Using Faba Beans as a protein source for Danish dairy cows

Yannick Schipper

EED livestock production

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Thesis coach: Daan Westrik

13 January 2020

Dronten

Preface:

This research was carried out to help the Danish farmers in their decision making about the protein source they will use to feed their dairy cows. My motivation was to study alternative protein sources utilization to soybean meal and rapeseed meal to reduce the environmental impact of dairy farming.

This study was part of a project of the cattle feeding department from SEGES. I want to thank all the participants to the project. I want to thank the farmers who took part in this project. I want to thank Jon Birger Pedersen for his explanations about the faba beans cultivation in Denmark. I want to thank Betina Amdisen Røjen and Rudolf Thøgersen for their support all along this research, I am grateful for their availability.

Glossary:

- DM: Dry Matter
- NIR: Near infrared spectroscopy
- GMO: Genetically Modified Organism
- Ha: Hectare
- P: Phosphorus
- DMS: Dairy management system
- TMR: Total mixed ration
- SCC: somatic cell count

Summary:

In recent years the dairy industry had to face new environmental regulations and consumption evolutions. The soybean meal utilization as a protein source is not adapted to the GMO-free milk production. That's why there was a growing interest for GMO-free rapeseed meal to replace soybean meal but since 2017 the Danish phosphorus regulation makes it harder to utilize phosphorus rich rapeseed meal. This explains a growing interest in Denmark for pulses cultivation. The main pulses are lupine, faba beans and field peas. The faba beans seem to have to highest yields in Denmark and have a high crude protein concentration. Nevertheless, it is necessary to make further research to compare the possible milk production and the costs related to the utilization of faba beans compared to a production system based on soybean meal and rapeseed meal. The objective is to provide clear, reliable and representative result on the milk production and the costs by using faba beans for Danish farms. The goal is to support the farmers taking the best decisions about the protein source they use to improve their revenues on the farms. What are the effects on the dairy farms revenues of using faba beans in comparison with using soybean meal or rapeseed meal as protein sources for Danish dairy cows? The results on the production of the cows are based on a trial conducted in 11 Danish farms and 2 300 cows took part to the project in total. The cows were fed a control treatment with soybean meal or rapeseed meal as protein source and a faba bean treatment with faba beans conserved and processed with different methods depending on the farms. The trial supported the results of the literature research and showed no difference in milk production and protein content for the control and the faba bean treatment. There was a significant difference in fat content between the control and the faba beans trial and no previous researches showed this result. It is possible that the nature of the starch in faba beans is different than the starch in the cereals used in the control treatment and that the faba bean starch improves the fat content in the milk. The research on the buying costs of soybean meal, rapeseed meal and faba beans show that faba beans and rapeseed meal have similar costs and soybean meal is more expensive with equivalent protein content. It seems that cultivating faba beans on the farm is the best option to maximize milk the production cost. Nevertheless the production cost of faba beans is closely related to the yield so the land should be adapted to faba bean cultivation. Based on this research, the Danish farmers should consider using faba beans instead of soybean meal and rapeseed meal.

Chapter 1: Introduction

The Danish cows are probably the most productive cows in Europe with an average production close to 10.000kg milk per year (SEGES, 2015). These high yields are possible with a production system based on home grown maize and grass and purchased protein sources for the rations of the cows. The European citizens and the governments are caring more and more about the environmental impact of dairy. That's why choosing the right protein source to feed the cows is a tool to produce milk in an environmental friendlier way. The goal of the following introduction to our study is to show the different protein sources and the limits of their utilization. The aim is to understand why there is a growing interest for faba beans utilization in dairy cows' diet.

The soybeans produced in America as Genetically Modified Organisms (GMO's) are a great source of protein for cows, but it is ethically not adapted to the consumers will. Soybean meal is the vegetable source of protein that has the highest protein content and is because of that widely used for animal feeding. That's why the European dairy farmers rely on American soybean meal imports as a protein source for the dairy cows. In 2013 on average 61% of all the supplemental protein (excluding fish meal) fed to all European livestock was imported Soybean meal (De Visser, Schreuder & Stoddard, 2014). In America the surface used to grow soybeans raised from 37 to 79 million hectares between 1986 and 2010 and the cultivation area expanded on previous savannahs and rain forests areas. In the meantime, the land used to grow non-GMO soybeans decreased from 44M ha in 1996 to 7M ha in 2010 (Garrett, Rueda & Lambin, 2013) showing a big utilization of GM soybeans. The consequences on human health of biotechnologies used to make GMO's are still unclear. The European consumers do not trust products based on GMO's and that is why the dairy industry develops GMO free dairy products.

The GMO-free dairy products market has expanded, and the farmers are using rapeseed meal as a GMO-free protein source. In 2016, Arla foods, the seventh biggest dairy corporation worldwide and collecting milk in Northern Europe, collected 20% of the milk as GMO free milk (Arla Foods, 2016, para.3). To produce this GMO-free milk, the Danish farmers had to find alternative protein sources for their cows. The alternative was rapeseed meal. In recent years, there is a growing demand for canola due to it utilization in human food and for the biofuel industry. The oil extraction results in rapeseed meal (canola meal) and once fed to cattle, the performances are comparable to the utilization of soybean meal. With 80% self-sufficiency in rapeseed meal production, Europe can supply the GMO-free protein source needed by the farmers (European Commission, 2018). Using rapeseed meal is possible for the production of GMO-free milk, but there is a high concentration of phosphorus and it is a problem for the environment.

The new phosphorus regulation in Denmark pushes the farmers to manage their phosphorus outputs. In 2017 the ministry of environment and food of Denmark created the direct Phosphorus (P) ceilings. The legislation is due to a risk of eutrophication. In regions were the input of P (manure and fertilizer) are higher than the outputs (P needed by the plants) a development of algae and microorganisms in surface water can occur, resulting in fish losses and biodiversity losses in surface water (Powell, Jackson-Smith, Satter & Bundy, 2002). The legislation limits the P output of the farms to on average 33kg P per hectare and per year. By limiting the phosphorus concentration in the diets, the concentration of P in the manure is reduced and the farmers can monitor their total Phosphorus production and fertilize their crops effectively (Ministry of environment and food of Denmark, 2017). The best way to reduce the P output is limiting the phosphorus imported on the farm and specifically the phosphorus content of imported protein rich feedstuffs for the cows.

The high phosphorus content of rapeseed meal makes the phosphorus outputs management on the farms harder and thus it is important to search for a protein source that has a lower phosphorus content. Rapeseed meal, soybean meal, faba beans are the protein sources with the highest content of protein per kg dry matter and their phosphorus content varies. Table 1 show that the phosphorus/protein ratio differs between the three protein sources. Rapeseed meal has a higher phosphorus content per gram protein than soybean meal and faba beans and thus is using faba beans in dairy cows ration a way to reduce the phosphorus outputs per gram protein fed to the cows.

Table 1

Phosphorus compared to the protein concentration for rapeseed meal, soybean meal and faba beans in the NorFor system

Name	Dry matter (g/kg)	Crude protein (g/kg)	Phosphorus (g/kg)	Phosphorus/Protein ratio (mg/g)
Rapeseed expeller, 00, 10% fat	885	344	11,1	32,267442
Soya bean extracted	876	487	7,6	15,605749
Faba beans	850	309	6	19,417476

Source: NorFor feed tables

In summary, soybean meal was used previously because it is the vegetable protein source with the highest protein content, but it is mainly GMO and European concerns about GMO’s helped the development of a GMO-free dairy industry. The development of rapeseed for biofuel helped to develop a GMO-free dairy production system based on rapeseed meal as a protein source. But since 2017, the direct phosphorus ceilings legislation in Denmark pushed the farmers and advisors to consider other protein sources than rapeseed meal since its phosphorus content is high and might be a problem to meet the maximum output levels of phosphorus on the farms.

There is more and more interest in using faba beans as a protein source in Denmark. Indeed, since home grown faba beans is a non-GMO protein source and it has a lower phosphorus content in comparison with rapeseed meal, faba beans seems to be a possible solution as a protein source for cows.

It is necessary to study the reasons why faba beans is preferred as a protein source over other pulses and namely the ability of faba beans to be grown in Denmark and compare it to other possible protein sources. Then, it is necessary to summarize previous studies on the performances (milk production and composition) of the dairy cows fed faba beans compared to cows fed soybean meal or rapeseed meal. The aim is to identify a knowledge gap that needs to be answered.

Faba beans is a nutrient rich feed stuff and its production is adapted to the Danish Climate conditions (see table 2). In 2015 the main pulses grown in Europe are peas (34% of total pulses surface), faba beans (28% of total pulses surface) and lupins (12% of total pulses surface) (Eurostat, 2019). Field peas yield on average 4,9 ton per hectare and faba beans yield on average 5,3 ton per hectare over the last 8 years and seems therefore better adapted to Danish conditions (Pedersen, 2019). The crude protein content is lower, respectively 30,9% and 23,9% crude protein per kilogram DM for faba beans and field peas (NorFor, 2019). Finally, faba beans are easier to grow as a single crop. Because its strong stems the faba beans do not lodge like field peas would do (the whole plant falls because of the weight). Lupins have a high crude protein content (34,9%, faba beans 30,9%) but the yield per hectare is too low to compete with faba beans. The average yield of lupin seed is between 1,5 and 3 tons per hectare under Australian conditions (Grains Research & Development Corporation, 2017) and 5,3 tons per hectare for faba beans under Danish conditions. Unlike lupins, faba beans have a high starch content (respectively 1,7% and 41,2%) and can easily replace a cereal in the cow’s ration (NorFor, 2019). So, if faba beans cultivation in Denmark is possible and offers the best yields between the main pulses, it is necessary to study previous research about the performances of dairy cows with faba beans.

Table 2

Comparison between main pulses grown in Europe on their yield and protein and starch content

	Faba beans	Field peas	Lupin seeds
Yield (Ton/hectare)	5,3	4,9	1,5- 3
Crude protein content (%)	30,9	23,9	34,9
Starch content (%)	41,2	46,2	1,7
Source	(NorFor, 2019) (Pedersen, 2019)	(NorFor, 2019) (Pedersen, 2019)	(NorFor, 2019) (Grains Research & Development Corporation, 2017)

The results on different researches comparing faba beans and soybean meal and rapeseed meal as protein sources in dairy cows' ration, are slightly diverging (see Table 3). A Canadian study (Cherif et al., 2018) showed no differences in feed intake, milk production and milk composition for 9 Holstein cows fed a ration based on corn and alfalfa silage and supplemented for 35 days with either concentrates composed of soybean meal and corn grain or concentrates composed of ground or rolled faba beans. This research showed that with 16% crude protein in the 3 treatments the performances were similar with different protein sources. It also shows that the performances in that research are similar if the faba beans are rolled or ground (Cherif et al., 2018). A similar study was conducted in Italy (Volpelli et al., 2010) with Reggiana dairy cows yielding 21kg of milk per day where soybean meal was partially replaced by heat treated faba beans in the hay and grass-based diet. Once again, there was no differences on milk production and milk composition in the control treatment and the treatment where the cows were fed faba beans. A study of Hansen et al (2018) showed that the performances of the production and milk composition were similar for 40 cows fed a ration based on clover grass and maize silage and supplemented with concentrate based on different protein sources. In this research, the performances of the cows were compared with concentrates based on soybean meal or rapeseed meal with wheat and heat treated faba beans and untreated faba beans. It turned out that the production and milk composition of the cows was similar when the cows were fed soybeans meal, rapeseed meal, untreated faba beans and heat treated faba beans. Nevertheless, the milk protein was lower for the cows fed the heat treated faba beans when the other treatment had similar protein in milk, showing a possible overheating of the crude protein. Finally, a Finnish research (Puhakka, Jaakkola, Simpura, Kokkonen& Vanhatalo, 2016) studied the effect of rapeseed meal substitution by faba beans as protein source in a grass silage-based ration. The experiment was conducted on 12 Ayrshire cows. The outputs are that the cows fed faba beans instead of rapeseed meal produces less milk and the milk protein yield was also lower. The milk urea was higher in the milk of the cows fed faba beans, showing a poorer utilization of the protein in the faba beans diet.

Table 3

Different results on 4 studies on the effect of replacement of rapeseed meal and soybean meal by faba beans

Autor	Animals	Period	Base ration	Treatments (base of concentrates	Effect on production
Cherif et al.	9 Holstein cows	35 days	Corn and alfalfa silage	Soybean meal and corn grain; ground faba beans; rolled faba beans	No effect
Volpelli et al.	80 Reggiana cows	17 weeks	Grass and hay	Soybean meal; heat treated faba beans	No effect
Hansen et al.	40 Holstein cows	12 weeks	Clover-grass and corn silage	Soybean meal and wheat; rapeseed meal and wheat; untreated faba beans; heat treated faba beans	No effect on production but lower protein yield in heat treated faba beans treatment
Puhakka, Jaakkola, Simpura, Kokkonen& Vanhatalo	12 Ayrshire	9 weeks	Grass silage	Rapeseed meal; faba beans	Lower milk and protein yield with faba beans treatment

The literature review shows that because of its high concentration in crude protein, in starch and its higher yields in Denmark compared to lupin and peas, faba beans are the best option for Danish farmers to produce a pulse they can feed to the cows as a protein source (Pedersen, 2019 and Eurostat, 2019). The literature review also shows through different studies that it is possible that the dairy cows perform (feed intake, milk production and milk composition) as well with a protein rich concentrate based on faba beans as with soybean meal or rapeseed meal as protein source. Nevertheless, some studies show no differences in the production of the cows with the different diets (Cherif et al., 2018) ;(Volpelli et al., 2010) and some studies show a lower production with diets composed of faba beans (Puhakka, Jaakkola, Simpura, Kokkonen& Vanhatalo, 2016 and Hansen et al., 2018). The studies have also different outputs depending on the processing of the faba beans, with some studies in which the milk production and composition is affected by the treatment of the faba beans (Hansen et al, 2018) and some studies in which it does not affect the performances of the cows (Cherif et al., 2018). If the literature research showed that faba beans can be grown in Denmark for a good quality and yield, we do not know if growing faba beans on the farms to feed it to the cows is more profitable/less expensive than buying a protein rich feedstuff like rapeseed meal or soybean meal. There is no literature available comparing the costs for the farmers of different protein sources and specifically no research on costs of soybean meal or rapeseed meal compared to faba beans. The literature research is not unanimous if the cows are producing as much with faba beans as with rapeseed meal and soybean meal. The researches related on production and milk components were run in different countries (Finland, Italy, Canada and Denmark) and with different breeds (Reggiana, Ayrshire, Holstein). These differences can have an impact on the results of the trials. It is necessary to do further research to compare the production of the cows fed faba beans and the cows fed soybean meal or rapeseed meal to confirm the results of the Danish research (Hansen et al., 2018). These different knowledge gaps lead to a question that needs to be answered.

What are the effects on the dairy farms revenues of using faba beans in comparison with using soybean meal or rapeseed meal as protein sources for Danish dairy cows?

This research question can be answered by having a technical and economical approach. Revenues are influenced by the productions (technical) and the costs (economical). The main question can be answered by providing results on different sub-questions.

- ⇨ Is there a difference in feed intake, milk production and milk composition for cows fed faba beans compared to cows fed soybean meal or rapeseed meal?
- ⇨ What are the production costs of faba beans for the Danish farmers?
- ⇨ How much does it cost for the Danish farmers to buy faba beans?
- ⇨ How much does it cost to buy soybean meal and rapeseed meal?

By relating the results of these questions, it is possible to give an answer on the effect of using faba beans instead of soybean meal or rapeseed on the revenues of the farms.

This study aims to provide more information to the farmers to be able to better decide about the protein source they should use for their operation. One goal is to know the economical consequences of using local produced or self-produced protein sources for the cows rations on the production cost of milk. This study has as objective to identify possible alternative protein rich feedstuffs and identify the limits to their utilization so that further research can be made to ease the alternative protein sources utilization in the future (varieties selection for higher yields, climate adapted, higher nutritive value…). This study could have influence on the dairy farms because they could increase their independence from world market for feedstuffs (soybean meal) and stabilize their revenues.

Chapter 2: Material and method

Is there a difference in feed intake, milk production and milk components for cows fed faba beans compared to cows fed soybean meal or rapeseed meal?

A. Farms characteristics:

An experiment was conducted to know if there is a difference on milk production and milk components for cows fed diets with faba beans instead of soybean or rapeseed. This trial was run in 11 farms in Jutland area in Denmark (see table 3 for farms characteristics).

Table 4

Farms characteristics for the trial

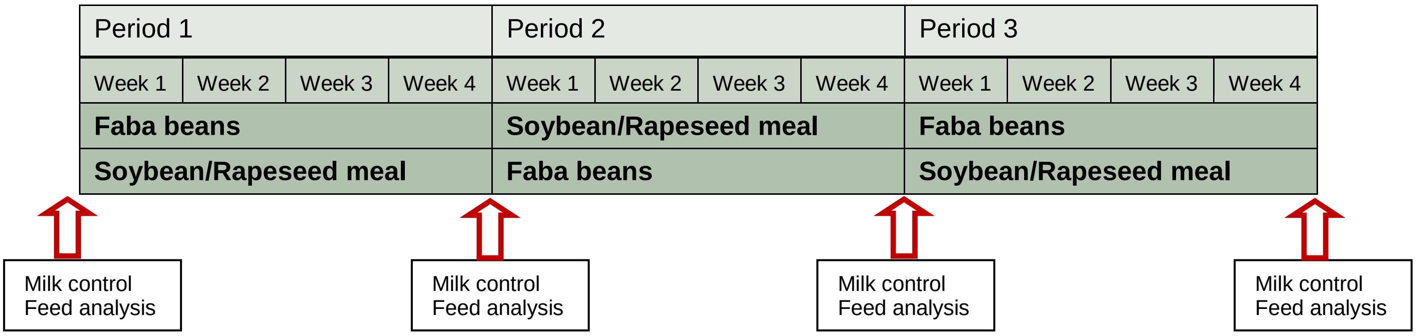
Farm	Treatment	Type[3]	Breed[4]	Cows	Production (Kg/cow/year)	Ration	Milking
1	N-Y-N[1]	C	H	255	10,300	TMR	Parlor
2	Y-N-Y[2]	C	H	173	12,500	TMR	Parlor
3	Y-N-Y	C	H	179	10,900	TMR	Parlor
4	N-Y-N	C	H	216	10,100	TMR	Parlor
5	Y-N-Y	C	H	214	10,800	PMR	Robot
6	N-Y-N	O	H	112	8,100	TMR	Parlor
7	N-Y-N	O	H	176	9,500	TMR	Parlor
8	Y-N-Y	O	H	240	10,800	PMR	Parlor
9	Y-N-Y	O	H+C	174	10,400	PMR	Parlor
10	Y-N-Y	O	H	164	10,700	PMR	Robot
11	N-Y-N	O	H+C	397	10,800	PMR	Caroussel

[1] N-Y-N stands for no-yes-no, meaning in first period without, second period with, third period without faba beans in the ration.
[2] Y-N-Y stands for yes-no-yes, meaning in the first period with, second period without and third period with faba beans in the diet.
[3] For the type of farm we registered the conventional farms (C) and the organic farms (O).
[4] For the breeds we registered the Holstein herds (H) and the crossbreds (C).

B. Experimental design:

The trial was conducted as a crossover design, over 12 to 15 weeks divided in 3 periods of 4 to 5 weeks (see figure 1). A crossover design is a way to conduct an experiment where all the cows are assigned to the 2 treatments. That mean that the cows receive one treatment during 4 weeks before crossing over to the second treatment for another 4 weeks. During the first period five farms fed their cows a mix of rapeseed meal and soybean meal (farms 1,4,6,7,11) while the 6 other farms fed faba beans (farms 2,3,5,8,9,10). For the second period it was the other way around, so the cows switched to another diet. During the last period of 4 weeks the farmers fed the cows the diet they had in the first period. During the periods the cows were fed soybean meal and rapeseed meal was called “control period” and when the cows were fed faba beans was called “faba beans period”. At the beginning of the trial the cows had a milk control, they had milk controls again at the end of each period. This explains why the periods were not exactly 4 weeks but can be a bit longer because of the milk control that was done every 4 to 5 weeks.

Figure 1: The organization of the trial for the different periods:



Justification of this protocol: First for the analysis of the results and accuracy of the trial. By having a group of farms with 2 control periods and a group of farms with 2 faba beans periods, the results will be more accurate and analyzable in a statistic way. Indeed, the differences between the productions and milk components can be easily explained because of the use of faba beans or not. If there are no significant differences between the groups, using faba beans instead of rapeseed meal or soybean meal has no consequences. On the other hand, if using faba beans instead of soybean meal or rapeseed meal influences production and components it will be easier to justify because for the same milk control the production and components will drop for some farms and increase for others. For each farm 4 milk controls will be made with a different diet every time (the farms change to the other diet after the milk control) and between each control there is at least 4 weeks of treatment period. That give enough time to the rumen flora to have a transition if needed and the cows have a good utilization of the diet at every milk control.

The experimental design had to be convenient, adapted for the farmers, who are volunteers for this research and get no financial help. The trial should not add feeding costs and labor costs to the farmer. That is why it was not possible to split the herds in half and give simultaneously different diets to the cows. It is the most convenient just to change one feedstuff in the ration from one period to another and all the cows would change from one diet to another and then back to the first diet.

C. Feeding characteristics:

For the experiment 9 farmers cultivated their own faba beans and 2 farmers sold a part of their stock to 2 other farmers taking part in the trial (see table 4 for feed analysis). The farmers used spring varieties faba beans because of higher yields and winter hardiness. The seeds would be sowed in March to April and harvested during September or October. This long growing season makes the harvest (in the fall) the hardest period to manage because of wet fields (Pedersen, 2019, p.15). The main limits for the farmers were that faba beans can suffer from dry periods, very hard frost, and a bad soil structure (compacted soils). Faba beans are also sensitive to diseases and fungi and there should be as least 6 years beween two cultivations on the same field (Pedersen, 2019, p.14). The faba beans selection is now focused in Denmark on making the growing season shorter and in a lower perspective increasing yields.

Table 5

The faba beans used for the trial

Farm	DM (g/kg)	Crude protein (g/kg dm)	Soluble CP (%)	Starch (g/kg dm)	NDF (g/kg dm)	Crude fat (g/kg dm)	Mold (CFU/g)	Yiest (CFU/g)
1[1]	872	282	59	351	-	229	1.400.000	<100
2	868	305	46	412	124	207	100	<100
3	855	275	64	425	130	211	270	200
4	831	280	66	386	137	229	<100	<100
5	837	289	58	373	173	203	<100	<100
6 and 7	845	293	60	369	155	201	1.500	<100
8	908	308	22	369	101	209	4.100	<100
9[1]	907	284	15	370	212	209	300	<100
9	918	254	17	379	182	229	100	1.600
10 and 11	900	281	20	407	134	200	2.400	<100

[1] Faba beans harvested in 2017, all the other faba beans are from 2018

The dry matter content of the faba beans vary between conservation methods (see table 5). The conservation methods, processing of faba beans are different between the farms. The farmers had the liberty for the conservation and processing of the faba beans based on their machinery available, labor availability and contractor availability. The replacement mix (protein rich concentrate used by the farmer before the trial started), is also different between the farms because of their different suppliers. The farmers used the protein concentrates they use normally for the "control period" and faba beans processed or not for the "faba beans period". The protein sources and concentrates are not homogenous but with 11 farms in the trial and 2 300 cows used for the trial, the results will be accurate and there will be statistical outputs. The differences on conservation and processing method of faba beans and percentage of soybean meal or rapeseed meal in the concentrates will not have significant consequences on the results. The voluntary choice of having different feeds for the farms is to have a general output/answer that is applicable in most of the Danish farms. The purpose of the trial is to know if there is a difference in performances for the cows when they are fed faba beans or rapeseed meal or soybean meal regardless of the conservation, processing methods and the replacement concentrate.

Table 6

The feeding characteristics for this trial and its utilization for the research

Farm	Faba beans (average Kg/day)	Faba beans conservation	Processing	Replacement concentrate mix
1	1,6	Dried	Miller	Rapeseed cake and Soybean concentrate + grain blend
2	2,4	Toasted	Miller	Rapeseed product + cereals
3	1,5	Dried	Crimper	Rapeseed product and Soybean concentrate+ cereals
4	1,7	Acid+ silage	Crimper	Rapeseed + corn cob
5	1,5	Acid+ silage	Crimper	Rapeseed and Soybean concentrate + grain blend
6	1,5	Dried	Crimper	Soybean cake + corn and cereals blend
7	1,5	Dried	Crimper	Sobean cake + corn and cereals blend
8	1,8	Toasted	Roller	Soybean cake + corn and corn cob
9	1,5	Toasted	Crimper	Soybean cake + corn and cereals blend
10	1,6	Toasted	Roller	Soybean product + corn and cereals blend faba beans from 2,8 to 1,2Kg
11	1,4	Toasted	Roller	Soybean cake + cereals

D. Sampling and analysis:

Before the trial started every feedstuff that was used in the rations was sampled on the farms and was analyzed in the laboratory using Near Infrared Spectroscopy (NIR) (see table 6 for the frequencies of the sample collection). The week before the milk control on each farm (last 6 days and day of the milk control), the ration nutritive composition was daily calculated based on the feed analysis of every feedstuff and the exact ration formulation (exact amount of every feeds put in the feeding mixer). The day of the milk control, TMR samples were taken with a wide box that was put on the feed table of the cows and during distribution of the ration some feed felt into the bucket.

- The bucket is emptied on plastic surface to form a pile
- The pile is divided in 4 equal parts

- 2 opposite parts are selected and put together on a pile and 2 parts are put again in the bucket
- The pile is divided in 4 equal part
- 2 other opposite parts are selected and put together on a pile and 2 parts put again in the bucket
- And so on until the size of the pile is small enough to fit in a bag

The ration was analyzed with a NIR analysis to have the exact composition of the feed and put it in relation with the calculated ration nutritive composition. During each period the rations were formulated with the Danish Dairy Management System (DMS program). This program is used by the Danish farmers to formulate their rations based on their feedstuffs analysis and their herd requirements using the NorFor feed evaluation system. The farmers reported daily the number of cows milked and the amount of milk that was discarded for the tank.

The individual milk control was made during each period of the trial (beginning and every period the treatment changed for the cows). The average production of each cow and the milk composition (protein and fat content, somatic cell count) was pooled for each milk control. The milk in the tank was reported daily with the fat and protein and somatic cell count in the tank.

The daily data like number of cows, milk discarded and milk in the tank and its composition was collected. The calculated ration data collected 7 days per period was put in relation with the number of cows milked and the discarded milk to have the feed intake and milk production per cow and per kg DM ration. Finally, the once per period data like the individual milk control and the ration NIR analysis was collected.

The data was pooled by period and by treatment (faba beans and control). The data was analyzed using a linear mixed model with SAS statistics program. This analysis model is well adapted to show the relationship between a dependent variable and an independent variable. The independent variable was the treatments so using faba beans and using soybean meal and rapeseed meal. The milk production, the feed intake, the protein and fat content were dependent of the treatments, so they were the dependent variable. For the feed stuff analysis, the independent variables were using faba beans and using soybean meal and rapeseed meal. In this case the dependent variables were forage intake, concentrates intake, crude protein, crude protein utilization, starch, NDF, fatty acids, cation anion balance, energy losses. In this trial it was necessary to use a linear mixed model because there was non-independence in the total number of cows. Indeed, the cows were divided in 11 farms so there are different factors that may not be independent like the management on each farm.

The results were significant different if the P-value was smaller than 0,05. There was a tendency for a difference when the P-value was between 0,05 and 0,1.

Table 7

Sampling scheme

Frequency of sample collection	Before the trial start	Daily	4 times (once per period)
Number of cows		X	
Discarded milk		X	
Ration distribution- rests			X (7 days)
Ration NIR analysis			X
Feedstuffs analysis	X		
Individual milk control (milk, fat, protein, SCC[1])	X		X
Milk production, fat and protein, SCC in the tank		X	

[1] *SCC: Somatic Cell Count*

<u>How much does the importation/buying of soybean meal and rapeseed meal costs?</u>

The cost of soybeans meal and rapeseed meal was found in literature research and namely internet reports on commodity prices evolutions. The monthly price was averaged over the period January 2015 to September 2019 for rapeseed meal and the period January 2015 to October 2019 for soybean meal. Every month the prices were updated and used to calculate the average price of soybean meal and rapeseed meal over the last 5 years. The information on soybean meal prices will be retrieved from worldwide market analysis agencies as ISTA Mielke GmbH (OIL WORLD); US Department of Agriculture and World Bank by using key words as commodity prices, soybean meal market trends, soybean meal price evolution. This source is used because there is a monthly price for soybean meal showing that the information is up-dated. The source is related to the USDA who is the most important agency for agriculture in the USA.

The information on rapeseed meal prices will be retrieved from Agriculture and Horticulture Development Board by using key words as commodity prices, rapeseed meal market trends, oil legumes by-products price evolution, Canola meal prices. This source is used because it is regularly updated since the monthly price of rapeseed meal is reported. The UK is in the EU and we can expect their prices to be similar to the prices for rapeseed meal in Denmark.

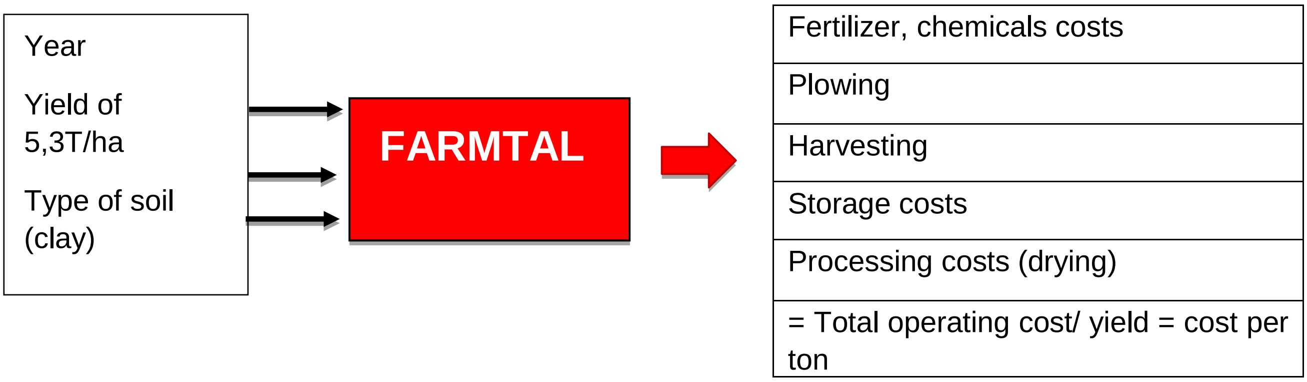
The costs will be translated in euros per metric ton.

How much does the production of faba beans costs for the Danish farmers?

The cost of producing faba beans on the farms was calculated by using a Danish tool called Farmtal (see figure 2 for the system utilization). It is a tool that is calculating the cost of producing numerous crops based on the management of the crop on the farm that the farmer puts manually in the system (organic or conventional, number of fertilizer application, number of chemical application). The production cost considers the diesel and labor used during plowing, sowing, application of fertilizer or chemical, harvest. The production cost is also influenced by the climate conditions of the year and the labor costs. Every trimester advisors and researchers are putting the costs of fossil energy sources, fertilizers and chemicals and the losses due to the climate, in the system to keep an updated, percise tool.

The tool was used to give the average over the 5 last years (years 2014,2015,2016,2017,2018 and prediction of 2019) of the average faba beans production cost for a yield of 5,3 ton per hectare (as the literature review showed that 5,3 ton was the average over the last 8 years in Denmark). The results of the costs over the 5 years will be analyzed in the discussion in relation to the costs of buying soybean meal and rapeseed meal.

Figure 2: Use of farmtal tool to calculate the average production cost of faba beans in Denmark



How much does it cost to buy faba beans?

The cost of buying faba beans for Danish farmers was retrieved from farmtal online that is also used to calculate the production cost of faba beans. This tool is used to have a prediction of the gross profit per hectare faba beans. That means that the program calculates based on the prices for seeds, fertilizers, chemicals and labor and based on the market price of the faba beans, the gross profit per hectare faba beans. The market price of faba beans is up- dated every trimester on farmtal online. The price is calculated per kilo faba beans, so it will be converted to euros per metric ton. This source is used because the program is up-dated by Danish advisors and researchers with Danish commodity prices. The program indicates an average market price in all Denmark over a year.

The utilization of literature is not adapted to have information on the market price or buying cost of faba beans because there is no data and documents about faba beans prices in Denmark. The faba beans are also used for human consumption so literature research could show higher prices for faba beans for animal feed than the reality because human food is more expensive than animal feed.

Chapter 3: Results of the research

Results of the soybean meal and/or rapeseed meal treatments and the faba beans treatment on the milk production and composition of the cows:

The experiment was not conducted simultaneously on all the farms depending on the harvest period of faba beans but also corn silage. The data was collected over a period of 21 weeks in total. The data was pooled per farm and period. The outputs of the linear mixed model analysis were divided per treatment.

The material and method showed the faba beans analysis on each farm. The chemical composition of the faba beans were slightly different depending on the conservation process used and the processing method. Nevertheless the diets in both treatments were formulated to fulfill the lactation requirements of the cows. In table 8, the chemical analysis of de diets for the control treatment (soybean meal or/and rapeseed meal) and faba beans treatment was similar to the calculated rations with DMS program. The crude protein content was 166g/kg and 169g/kg respectively for the control and faba bean treatment and the crude protein digestibility was 70.1g/kg and 69.1g/kg respectively for the control and faba bean treatment. The NDF, starch and fat content of the control treatment was respectively 299g/kg, 185g/kg and 41.2g/kg. For the faba beans treatment the NDF, starch and fat content was respectively 285g/kg, 199g/kg and 38g/kg

Table 8

TMR and PMR average compositions for faba beans rations or soybean meal and rapeseed meal ration

	Control		Faba beans	
	Calculated with the NorFor evaluation program	Analyzed	Calculated with the NorFor evaluation program	Analyzed
Dry matter g/kg (NorFor)	399	388	408	389
Crude protein (g/kg DM)	165	166	167	169
Organic matter digestibility (%)	79.8	79.5	80	80.6
Crude protein digestibility (g/kg DM)	70.9	70.1	73.6	69.1
Starch (g/kg DM)	206	183	206	199
NDF (g/kg DM)	310	299	300	285
Crude fat (g/kg DM)	41	41.2	39.5	38

During the trial a sample of milk was taken in the milk tank on a daily basis. The samples were analyzed for fat and protein yield, fat and protein content, and the production recorded was added to the total discarded milk to have the herd production. The samples taken during the control period and the faba bean period were compared with a linear fixed model analysis. The table 9 shows the results on the milk tank samples and show no significant differences on the milk yield, the fat yield, the protein yield and the protein content between the control and the faba beans treatment. The table 9 shows that the fat content in the milk tank had a tendency to be different (P-value of 0.05) between the control treatment with 4.18% of fat and the faba beans treatment with 4.22% fat. Nevertheless, the ECM yield was not significant different with 32kg/day and 31.7kg/day respectively for the control treatment and the faba beans treatment.

Table 9

Results of the milk production and composition based on the milk tank samples

	Treatment			
	Control	Faba beans	SEM[2]	P-Value
Milk yield (kg/day)	31	30,6	0,78	0,11
Fat yield (kg/day)	1,29	1,29	0,03	0,81
Protein yield (kg/day)	1,1	1,09	0,03	0,10
Fat (%)	4,18	4,22	0,04	0,05
Protein (%)	3,55	3,56	0,02	0,56
ECM yield[1] (kg/day)	32	31,7	0,87	0,30

[1] Energy corrected milk

[2]Standart error of mean

During the trial and every month the herd had an individual milk control. The farms had a different treatment between each milk control. The table 10 shows the results of the statistical analysis for milk production and milk composition. The milk yield, fat, and protein yield were respectively on average 31.9kg/day, 1.33kg/day, and 1.13kg/day for the cows fed the control treatment. These results were not significant different form the cows fed the faba beans treatment that had respectively 31.6kg/day, 1.34kg/day, and 1.12kg/day for the milk yield, fat yield and protein yield. The fat content was significant different between the cows fed the control treatment and the cows fed the faba beans treatment with respectively 4.16% and 4.23% fat. Nevertheless, the ECM production was not significant different with respectively 32.8kg ECM for both treatments. The protein content was not significant different for the control treatment and the faba beans treatment with respectively 3.52% and 3.53% protein per kg milk.

Table 10

Results of the individual milk control for the soybean meal and/or rapeseed meal treatment and the faba beans treatment

	Treatment			
	Control	Faba beans	SEM	P-Value
Milk yield (kg/day)	31,9	31,6	0,75	0,35
Fat yield (kg/day)	1,33	1,34	0,03	0,38
Protein yield (kg/day)	1,13	1,12	0,03	0,51
Fat (%)	4,16	4,23	0,05	0,02
Protein (%)	3,52	3,53	0,03	0,56
ECM yield[1] (kg/day)	32,8	32,8	0,84	0,93

[1] Energy corrected milk

<u>Results of the average soybean meal and the rapeseed buying cost:</u>

The table 11 shows that the average price over the last five years for soybean meal with 44 to 46% protein was 333.4€ per metric ton. This means that the price is 7.41€ per kg crude protein from soybean meal with 44-46% crude protein. The average price for rapeseed meal with 34% protein was 217.66€ per metric ton over the period 2015 to 2019. When the price per ton is converted to price per kg crude protein, the rapeseed meal with 34% protein costs 6.4€ over the last five years.

Table 11

Average market price and price per kg protein of rapeseed meal and soybean meal

	Soybean meal 44 - 46% spot	Rapeseed meal 34% spot
Average price in €/metric ton 2015	350,94€	210,38€
Average price in €/metric ton 2016	338,42€	198,81€
Average price in €/metric ton 2017	311,08€	205,51€
Average price in €/metric ton 2018	342,75€	248,59€
Average price in €/metric ton 2019	308,76€	227,46€
Average price in €/metric ton over 5 years	333,4€	217,66€
Price per kg crude protein	7,41€/kg CP	6,4€/kg CP
Source	ISTA Mielke GmbH (OIL WORLD); US Department of Agriculture and World Bank	Agriculture and Horticulture Development Board

Results of the average faba beans production and buying cost:

The table 12 shows the average production and buying costs for faba beans. The raw data is in appendix The average production cost in Denmark for faba beans with 30.9% crude protein was 165€ per ton over the 2015 to 2019 period. That means that the cost represents 5.34€ per kg crude protein. The average price of buying cost for faba beans with 30.9% crude protein was 193€ per ton over the last five years. When the price per ton is converted to price per kg crude protein, faba beans with 30.9% crude protein cost 6.25€ over the last five years.

To sum up the results of the research, there was no difference in milk production and composition for the cows fed faba beans instead of soybean meal or rapeseed meal. Excepted for the fat content who was significant different for cows fed faba beans with 4.23% per kg milk than for cows fed soybean meal or rapeseed meal with 4.16% per kg milk.

The price of soybean meal is the highest with a price of 333.4€ per metric ton or 7.41€ per kg crude protein, rapeseed meal costs 217.66€ per metric ton or 6.4€ per kg crude protein and finally faba beans production costs is 165€ per metric ton or 5.34€ per kg crude protein and 193€ per metric ton or 6.25€ per kg crude protein when it is bought.

Table 12:

Average production cost and cost per kg protein of faba beans

	Faba beans production cost with 30.9% CP	Faba beans buying cost/price with 30.9%CP
Average cost per ton in euros in 2014	159€	200.7€
Average cost per ton in euros in 2015	156€	184.6€
Average cost per ton in euros in 2016	164€	170€
Average cost per ton in euros in 2017	171€	187.3€
Average cost per ton in euros in 2018	171€	214€
Average cost per ton in euros in 2019	173€	200.7€
Average cost over the period in euros per ton	165€	193€
Price per kg crude protein	5,34€/kg CP	6,25€/kg CP
Source	Farmtal online	Farmtal online

Chapter 4: Discussion

Interpretation and discussion of the production and milk composition results with faba beans as replacement for soybean and rapeseed meal:

The objectives of the research was to have a clear idea of the economical consequences of using local produced faba beans on the milk production costs by this is meant the price of the protein source but also the milk production permitted by it utilization. This research would also help to identify possible improvements that can be made to make the utilization of faba beans more profitable or economically viable. These objectives contribute to help the farmers to stabilize their revenues by gaining independency on the world market for feedstuffs (like soybean meal or rapeseed meal).

To give a global answer to the objectives discussed above, it was necessary to conduct a trial on the performances of the cows fed faba beans in comparison to the cows fed soybean meal or rapeseed meal.

The results showed that the production of milk was similar with the different protein sources. This supports the results from the research of Hansen et al. , Volpelli et al. , and Cherif et al. showing that the milk production was similar for rations containing faba beans and rations containing rapeseed meal or soybean meal.

The protein yield and content in the milk was also similar for the control treatment and for the faba beans treatment, contrarily to the research from Hansen et al and Puhakka, Jaakkola, Simpura, Kokkonen& Vanhatalo showing a lower protein content with rations containing faba beans. The lower protein content in the milk of faba beans treatment was explained in the literature review by a possible overprotected protein in heat treated faba beans rations. The protein by-passing the rumen was not efficiently absorbed in the intestines and thus the protein content in the milk was lower. In this trial the protein content with the different treatments was similar so it is probable that the different faba beans conservation methods and processing methods used by the farmer had no negative effects on the digestibility and are thus all adapted for an efficient ration.

Based on the individual milk controls sampled during the trial, the fat content was significant different between the cows fed faba beans and the cows fed soybean meal or rapeseed meal. This result seems reliable because the Standard Error of Mean is low with 0.04. This means that the results were closely spread around the average. This result could be explained by a difference in the percentage of fat in the ration but with respectively 4.12% and 3.8% crude fat for the control treatment and the faba bean treatment, the percentage is too low to have an incidence of the digestibility of the ration. The ration and namely the fiber digestibility can be lower with 6% or more crude fat in the ration. This result might be explained by the type of starch in faba beans that is different from the starch in the cereals combined with the soybean meal and rapeseed meal rations. In 9 out of 11 farms the soybean meal or rapeseed meal was supplemented with cereals or grain blends. Cereals like wheat or triticale have a high degradation rate; they are precursor to propionate which results in milk production more than milk fat production. The high degradation rate also speed up the transit form the rumen to the intestines. The higher fat content in the faba beans treatment could be explained by starch that is has a slower release in the rumen (slower degradation rate). The ration has a slower transit from the rumen to the intestines which give enough time to the bacterial to degrade the fiber and the organic matter is overall better digested. The higher organic matter digestibility for the faba beans rations than the control ration that are respectively 80.6% and 79.5% support this idea. The fiber in the ration is transformed to butyrate and acetate in the rumen. Butyrate and acetate are precursors to milk. There were no articles found in the literature review showing a difference for milk fat content between faba beans rations and soybean meal or rapeseed meal. There must be further research made to support this result and prove the benefits of faba beans starch on the milk fat content.

The farms used for this trial were volunteers. There were 6 organic farms and 5 conventional farms taking part to the trial. The goal of the research was to have an output on the utilization of faba beans on the Danish farms. Nevertheless, less than 10% of the Danish farms are organic in Denmark so the group of farms used for the research is not representative from the Danish farms population. It was more important to find a maximum of farms who wanted to participate to the trial than having a population of farm representative of the total population especially because the nature of the farms should not have consequences on the results of the trial.

To have a global result of the utilization of faba beans on Danish farms the feedstuff used were different on all the farms. The ration formulation was similar for the faba beans treatment and the control treatment. The advantage is that in the case of milk production, the results show no differences with both treatments and this corresponds to the results of the literature so it is reliable. For fat content the literature review do not show the same result and because there are different farms, different feedstuffs, different environments it is harder to determine the origin of this difference than on an experimental farm with the same environment, the same animals, and the same feedstuffs.

In summary the research confirms the results of previous research about a similar milk production and protein content for cows fed faba beans and cows fed soybean meal or rapeseed meal. This shows that independently from the faba beans conservation and processing method, the milk production is comparable between the two treatments. The fat content of the cows fed faba beans was higher than the cows from the control treatment. This could be explained by the nature of the starch in the faba beans that is beneficial for high lactating dairy cows to digest the total organic matter. It was decided to make a research with different farms and different feedstuffs to give a global advice with the results but it is hard to identify the origin of a higher fat content with the faba beans trial so there is a need to make further research on the fat content in the milk. It is necessary to relate the outputs on the milk production for the different feedstuffs with their costs.

<u>Interpretation and discussion of the soybean meal and rapeseed meal buying costs</u>

The goal of the research on the average buying costs for soybean meal and rapeseed meal is to compare it with the production and buying costs of faba beans. The comparison between the different protein sources will help to identify a feedstuff that is cheaper to optimize the milk production costs.

The research showed that the average price for soybean meal and rapeseed meal was respectively 333.4€ and 217.66€ per metric ton. The higher price for soybean meal can be explained first by higher protein content with 44 to 46% crude protein for soybean meal and 34% crude protein for rapeseed meal. To compare the prices the cost were converted by price per kg crude protein. The higher price for soybean meal is explained by the high demand for this feedstuff. The poultry, pigs, cattle and other livestock production are using soybean meal. The nature of the protein is especially adapted for poultry and pig production.

To conduct this research the data was retrieved on the ISTA Mielke GmbH (OIL WORLD); US Department of Agriculture and World Bank website for soybean meal and the Agriculture and Horticulture Development Board website for rapeseed meal. The ISTA Mielke GmbH is a international organization so the prices for soybean meal are form the world market. The AHDB is an organization from the United-Kingdom so the prices for rapeseed meal are probably form the English or European market. There was a will to compare different sources on the prices of soybean and rapeseed meal but there was no additional data available on the commodity prices.

<u>Interpretation and discussion of the production and buying costs of faba beans</u>

The production cost of faba beans is on average 165€ per ton and the buying cost is 193€ per ton over the last five years. We expected the production costs to be lower than the buying costs because the producer margin and transport is added. The research also shows that the price of rapeseed meal and faba beans is similar when it is converted to the same crude protein content.

The farmers have to consider that the production cost is closely related to the yield of faba beans. That’s why the soil and the climate should be adapted on the farm to produce faba beans. If the soil and climate is adapted to wheat production it might be profitable for the farmer to cultivate wheat and sell it for a high price to buy faba beans back.

The data used for the research is based on Danish prices and is often up-dated so we expect it to be accurate and representative of the real prices for the Danish farmers.

General outputs and discussion of the research

The research showed that faba beans conserved and processed with different methods can be used to feed the cows and have comparable productions and milk composition than cows fed soybean meal or rapeseed meal. The research showed that the soybean meal is the most expensive protein source and that the cost of buying faba beans and rapeseed meal is comparable. The production of faba beans on the farms seems to be the cheapest solution.

This means that based on this research, the faba beans cultivation on the farm has a positive effect on the revenues in comparison with buying soybean meal, rapeseed meal or faba beans. Most of the Danish farmers use their land to make forages for their cattle. For the farmers who have no land available for faba beans cultivation, buying faba beans instead of rapeseed meal has no effect on the revenues but benefits to the environment. The price for faba beans is comparable to rapeseed meal but the phosphorus content in rapeseed meal is higher than in faba beans. Faba bean cultivation has also agronomic benefits because the crop can stock nitrogen in the soil and it could be used by other crops the year following faba beans.

Chapter 5: Conclusion and recommendations

This research was conducted to support the farmers with decision making about the protein source they should use to feed their cows. The objective is to measure the effects of faba beans utilization instead of soybean or rapeseed meal on the revenues of the farms. In order to answer this research question, the production and milk composition needed to be compared for cows fed faba beans and for cows fed soybean meal or rapeseed meal. The buying and production cost of faba beans was compared to the buying cost of soybean meal, rapeseed meal. The research confirmed the literature results that the production of the cows was similar between cows fed soybean or rapeseed meal and the cows fed faba beans. The nature and degradation rate of the starch explains probably that the fat content was higher for the cows fed faba beans. The research also showed that the soybean meal was more expensive than rapeseed for equivalent protein content. Finally with an average price of 165€, the faba bean production costs are even lower than rapeseed meal. The price for buying faba beans is similar to the buying cost rapeseed meal for equivalent nitrogen content. Based on this research, using self cultivated faba beans to replace soybean or rapeseed meal has positive effect on the revenues of the farm. We can also say that buying faba beans instead of buying rapeseed meal has no effects on the revenues but has positive effects on the agronomic system of the farms. These results are based on a large scale trial including 11 farms. The costs of the protein sources are based on reliable sources. The farmers should consider using faba beans to feed their cattle in the future but they should take into account their land availability, the soil and climate, the evolution of the market prices…

Tables:

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Appendix:

Appendix 1: Soybean meal price over the last five years

Appendix 2: Rapeseed meal price over the last five years

Appendix 3: Production and price for faba beans in Denmark over the last five years

Appendix 1: Soybean meal price over the last five years

Soybean Meal – Monthly Price (Euro per Metric Ton)

Month	Price	Change	Average per Year
Oct 2014	362,22	-	
nov-14	389,7	7.59 %	
déc-14	379,55	-2.60 %	
janv-15	381,74	0.58 %	
févr-15	368,62	-3.44 %	
mars-15	380,62	3.25 %	
avr-15	369,38	-2.95 %	
May 2015	346,09	-6.31 %	
juin-15	345,15	-0.27 %	
juil-15	370,4	7.31 %	
août-15	346,49	-6.45 %	
sept-15	333,61	-3.72 %	
Oct 2015	331,96	-0.49 %	
nov-15	326,13	-1.76 %	
déc-15	311,1	-4.61 %	350,9408
janv-16	309,9	-0.38 %	
févr-16	291,59	-5.91 %	
mars-16	287,57	-1.38 %	
avr-16	305,31	6.17 %	
May 2016	372,54	22.02 %	
juin-16	416,58	11.82 %	
juil-16	397,57	-4.56 %	
août-16	355,63	-10.55 %	
sept-16	328,19	-7.72 %	
Oct 2016	328,44	0.08 %	
nov-16	329,99	0.47 %	
déc-16	337,67	2.33 %	338,415
janv-17	349,34	3.46 %	
févr-17	351,01	0.48 %	
mars-17	337,62	-3.82 %	
avr-17	322,58	-4.45 %	
May 2017	311,64	-3.39 %	

juin-17	294,17	-5.61 %	
juil-17	295,95	0.61 %	
août-17	279,66	-5.50 %	
sept-17	287,1	2.66 %	
Oct 2017	300,5	4.67 %	
nov-17	299,29	-0.40 %	
déc-17	304,08	1.60 %	311,0783
janv-18	308,15	1.34 %	
févr-18	341,16	10.71 %	
mars-18	361,03	5.82 %	
avr-18	376,05	4.16 %	
May 2018	388,5	3.31 %	
juin-18	360,8	-7.13 %	
juil-18	347,92	-3.57 %	
août-18	336,03	-3.42 %	
sept-18	323,43	-3.75 %	
Oct 2018	330,49	2.18 %	
nov-18	322,2	-2.51 %	
déc-18	317,27	-1.53 %	342,7525
janv-19	317,03	-0.08 %	
févr-19	311,26	-1.82 %	
mars-19	304,92	-2.04 %	
avr-19	303,91	-0.33 %	
May 2019	303,28	-0.21 %	
juin-19	321,08	5.87 %	
juil-19	310,95	-3.15 %	
août-19	303,22	-2.49 %	
sept-19	302,7	-0.17 %	
Oct 2019	309,2	2.15 %	308,755
		Average over the last 5 years	335,7967

Appendix 2: Rapeseed meal price over the last five years

	Rapeseed meal	
	34%, Spot, Ex-mill Erith	
	Monthly average	5-year rolling average
	194,00	191,75
	188,00	192,47
	184,00	193,26
	185,00	193,86
	192,50	194,76
	192,50	195,20
	172,00	195,27
	174,75	194,88
	163,25	194,33
	163,60	193,81
	149,33	192,92
	141,33	191,61
	148,75	190,92
	137,67	190,36
	153,67	190,08
	163,00	190,09
	179,75	190,24
	179,75	190,52
	177,00	191,11
	173,00	191,28
	163,20	191,24
	167,00	191,60
	171,00	192,15
	171,00	192,24
	175,00	192,29
	175,00	192,07
	192,40	192,07
	181,33	191,85
	173,00	191,46
	177,20	191,18
	166,75	189,68
	162,33	187,94
	161,67	186,38
	158,00	184,72
	162,33	184,28
	166,67	182,70
	165,50	182,37
	188,00	182,47
	201,00	181,70
	216,75	180,96
	212,50	179,70
	207,00	180,20
	214,67	180,86
	228,75	181,72
	220,50	182,09
	208,25	182,11

	209,80	182,61
	209,00	182,63
	207,75	182,02
	207,50	181,24
	192,20	181,44
	188,25	180,99
	182,20	180,45
	185,50	180,51
	182,50	180,89
	180,20	181,15
	177,00	181,08
Average over the last 5 years in £	181,15	
	216,60	
Average in €		

Appendix 3: Production and price for faba beans in Denmark over the last five years

Conventional faba beans							
Soil clay							
Without watering							
Year		**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Yield	**Ton/hectare**	5,3	5,3	5,3	5,3	5,3	5,3
Production							
Profit		7950	7314	6731	7420	8480	7950
Cost per ton		200.7€	184.6€	170€	187.3€	214€	200.7€
Operational costs							
Seeds	230 kg	**-736**	**-690**	**-920**	**-1150**	**-1150**	**-1092,5**
Phosphorus fertilizer	25 kg	**-300**	**-300**	**-300**	**-300**	**-300**	**-300**
Potassium fertilizer	47 kg	**-282**	**-282**	**-282**	**-235**	**-246,75**	**-246,75**
Weed control		**-260**	**-363**	**-363**	**-550**	**-500**	**-490**
Disease control		**-40**	**-40**	**-40**	**-40**	**-75**	**-125**
Pest control		**-100**	**-108**	**-108**	**-70**	**-70**	**-70**
Total operational costs	Dkr/hectare	**-1718**	**-1783**	**-2013**	**-2345**	**-2341,75**	**-2324,25**
Remaining profit		6232	5531	4718	5075	6138,25	5625,75
Labor and machinery costs							
Plowing	1 time	**-675**	**-675**	**-675**	**-675**	**-675**	**-725**
Slurry	1 time	**-140**	**-140**	**-140**	**-140**	**-140**	**-150**
-1	1 time	**-160**	**-160**	**-160**	**-160**	**-160**	**-175**
Harrowing and sowing	1 time	**-375**	**-375**	**-400**	**-400**	**-400**	**-400**
Spraying	3 times	**-480**	**-480**	**-525**	**-525**	**-525**	**-540**
Harvesting	1 time	**-1050**	**-1050**	**-1000**	**-1000**	**-1000**	**-1039**
Stocking and transport costs		**-300**	**-300**	**-300**	**-300**	**-300**	**-296,73**
Drying		**-690**	**-690**	**-780,16**	**-736**	**-736**	**-697,5**
Additional costs		**-500**	**-500**	**-500**	**-500**	**-500**	**-500**
Total labor and machinery costs	Dkr/hectare	**-4370**	**-4370**	**-4480,16**	**-4436**	**-4436**	**-4523,23**
Remaining profit		1862	1161	237,84	639	1702,25	1102,52
Total cost in DKK		**6088**	**6153**	**6493,16**	**6781**	**6777,75**	**6847,48**
Total cost in Euro		**815,792**	**824,502**	**870,083**	**908,654**	**908,219**	**917,562**
Cost per ton		**153,923**	**155,566**	**164,167**	**171,444**	**171,362**	**173,125**