	**0 kr**	0.0	**0 kr**	0.0	**0 kr**
Bekämpning	886 kr	tim		0.0	**0 kr**	0.0	**0 kr**	0.0	**0 kr**
Slåtterkross	842 kr	tim		0.5	**383 kr**	0.5	**383 kr**	0.5	**383 kr**
Rundbalspress per bal	129 kr	st		13	**1,720 kr**	20	**2,580 kr**	27	**3,440 kr**
Plast och nät per bal	42 kr	st		13	**560 kr**	20	**840 kr**	27	
Övrig kostnad för skörd	0 kr	tim		0.0	**0 kr**	0.0	**0 kr**	0.0	**1,120 kr**
Baltransport	610 kr	tim		0.20	**122 kr**	0.3	**183 kr**	0.4	**244 kr**
Övrigt arbete	0 kr	tim		0.0	**0 kr**	0.0	**0 kr**	0.0	**0 kr**
Analys grönmassa	795 kr	st		1.0	**795 kr**	1.0	**795 kr**	1.0	**795 kr**
Ränta rörelsekapital	3.0%	0.4		7261	**87 kr**	8462	**102 kr**	9663	**116 kr**
Summa kostnadsnivå 2					**5,729 kr**		**6,944 kr**		**8,159 kr**
Resultatnivå 2	*Inklusive arbete*				**-3,449 kr**		**-2,714 kr**		**-1,979 kr**
Produktionskostnad per kg:					**2.45 kr**		**1.90 kr**		**1.63 kr**
Produktionskostnad per kg producerat råprotein:					***15.31 kr***		***11.89 kr***		***10.19 kr***

8.1.5 Helsädesens åkerböna (Whole crop faba beans)

Schablonkalkyl											
ÅKERBÖNA HELSÄDESENS			rp	**17%**							
Norra Sverige											
Produktionskalkyl Växtodling											
Andelen baljväxt: > 70 %											
Förväntad skörd: 6000 kg ts/ha											
Intäkter	Pris	Enhet		Kvant.	**Summa**		Kvant.	**Summa**		Kvant.	**Summa**
Helsädesensilage	1.3 kr	kg ts		3000	**3,900 kr**		4500	**5,850 kr**		6000	**7,800 kr**
Miljöstöd	0 kr	ha		0	**0 kr**		0	**0 kr**		0	**0 kr**
Summa intäkter:					**3,900 kr**			**5,850 kr**			**7,800 kr**
Mängd producerat råprotein:					*510*	*kg*		*765*	*kg*		*1020*
Kostnadsnivå 1											
Utsäde Åkerböna	6.5 kr	kg		175	**1,138 kr**		175	**1,138 kr**		175	**1,138 kr**
Utsäde Vårvete	3.9 kr	kg		65	**254 kr**		65	**254 kr**		65	**254 kr**
Flytgödsel	0 kr	ton		0	**0 kr**		0	**0 kr**		0	**0 kr**
Gödning N	10 kr	kg		0	**0 kr**		0	**0 kr**		0	**0 kr**
Gödning P	18 kr	kg		22.5	**405 kr**		22.5	**405 kr**		22.5	**405 kr**
Gödning K	7 kr	kg		45	**315 kr**		45	**315 kr**		45	**315 kr**
Gödning S		kg									
Växtskydd ogräs	195 kr	ha		0	**0 kr**		0	**0 kr**		0	**0 kr**
Växtskydd insekt	0 kr	ha		0	**0 kr**		0	**0 kr**		0	**0 kr**
Växtskydd svamp	0 kr	ha		0	**0 kr**		0	**0 kr**		0	**0 kr**
Ensileringsmedel	8.5 kr	L		0	**0.0 kr**		0	**0.0 kr**		0	**0.0 kr**
Summa kostnadsnivå 1					**2,111 kr**			**2,111 kr**			**2,111 kr**
Resultatnivå 1					**1,789 kr**			**3,739 kr**			**5,689 kr**
Kostnadsnivå 2											
Lejd											
Plöjning	992 kr	tim		0.8	**827 kr**		0.8	**827 kr**		0.8	**827 kr**
Harvning	990 kr	tim		0.2	**198 kr**		0.2	**198 kr**		0.2	**198 kr**
Vältning	874 kr	tim		0.2	**194 kr**		0.2	**194 kr**		0.2	**194 kr**
Sådd	1,041 kr	tim		0.7	**694 kr**		0.7	**694 kr**		0.7	**694 kr**
Gödningsspridning	595 kr	tim		0.3	**149 kr**		0.3	**149 kr**		0.3	**149 kr**
Flytgödselspridning	18 kr	ton		0.0	**0 kr**		0.0	**0 kr**		0.0	**0 kr**
Bekämpning	886 kr	tim		0.2	**161 kr**		0.2	**161 kr**		0.2	**161 kr**
Slåtterkross	842 kr	tim		0.5	**383 kr**		0.5	**383 kr**		0.5	**383 kr**
Rundbalspress	129 kr	st		13	**1,720 kr**		20	**2,580 kr**		27	**3,440 kr**
Plast och nät	42 kr	st		13	**560 kr**		20	**840 kr**		27	**1,120 kr**
Baltransport	610 kr	tim		0.20	**122 kr**		0.3	**183 kr**		0.4	**244 kr**
Övrigt arbete	0 kr	tim		0.0	**0 kr**		0.0	**0 kr**		0.0	**0 kr**
Analys grönmassa	795 kr	st		1.0	**795 kr**		1.0	**795 kr**		1.0	**795 kr**
Ränta rörelsekapital	3.0%	0.4		7913	**95 kr**		9114	**109 kr**		10315	**124 kr**
Summa kostnadsnivå 2					**5,897 kr**			**7,113 kr**			**8,328 kr**
Resultatnivå 2		*Inklusive arbete*			**-4,108 kr**			**-3,374 kr**			**-2,639 kr**
Produktionskostnad per kg:					**2.67 kr**			**2.05 kr**			**1.74 kr**
Produktionskostnad per kg producerat protein:					***15.70 kr***			***12.06 kr***			***10.23 kr***

8.1.6 Helsädesens foderviker (Whole crop vetch)

Schablonkalkyl										
VICKER HELSÄDESENS			rp	**18%**						
Norra Sverige										
Produktionskalkyl Växtodling										
Andelen baljväxt: > 70 %										
Förväntad skörd: 6000 kg ts/ha										
Intäkter	Pris	Enhet		Kvant.	**Summa**		Kvant.	**Summa**	Kvant.	**Summa**
Helsädesensilage	1.3 kr	kg ts		3000	**3,900 kr**		4500	**5,850 kr**	6000	**7,800 kr**
Miljöstöd	0 kr	ha		0	**0 kr**		0	**0 kr**	0	**0 kr**
Summa intäkter:					**3,900 kr**			**5,850 kr**		**7,800 kr**
Mängd producerat råprotein:					*540*	*kg*		*810*	*kg*	*1080*
Kostnadsnivå 1										
Utsäde Vicker	15.0 kr	kg		75	**1,125 kr**		75	**1,125 kr**	75	**1,125 kr**
Utsäde Havre	3.9 kr	kg		50	**193 kr**		50	**193 kr**	50	**193 kr**
Flytgödsel	0 kr	ton		0	**0 kr**		0	**0 kr**	0	**0 kr**
Gödning N	10 kr	kg		0	**0 kr**		0	**0 kr**	0	**0 kr**
Gödning P	18 kr	kg		22.5	**405 kr**		22.5	**405 kr**	22.5	**405 kr**
Gödning K	7 kr	kg		45	**315 kr**		45	**315 kr**	45	**315 kr**
Gödning S		kg								
Växtskydd ogräs	195 kr	ha		0	**0 kr**		0	**0 kr**	0	**0 kr**
Växtskydd insekt	0 kr	ha		0	**0 kr**		0	**0 kr**	0	**0 kr**
Växtskydd svamp	0 kr	ha		0	**0 kr**		0	**0 kr**	0	**0 kr**
Ensileringsmedel	8.5 kr	L		0	**0.0 kr**		0	**0.0 kr**	0	**0.0 kr**
Summa kostnadsnivå 1					**2,038 kr**			**2,038 kr**		**2,038 kr**
Resultatnivå 1					**1,863 kr**			**3,813 kr**		**5,763 kr**
Kostnadsnivå 2										
Lejd										
Plöjning	992 kr	tim		0.8	**827 kr**		0.8	**827 kr**	0.8	**827 kr**
Harvning	990 kr	tim		0.2	**198 kr**		0.2	**198 kr**	0.2	**198 kr**
Vältning	874 kr	tim		0.2	**194 kr**		0.2	**194 kr**	0.2	**194 kr**
Sådd	1,041 kr	tim		0.7	**694 kr**		0.7	**694 kr**	0.7	**694 kr**
Gödningsspridning	595 kr	tim		0.3	**149 kr**		0.3	**149 kr**	0.3	**149 kr**
Flytgödselspridning	18 kr	ton		0.0	**0 kr**		0.0	**0 kr**	0.0	**0 kr**
Bekämpning	886 kr	tim		0.2	**161 kr**		0.2	**161 kr**	0.2	**161 kr**
Slåtterkross	842 kr	tim		0.5	**383 kr**		0.5	**383 kr**	0.5	**383 kr**
Rundbalspress	129 kr	st		13	**1,720 kr**		20	**2,580 kr**	27	**3,440 kr**
Plast och nät	42 kr	st		13	**560 kr**		20	**840 kr**	27	**1,120 kr**
Baltransport	610 kr	tim		0.20	**122 kr**		0.3	**183 kr**	0.4	**244 kr**
Övrigt arbete	0 kr	tim		0.0	**0 kr**		0.0	**0 kr**	0.0	**0 kr**
Analys grönmassa	795 kr	st		1.0	**795 kr**		1.0	**795 kr**	1.0	**795 kr**
Ränta rörelsekapital	3.0%	0.4		7840	**94 kr**		9041	**108 kr**	10242	**123 kr**
Summa kostnadsnivå 2					**5,897 kr**			**7,112 kr**		**8,327 kr**
Resultatnivå 2	*Inklusive arbete*				**-4,034 kr**			**-3,299 kr**		**-2,565 kr**
Produktionskostnad per kg:					**2.64 kr**			**2.03 kr**		**1.73 kr**
Produktionskostnad per kg producerat protein:					***14.69 kr***			***11.30 kr***		***9.60 kr***

8.1.7 Helsädesens lupiner (Whole crop lupins)

Schablonkalkyl										
LUPIN HELSÄDESENS		rp	**18%**							
Norra Sverige										
Produktionskalkyl Växtodling										
Förväntad skörd: 4000 kg ts/ha										
Andelen baljväxt: > 70 %										
Intäkter	Pris	Enhet		Kvant.	**Summa**		Kvant.	**Summa**	Kvant.	**Summa**
Helsädesensilage	1.3 kr	kg ts		2000	**2,600 kr**		3000	**3,900 kr**	4000	**5,200 kr**
Miljöstöd	0 kr	ha		0	**0 kr**		0	**0 kr**	0	**0 kr**
Summa intäkter:					**2,600 kr**			**3,900 kr**		**5,200 kr**
Mängd producerat råprotein:					*360*	*kg*		*540*	*kg*	*720*
Kostnadsnivå 1										
Utsäde Sm.bl Lupin	8.0 kr	kg		75	**600 kr**		75	**600 kr**	75	**600 kr**
Utsäde Foderkorn	3.8 kr	kg		50	**190 kr**		50	**190 kr**	50	**190 kr**
Flytgödsel	0 kr	ton		0	**0 kr**		0	**0 kr**	0	**0 kr**
Gödning N	10 kr	kg		0	**0 kr**		0	**0 kr**	0	**0 kr**
Gödning P	18 kr	kg		16.5	**297 kr**		16.5	**297 kr**	16.5	**297 kr**
Gödning K	7 kr	kg		25	**175 kr**		25	**175 kr**	25	**175 kr**
Gödning S		kg								
Växtskydd ogräs	487 kr	ha		1	**487 kr**		1	**487 kr**	1	**487 kr**
Växtskydd insekt	0 kr	ha		0	**0 kr**		0	**0 kr**	0	**0 kr**
Växtskydd svamp	0 kr	ha		0	**0 kr**		0	**0 kr**	0	**0 kr**
Ensileringsmedel	8.5 kr	L		0	**0.0 kr**		0	**0.0 kr**	0	**0.0 kr**
Summa kostnadsnivå 1					**1,749 kr**			**1,749 kr**		**1,749 kr**
Resultatnivå 1					**851 kr**			**2,151 kr**		**3,451 kr**
Kostnadsnivå 2										
Lejd										
Plöjning	992 kr	tim		0.8	**827 kr**		0.8	**827 kr**	0.8	**827 kr**
Harvning	990 kr	tim		0.2	**198 kr**		0.2	**198 kr**	0.2	**198 kr**
Vältning	874 kr	tim		0.2	**194 kr**		0.2	**194 kr**	0.2	**194 kr**
Sådd	1,041 kr	tim		0.7	**694 kr**		0.7	**694 kr**	0.7	**694 kr**
Gödningsspridning	595 kr	tim		0.3	**149 kr**		0.3	**149 kr**	0.3	**149 kr**
Flytgödselspridning	18 kr	ton		0.0	**0 kr**		0.0	**0 kr**	0.0	**0 kr**
Bekämpning	886 kr	tim		0.2	**161 kr**		0.2	**161 kr**	0.2	**161 kr**
Slåtterkross	842 kr	tim		0.5	**383 kr**		0.5	**383 kr**	0.5	**383 kr**
Rundbalspress	129 kr	st		9	**1,147 kr**		13	**1,720 kr**	18	**2,293 kr**
Plast och nät	42 kr	st		9	**373 kr**		13	**560 kr**	18	**747 kr**
Baltransport	610 kr	tim		0.13	**81 kr**		0.2	**122 kr**	0.3	**163 kr**
Övrigt arbete	0 kr	tim		0.0	**0 kr**		0.0	**0 kr**	0.0	**0 kr**
Analys grönmassa	795 kr	st		1.0	**795 kr**		1.0	**795 kr**	1.0	**795 kr**
Ränta rörelsekapital	3.0%	0.4		6751	**81 kr**		7551	**91 kr**	8352	**100 kr**
Summa kostnadsnivå 2					**5,083 kr**			**5,893 kr**		**6,703 kr**
Resultatnivå 2					**-4,232 kr**			**-3,742 kr**		**-3,252 kr**
Produktionskostnad per kg:					**3.42 kr**			**2.55 kr**		**2.11 kr**
Produktionskostnad per kg producerat protein:					***18.98 kr***			***14.15 kr***		***11.74 kr***

8.2 APPENDIX 2. FEED DATA EXTRACTED FROM THE CNCPS 6.5 DATABASE.

							Calculated according to Higgs et al. 2015															
							Ammonia	Soluble true protein	Insoluble true protein	Fiber-bound protein	Indigestible protein											
	DM	CP	SP	Ammonia	ADIP	NDIP	PA1	PA2	PB1	PB2	PC	Ether Extract	NFC	Sugar	Starch	Soluble Fiber	ADF	NDF	pef	Lignin	Ash	Reference
		(% DM)	(% CP)	(% SP)	(% CP)	(% CP)	(% DM)	(% DM)	(% DM)	(% DM)	(% DM)	(% DM)	(% DM)	(% DM)	(% DM)	(% DM)	(% DM)	(% DM)	(%)	(% NDF)	(% DM)	
Forage and whole crop protein																						
Clover Silage 21 CP 40 NDF 15 LNDF	40	21.0	59.0	14.1	7.1	14.4	1.7	10.6	5.6	1.5	1.5	3.7	25.4	3.7	1.5	12.5	31.7	40.2	80.0	17.2	9.7	CNCPS4060
Clover Silage 19 CP 47 NDF 15 LNDF	40	19.0	59.5	16.2	8.2	16.1	1.8	9.5	4.6	1.5	1.6	4.2	20.6	3.1	1.3	9.7	36.4	46.5	80.0	17.0	9.7	CNCPS4059
Clover Silage 17 CP 53 NDF 15 LNDF	40	17.0	59.5	18.3	9.3	17.8	1.8	8.3	3.9	1.4	1.6	4.4	16.1	2.5	1.1	7.4	41.0	52.8	80.0	16.7	9.7	CNCPS4058
Grass Silage 16 CP 55 NDF 6 LNDF	35	16.0	53.3	13.3	8.1	21.8	1.1	7.4	4.0	2.2	1.3	3.3	18.2	4.8	2.3	2.5	35.3	55.0	85.0	9.2	7.5	CNCPS4014
Orchardgrass Silage 13 CP 60 NDF 11 LNDF	38	13.0	54.1	14.7	8.6	21.7	1.0	6.0	3.1	1.7	1.1	4.4	13.6	3.7	2.5	2.3	38.2	60.0	85.0	9.3	9.0	CNCPS4019
Timothy Hay14 CP 55 NDF 5 LNDF	89	14.0	31.7	0.0	8.4	31.2	0.0	4.4	5.2	3.2	1.2	2.5	21.5	10.4	2.2	8.9	34.8	55.0	95.0	8.6	7.0	CNCPS4032
Alfalfa Silage 20 CP 40 NDF 17 LNDF	35	20.0	60.0	13.9	7.2	14.4	1.7	10.3	5.1	1.4	1.4	4.4	26.6	3.7	1.6	14.5	31.5	40.0	75.0	17.1	9.0	CNCPS4054
Mix Silage 13 CP 56 NDF 14 LNDF	40	13.0	53.0	15.8	8.6	21.6	1.1	5.8	3.3	1.7	1.1	3.2	17.3	3.8	1.2	6.0	38.3	56.5	85.0	12.4	10.0	CNCPS4068
Rye Grass Silage 15 CP 58 NDF 8 LNDF	35	14.7	55.5	14.5	7.7	20.5	1.2	7.0	3.5	1.9	1.1	4.9	12.4	3.3	2.8	0.0	36.4	57.0	80.0	9.1	11.0	CNCPS4079
Barley Silage 14 CP 50 NDF 8 LNDF	35	14.0	67.0	12.5	6.7	11.1	1.2	8.2	3.1	0.6	0.9	3.9	25.8	3.7	4.1	10.7	31.3	50.0	75.0	8.0	6.3	CNCPS3003
Soy Bean Silage	38	19.6	46.5	18.4	10.9	22.1	1.7	7.4	6.2	2.2	2.1	4.9	13.2	4.1	1.8	1.5	40.3	51.6	85.0	17.9	10.7	CNCPS3081
Oat Silage 13 CP 60 NDF 16 LNDF	32	12.5	63.0	14.7	8.1	15.0	1.2	6.7	2.7	0.9	1.0	3.1	15.3	3.9	2.1	6.4	39.2	60.0	90.0	8.9	9.2	CNCPS3075
Wheat Silage 12 CP 58 NDF 10 LNDF	33	12.0	65.8	12.7	7.2	13.4	1.0	6.9	2.5	0.7	0.9	3.3	18.9	4.2	5.9	2.9	37.8	58.3	90.0	8.6	7.5	CNCPS3085
Vetch Hay	90	14.9	45.0	0.0	3.4	10.7	0.0	6.7	6.6	1.1	0.5	2.3	29.0	11.2	0.3	17.5	32.5	46.9	85.0	12.2	6.9	CNCPS4081
Protein Supplement																						
Canola Meal Expelled	90	36.0	26.7	0.0	8.4	22.7	0.0	9.6	18.2	5.2	3.0	5.7	20.9	10.9	2.6	7.4	21.1	30.1	40.0	26.6	7.3	CNCPS2005
Canola Meal Solvent	90	41.5	30.0	0.0	6.2	22.0	0.0	12.5	19.9	6.6	2.6	4.8	18.1	10.3	2.6	5.1	20.4	27.7	40.0	26.6	8.0	CNCPS2006
Linseed Meal Expelled	90	32.0	40.0	0.0	2.7	10.8	0.0	12.8	15.7	2.6	0.9	3.5	26.6	9.1	8.9	8.6	18.3	31.4	40.0	24.0	6.5	CNCPS2019
Linseed Meal Solvent	88	33.0	41.0	0.0	2.7	5.6	0.0	13.5	17.6	1.0	0.9	1.5	27.6	9.1	8.9	9.6	18.3	31.4	40.0	24.0	6.5	CNCPS2020
Lupins	94	34.2	67.7	0.0	1.8	10.0	0.0	23.2	7.6	2.8	0.6	8.1	29.4	16.4	3.3	9.7	17.6	25.5	40.0	8.2	2.8	CNCPS2021
Lupins Sweet	86	36.6	72.4	0.0	0.8	2.3	0.0	26.5	9.3	0.5	0.3	5.5	29.1	2.5	2.7	24.0	17.6	25.1	40.0	8.2	3.7	CNCPS2043
Soybean Meal Extruded	91	43.7	13.4	0.0	1.9	3.7	0.0	5.9	36.2	0.8	0.8	15.5	15.9	8.1	2.7	5.1	8.7	19.2	40.0	7.7	5.7	CNCPS2025
Soybean Meal 44 Solvent	90	49.0	33.0	0.0	2.2	2.4	0.0	16.2	31.6	0.1	1.1	2.8	25.9	11.5	2.4	11.9	7.9	15.0	40.0	8.4	7.3	CNCPS2026
Soybean Meal 47.5 Solvent	90	51.5	20.0	0.0	1.8	2.0	0.0	10.3	40.2	0.1	0.9	2.8	29.0	10.9	1.9	16.2	6.8	10.0	40.0	8.5	6.7	CNCPS2027
Soybean Rolled Roasted	93	41.7	11.6	0.0	1.2	14.6	0.0	4.8	30.8	5.6	0.5	21.7	16.7	11.8	4.4	0.5	8.7	13.7	50.0	13.2	6.2	CNCPS2028
Soybean Steam Flaked	90	41.4	16.0	0.0	2.1	4.5	0.0	6.6	32.9	1.0	0.9	20.2	17.9	9.2	2.5	6.3	8.6	15.2	55.0	7.1	5.3	CNCPS2030
Soybean Whole Extruded	94	43.0	9.1	0.0	2.3	11.0	0.0	3.9	34.3	3.7	1.0	13.8	24.2	12.6	4.3	7.3	6.0	13.0	50.0	6.6	6.0	CNCPS2031
Soybean Whole Flaked	90	43.0	15.5	0.0	2.0	4.5	0.0	6.7	34.4	1.1	0.9	20.1	21.1	13.3	4.0	3.8	6.0	10.0	55.0	7.1	5.8	CNCPS2032
Soybean Whole Raw	90	41.8	44.0	0.0	1.9	4.1	0.0	18.4	21.7	0.9	0.8	20.7	19.0	12.2	3.3	3.4	6.3	13.0	50.0	8.2	5.6	CNCPS2033
Soybean Whole Roasted	93	41.7	7.4	0.0	3.4	11.5	0.0	3.1	33.9	3.4	1.4	18.8	20.7	13.0	4.4	3.3	6.0	13.0	50.0	11.5	5.8	CNCPS2034

CNCPS Protein Fractions (Higgs et al. 2015)

PA1	Ammonia	$Ammonia_j \times (SP_j/100) \times (CP_j/100)$
PA2	Soluble true protein	$SP_j \times CP_j/100 - PA1_j$
PB1	Insoluble true protein	$CP_j - (PA1_j + PA2_j + PB2_j + PC_j)$
PB2	Fiber-bound protein	$(NDICP_j - ADICP_j) \times CP_j / 100$
PC	Indigestible protein	$ADICP_j \times CP_j / 100$

SP = soluble protein (%CP)

ADICP = acid detergent insoluble CP (%CP)

NDICP = neutral detergent insoluble CP (%CP)

CP = crude protein (%DM)

Ammonia (%SP)

8.3 Appendix 3. Feed data extracted from the NorFor feed database.

Group-Code	Name (Sv)	Name (Eng)	Region	NEL20	PBV20	AAT20	DM	Ash	CP	CF	NDF	iNDF	Starch	Tot. Acids	sCP	NH3N	pdCP	sCP+pdCP	iCP	kdCP
				MJ/kg DM	g/kg DM	g/kg DM	g/kg	g/kg DM	g/kg DM	g/kg DM	g/kg DM	g/kg NDF	g/kg DM	g/kg DM	g/kg CP	g N/kg N	g/kg CP	g/kg CP	g/kg CP	%/hr
Grains																				
001-0001	Korn, kärna	Barley, kernels	Sverige	7.11	-27	96	870	23	117	21	176	162	584	0	309	0	674	983	59	24.4
001-0003	Havre, kärna, medel NDF	Oats, medium NDF	Sverige	6.40	-5	86	870	33	119	48	285	392	450	0	430	0	509	939	33	35.0
001-0005	Vete, kärna	Wheat, kernels	Sverige	7.81	-46	115	870	18	122	21	123	187	650	0	272	0	697	969	29	14.3
Protein concentrates																				
002-0035	Lin, frö, expeller	Linseed, expeller	Sverige	6.96	194	77	900	50	297	198	465	515	26	0	645	0	319	964	36	12.4
002-0042	Rapsmjöl	Rapeseed meal, extracted	NorFor	6.63	172	148	884	74	385	40	279	480	26	0	190	0	762	952	58	9.3
002-0044	Rapsexpeller, 00, 10% fett	Rapeseed expeller, 00, 10% fat	NorFor	7.37	149	126	885	67	344	112	257	488	21	0	270	0	689	959	93	8.3
002-0048	Rapsexpeller, 00, 13% fett	Rapeseed expeller, 00, 13% fat	NorFor	7.74	143	122	890	65	331	146	248	488	21	0	270	0	689	959	93	8.3
002-0049	Rapsexpeller, 00, 20% fett, kallpressad	Rapeseed expeller, 00, 20% fat, cold pressed	NorFor	8.60	128	113	890	60	301	225	228	488	21	0	270	0	689	959	93	8.3
002-0053	Soja, bönana, mjöl	Soya bean, extracted	NorFor	8.30	210	218	876	74	487	29	135	61	62	0	126	0	874	1	18	7.5
002-0054	Soja, böna, mjöl, avskalat frö	Soya bean, decorticated, extracted	NorFor	8.53	239	228	885	68	528	24	102	61	49	0	144	0	856	1	18	7.5
002-0056	Soja, böna, expeller	Soya bean, expeller	NorFor	8.94	203	209	934	61	468	81	118	61	62	0	141	0	859	1	19	7.5
002-0090	Hampfrökaka	Hemp seed cake	NorFor	6.02	164	116	912	66	351	135	388	845	12	0	198	0	533	731	76	13.5
002-0092	ExPro-00E	ExPro-00E	Norge	6.52	109	184	895	78	359	46	364	376	9	0	80	0	847	927	73	5.8
002-0007	Raps, frö, 00	Rapeseed, seed	NorFor	12.14	101	75	914	45	211	461	167	354	15	0	312	0	633	945	88	13.2
002-0008	Soja, böna	Soya beans	NorFor	9.93	269	65	900	55	410	222	94	61	55	0	764	0	236	1	134	8.0
002-0009	Soja, böna, rostad	Soyabeans, toasted	NorFor	9.94	182	141	900	55	410	222	94	61	55	0	106	0	894	1	134	8.0
002-0088	Hampa, frö	Hemp seed (estimated)	NorFor	8.20	124	84	907	55	256	274	300	845	50	0	500	0	231	731	76	13.5
003-0004	Lupiner gula (skattat)	Yellow lupins, estimated	NorFor	8.31	266	106	915	38	419	49	249	32	20	0	497	0	483	980	29	34.2
003-0005	Lupiner blå smalbladig	Narrow-leafed lupins, estimated	NorFor	8.25	202	101	885	39	349	63	250	20	17	0	746	0	246	992	28	18.6
003-0006	Ärter, kärna	Peas	NorFor	7.75	87	104	850	30	239	19	110	13	462	0	729	0	270	999	35	10.2
003-0007	Åkerböna, kärna	Faba beans	NorFor	7.88	159	101	850	37	309	19	146	32	412	0	685	0	313	998	35	15.9
003-0019	Åkerböna kärna, rostad (skattad)	Faba beans, hard toasted	NorFor	7.75	53	184	873	37	309	19	146	32	412	0	158	0	840	998	64	4.0
003-0020	Lupiner blå (smalbladig)	Narrow-leafed lupins	NorFor	8.06	55	227	960	44	349	57	254	16	11	0	206	0	774	980	50	2.4
003-0021	Åkerböna, lättrostad	Faba beans, soft toasted	NorFor	7.77	147	106	870	37	309	19	146	32	412	0	504	0	494	998	59	14.7
003-0013	Vicker, kärna	Vetch, kernels	Sverige	0.00	NaN	NaN	870	40	300	20	NaN	NaN	NaN	0	NaN	NaN	NaN	NaN	NaN	NaN
Cereal by-products																				
001-0037	Spannmålsdrank, torkad. Agrodrank	Distillers dried grain, wheat	NorFor	7.54	139	143	900	55	347	68	257	255	35	0	235	0	719	954	36	9.2
001-0038	Spannmålsdrank, torkad. Agrodrank	Distillers dried grain, wheat	NorFor	7.54	139	143	900	55	347	68	257	255	35	0	235	0	719	954	36	9.2
001-0102	Maltgroddar (skattat värde)	Malt sprouts	NorFor	6.33	145	101	950	72	318	28	438	147	50	0	488	0	436	924	75	10.0
001-0100	Mäsk, färsk drav	Brewers grain, fresh	NorFor	5.93	46	106	259	34	215	108	525	298	50	0	45	0	870	915	159	7.3
001-0101	Spannmål drank, färsk	Distillers grain, fresh	NorFor	7.21	107	145	115	56	320	70	276	285	30	0	283	0	677	960	46	5.9
001-0103	Brewers grain, ensiled	Brewers grain, ensiled	NorFor	5.99	51	103	259	34	215	108	525	298	50	34	45	0	870	915	159	7.3
Forage																				
006-0435	Rödklöver ensilage 1:a skörd	Red clover silage, first cut	Sverige	5.87	81	81	300	90	209	45	333	262	25	70	505	50	447	952	48	8.7
006-0474	Blandvall ensilage 1:a skörd "tidig"	Grass clover silage, first cut, early	Sverige	6.34	42	80	340	75	164	44	472	133	10	70	720	50	235	955	36	13.4
006-0483	Timotej ensilage 1a sk "rel tidig"	Timothy silage, first cut, mid June	Sverige	6.26	-8	82	340	80	119	26	576	129	0	70	664	50	237	901	58	8.9
Whole crop																				
006-0260	Raps, hela plantan ensilerad	Rape silage	NorFor	6.18	-20	83	180	108	111	45	383	132	0	95	290	50	664	954	133	6.5
006-0288	Åkerböna, helsädesensilage	Fabe beans whole crop silage	NorFor	5.97	56	73	270	90	170	25	378	345	100	122	599	108	355	954	68	9.0
006-0250	Korn, helsädesensilage	Barley whole crop silage	Sverige	5.17	10	70	400	66	126	25	469	292	136	72	467	74	398	865	134	10.3
006-0251	Havre-Ärt, helsädesensilage, 50% Ärter	Oats-peas whole crop silage, 50% peas	Sverige	5.10	18	70	366	72	131	28	474	304	95	79	477	75	469	946	85	5.5
006-0252	Åkerböna-vete, helsädesensilage, 50% vete	Fababean-wheat whole crop silage 50% wheat	Sverige	5.10	30	70	345	73	144	24	441	324	125	72	438	69	499	937	90	7.8
006-0254	Ärter/Vicker/Havre, hela plantan, axgång till blomning, ensilerad	Pea/oat/vetch whole crop silage	Sverige	5.15	18	72	366	69	135	30	464	514	100	67	467	45	479	946	85	5.5
006-0132	Lupiner, helsäd	Lupin, whole crop fresh	Denmark	5.66	34	92	150	80	178	24	401	328	0	0	365	0	589	954	68	9.0

8.4 Appendix 4. Replicating the WP3 analysis with NorFor

Avrapportering till NJV 2018-12-10

Uppdrag

Uppdraget av prefekt Mårten Hetta vid Institutionen för norrländsk jordbruksvetenskap, SLU var att komplettera slutrapporten ”Lönsam produktion och användning av proteinfoder till mjölkkor i norra Sverige” med beräkningar utfört med NorFor-modellen.

Målet var enligt projektledare professor David Parsons att komplettera ovan nämnda rapport enligt RJNs önskemål “We also strongly advise that you complete the economic evaluation in 4.3.3. with the same calculations in NorFor. The reason is that NorFor is the program that most advisors use in Sweden and this type of information is of great importance to them, especially if you will come up with a totally different answer from NorFor.”

Material och metoder

Verktyget som användes för uppdraget var det svenska verktyget IndividRAM version 6.27 (Växa Sverige) med databasversion 6.55, NorFor Plan 1.24.0.660, FST revision 1.99 och FRC revision 1.92. För att kunna beräkna behövs indata för foder och djur och restriktioner för optimeringen, vilket definieras nedan.

Indata för foder

Fodermedlen som användes i studien var enligt nutritionella värden i NorFors fodermedelstabell 8 december 2018 (figur 1). Foderpriser som användes för Expro® värmebehandlad rapsmjöl var 2:60, 3:13, 3:75 och 5:00 kronor per kg torrsubstans. Fast pris på vallensilage, korn, foderkalk, monokalciumfosfat och magnesiumoxid var 1:00, 1:50, 0:80, 5:00 respektive 5:00 kronor per kg TS.

Fodermedel						Protein		Fett		NDF	Stärkelse	Mineraler			Struktur...	Standardfodervärde		
Grp nr	Kod nr	Parti nr	Namn	Typ nr	Rgn nr	Råprot g/kg TS	sRåprot g/kg råprot	Råf g/kg TS	Fettsyr g/kg råfett	NDF g/kg TS	Stä g/kg TS	Ca g/kg TS	P g/kg TS	Mg g/kg TS	FV FV/kg TS	AAT20 g/kg TS	PBV20 g/kg TS	NEL20 MJ/kg TS
1	1	2	Korn, kärna	1	4	117	309	21	700	176	584	0,5	3,8	1,3	0,22	96	-27	7,11
3	5	6	Lupiner blå smalbladig	6	7	349	746	63	850	250	17	3,4	5,8	2,2	0,22	101	202	8,25
3	6	6	Ärter, kärna	6	7	239	729	19	700	110	462	1,3	4,6	1,3	0,22	104	87	7,75
3	7	6	Åkerböna, kärna	6	7	309	685	19	700	146	412	1,3	6,0	1,5	0,22	101	159	7,88
6	165	2	Ensilage, blandvall (1-50%	15	4	149	532	33	390	483	10	5,5	2,7	1,9	0,50	84	20	6,04
11	2	2	Kalksten	24	7	0	0	0	0	0	0	380,0	0,0	0,0	0,22	0	0	0,00
11	3	1	Monokalciumfosfat	24	7	0	0	0	0	0	0	160,0	227,0	10,0	0,22	0	0	0,00
11	7	1	Magnesiumoxid	24	7	0	0	0	0	0	0	0,0	0,0	560,0	0,22	0	0	0,00
18	19	6	Expro(R) Raps mjöl värme	43	7	407	84	45	900	279	9	7,8	11,2	5,6	0,22	188	134	7,11
18	33	6	Sojamjöl non-GM Denofa	43	7	528	173	12	700	125	49	3,5	7,1	3,2	0,22	221	246	8,38

Figur 1. Näringsvärden i de fodermedel som har använts i uppdraget.

Indata för djur

Foderstatsberäkning gjordes till en mjölkko med en levandevikt på 640 kg, var 120 dagar efter kalvning och avkastade 35 kg mjölk (4,3% fett och 3,5% protein).

Restriktioner

Optimeringsinställningarna sattes så att foderstaten skulle täcka minst 100% av djurets energibehov (159,4 MJ nettoenergi) och fodermängden skulle inte överstiga djurets intagskapacitet men ändå vara mätt (mellan 8,64 och 8,91 fyllnadsenheter). Proteinbehovet skulle täckas med minst 15 g AAT per MJ nettoenergi (tillgängligt för mjölkproduktion) och minst PBV 10 gram per kg torrsubstans, vidare var den övre gränsen på 40 g PBV per kg torrsubstans exkluderad. Mineralbehovet för kalcium, fosfor och magnesium skulle täckas (129, 79 respektive 46 gram per dag). Vombelastningstalet (socker plus vomnedbruten stärkelse dividerat med fiber) begränsades till 0,6. Undantag i uträkningarna var rekommendationen för fett i foderstaten, vilket i annat fall är minst 20 gram fettsyror per kg torrsubstans).

Resultat

Genom att ge rapsmjöl, i detta fall Expro®, en rad olika priser mellan 2:60 och 5:00 kronor per kg torrsubstans i NorFors fodervärderingssystem erhölls en skattning av ersättningsvärdet för ärter, åkerböna, lupin och sojamjöl. Produktionskostnaden eller inköpspriset av ärter, åkerböna, lupin och sojamjöl då det helt kan ersätta Expro® i foderstat med vallensilage, korn och mineraler visas i tabell 1.

Tabell 1. Värde för ärter, åkerböna, lupin och sojamjöl då de var för sig ersätter Expro® (rapsmjöl) vid 2:60, 3:13, 3:75 eller 5:00 kr per kg torrsubstans (TS) i fodervärderings-systemet NorFor vid optimering av minsta foderkostnad till en ko som producerar 35 kg mjölk

	kr per kg TS			
Expro® rapsmjöl	**2:60**	**3:13**	**3:75**	**5:00**
Ersättningsvärde				
Ärter, kärna	1:78	1:83	1:89	2:01
Åkerböna, kärna	1:85	1:91	1:98	2:12
Lupin, kärna	2:09	2:21	2:35	2:64
Sojamjöl, GMO-fri	3:83	4:76	5:83	7:96

Foderstater och foderstatskontroller för respektive pris visas i figur 2, 3, 4 och 5.

Fodermedel	35 kg mjölk (1)				35 kg mjölk (2)				35 kg mjölk (3)				35 kg mjölk (4)				35 kg mjölk (5)			
	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg
18-19-2 RSM 2,60	2,05				0,00				0,00				0,00				0,00			
3-5-2 Lup R2,60	0,00			0,00	2,87				0,00			0,00	0,00			0,00	0,00			0,00
3-6-2 Pea R2,60	0,00			0,00	0,00			0,00	7,81				0,00			0,00	0,00			0,00
3-7-2 F bean R2,60	0,00			0,00	0,00			0,00	0,00			0,00	5,72				0,00			0,00
18-33-2 SBM R2,60	0,00			0,00	0,00			0,00	0,00			0,00	0,00			0,00	0,89			
1-1-1 Barley	7,89				6,02				0,70				3,02				9,08			
6-165-1 Silage ley (1-50% clover)	13,93				14,57				14,63				14,54				13,73			
11-2-1 Limestone	0,09				0,09				0,10				0,11				0,12			
11-3-1 Monokalciumfosfat	0,00				0,00				0,00				0,00				0,01			
11-7-1 Magnesiumoxid	0,00				0,01				0,01				0,01				0,01			

Foderstatskontroll	Värde	Lås	Min	Max	Värde	Lås	Min	Max	Värde	Lås	Min	Max	Värde	Lås	Min	Max	Värde	Lås	Min	Max
TS-intag, kg TS/dag	24				23,6				23,3				23,4				23,8			
Kraftfoder, kg TS/dag	10				9				8,6				8,9				10,1			
NEL tot, MJ/dag	159,4				159,4				159,4				159,4				159,4			
NEL, MJ/kg TS	6,66				6,76				6,86				6,82				6,69			
NEL-bal, %	100		100	101	100		100	101	100		100	101	100		100	101	100		100	101
AAT/NEL, g/MJ	16,5		15		15		15		15		15		15		15		15,3		15	
AAT-bal, %	97,8				93,6				93,6				93,6				94,6			
PBV, g/kg TS	10		10		24		10		38		10		43		10		10		10	
Råprot, g/kg TS	163				168				181				187				154			
Fettsyr, g/kg TS	16			45	18			45	13			45	13			45	13			45
NDF, g/kg TS	363				374				346				359				350			
Vombelast, g/g NDF	0,46			0,6	0,36			0,6	0,39			0,6	0,41			0,6	0,55			0,6
Stä, g/kg TS	199				157				179				182				230			
Ca tot, g/dag	129		129		129		129		129		129		129		129		129		129	
P tot, g/dag	91		79		79		79		79		79		85		79		79		79	
Mg tot, g/dag	48		46		46		46		46		46		46		46		46		46	
Tuggtid, min/kg TS	44				45				44				44				44			
FV tot, FV	8,91		8,64	8,91	8,91		8,64	8,91	8,91		8,64	8,91	8,91		8,64	8,91	8,91		8,64	8,91

Figur 2. Foderstater optimerade med NorFors fodervärderingssystem när Expro® rapsmjöl med priset 2:60 kr per kg TS (RSM 2,60) ersätts av lupin (Lup R2,60), ärter (Pea R2,60), åkerböna (F bean R2,60) respektive sojamjöl (SBM R2,60). Bland foderstatskontrollerna ses vilka parametrar som går mot en restriktion som gulmarkerade. Foderstatskontroller med röda siffror visar när foderstatens resultat understiger en rekommendation (ej restriktion i optimeringen), medan blå siffor visar när det överstiger (ej restriktion i optimeringen).

Fodermedel	35 kg mjölk (1)				35 kg mjölk (2)				35 kg mjölk (3)				35 kg mjölk (4)				35 kg mjölk (5)			
	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg
18-19-3 RSM 3,13	2,05				0,00				0,00				0,00				0,00			
3-5-3 Lup R3,13	0,00			0,00	2,87				0,00			0,00	0,00			0,00	0,00			0,00
3-6-3 Pea R3,13	0,00			0,00	0,00			0,00	7,81				0,00			0,00	0,00			0,00
3-7-3 F bean R3,13	0,00			0,00	0,00			0,00	0,00			0,00	5,72				0,00			0,00
18-33-3 SBM R3,13	0,00			0,00	0,00			0,00	0,00			0,00	0,00			0,00	0,82			
1-1-1 Barley	7,89				6,02				0,70				3,02				9,55			
6-165-1 Silage ley (1-50% clöver)	13,93				14,57				14,63				14,54				13,31			
11-2-1 Limestone	0,09				0,09				0,10				0,11				0,12			
11-3-1 Monokalciumfosfat	0,00				0,00				0,00				0,00				0,01			
11-7-1 Magnesiumoxid	0,00				0,01				0,01				0,01				0,01			

Figur 3. Foderstater optimerade med NorFors fodervärderingssystem när Expro® rapsmjöl med priset 3:13 kr per kg TS (RSM 3,13) ersätts av lupin (Lup R3,13), ärter (Pea R3,13), åkerböna (F bean R3,13) respektive sojamjöl (SBM R3,13). Foderstatskontroller kan ses i figur 2 och figur 5.

Fodermedel	35 kg mjölk (1)				35 kg mjölk (2)				35 kg mjölk (3)				35 kg mjölk (4)				35 kg mjölk (5)			
	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg
18-19-4 RSM 3,75	1,70				0,00				0,00				0,00				0,00			
3-5-4 Lup R3,75	0,00			0,00	2,87				0,00			0,00	0,00			0,00	0,00			0,00
3-6-4 Pea R3,75	0,00			0,00	0,00			0,00	7,81				0,00			0,00	0,00			0,00
3-7-4 F bean R3,75	0,00			0,00	0,00			0,00	0,00			0,00	5,72				0,00			0,00
18-33-4 SBM R3,75	0,00			0,00	0,00			0,00	0,00			0,00	0,00			0,00	0,82			
1-1-1 Barley	9,33				6,02				0,70				3,02				9,55			
6-165-1 Silage ley (1-50% clover)	12,69				14,57				14,63				14,54				13,31			
11-2-1 Limestone	0,11				0,09				0,10				0,11				0,12			
11-3-1 Monokalciumfosfat	0,00				0,00				0,00				0,00				0,01			
11-7-1 Magnesiumoxid	0,00				0,01				0,01				0,01				0,01			

Figur 4. Foderstater optimerade med NorFors fodervärderingssystem när Expro® rapsmjöl med priset 3:75 kr per kg TS (RSM 3,75) ersätts av lupin (Lup R3,75), ärter (Pea R3,75),

åkerböna (F bean R3,75) respektive sojamjöl (SBM R3,75). Foderstatskontroller kan ses i figur 2 och figur 5.

Fodermedel	35 kg mjölk (1)				35 kg mjölk (2)				35 kg mjölk (3)				35 kg mjölk (4)				35 kg mjölk (5)			
	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg	Giva, kg	Lås	Min, kg	Max, kg
18-19-5 RSM 5,00	1,70				0,00				0,00				0,00				0,00			
3-5-5 Lup R5,00	0,00			0,00	2,85				0,00			0,00	0,00			0,00	0,00			0,00
3-6-5 Pea R5,00	0,00			0,00	0,00			0,00	7,81				0,00			0,00	0,00			0,00
3-7-5 F bean R5,00	0,00			0,00	0,00			0,00	0,00			0,00	5,73				0,00			0,00
18-33-5 SBM R5,00	0,00			0,00	0,00			0,00	0,00			0,00	0,00			0,00	0,82			
1-1-1 Barley	9,33				6,04				0,70				3,01				9,55			
6-165-1 Silage ley (1-50% clover)	12,69				14,57				14,63				14,54				13,31			
11-2-1 Limestone	0,11				0,09				0,10				0,11				0,12			
11-3-1 Monokalciumfosfat	0,00				0,00				0,00				0,00				0,01			
11-7-1 Magnesiumoxid	0,00				0,01				0,01				0,01				0,01			

Foderstatskontroll	Värde	Lås	Min	Max	Värde	Lås	Min	Max	Värde	Lås	Min	Max	Värde	Lås	Min	Max	Värde	Lås	Min	Max
TS-intag, kg TS/dag	23,8				23,6				23,3				23,4				23,8			
Kraftfoder, kg TS/dag	11,1				9				8,6				8,9				10,5			
NEL tot, MJ/dag	159,4				159,4				159,4				159,4				159,4			
NEL, MJ/kg TS	6,69				6,76				6,86				6,82				6,69			
NEL-bal, %	100		100	101	100		100	101	100		100	101	100		100	101	100		100	101
AAT/NEL, g/MJ	15,7		15		15		15		15		15		15		15		15		15	
AAT-bal, %	95,7				93,6				93,6				93,6				93,6			
PBV, g/kg TS	10		10		24		10		38		10		43		10		10		10	
Råprot, g/kg TS	157				168				181				187				152			
Fettsyr, g/kg TS	16			45	18			45	13			45	13			45	13			45
NDF, g/kg TS	346				374				346				359				345			
Vombelast, g/g NDF	0,55			0,6	0,36			0,6	0,39			0,6	0,41			0,6	0,58			0,6
Stä, g/kg TS	235				158				179				182				241			
Ca tot, g/dag	129		129		129		129		129		129		129		129		129		129	
P tot, g/dag	89		79		79		79		79		79		85		79		79		79	
Mg tot, g/dag	46		46		46		46		46		46		46		46		46		46	
Tuggtid, min/kg TS	42				45				44				44				43			
FV tot, FV	8,64		8,64	8,91	8,91		8,64	8,91	8,91		8,64	8,91	8,91		8,64	8,91	8,82		8,64	8,91

Figur 5. Foderstater optimerade med NorFors fodervärderingssystem när Expro® rapsmjöl har priset 5:00 kr per kg TS (RSM 5,00) ersätts av lupin (Lup R5,00), ärter (Pea R5,00), åkerböna (F bean R5,00) respektive sojamjöl (SBM R5,00). Bland foderstatskontrollerna ses vilka parametrar som går mot en restriktion som gulmarkerade. Foderstatskontroller med röda siffror visar när foderstatens resultat understiger en rekommendation (ej restriktion i optimeringen), medan blå siffor visar när det överstiger (ej restriktion i optimeringen).

Stockholm 2018-12-10

Maria Åkerlind, Växa Sverige

maria.akerlind@vxa.se