Organic milk production based entirely on home-grown feed

Ph.D. Thesis

by

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Preface and acknowledgements

The present thesis intends to meet the requirements for obtaining a Ph.D. degree from The Royal Veterinary and Agricultural University (RVAU), Copenhagen. The Ph.D. study was conducted at Department of Agroecology at The Danish Institute of Agricultural Sciences and at Department of Animal Science and Animal Health (until 2002, subsequently Department of Veterinary Pathobiology) at The Royal Veterinary and Agricultural University. The Ph.D. study was financed by the Danish Research Centre for Organic Farming (DARCOF) and by the Danish research programmes: Demonstration and development of new, organic farming systems 1999-2003 (Øko-Demo II) and Research in Organic Farming 2000-2004 (FØJO II) under the project: Organic dairy production systems. Supervisors for the Ph.D. study were Senior Scientist Troels Kristensen, Ph.D., Danish Institute of Agricultural Sciences, and Professor Stig Milan Thamsborg, The Royal Veterinary and Agricultural University.

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Papers and manuscripts included

The work in the thesis, including the five appended papers/manuscripts listed below, forms the evaluation material for the Philosophiae Doctorae degree of The Royal Veterinary and Agricultural University. The appended papers are numbered I to V and in the thesis these papers are referred to by the authors' names and year of publication followed by paper I-V.

I. Mogensen, L. 2002. Mælkeproduktion baseret på 100% økologisk fodring. Hvad siger den økologiske landmand? - Resultater fra interviewundersøgelse. I: (Sehested, J., Kristensen, T.) Økologisk mælkeproduktion – Strategier og foderforsyning ved 100% økologisk fodring. FØJO-rapport nr. 17. Forskningscenter for Økologisk Jordbrug. 15-26.

II. Mogensen, L. & Kristensen, T. 2002. Effect of barley or rapeseed cake as supplement to silage for high-yielding organic dairy cows. Acta Agric. Scand., Sect. A, Animal Sci. 52:4, 243-252.

III. Mogensen, L. & Kristensen, T. 2003. Concentrate mixture, grass pellets, fodder beets, or barley as supplements to silage ad libitum for high-yielding dairy cows on organic farms. Acta Agric. Scand., Sect. A, Animal Sci. 53: 4, 186-196.

IV. Mogensen, L., Ingvartsen, K. L., Kristensen, T., Seested, S. & Thamsborg, S.M. 2004a. Organic dairy production based on rapeseed, rapeseed cakes, or cereals as supplement to silage ad libitum. Acta Agric. Scand., Sect A, Animal Sci. 54, 81-93.

V. Mogensen, L. et al. 2004b. Productivity, economy, and nutrient balances on organic dairy farms with different types of home-grown supplement for winterfeeding. In preparation.

Abbreviations

AAT	Amino acids absorbed from the small intestine
BCS	Body condition score
CLA	Conjugated linolic acid
DM	Dry matter
ECM	Energy corrected milk
GM	Gross margin
IFOAM	International Federation of Organic Agriculture Movements
K	Potassium
LU	Livestock unit
MPU	Milk producing unit
N	Nitrogen
P	Phosphorus
PBV	Protein balance in rumen
SFU	Scandinavian feed unit

Summary

The aim of the Ph.D. project was to examine the consequences for the farm of an organic milk production based entirely on home-grown feed. The project included interviews that identified what in farmers' opinion is crucial for obtaining organic milk production based entirely on home-grown feed (paper I), production experiments that examined the effects of different types of home-grown concentrated feed on milk production (papers II, III, and IV) and scenario calculations that described the consequences for productivity, economy, and nutrient balances of organic milk production based entirely on home-grown feed (paper V).

With a market share of 25%, organic milk production is the most important organic livestock production in Denmark. Organic milk production differs from conventional production because the organic production is based on the organic principle aims. These aims are put into practice by use of standards. A common organic regulation was introduced in the EU in 1999 (EU Regulation No 1804/1999). However, there is still a great diversity in production conditions and systems across Europe. According to the EU regulation (1999) all organic cows must be fed entirely organically grown feed as of 2005, and preferably the feed should be grown on the farm. The challenge related to this new situation is substantial and will be different in different European countries.

The objective of the first part of the project was to identify farmers' attitudes towards the question: Can organic milk production in Denmark be based entirely on home-grown feed and how? (paper I). The study was conducted in 1999 and included six organic dairy farmers. The principle of 100% organically grown feed had a wide support among all the farmers interviewed. This was especially due to the fact that they want the consumers to continue to trust their products. When some farmers imported the allowable amount of conventionally grown feed at that time it was for financial reasons, only. Several farmers wanted to be self-supplying with feed from a financial point of view, some farmers saw a closed system having a value in itself while others gave higher priority to producing crops for sale than to be self-supplying with feed. Once 100% organically grown feed becomes a requirement in the EU in 2005, some farmers intend to use home-grown feed only: clover-grass, maybe whole crop silage, and barley. Others intend to continue to import feed (paper I).

Specific problems identified by the interviews were to match the need for energy and nutrients of a dairy cow in early lactation with crops which could be grown in an organic crop rotation under Northern European conditions. It is obvious to construct a feed ration with a high proportion of clover-grass silage and with barley as supplement. However, such a ration will be fairly high in starch and the level of protein and fatty acids will be low compared with the typical standards for dairy rations.

The specific circumstances in the organic dairy farming system, where the farm strives to be a closed system based on clover-grass and with a close connection between fields and stable, makes it advantageous to use production experiments on private farms to examine the effects of different feeding rations. The organic dairy farming system differs further from the conventional farming system by typically including a higher proportion of roughage in the ration, a longer period of flat-rate feeding, and a lower energy level at the beginning of the lactation. This affects the lactation curve as well as the feed efficiency. The best way to include all these complexities is to make the examination within the organic system on the organic farm.

In paper II, a supplement of home-grown barley was compared with a supplement of imported rapeseed cake. An experiment was carried out with 103 cows in two groups on two farms. The cows in each group received solely barley or an isoenergetic mixture of rapeseed cake and barley as supplement. Neither daily milk yield, milk fat content, protein content, nor energy corrected milk yield (ECM) were significantly different in the barley and rapeseed cake treatments. Traditionally, a negative effect of a barley ration on milk yield would be expected due to a lower content of amino acids absorbed (AAT) and fatty acids and a higher level of starch than in a ration with rapeseed cake. An explanation of the lack of effect may be a positive effect of a high proportion of high-quality roughage, mainly clover-grass (paper II).

In paper III**,** a supplement of barley was compared with a supplement of grass pellets, fodder beets, or concentrate mixture. Three experiments were carried out with 246 cows in two groups on three farms. The cows in one group on each farm received barley while the cows in the other group on each farm received a concentrate mixture, grass pellets, or fodder beets. Compared to barley supplement of a concentrate mixture resulted in a higher ECM yield. This may be explained by the desirability of a balanced diet. Supplement of fodder beets compared to barley at the same level of dry matter (DM) resulted in a milk yield reduction, which could be expected due to the lower energy supply. Supplement of grass pellets instead of barley at the same level of dry matter resulted in similar milk and ECM yields. This may be due to a positive effect of grass pellets on the diet composition (paper III).

In paper IV, a supplement of barley was compared with a supplement of rapeseed or rapeseed cake. All rations were composed in a way in which it should be possible to grow the ingredients at an equal area per cow, as area per cow is a limiting factor in a system self-supplying with fodder. Two experiments were carried out with 174 cows distributed in three or two groups on two farms, respectively. The supplement of rapeseed/cereal pellets compared with cereals only tended to decrease milk fat and protein content, while fat and protein yield were unaffected. Milk yield was increased by supplement of rapeseed/cereal pellets compared with cereals in experiment 1, but unaffected in experiment 2. Consequently, ECM yield tended to increase in experiment 1, but decreased in experiment 2. The different effects in the two experiments may be caused by differences in roughage quality as the proportion of clover-grass silage and the average *in vitro* digestibility of the roughage were lower in experiment 2 than in experiment 1. The supplement of rapeseed cake compared with cereals changed neither milk composition nor yield as the lower energy intake in the rapeseed cake ration was not totally compensated for by the positive effect of the more harmonious composition of nutrients (paper IV).

The objective of the study in paper V was by scenario calculations to describe the consequences for productivity, economy, and nutrient balances on the organic dairy farm of different types of home-grown supplement for winterfeeding. There were greater differences in output due to differences in roughage quality and level of concentrated feed than due to differences in type of supplement. From a financial point of view, a high feeding level achieved by high-quality roughage and a normal level of concentrated feed was most attractive. It was not profitable to decrease the level of concentrated feed when the marginal feed efficiency was high. Supplement of grass pellets or fodder beets were characterized by a higher crop and milk production per ha compared to supplement of barley. Supplement of rapeseed/barley gave the same crop and milk production per ha as supplement of barley. Growing rapeseed for rapeseed cakes resulted in a low crop and milk production per ha as well as a low financial output. In a farming system self-supplying with feed and manure, nitrogen (N) input from fixation is a factor with great effect on N balances. Therefore, the financially attractive scenario with supplement of grass pellets gave a high N surplus/ha (paper V).

In conclusion, with the preset pricing of milk and bought-in concentrated feed a system based on home-grown feed can be financially more attractive than a system based on imported feed. The area per cow needed to grow the ration in a system self-supplying with feed and manure is about 1.7 ha with a variation from 1.4 to 2.0 ha depending on feeding level, type of supplement and roughage, and yield potential in different crops. Only 10% of the present organic dairy farms in Denmark have more than 1.70 ha per cow. In a self-supplying organic dairy farming system focus on roughage – quantity and quality – will increase even more, and become one of the most important factors in the system. Increased feeding level caused by increased roughage quality will pay off. A decreased feeding level caused by decreased level of concentrated feed will not be financially attractive if the marginal feed efficiency in the herd is high. There will only be minor variation in the financial output from the farm dependent on type of concentrated feed used. However, there are reasons to believe that a comprehensive composition of the ration is necessary for health reason.

Dansk sammendrag

Det overordnede mål med dette ph.d.-projekt var at belyse de bedriftsmæssige konsekvenser for malkekoens foderforsyning og produktion af at gennemføre en økologisk mælkeproduktion baseret 100% på hjemmeavlet foder. Projektet omfattede interview af økologiske landmand vedrørende selvforsyning med økologisk foder (artikel I). Derudover indeholdt projektet tre serier produktions-forsøg, hvor effekten på mælkeydelse af forskellige typer tilskudsfoder blev undersøgt (artikel II, III, IV). Endelig blev der opstillet scenarier for forskellige økologiske mælkeproduktionssystemer til at vurdere den samlede virkning for bedriftens produktivitet, økonomi og næringsstofbalancer af 100% selvforsyning med økologisk foder.

Økologisk mælkeproduktion er den vigtigste økologiske driftsgren i Danmark med en økologisk markedsandel på konsummælk på 25%. Økologisk mælkeproduktion adskiller sig fra konventionel mælkeproduktion ved at være baseret på de økologiske principper og værdier. Disse principper omsættes til praksis ved hjælp af de økologiske regler. EU fik et fælles regelsæt i 1999 med virkning fra 2000. Disse regler kræver, at økologiske køer udelukkende fodres med økologisk dyrket foder fra år 2005. Da der er meget forskellige produktionsbetingelser i de forskellige EU-lande, vil det være forskelligt, hvad landmændene i de enkelte lande ser som den største udfordring ved at skulle fodre med 100% økologisk foder.

Projektets første delmål var at undersøge økologiske landmænds holdning til spørgsmålet: Kan økologisk mælkeproduktion i Danmark gennemføres udelukkende ved brug af hjemmeavlet foder og hvordan? (artikel I). Seks økologisk landmænd blev interviewet i 1999. Det økologiske princip om at bruge 100% økologisk foder havde fuld opbakning hos alle de interviewede landmænd. Dette skyldes især hensynet til, at forbrugerne fortsat skulle have tillid til de økologiske produkter. Når nogle af landmændene indkøbte den mængde konventionelt foder, man måtte købe efter de daværende regler (15% af foderenhederne), var det af økonomiske årsager. Nogle af landmændene ønskede at være selvforsynende med foder, men af forskellige årsager. Nogle af hensyn til økonomien, nogle fordi de så et lukket system som en værdi i sig selv. Andre landmænd foretrak at dyrke salgsafgrøder frem for at være selvforsynende med foder. Nogle af landmændene regnede med at fodre med hjemmeavlet foder: kløvergræs, byg og måske helsæd, når der blev krav om 100% økologisk foder, mens andre landmænd forventede fortsat at indkøbe en del af foderet (artikel I).

- Dansk sammendrag -

Når en højtydende ko skal fodres udelukkende med foder, der kan dyrkes økologisk under nordeuropæiske forhold, er den største udfordring at opfylde behovet for energi og specifikke næringsstoffer. Ud fra kendskabet til de afgrøder, der hidtil typisk er blevet dyrket økologisk, er det oplagt at formulere en ration baseret på kløvergræs og korn. En sådan ration vil dog få et alt for højt indhold af stivelse, og indholdet af protein (AAT) og fedtsyrer vil blive for lavt.

Et af de økologiske principper er, at det økologiske produktionsystem er et lukket system med en tæt forbindelse mellem mark og stald, hvilket gør det oplagt at vælge produktionsforsøg på private gårde, når man skal undersøge effekten af forskellige foderrationer. Økologisk mælkeproduktion adskiller sig endvidere fra konventionel mælkeproduktion ved typisk at indeholde en større andel grovfoder i rationen, en længere periode med fast tildeling af kraftfoder, et lavere foderniveau lige efter kælvning og dermed en fladere laktationskurve og en højere fodereffektivitet. Den bedste måde at tage højde for disse specielle forhold på er at foretage produktionsforsøgene i det økologiske system på den økologiske gård.

I artikel II blev tilskud af byg sammenlignet med tilskud af rapskage, idet rapskage tidligere typisk udgjorde den indkøbte konventionelle del af rationen, og byg var det oplagte valg af et hjemmeavlet tilskudsfoderemne. I forsøget indgik i alt 103 køer på to gårde, hver med to forsøgshold. Køerne på de to forsøgshold fik tildelt samme mængde energi i tilskudsfoder, enten som byg eller som en blanding af rapskage og byg. Der var ingen signifikant effekt hverken på mælkeydelsen i kg, mælkens indhold af fedt og protein eller ydelsen i kg energikorrigeret mælk (EKM). Umiddelbart ville man forvente en negativ effekt af bygrationen på mælkeydelsen pga. et lavere indhold af aminosyrer absorberet i tarmen (AAT) og et lavere indhold af fedtsyrer end i rapskagerationen. At der ikke var nogen effekt, skyldes sandsynligvis en positiv effekt af det store indhold af letfordøjeligt kløvergræsensilage i ad libitum foderet, samt at hyppige tildelinger af byg delvis har ophævet den negative effekt af stivelsen i bygrationen (artikel II).

I artikel III blev byg sammenlignet med tilskud af enten grønpiller, roer eller en indkøbt kraftfoderblanding. Der blev udført forsøg på tre private gårde med i alt 246 køer, opdelt på to hold inden for gård. På hver gård var der et hold, der fik tilskud af byg, mens det andet hold fik enten grønpiller, roer eller kraftfoderblanding. Køerne, der fik tildelt kraftfoder, havde en højere EKM-ydelse end køer, der fik samme antal FE fra byg. Forklaringen er sandsynligvis en positiv effekt af det mere afbalancerede næringsstofindhold i kraftfoderrationen. Roer og byg blev tildelt som samme mængde tørstof, og den lavere energi i roerationen gav udslag i en lavere ydelse. Grønpiller og byg blev tildelt som samme mængde tørstof, uden at den lavere energi i grønpillerationen påvirkede EKM ydelsen signifikant. Dette kunne sandsynligvis relateres til en positiv effekt af grønpillerne på foderomsætningen (artikel III).

I artikel IV blev tilskud af byg sammenlignet med tilskud af valsede rapsfrø eller rapskage. Alle rationer skulle dyrkes på samme areal per ko, da ha/ko er en begrænsende faktor i et system, der er selvforsynende med foder. Der blev udført to forsøg med i alt 174 køer på to private gårde med henholdsvis to og tre forsøgshold. Der var en tendens til, at mælkens indhold af fedt og protein var lavere, når tilskudsfoderet bestod af rapsfrø/kornpiller sammenlignet med byg. Køer, der fik rapsfrø-/bygtilskud havde en højere mælkeydelse i kg end køer, der fik byg, i det ene forsøg, mens det var omvendt i det andet forsøg. Denne forskel kunne måske tilskrives forskelle i kvaliteten af ad libitum foderet, hvor der indgik mere kløvergræsensilage, og der generelt var en højere fordøjelighed af rationen i det forsøg, hvor der blev fundet en positiv effekt på ydelsen. Idet rationerne var arealbaserede, blev energitildelingen lavere for en ration med tilskud af rapskage end for en ration med tilskud af byg. Det lavere foderniveau til trods var der ikke signifikante forskelle på mælkeydelse eller mælkens sammensætning. Dette må igen nok tilskrives en positiv effekt af en mere harmonisk ration, når tilskudsfoderet bestod af rapskage sammenlignet med byg (artikel IV).

Formålet med artikel V var ved hjælp af scenarieberegninger at beskrive, hvilke konsekvenser det har for produktivitet, økonomi og næringsstofbalancer at bruge forskellige typer tilskudsfoder i vinterrationen. To forskellige niveauer af tilskudsfoder (normalt og lavt) og to forskellige kvaliteter/typer af grovfoder (høj fordøjelighed/stor andel kløvergræs og lav fordøjelighed/stor andel helsæd) blev undersøgt, hvilket resulterede i tre forskellige foderniveauer. Det højeste foderniveau, der blev opnået ved normalt niveau af tilskudsfoder (6 FE/ko/dag) og grovfoder af høj kvalitet, var økonomisk mest fordelagtigt. Der var større forskel på output afhængigt af grovfoderkvalitet og niveau af tilskudsfoder end af at dyrke/fodre med forskellige typer tilskudsfoder. Systemer med tilskud af grønpiller eller roer gav såvel højere udbytte pr. ha som højere mælkeproduktion pr. ha sammenlignet med et system med byg som tilskudsfoder. Et system med tilskudsfoder bestående af rapsfrø/korn gav samme output pr. ha af afgrøder, mælk og kroner som et system med byg som tilskudsfoder. Hvis man dyrkede raps til egenproduktion af rapskage, var resultatet et lavt markudbytte pr. ha og derfor en lav mælkeproduktion per ha og et lavt økonomisk afkast. Systemet med grønpiller, som var økonomisk mest fordelagtigt, var også det med det højeste N-overskud pr. ha og dermed den største risiko for udvaskning (artikel V).

På baggrund af denne ph.d.-afhandling kan det konkluderes, at med den anvendte prisrelation mellem solgt mælk og indkøbt kraftfoder kan det være økonomisk mest fordelagtigt at basere sit produktionssystem på hjemmeavlet foder. Det kræver dog omkring 1,7 ha per ko, hvis bedriften skal være selvforsynende med både foder og husdyrgødning. Det nødvendige areal varierer mellem 1,4 og 2,0 ha afhængigt af, hvilket foderniveau man vælger, og hvilke afgrøder der dyrkes til tilskudsfoder og grovfoder. Det er kun 10% af de nuværende økologiske mælkeproducenter, der råder over mere end 1,7 ha per ko. I et system, der er selvforsynende med foder, øges fokus på grovfoder – mængde og kvalitet – yderligere, da det bliver en af de mest betydende faktorer i systemet. Det kan altid betale sig at øge foderniveauet, hvis stigningen skyldes forbedret grovfoder-kvalitet. Derimod afhænger det af besætningens fodereffektivitet og marginale fodereffektivitet, om det kan betale sig at sænke/øge niveauet af tilskudsfoder. Det økonomiske afkast varierer kun i mindre omfang afhængigt af, hvilken afgrøde man dyrker som tilskudsfoder, men af hensyn til koens sundhed er det fordelagtigt med en alsidig ration.

1. Introduction to organic milk production

1.1. The history of organic milk production – with the focus on Denmark

For many years there have been several ways to regard and practice alternative agriculture parallel with mainstream agriculture. During the 1920s, an idea was conceived of a cycle in nature of animals' and plants' use of nutrients. Recycling of nutrients became a common denominator for alternative ideas of agriculture. In Germany in 1924, the philosopher, Rudolf Steiner, developed his ideas of an agricultural system where nutrients circulate, and animals, humans, soil, and crops work together as one organism (Steiner 1924). The biodynamic agriculture was generated on the basis of these ideas – the anthroposophy (Vogt 2000). In Denmark the first biodynamic farms were established in the 1930s (Brochmann 1988). In England Sir Albert Howard was interested in how the fertility of the soil could be preserved and improved, as well as in the idea of looking at the whole farming systems, not just part of it (Howard 1943, Balfour 1946).

In the 1970s, the public became aware of the environmental effects of agriculture, and the interest in alternative, sustainable ways of production, as e.g. organic agriculture, rose. The movement for organic agriculture was based on holistic aspects including use of resources, pollution, and food quality with natural science as the conceptual basis. The IFOAM (International Federation of Organic Agriculture Movements) was founded in 1972 and today the organisation counts associations from 107 countries.

The first organic farms in Denmark were established in 1960-1970. These pioneers were typically townsmen who moved into the country to run a farm based on sustainable agriculture. The proportion of organic food on the market was very modest - below 1%. In 1981, the Danish Association of Organic Farming [in Danish: Landsforeningen Økologisk Jordbrug] was founded with its own regulation and principles strongly inspired by the IFOAM. From 1987 to 1992 politicians and media drove the development of organic agriculture in Denmark forward. In 1987 Denmark, as the first country, introduced governmental rules for organic farming (Anonymous 1987a, Anonymous 1987b) together with subsidies and premiums, and organic farms were approved by government authorities. This had the result that conventional farmers began to convert to organic farming. In 1989 0.3% of the dairy farms were organic (70 herds). In 1990, the Danish Ø-label was introduced on the market and the consumers' interest in organic farming increased. The year 1993 was a landmark; for the first time there was a lack of organic products. In two years the demand for organic milk had been multiplied by five. A strong demand from the market in the 1990s combined with high prices for organic milk and financial subsidies attracted more farmers. In 2000, the number of organic dairy farms culminated at 8.4% or 827 farms (Anonymous 2004e). From 2000 a recession was seen: the consumption stagnated and there was a surplus production – less than 50% of the organically produced milk was sold as organic products. The premiums were reduced correspondingly.

From the summer 2001 it became possible to buy milk produced by cows fed 100% organically grown feed. For a longer period the small dairy ´ØkoMælk´ had worked towards introducing a requirement for 100% organically grown feed as of summer 2001. ´Arla Foods´ introduced the same requirement at the same time (Anonymous 2001). Suddenly the majority of the organic milk in Denmark was based on 100% organically grown feed four years before it was supposed to be a requirement according to the EU regulation (1999). When Arla Food introduced the requirement of 100% organically grown feed it was also an attempt to reduce the surplus production of organic milk and all their organic farmers had to draw up new contracts (Anonymous 2001).

Today some organic farmers are reverting to conventional management or getting out of farming because of poor market conditions (Vaarst et al. 2003b) and the number of organic dairy farms in June 2004 was 550 farms or only two thirds of the number of farms in 2000 (Anonymous 2004e). However, organic milk production has a considerable share of the Danish market - more than 25% of all skim and low-fat milk sold in shops are in fact organically produced (Anonymous 2004d) and organic farming continues as a strong source of inspiration for the conventional farming community.

1.2. The present organic milk production in Europe

Organic farming varies widely across Europe (Roderik et al. 2003). In part, this is because organic farming as a movement and a concept has developed differently in different European countries, but it is also because of varying climate, landscape, farm structure, animal disease pressure, and other farming conditions, as well as of differences in traditions and demand for various products. Indeed, adaptation to local conditions is a basic principle of organic farming (Roderik et al. 2003). In the Mediterranean countries, livestock only plays a minor role in organic farming (Graf & Willer 2000), and the opposite end of the scale we find in the UK where in 2002 92% of the land registered organic was grassland for livestock (Soil Association 2002).

Fodder production

In most EU countries, organic farming tends to be concentrated in areas considered to be of marginal agricultural potential (Roderik et al. 2003). For example, in the alpine areas of Switzerland and Austria, the basis of agriculture is the use of grassland for the production of milk and meat by ruminants, especially cattle (Roderik et al. 2003). In parts of Scandinavia and in the alpine regions, the cold climate and short growing-season limit the kind of crops that can be grown here (Steinshamn & Thuen 2000). In many regions, the growing-season is not long enough for cereals to reach maturity, and this restricts the range of protein fodder that can be grown. Contrary to this, the supply of inexpensive imported animal feed has historically been important in industrialized production systems, for example in The Netherlands (Roderik et al. 2003).

Housing and pasturing

In regions of high rainfall, livestock frequently requires housing (Roderik et al. 2003). However, bedding-straw can be a limiting factor, both because of unavailability and of high costs. Alternatives to this are cubicle housing or slatted floors. In many areas of Europe cattle traditionally have been tethered and this is still practised in several countries. Therefore, EU Regulation (1999) on tethering and proportion of floor area that may be slatted present organic farmers with a considerable number of practical restrictions (Roderik et al. 2003). The legislative requirement for cows' time at pasture varies between countries. For example, in Norway and Sweden, all dairy cows must be at pasture for at least two months during summer (Lund 2000a) whereas the requirement is five months in Denmark (Anonymous 2004a).

Level of milk yield per cow

Organic milk production in Denmark is generally based on high-yielding dairy cows of same genetic make-up as cows in conventional production systems (Kjeldsen et al. 1999). The average milk production of organic herds in Denmark in 2001/02 was 9% lower than that of conventional herds (Trinderup & Enemark 2003). Padel (2000) reports a range of 80-105% of conventional milk yield levels in organic herds in various European countries. For example, German and Swedish studies have indicated a reduction of about 20% (Krutzinna et al. 1996b, Hamilton et al. 2002). The milk production in Danish organic herds is significantly higher than in other European countries, e.g. Switzerland (Muhlebach & Muhlebach 1994), Germany (Krutzinna et al. 1996b), and England

(Lampkin 1994). This may be due to the fact that organic farming in the latter countries historically developed from crop production to mixed farming, while the situation in Denmark was the opposite.

Market

The total market share of organic products in the EU is still quite low, ranging from less than 0.5% in nine out of 18 countries to 5-9% for some major product groups in other countries (Michelsen et al. 1999). The largest market shares are seen in Denmark (more than 3%) followed by Austria and Sweeden (2.5%) (Wier & Calverley 2001). The market shares also differ much from product to product. Milk for consumption showed some of the highest market shares (Kristensen & Thamsborg 2002). In Austria, Denmark, Switzerland, and Finland milk products are the most important organic products (Michelsen et al. 1999). In Denmark in 2003, organic milk accounted for 25% of the market for consumption (Anonymous 2004b), and in Switzerland the share was 30% of the market (Vaarst et al. 2003a). Market shares for meat from ruminants and processed milk (e.g. cheese) are often considerably lower than for drinking milk (Kristensen & Thamsborg 2002).

1.3. Principle and rules that affect feeding of organic dairy cows

Organic farming is based on principle aims regarding nature, environment, food production, farming, and society. These aims are put into practice by use of standards, often stated as minimum requirements. The standards are not seen as aims themselves, but as means to achieve these aims. Consequently, the standards are being developed over the years parallel with the development of the organic farming.

The principle aims of organic production are formulated by IFOAM (2002). In August 2000, the European countries implemented the EU Regulation (No 1804/1999, supplementing regulation No 2092/91) that provided standards for the rights to label food from livestock as organically produced. It includes, e.g. specification for housing conditions, animal nutrition, use of veterinary medicine and animal care. The regulation is based partly on the guidelines formulated by the IFOAM (2002). A Danish farmer who produces organic milk in 2004 must follow the national rules (Anonymous 2004a) in which the requirements from the EU Regulation No 1804 (1999) are incorporated. In addition to these, the Danish Organic Growers’ Organization (Økologisk Landsforening, former LØJ) and the Danish Dairy Board stipulate some rules that, among other things, since summer of

2001 required feeding based entirely on organically grown feed, if the farmer has entered into a contract about it (Pedersen & Ingvorsen 2004).

Organically grown feed

One of the basic principles for organic farming is that livestock must be fed organically produced feed (IFOAM 2002). However, for many years it has not been possible to achieve that goal due to shortage of supplies. Therefore, a limited proportion of conventionally grown feed has been permitted. Until 2000, the national rules required that 85% of the energy in the feed ration to ruminants was organically grown (75% the first two years after conversion) (Anonymous 1992). In August 2000, when the EU Regulation (No 1804/1999) was implemented, the national rules were tightened up so that 90% of the dry matter (DM) must be organically grown (Anonymous 2000a). From September 2004, only organically grown barley, oat, wheat, rye, triticale, and roughage may be used (Anonymous 2004a). Finally, the EU Regulation No 1804/1999 requires that all organic cows in Europe as of 2005 must be fed entirely organically produced feedstuffs (EU Regulation No 1804/1999).

Locally grown feed

Other principles of organic farming include reliance on internal farm resources rather than on external input (IFOAM 2002). As far as possible, livestock enterprises should be based on own land and supported from the farm’s own resources. This excludes very intensive systems that depend heavily on bought-in feeds (Lampkin et al. 2002). IFOAM (2002) sets a goal of fodder self-sufficiency at 50% from the farm or produced in cooperation with other farms in the region. However, it is presently not a requirement according to the EU Regulation (No 1804/1999) that the feed is produced on the livestock farm itself, but it is preferred. Presently, national rules set no requirements on degree of self-sufficiency with fodder. However, the Danish Organic Growers’ Organization have earlier included the requirement that by 2002, a minimum of 50% of the feed must originate from the farm or be produced in cooperation with other farms in the region (<25 km) (Anonymous 1998).

Danish produced feed

According to the Danish Organic Growers’ Organisation and the Danish Dairy Board the conventional part of the feed, if any, must be produced in Denmark.

Roughage

The EU regulation (1999) requires that at least 60% of the DM in the daily ration is to consist of roughage, fresh or dried fodder, or silage, though 50% is accepted for the first three months of lactation. The aim is to make sure that the rumen can function effectively and that the ruminants' nature as a grass-fed animal is respected (Padel et al. 2003). Furthermore, in Denmark the national rules require that from 15 April to 1 November all animals must have access to grazing for at least 150 days, though calves younger than four months can be kept on stable (Anonymous 2004a).

Livestock density

Another principle in organic farming is the demand for a harmonious balance between crop production and herd size (IFOAM 2002). Stocking rate should therefore reflect the inherent carrying capacity of the farm and not be increased by reliance on 'borrowed' land (Padel et al. 2003). According to the EU regulation (1999) a maximum of 170 kg total-N/ha from manure must be applied as fertilizer. However, the Danish national standards require that the maximum is only 140 kg total-N (Anonymous 2004a).

1.4. The present organic milk production in Denmark – and how it differs from conventional milk production

It is characteristic for the milk production in Denmark that the number of cows was halved from 1975 to 2003, whereas the total milk production was reduced by 4% only. The reason for this was a drastic increase in milk production per cow. From 1992 to 2002 the milk production per cow increased by 21%. In 2002/2003 the average milk yield in monitored herds was 8,224 kg per cow per year with 4.32% fat and 3.47% protein (Anonymous 2003).

In 2003, 10% of the milk delivered to dairies in Denmark was produced by organic herds (Anonymous 2004b). The organic herds have average milk quotas which were 11% higher than the conventional ones (669 versus 602 t per year) (Anonymous 2004b) and the organic herds are generally larger (93 cows versus 77 cows) (Trinderup and Enemark 2003). The organic herds are mainly housed in loose house systems (94%), whereas only 61% of the conventional herds are housed in such systems (Anonymous 2004b).

A comparison between 3,600 conventional and 360 organic herds (dual purpose breed) in 2001/2002 showed that the milk production was 9% lower in the organic herds (7,782 versus 8,510 kg ECM). Milk fat content was lower in the organic than in the conventional Danish Holstein herds, 3.99% versus 4.10%, and the difference in protein content was 3.30% versus 3.37% (Trinderup & Enemark 2003). During the winter period, milk protein content was found to be 0.1 percent point lower in organic than in conventional herds, whereas there was no difference during summer (Jørgensen et al. 2004b). The lower milk production in organic herds may be explained by a lower level of feeding (Kjeldsen et al. 1999). There was no difference in the genetic potential between organic and conventional herds (Kjeldsen et al. 1999).

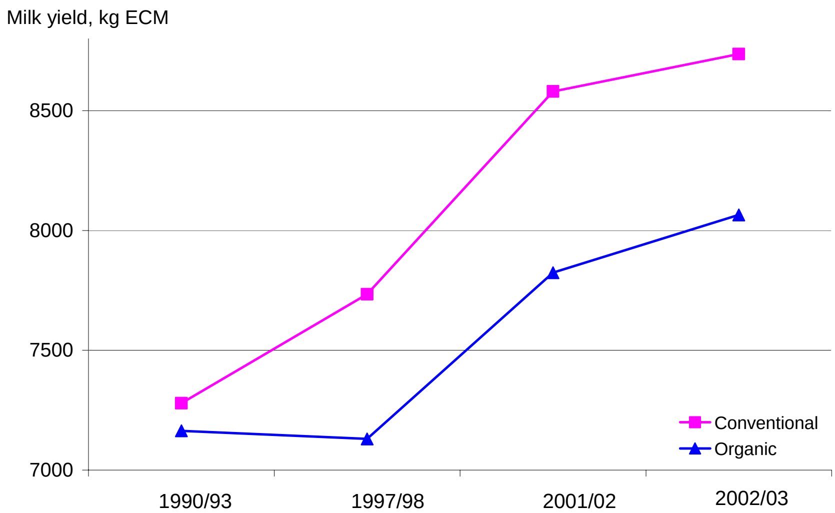

Figure 1. Development in milk yield per cow per year (dual purpose breed) in organic and conventional herds over time (data from Kristensen & Kristensen 1998, Enemark & Kjeldsen 1999, Trinderup & Enemark 2003, Kjeldsen 2004a).

As shown in Figure 1 the difference between organic and conventional herds as regards milk production per cow per year has increased over the last 10 years. In 1990-1993, the milk production level in organic case study herds was only 2% lower than in conventional case study herds (Kristensen & Kristensen 1998). The difference was 8% in 1997/1998 between 240 organic and 7,791 conventional herds with dual-purpose breed (Enemark & Kjeldsen 1999), 9% in 2001/2002 between 341 organic and 3,221 conventional herds with Danish Holstein (Trinderup & Enemark 2003), and 8% in 2002/2003 between 274 organic and 2,803 conventional herds with Danish

Holstein (Kjeldsen 2004a). The reason for this development could be differences in optimising the production level in organic and conventional production or the fact that the organic standards restrict the maximum feeding level that can be obtained under organic feeding conditions.

The principles and standards in organic farming, the fact that the farmer strives to have a closed system, produce feed for his own animals, and incorporate the manure into crop production, have as a result that feeding of the organic dairy herd is very different from feeding of the conventional dairy herd.

Clover-grass is the cornerstone of the organic crop production because of fixation of N from the air. Consequently, clover-grass covers 43% of the area in rotations on Danish organic dairy farms as opposed to 31% of the area in rotations on conventional dairy farms (Nielsen 2004). On organic farms, clover-grass makes up more than half the total energy intake during the summer period, and in the winter period clover-grass silage covers an average of 62% of the total roughage intake (Mogensen et al. 1999, Mogensen 2004b). It is also a characteristic that the organic dairy cows in Denmark are given large amounts of cereals. The average was 922 SFU/cow/year (Mogensen 2004b) and more than 1,442 SFU per cow per year in the 25% of the herds with the highest level (Mogensen et al. 1999). Import of concentrated feed to an organic herd has been lower than to a conventional herd because of higher prices of organically produced feed than of conventionally grown feed and because the market for organically grown feed is more uncertain, which makes it more risky to base the production on imported feed. Within the organic system, higher crop yields in roughage than in crops for concentrated feed (Mogensen et al. 1999) have increased the focus on roughage even more in the organic system than in the conventional system.

As shown in Table 1, the content of digestible crude protein per SFU was independent of the farming system, whereas AAT was lower and protein balance in rumen (PBV) and starch content per SFU higher in the organic ration (Kjeldsen et al. 1999). The higher content of starch and lower supply of fatty acids in the organic feeding rations is probably the reason why milk fat content consistently was 0.1 percent point lower in the organic than in the conventional herds (Jørgensen et al. 2004b).

Table 1. Difference between organic and conventional feeding ration for cows in early lactation in the winter of 1998/99 (Kjeldsen et al. 1999).

System	Organic	Conventional
Number of herds	33	1811
SFU/cow/day	17.9	18.6
AAT, g/SFU	90	96
PBV, g/SFU	20	16
Digestible crude protein, g/SFU	131	134
Fatty acids, g/SFU	28	32
Starch, g/SFU	206	135
Fill, FFk/SFU	0.40	0.37

The higher level of roughage in the organically grown feed ration compared with the typical conventionally grown feed ration (Kristensen & Kristensen 1998, Kjeldsen et al. 1999) has influenced the distribution of feed during lactation. The feeding level for organic cows is lower at the beginning of the lactation, 1 to 2 SFU per cow per day, because of a higher fill factor of roughage compared to concentrates and a limited feed intake capacity (Kristensen & Kristensen 1998). The energy concentration in the roughage is almost identical in organically and conventionally grown rations (Kristensen & Kristensen 1998). The flat-rate feeding strategy is most often used in both farming systems, with a herd specific amount of concentrates given to all cows in early lactation irrespectively of milk yield. However, the length of the flat-rate period is typically longer, up to from 36 to 40 weeks after calving in the organic system opposed to typically 24 weeks in the conventional system (Kristensen & Kristensen 1998). Therefore, the lactation curve in the organic system differs from what is typically found for conventional cows (Kristensen & Kristensen 1998, see Figure 2). The milk yield starts at a lower level for organic cows, and the lactation curve is less steep in the organic system.

The differences in feeding practice between organic and conventional dairy herds have been found to affect the feed efficiency defined as the sum of standard energy requirements for maintenance, reproduction, live weight, and milk production in percentage of the total feed intake (Kristensen & Mogensen 2000). At a feeding level of 5,240 SFU per cow per year, a feed efficiency of 87.9% for organic cows was found versus 86.4% for conventional cows (Kristensen 1997a). The main explanation for the difference in feed efficiency was difference in milk yield persistency (defined as the daily milk yield per cow 24 weeks after calving in percentage of the milk yield per cow six weeks after calving). The milk yield persistency was 86.5% in the organic and 82.4% in the conventional herd (Kristensen 1997a).

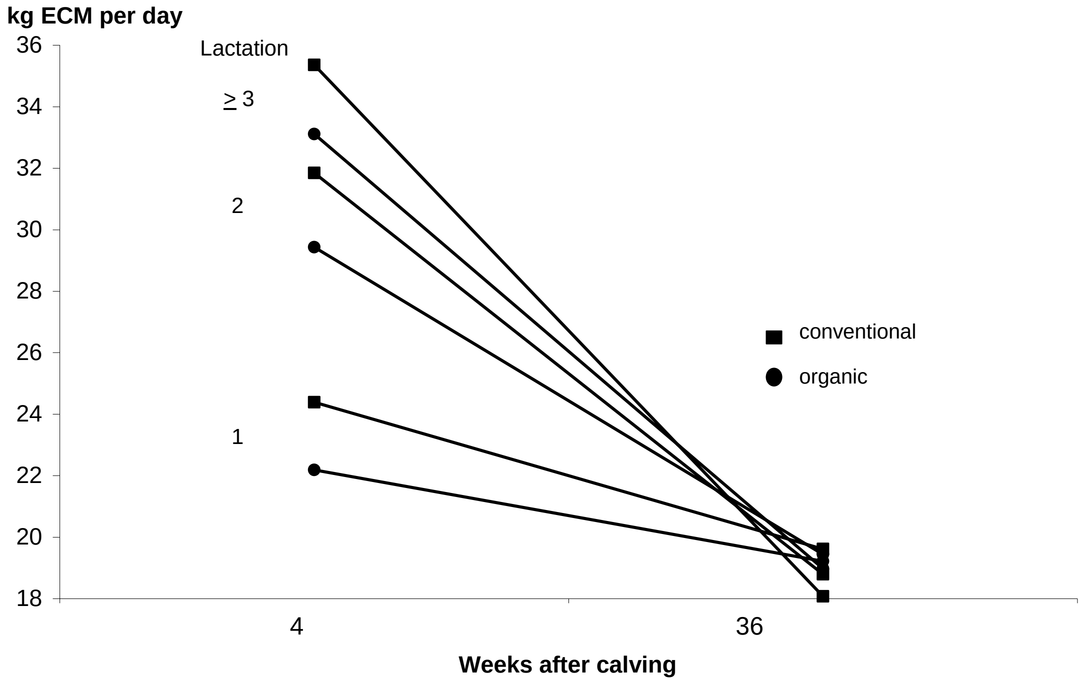

Figure 2. Curves of lactation for organic and conventional cows 1, 2, or >2 parity (Kristensen & Kristensen 1998).

Milk production based entirely on organically grown feed was introduced in the summer of 2001 because of a requirement from the majority of the dairy industry in Denmark. Most farmers tried to maintain the level of milk yield per cow despite the fact that the feed had to be 100% organically grown (Mogensen & Jørgensen 2003). However, according to a questionnaire survey including 18 farm advisers, milk yield per cow was reduced in almost half the herds. The 100% organically grown feed rations typically included a high level of cereals and clover-grass silage (Mogensen & Jørgensen 2003).

The changes in the feeding after introducing 100% organically grown feed on five case study farms are shown in Table 2 (Mogensen 2004b). The average feeding level was unchanged after introducing 100% organically grown feed. During the winter the proportion of clover-grass silage was increased and proportion of whole crop silage decreased on all farms. The proportion of roughage in the ration was increased on four farms during summer (from 68.1% to 71.6%) and on all farms during winter (from 58.0% to 62.0%). Cereal supplement was increased on all farms during summer and on four farms during winter. One farm introduced a supplement of lupine seed after the change to 100% organically grown feed.

Table 2. Feeding before and after introducing 100% organically grown feed on five case study farms, SFU per cow per year.

	90% organically grown ration 2000-2001			100% organically grown ration 2001-2003		
	Average	Minimum	Maximum	Average	Minimum	Maximum
Clover-grass, fresh	1,368	896	1,710	1,195	907	1,824
Clover-grass silage	1,223	647	1,974	1,864	1,585	2,061
Whole crop silage	1,032	617	1,365	667	434	1,000
Maize silage	117	0	474	202	0	914
Cereal	963	747	1,300	1,291	913	1,567
Grass pellets	301	111	650	211	0	363
Beet pellets	315	141	526	0	0	0
Concentrates	365	56	803	335	34	877
Rapeseed cake	214	12	427	14	0	42
Lupine seed	0	0	0	58	0	298
Total	5,909	5,741	6,227	5,877	5,765	5,947

After the introduction of feeding based entirely on organically grown feed, the proportion of clover-grass in crop rotation was increased on all farms. Clover-grass covered 38% of the area in rotation before and 51% after the introduction of 100% organically grown feed. In the period the herd size was increased (by between 5 and 15%) on all farms. However, on three farms the area was increased relatively more and, consequently, the livestock density per ha was decreased on these farms (by between 5 and 10%), whereas livestock density was unchanged on one and increased on the last farm. The degree of self-sufficiency with feed was increased from 86% of SFU before to 95% of SFU after the introducing of 100% organically grown feed. Milk production per cow per year decreased on two farms (by 6 or 7%), was unchanged on two farms, and increased on the last farm (10%).

A questionnaire survey among 91 organic dairy farmers in 2003 also indicated only minor changes in feeding level when introducing 100% organically grown feed (Jørgensen et al. 2004a). The proportion of clover-grass silage and maize silage was reported to increase while grazing decreased (from 8.3 to 7.0 SFU/cow/day). The concentrated feed contained more cereal and grass pellets and less rapeseed cake and fodder beet pellets after the introduction of 100% organic feeding (Jørgensen et al. 2004a).

1.5. The challenge of organic milk production based entirely on home-grown feed

Organic milk production in Denmark in 2004 is primarily based on 100% organically produced feed. However, very seldom the production is based entirely on home-grown feed. Typically, all the roughage is grown on the farm while the concentrated feed is partly home-grown and partly bought-in. The level of self-sufficiency with energy in fodder averaged 83% on 20 case study farms with organic milk production in the period 1989-97, meaning that 17% of the energy in the fodder (SFU) was bought in (Mogensen et al. 1999). The degree of self-sufficiency with fodder on the individual farm depends in part on the area available for fodder production per cow, choice of crops grown and on yield level from these crops, in part on feeding level per cow and composition of the ration.

The average area available for fodder production on dairy farms in Denmark in 2002 was 1.08 ha per cow on conventional farms and 1.30 ha per cow on organic farms (permanent grassland included) (Anonymous, 2002b). On the 628 farms with organic milk production in 2002, the average farm size was 94 cows and 121 ha, or 1.30 ha per cow. The variation in livestock density relative to total area (inclusive permanent pasture) is shown in Figure 3.

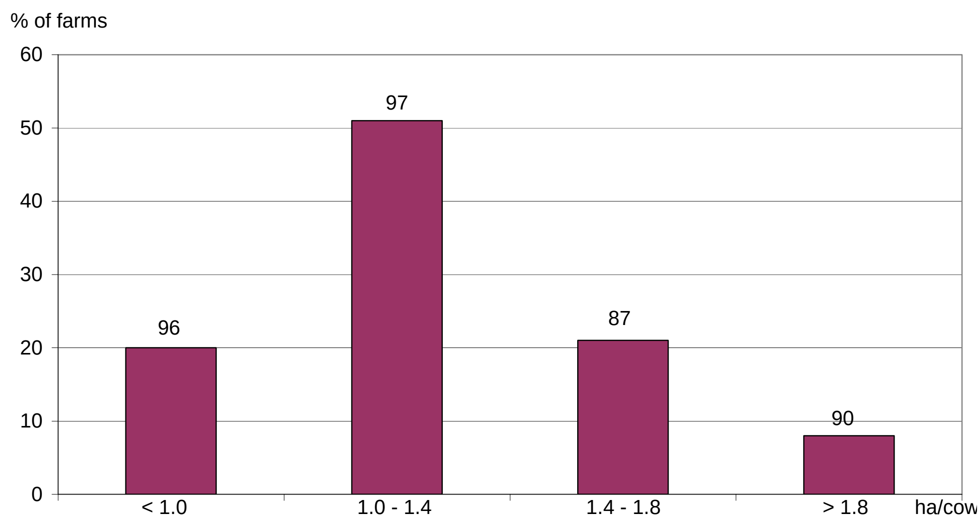

Figure 3. Grouping of farms with organic milk production according to area per cow - average herd size is shown above the column (Mogensen 2004c).

The average crop production per ha in rotation on seven case study farms with organic milk production in the period 2000-2002 was 5,100 SFU +/-700 (Nielsen 2004) as shown in Table 3.

Table 3. Crop yield on case study farms with organic milk production, SFU/ha (kg/ha).

Period	1989-97	2000-02
Number of organic dairy farms	20 [1)]	7 [2)]
Livestock density, ha/cow	1.20	1.52
Clover-grass in rotation	5,608	5,700
Whole crop incl. clover-grass undersown	4,301	4,700
Spring cereals	(3,859) [3)]	3,600
- Spring barley	-	3,600 (3,800)
- Spring oats	-	3,600 (4,500)
Maize for silage	-	6,500 [4)]
Rapeseed	-	2,900 (1,680) [5)]
Fodder beet excl. tops	8,542	-
Permanent pasture	2,751	2,022
SFU/ha incl. permanent pasture	4,732	4,700
SFU/ha in rotation	5,044	5,100

1) Mogensen et al. 1999
2) Nielsen 2004
3) 2,100 kg straw
4) Including other organic dairy farms, a variation from 3,300 to 10,800 SFU/ha
5) Including other organic dairy farms, rapeseed was grown on only 50 ha

In a system self-supplying with fodder, average crop yield per ha is assumed to decrease. With no fodder import, there will be feed for fewer cows and, consequently, a lower production of manure. A lower supply of N will decrease crop yield. So far, the bought-in feed has typically consisted of concentrated feed (Mogensen et al. 1999) and as the expected crop yield is lower in cereals than in crops for roughage (Mogensen et al. 1999) average production per ha will decrease when crops for concentrated feed make up a higher proportion of the area grown.

The challenge for a feed ration for dairy cows in early lactation based entirely on organically home-grown feed is to match the need for energy and nutrients throughout the lactation with crops which can be grown in an organic crop rotation under Northern European conditions. The relevant crops to consider in this region are primarily clover-grass and barley. Alternative crops could be rapeseed, maize, lupine, and pea. As the expected crop yield in terms of net energy is highest in clover-grass and higher in barley than in rapeseed and lupines, it is obvious to formulate a feed ration with a high proportion of clover-grass silage and barley as the only concentrated feed. However, such a ration will probably not match the need for nutrients and energy of a dairy cow in early lactation as the ration will be fairly high in starch and the level of protein, AAT, and fatty acids in the ration will be lower than stipulated in the Danish recommendations (Strudsholm et al. 1999). This is assumed to lower the milk yield (Børsting et al. 2003a, Kristensen 1997b) and the level of starch may reach a critical level in relation to ruminal digestion (Agabriel et al. 1997) and health (Mortensen & Hesselholt 1986, Gasa et al. 1991).

1.6 The aim of the Ph.D. project

The overall aim of the Ph.D. project was to examine the consequences for the organic dairy farm of a milk production based entirely on home-grown feed and to clarify the influence on feed supply and milk production. To reach this aim, the following sub-objectives were made:

- Identify what, in farmers' opinion, are the crucial preconditions for obtaining 100% home-grown feed on the farm (paper I)
- Examine the effect of different feeding rations based on 100% home-grown feed on milk production (papers II, III, and IV)
- Examine the consequences of entirely home-grown feed for productivity, economy, and nutrient balances on the organic dairy farm (paper V)

1.7. Outlines of the Ph.D. project and introduction to papers

The project includes interviews that identify what, according to the farmers, are the crucial preconditions for obtaining an organic milk production based entirely on home-grown feed (paper I). Also production experiments that examine the effect of different types of concentrated feed, based entirely on home-grown feed, on milk production (papers II, III, and IV) were included in the Ph.D. project**,** together with scenario calculations that describe the consequences for productivity, economy, and nutrient balances on the organic dairy farm of milk production based entirely on home-grown feed (paper V).

Introduction to Paper I: What, according to the farmers, is crucial for obtaining an organic milk production based entirely on home-grown feed?

As an inspiration to the rest of the Ph.D. project and to make sure that the Ph.D. project was based on the actual situation among the organic dairy farmers, six organic dairy farmers were interviewed in depth about prospects and obstacles to an increase in the proportion of organic feed in the ration as well as to an increase in the proportion of home-grown feed. Farmers with some years of experience of organic farming (4 to 23 years) were chosen because it was important that they related principles and rules to the background of their own experiences. The number of interviews was not decided in advance, and new interviews were included as long as they contributed to more information. With the resulting six interviews it was the aim to describe the variation in attitudes of organic farmers. According to Kvale (1994) this type of interview is a relevant method to uncover a new area.

The farmers were asked about the situation on their own farms, their personal goals, and their attitudes towards principles and rules regarding 100% organically grown feed and self-sufficiency on their farms. Furthermore, they were asked how they could actually adjust their own production to 100% organically grown feeding (see interview guide in appendix). Each interview was interpreted separately. All the interviews were recorded and analyzed using a pc-programme for qualitative analysis, where the preliminary work was made based on the original sound from the interview. For each interview all relevant quotations within the same topic were collected and summarized. Subsequently, each interview was interpreted using the hermeneutic spiral, meaning continuing interpreting until a meaning without intrinsic contradictions was reached (Kvale 1994). The interpretation and selected quotations were sent to the farmers and later discussed on the phone as a verification of the interpretation (Launsø & Rieper 1995). Later, the interviews were analysed according to topics across all interviews. These results are presented in paper I (Mogensen 2000).

Introduction to papers II, III, and IV: The effect of different types of home-grown concentrated feed for winterfeeding of cows in early lactation

100% home-grown feed can be a big challenge for an organic cow. The crucial question was identified (paper I) to be how to compose a ration - based on the crops that can be grown organically in Denmark - that can fulfil the need for AAT, PBV, and fatty acids without exceeding the recommended maximum level of starch? The present project chose to focus on the concentrated feed because this reflected the actual situation for organic milk production. All the feed must be grown organically as of 2005, and most farmers have so far imported concentrated feed as the allowed conventional part of the ration. The imported, conventional feed has typically supplied AAT, PBV, and fatty acids to the ration. Now the organic farmers have to replace this conventionally grown feed with some organically grown feed, and ideally home-grown feed.

As argued in section 1.4, the feeding system in organic herds differs markedly from the feeding system in conventional herds: high proportion of clover-grass and clover-grass silage, high proportion of roughage, longer period of flat-rate feeding, less steep lactation curve, etc. Therefore, results from research with different types of concentrated feed in a conventional feeding system cannot be applied properly in the organic farming context. Furthermore, as argued in section 1.2 organic milk production systems across Europe face very different conditions, and this also makes the most critical problems specific for each area.

On-farm production experiments were chosen as a way to examine the effect in the context where the results were to be used. On-farm production experiments is the only way to include the close connection between the feed produced in the fields and the use in the stable, which is a characteristic of the organic production system. On-farm experiments can include the special feeding strategies of organic farming. Finally, experiments on relatively large farms give a large number of cows compared with what is available at most research institutes, and this offers a possibility of describing the milk yield responses during lactation.

Three series of on-farm production experiments were conducted in organic dairy farms. The first experiment examined the effect of feeding imported, conventionally grown rapeseed cake versus home-grown barley. Before the introduction of EU regulation (Anonymous 2004a, EU Regulation No 1804/1999) a typical feeding ration for organic cows was based on a high proportion of home-grown roughage and barley and a small proportion (a maximum of 15% SFU) of imported, conventionally grown concentrated feed, often rapeseed cake. The experiment was conducted during a four-month winter period on two organic dairy farms. A total of 103 cows were included. Results from the experiment are presented in paper II (Mogensen & Kristensen 2002).

In the second series of experiments, different types of concentrated feed were examined: barley versus grass pellets, fodder beets, or an imported concentrate mixture. Barley is the type of concentrated feed, which is most often organically grown in Denmark, however, barley has some limitations in its use due to an unbalanced supply of starch. Grass pellets made of clover-grass could supply AAT to the ration and have shown a positive effect on digestion. Clover-grass is easy to grow and has a higher expected yield per ha than barley. However, these advantages must be weighed against the disadvantages of a high-energy consumption for production. Fodder beets are very attractive in a self-supplying system due to the high crop yield expected. The experiment was conducted over an eight-week winter period on three organic dairy farms. A total of 124 cows were included. Results from the experiment are presented in paper III (Mogensen & Kristensen 2003).

In a self-supplying system, the area per cow is a limiting factor. The third series of experiments examined different feed rations grown on the same area per cow. The types of concentrated feed included were barley, rapeseed/cereals or rapeseed cake. Rapeseed/cereals supply fatty acids to the ration, but the level of AAT is low. Rapeseed cake supplies both fatty acids and AAT. However, when growing rapeseed for rapeseed cake production the yield of rapeseed cake is very low and, consequently, the feeding level becomes low due to the fact that all rations were grown on the same area per cow. The experiments were conducted over an eight-week winter period on two organic dairy farms. A total of 174 cows were included and results from the experiment are presented in paper IV (Mogensen et al. 2004a).

Introduction to paper V: Productivity, economy, and nutrient balances for the organic dairy farm using different types of concentrated feed

The objective of the study in paper V was by scenario calculations to describe the consequences for productivity, economy, and nutrient balances on the organic dairy farm of different types of home-grown concentrated feed for winterfeeding. A static deterministic model, which calculates the consequences for the farming system of choosing different rations for winterfeeding, was developed in the Microsoft programme Excel. The model was built up of four components: input to the model, variables and constants used in the model, calculations made by the model, and output from the model. Input to the model was winterfeeding rations. In the model, assumptions were made regarding milk yield responses and feed efficiency depending on type of concentrated feed and quality of roughage. Furthermore, crop yield in different crops and yield response to change in supply of manure were defined as was an identical farm area. The model calculated milk production per cow, demand for feed per milk producing unit (MPU), area needed for growing the feed ration per MPU, and possible number of cows that could be fed. Output from the model were: production of milk and meat per herd, financial output from cattle production, crop yield at farm level and the financial output from fields, total financial output, and farm nutrient balances of nitrogen (N), phosphorus (P) and potassium (K). Results from the scenarios are presented in paper V (Mogensen et al. 2004b).

2. Organic milk production based entirely on home-grown feed

So far, all the roughage on an organic dairy farm has typically been home-grown, whereas some concentrated feed has been home-grown and some has been bought-in. When the milk production on a farm is changed to be based entirely on home-grown feed, land use must reflect the demand for feed. The composition of the feed ration: proportion and type of roughage and concentrated feed will affect the distribution of grown crops, and as potential crop yield differs from crop to crop the average crop yield per ha will differ dependent on the composition of the feeding ration.

2.1. Initiatives to produce milk entirely from home-grown feed

In the following, different initiatives for adjusting the organic dairy farm to produce milk entirely from home-grown feed are discussed in relation to the production of the cow, the herd and in the fields, financial output, N-balances as well as animal health. Traditionally, milk yield is related to the energy content of the feed ration (Kristensen et al. 2003c) as well as to the content of AAT (Madsen et al. 2003) and fatty acids (Børsting et al. 2003). In the present examination of how different initiatives to obtain milk production based entirely on home-grown feed affect productivity, milk production is related to both energy level and nutrient content, but also to the composition of the ration.

Initiative 1: Decreased amount of concentrated feed

One hypothesis was that a decreased proportion of concentrated feed in the ration would decrease the feeding level per cow, but increase the proportion of roughage in the ration. As crop yield in roughage typically is higher than in crops for concentrated feed (Mogensen et al. 1999) the average crop yield per ha is supposed to increase. Thereby, there will be feed for more cows and the potential milk production per ha might increase. Furthermore, strategies towards a lower production level and a higher reliance on home-grown roughage might be a way to overcome the inherent conflict between a high level of animal health and welfare and a wish for high productivity and low costs (Padel 2000, Sundrum 2001). The risk of some production diseases is supposed to decrease with decreased production level per cow (Butler & Smith 1989).

Initiative 2: Increased roughage quality

Another hypothesis was that an increased proportion of clover-grass silage and a decreased proportion of whole crop silage would increase the digestibility of the ration because research has shown a higher energy content (SFU/kg DM) in clover-grass silage than in whole crop (Kristensen & Kristensen 1998, Mogensen et al. 1999, Kjeldsen 2004b). With increased roughage quality, feeding level and milk production per cow are assumed to be increased (Kristensen et al. 2003c). Furthermore, the average crop yield per ha will increase, as crop yield (SFU) in clover-grass normally is higher than in cereals for whole crop silage (Mogensen et al. 1999).

Initiative 3: Improved composition of the ration by type of concentrated feed

The possibility of composing a balanced ration by appropriate concentrated feed is smaller in organic than in conventional feeding (Thamsborg et al. 2000). Organically grown concentrated feed is typical cereals in Denmark. The third hypothesis was that the nutrient composition of the ration can be improved by choosing other crops than cereals as concentrated feed. Rapeseed cake, grass pellets, lupine, and peas can supply protein. Rapeseed cake and rapeseed can supply fatty acids. Fodder beets and grass pellets can supply other types of carbohydrate than starch. An improved composition of the nutrients in the ration might have a positive effect on feed intake, efficiency, and milk production (Børsting et al. 2003a, Madsen et al. 2003). Furthermore, health may also be improved in some cases (Jakobsen & Hermansen 2001).

Initiative 4: Import of manure

Import of manure to the system will increase crop yield per ha (Tersbøl & Kristensen 1997). Thereby there will be feed for more cows and the potential milk production per ha might increase.

Additional initiatives

A prolonged lactation together with a reduced feeding level around calving is a way to increase the roughage proportion of the ration (Anonymous 2004c). This will allow a higher average crop yield per ha in the farming system.

2.2. How different initiatives affect productivity, economy and environment

An increased reliance on home-grown, organic feed will change not only the feeding and milk production of the herd, but also the total production of the dairy farm. Furthermore the total turnover of nutrients on the farm will be affected. Nitrogen farm balance can be used as an indicator of the long-term risk of nitrogen loss from the livestock farm (Halberg & Kristensen 1997). Finally, also possibilities and restrictions related to the crop rotation must be taken into account (Tersbøl &

Kristensen 1997). Table 4 gives a summary of the expected effects of the different initiatives, which are elaborated in the following.

Table 4. Effect at cow, herd, field, and farm level of different initiatives to obtain self-sufficiency with feed assuming an equal total area and different number of cows to be fed by the crops grown (100 = level before introduction of the initiative) (Mogensen et al. 2004b paperV).

Initiative / Impact at	1. Reduced level of concen-trated feed	2. Improved roughage quality whole crop → clover-grass silage	3. △ Type of concentrated feed: Barley vs. Grass pellets	Rape seed	Rape seed cake	Fodder beet	4. Import of manure
Cow level							
Feed intake, SFU/year	91	106	99	102	101	100	100
Milk yield, kg ECM/year	91	108	100	102	101	100	100
Feed efficiency, kg ECM/SFU	100	101	100	100	100	100	100
Health and reproduction	(-)	↑	↑	-	↑	-	-
Herd level							
Number of cows	112	100	108	97	88	108	107
Gross margin	93	110	106	99	88	106	108
Field level							
Ha/cow	89	100	92	103	113	93	97
SFU/ha	104	106	108	99	89	108	109
Clover-grass, % of area	115	135	128	100	91	107	105
Gross margin	113	107	116	95	79	104	109
Farm level							
Milk production, kg ECM/ha	102	108	107	99	89	108	109
N surplus, kg /ha	124	120	131	104	97	108	176
Gross margin per ha	70	134	108	101	85	99	109

Initiative 1: Decreased amount of concentrated feed

The average level of concentrated feed used on dairy farms with organic milk production was 2,025 SFU/cow per year (Mogensen 2004b) corresponding to 5.7 SFU/cow/day.

We investigated the consequences of reducing the level of concentrated feed from 6 to 3 SFU/day for cows in early lactation (Mogensen et al. 2004b paper V). It was shown that milk yield was reduced by 0.8 kg ECM per SFU level of concentrated feed was reduced, and that the financial output, rest for paying the land, was decreased by 30% when the feeding level of cows in early lactation was decreased from 18.4 to 16.6 SFU (6,143 versus 5,600 SFU/cow/year). At the lower feeding level there was a higher proportion of roughage in the ration, and clover-grass was grown on a greater part of the fields. Average crop yield was therefore increased (4,646 versus 4,640 SFU/ha), and the area per cow needed to grow the feed ration was decreased from 1.76 to 1.54 ha giving feed for more cows. Due to a lower feeding level, also milk yield per cow was decreased (from 8,007 to 7,300 kg ECM/year), but due to more cows, milk production per ha was increased by 2%. However, as the capacity costs (stable, labour) were assumed to be a fixed amount per cow, higher expenses due to more cows resulted in a lower financial output. Furthermore, the risk of N losses was increased, indicated by a higher N surplus per ha. The higher proportion of clover-grass in rotation gave a greater input to N balances by fixation (Mogensen et al. 2004b paper V).

The feed rations in the scenario calculations include a high proportion of high-quality clover-grass silage. Feed efficiency and marginal efficiency are higher when roughage is of a high quality (Kristensen et al. 2003). The marginal feed efficiency used in the scenario calculations is in agreement with Østergaard et al. (1989), but higher than in some investigations reported in literature: A three-year study at the organic research station, Rugballegård, showed that a reduction in daily supply of concentrate feed from 8 to 3 kg reduced milk production in early lactation by 0.3 kg per kg reduction in concentrated feed (Sehested et al. 2003). However, the marginal feed efficiency in this study was lower than expected by Kristensen & Aaes (1989). In another long-term study a reduction in daily supply of concentrated feed from 6 to 2 SFU reduced ECM yield during the first 24 weeks of lactation by 0.3-0.5 kg ECM per SFU-reduction in concentrated feed (Kristensen 1999, Kristensen 2004a). In a study of Norwegian Red Cattle, a reduction in daily amount of concentrate feed from 8.0 to 3.0 kg, reduced ECM yield by 0.5 kg per kg reduction in concentrated feed (Steinshamn & Thuen 2000). Fraser & Leaver (1988) and Berg & Ekern (1993) found that a reduction in daily supply of concentrated feed from 6 to 3 kg reduced milk yield by 0.7-0.8 kg per kg reduction in concentrated feed. The higher marginal efficiency in our investigation, compared with most others, is partly justified by the higher roughage quality, as a requirement for a high marginal efficiency, according to Kristensen et al. (2003), is high-quality roughage. Furthermore, a high level of feed efficiency is needed to obtain a high marginal feed efficiency as the relation between feed efficiency and marginal efficiency, according to Kristensen (1997a) and

Østergaard et al. (2003), is assumed to be fixed and independent of feeding level. Therefore, our results are useful in a situation where roughage quality is high and total concentrate level is moderate.

Reproduction is likely to be negatively influenced by decreased feeding level as the energy balance in early lactation becomes more negative (Butler & Smith 1989). This is often explained as a competition for nutrients between milk production and reproduction. For cows fed entirely with roughage, Sehested et al. (2003) found a tendency to an increasing number of days to first insemination, as well as a longer calving interval. However, Pryce et al. (1999) found no negative effects on reproduction of decreasing concentrate levels from 2,500 to 1,000 kg per lactation in high genetic merit dairy cows. Neither did Fraser & Leaver (1988). On that background, a reduction in level of concentrated feed, as in our investigations, is not supposed to affect reproduction negatively.

A decreased feeding level obtained by a decreased level of concentrated feed has a negative impact on milk production per cow, but the higher proportion of roughage in both diet and land use increases milk yield per ha.

Initiative 2: Increased roughage quality

On case study farms with organic milk production, the average composition of roughage on a feed unit basis consisted of 78% from clover-grass silage and fresh clover-grass, 21% from whole crop silage, and 1% from maize silage (Mogensen 2004b). The quality of silage defined as kg DM per SFU has in several studies been found to be higher in clover-grass silage than in whole crop silage (Kristensen & Kristensen 1998, Mogensen 2004b, Kjeldsen 2004b). In year 2003 the average quality of organically grown clover-grass silage was 1.18 kg DM/SFU versus 1.38 kg DM/SFU in whole crop silage (Kjeldsen 2004b).

The quality of the roughage used in the feed ration for early lactation cows has a great effect on feed intake (Van Soest 1994, Gruber et al. 2000), on feed efficiency, and on milk yield (Kristensen & Nørgaard 1987, Kristensen & Skovborg 1990, Schwarzenbacher 2001, Kristensen et al. 2003c) and might also influence the area needed to grow the ration (Kristensen 1997c).

A silage quality of 0.6 fill unit/SFU is realistic without extra cost or attention from the farmer (Thamsborg et al. 2000). Decreasing the roughage quality (decreased SFU/kg DM) and simultaneously increasing the fill factor (Figure 4) makes more concentrated feed necessary in the ration to keep feeding level and milk yield unchanged (Kristensen 1997c).

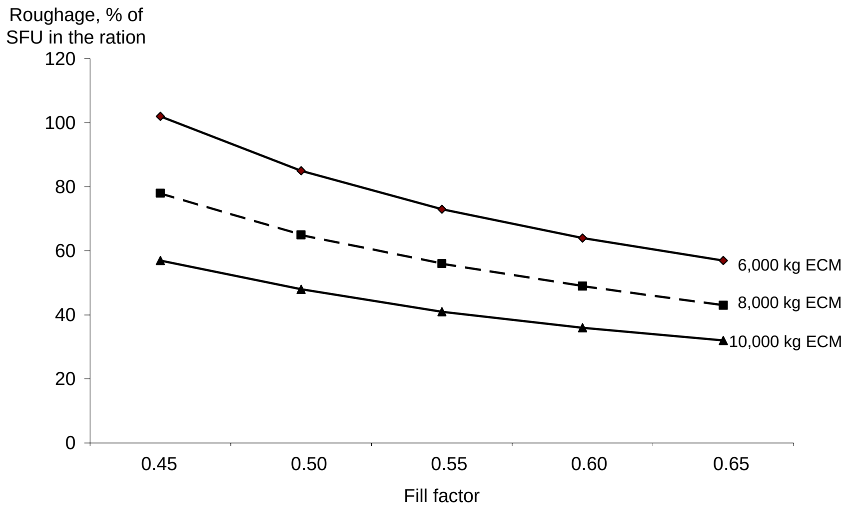

Figure 4. Effect of roughage quality defined as fill factor/SFU on possible proportion of roughage in the rations corresponding to expected milk yields of 6,000, 8,000, and 10,000 kg ECM (Kristensen 1997c).

Our scenario calculation showed that an organic farming system based on high-quality silage obtained by a high proportion of clover-grass silage (75% of SFU in roughage from clover-grass silage/fresh clover-grass/clover-grass pellets and 25% from whole crop) compared to a system with lower quality silage based on a higher proportion of whole crop silage (40% of SFU in roughage) gave a positive effect on financial output (Mogensen et al. 2004b paper V). The increased roughage quality resulted in an increase in feed intake from roughage due to a lower fill of clover-grass silage than of whole crop silage. A higher digestibility of the ration with a high proportion of clover-grass might have had a positive effect on feed efficiency at a given total feeding level (Kristensen et al 2003), but due to the higher feeding level, feed efficiency was actually slightly decreased. However, kg ECM/SFU was a bit higher in the system based on high-quality roughage. This was due to a higher milk yield and a relatively lower proportion of energy being allocated to maintenance at the high feeding level. Milk production per cow per year was increased from 7,461 to 8,086 kg ECM.

Even though the feeding level per cow was increased from 5,763 to 6,190 SFU/cow/year, the area needed to grow the ration was unchanged: 1.79 ha/cow. The reason was that the average crop yield per ha was increased from 4,076 to 4,302 SFU/ha due to a higher proportion of clover-grass in rotation and a higher expected crop yield in clover-grass compared to whole crop (Mogensen et al. 1999). There was feed for the same number of cows in the two systems. The milk production per ha was increased from 4,174 to 4,497 ECM/ha and the financial output was increased by 34% in the system with increased roughage quality obtained by a higher proportion of clover-grass silage in the ration (Mogensen et al. 2004b paper V). However, N surplus/ha was increased when more clover-grass was included in the ration. In a self-supplying farming system, the proportion of clover-grass in rotation becomes a factor with a great effect on N input due to fixation (Mogensen et al. 2004b paper V).

There is no doubt that the roughage quality is very important, and increased roughage quality is the most profitable way to attain a high degree of supply with home-grown feed. High-quality roughage increases feed conversion and milk production per ha.

Initiative 3: Type of concentrated feed

Concentrated feed rich in protein

Today the need for protein of a dairy cow is stated as g AAT/SFU, whereas the content of digestible crude protein was used until 1990 (Madsen et al. 2003). Traditionally, the nutrient value of different feedstuffs is assumed to be additive, independent of the composition of the ration. However, many interactions may take place when different feedstuffs are mixed in a ration (Hvelplund et al. 2003, Weisbjerg et al. 2003). For example the variation in rumen protein degradability and microbial protein synthesis depends, among other things, of the feeding level, which affects time for passage in the rumen and thereby the net-synthesis of protein (Hvelplund et al. 2003).

Based on the experiments by Kristensen (1997b) the response traditionally used is that ECM yield is increased by 0.3 to 0.5 kg per g AAT is elevated up to 90 g/SFU in the total ration (Madsen et al. 2003). However, when the ration includes a high proportion of easily digestible clover-grass silage the effect of increased level of AAT by use of high AAT in concentrated feed might be lower than the response traditionally used (Kristensen 1997b). This is probably due to an underestimated microbial protein synthesis in the roughage. In our results (Mogensen & Kristensen 2002 paper II) we found that a high proportion of roughage in the ration (70% of SFU) primarily based on easily digested clover-grass silage (68% of SFU from roughage) may have resulted in an optimal rumen environment supplied with plenty of fermentable carbohydrates. This may have stimulated the microbial protein synthesis in the rumen, and the utilization of the digestible protein in rumen may have increased and reached a higher level of AAT than calculated by the Nordic Protein Evaluation System (Madsen 1995). Experiments with supply of concentrated feed to dairy cows at pasture support the hypothesis as Kristensen & Aaes (1998) found: When considerable amounts of grass were included in the ration there was no effect on milk yield of increased level of AAT in the concentrated feed of up to 25 g/SFU.

In the Nordic Protein Evaluation System (Madsen 1995) is used a constant value for the content of amino acids in undegraded protein of 65% for roughage. Investigation by Skiba et al. (1996) showed a difference of amino acids in undegraded protein between clover-grass silage (60%) and wheat whole crop (49%). Furthermore, the synthesis of microbial amino acids in the AAT/PBV system is a constant of 125 g per kg carbohydrate digested in the rumen, but 135 g for fresh clover-grass (Hvelplund et al. 2003). Probably, as Aaes & Kristensen (1997) found that the synthesis of microbial amino acids was higher than 135 g in both fresh clover-grass and grass silage the level is also higher for clover-grass silage.

When the ration consisted of a lower proportion of roughage (52% of SFU), and the roughage consisted of a higher proportion of whole crop (57%) (Mogensen & Kristensen 2003 paper III), the effect of increased level of AAT on ECM yield followed the result by Kristensen (1997b). In the experiment by Kristensen (1997b), 52% of SFU in the ration was roughage and 48% of roughage was clover-grass silage.

In the following are discussed different types of concentrated feed that can supply AAT for the ration. The concentrated feed all originated from crops that can be grown organically under Northern European conditions.

According to our investigations growing rapeseed for rapeseed cake production was financially less attractive than growing barley as concentrated feed (Mogensen et al. 2004b paper V) (Table 4).

When the ration included a high proportion of easily digestible clover-grass silage, ECM yield of cows in early lactation were 2% higher with rapeseed cake than with barley supplement. The farming system with rapeseed cake supplement had a lower average crop yield per ha than the system with barley supplement (3,935 versus 4,444 SFU/ha) as only 1,470 SFU rapeseed cake can be produced per ha. The lower production in the rapeseed cake system gave feed for fewer cows than did the barley system. A lower milk production per ha was obtained in the rapeseed cake system (4,115 versus 4,644 kg ECM/ha) and gross margin (GM) was 15% lower. Even if crop yield in rapeseed was increased by 25% (2,500 kg rapeseed/ha) supply of rapeseed cake was still financially less attractive than supply of barley (Mogensen et al. 2004b paper V). However, rapeseed cake supplement is assumed to have a positive effect on health due to a more balanced ration than a ration based on starchy barley supplement (Jakobsen & Hermansen 2001).

Grass pellets supplied at a normal feeding level have a positive effect on rumen environment (Aaes 1991). However, the lower energy content per kg DM in grass pellets compared with other types of concentrated feed, becomes important at a lower feeding level (Aaes 1991). Our scenario calculations showed that compared with a system based on supplement of barley a system based on a supplement of grass pellets had a higher financial output (Mogensen et al. 2004b paper V). Due to a higher proportion of clover-grass in rotation crop production per ha was higher. Consequently, there was feed for more cows and the ECM production per ha was increased, whereas milk production per cow was identical in the grass pellet and barley systems. However, due to a high level of fixation from clover-grass an organic farming system based on supplement of grass pellets has a high N surplus (70 kg N/ha) (Mogensen et al. 2004b paper V). Furthermore, the question of overall fossil energy efficiency must be kept in mind when choosing concentrated feedstuffs for organic dairy cows. System modelling has shown that in terms of energy costs, grains are more favourable than grass pellets (Refsgaard et al. 1998).

Pea has a content of digestible crude protein twice as high as barley (Møller et al. 2000) though pea protein is less ideal for milk production since it contains more rumen degradable protein and in consequence less AAT. Expanding was found to increase content of AAT (Lund et al. 1998) whereas a later experiment with toasting only showed a minor effect on rumen protein degradability for peas (Lund et al. 2004). Literature is not conclusive regarding the effect of supplement of pea on milk production, as Khalili et al. (1999) found that peas could replace rapeseed without ECM yield reduction, whereas a later experiment showed that replacement of rapeseed with pea decreased ECM yield, and that supplement of peas or cereals gave similar ECM yields (Khalili et al. 2002). Scenario calculations by Thøgersen et al. (2002a) showed that a farming system based on supplement of peas resulted in productivity and financial output very similar to a system based on cereals if crop yield in peas and cereals were 3,500 and 4,300 kg/ha, respectively.

Lupines have a high content of crude protein, 36% of DM, but also a high rumen protein degradability, around 80% (Møller & Pedersen 2003). However, heat treatment of blue lupine was found to increase the level of AAT from 74 to 121 g/SFU, primarily due to an increase in duodenal flow of undegraded amino acids from feed (Lund et al. 2004). Also, a coarse versus a fine grinding has been discussed to decrease protein degradability in rumen (Nielsen & Beck 1997) though the greater particle size will increase the time spent in rumen and thereby neutralize the lower degradability. Allison et al. (2001) found similar milk yields from supplement of soy bean meal or heat-treated white lupine, but a decreased dry matter intake. In a review by Barneveld 1999, lupines could replace soy bean meal with similar milk yield when the rations were formulated to contain equal levels of DM and crude protein. In Denmark, it is only possible to grow blue lupine, which matures early. Compared with white lupines the content of crude protein and crude fat is lower in blue lupines (Møller & Pedersen 2003). Expected crop yield in lupines is between 2,500 and 4,500 kg/ha (Reffstrup 1998).

Concentrated feed rich in fatty acids

Oilseed is a relevant fat source when the ration is based on home-grown feed (Børsting et al. 2003a). Supplement of rapeseed of up to 1.5 kg can increase ECM yield of cows in early lactation by up to 5% compared with barley supplement (Mogensen et al. 2004a paper IV, Kristensen & Mogensen 2004). The level of fatty acids was 17 g/kg DM in a ration with supplement of barley and 43 g/kg DM in a ration with supplement of 1.5 kg rapeseed (Mogensen et al. 2004a paper IV). Hermansen et al. (1984) and Hermansen & Østergaard (1988) found that increasing supply of rapeseed from 0.75 to 1.5 kg per cow per day, increased milk yield by 4% but with a lower content of fat, as fat yield in kg was unaffected. Consequently ECM yield was almost unaffected. In the experiment by Hermansen & Østergaard (1988) the level of fatty acids was increased from 44 to 59 g/kg DM, and therefore the effect on ECM yield was lower which was in agreement with the result based on supply of animal fat (Østergaard et al. 1981, Strudsholm et al. 1999, Børsting et al. 2003a).

An effective hydrogenation in the rumen is considered necessary to obtain an increased milk production by supplying unsaturated fat as rapeseed. The hydrogenation is more effective when the ration has a high content of physical structure (Harfoot, 1981) and probably also for a ration with a high content of protein (Børsting et al. 2003b). When hydrogenation is ineffective, trans fatty acids and conjugated linolic acid (CLA) are formed in the rumen. When trans fatty acids and CLA are absorbed by the mammary gland, they reduce the de novo fat synthesis in the glands (Astrup 1987). Therefore, at a high supply of unsaturated fatty acids, a depression of milk fat can be seen (NRC, 2001). However, unsaturated fat from seeds has a smaller negative effect than oil. A likely reason for this is that unsaturated fat is released relatively slowly from the seeds and is hydrogenated in parallel with release (Hermansen & Østergaard, 1988).

A possible interaction between the effect of fat supply on milk yield and composition of the ration is rarely examined in literature (Casper et al. 1990, Børsting et al. 2003a). Hermansen & Østergaard (1988) argued that for a ration with a low physical structure or a high content of starch there could be a negative effect of supply of oil seed. Results from the experiments by Mogensen et al. (2004a paper IV) and Kristensen & Mogensen (2004) indicate that the effect of increased level of fatty acids on ECM yield could be influenced by type and quality of roughage. No or even negative effects of increased level of fatty acids on milk yield was seen, when roughage quality was lower (1.3 versus 1.2 kg DM/SFU) and the roughage included a higher proportion of whole crop (up to 70% of SFU in roughage). The slightly higher content of starch in the ration with the highest proportion of whole crop might have affected the response. Furthermore, the extremely low supply of AAT from a rapeseed supplement might also, to a higher degree, have had a negative effect on milk yield when roughage consisted of more whole crop.

Our investigations (Mogensen et al. 2004b paper V) showed that assuming that crop yield in rapeseed was 2,000 kg/ha (3,450 SFU) and crop yield in barley was 3,600 kg/ha (3,430 SFU), milk production per ha, crop production, and financial output were almost equal for two organic farming systems based on clover-grass silage ad libitum and supplement of either rapeseed/barley or barley. However, crop yield in rapeseed has been found to have a greater variation than crop yield in barley (Mejnertsen 2004). If crop yield in rapeseed was either increased or decreased by 25% (1,500-2,500 kg/ha), the financial output from the system with rapeseed supplement would either be increased or decreased by 4% relative to financial output from the system with barley supplement (Mogensen et al. 2004b paper V). Also Thøgersen et al. (2002) found that productivity and financial output were almost similar in scenario calculations with systems based on supplement of rapeseed or cereals, assuming a crop yield of 2,200 kg in rapeseed and 4,300 kg in cereals.

Concentrated feed supplying easily digestible carbohydrates

Due to the high crop yield expected (Mogensen et al. 1999) fodder beets are attractive in a self-supplying farming system. They are alternatives to supplement of barley (Krohn & Andersen 1979, Moate et al. 1999, Eriksson 2000) as neither digestion of NDF nor milk yield differed in diets based on 20% of DM from starch or sugar as supplement to grass silage (Stensig et al. 1998).

Our scenario calculations showed that an organic farming system based on a supplement of fodder beet resulted in the same financial output as a system with supplement of barley (Mogensen et al. 2004b paper V). The system with fodder beets had a higher crop production per ha, and there was feed for more cows than with a barley supplement. With the same milk production per cow in the two systems, ECM production per ha in the system with fodder beets was increased and so was financial output from the cattle production. Due to high capacity costs related to the high number of cows as well as to high expenses for growing fodder beet, gross margin is the same for systems with barley or fodder beets as concentrated feed (Mogensen et al. 2004b paper V). Crop yield potential in fodder beets could be higher than the 7,800 SFU/ha used in the scenario. If crop yield was 10,000 SFU/ha, GM2 would be 4% higher in the system with fodder beet than in the system with barley. Compared with a system with barley supplement a system with fodder beet resulted in only smaller differences in N balances (57 versus 53 kg N/ha) (Mogensen et al. 2004b paper V).

The reason for the reduced use of fodder beet in practice is primarily the problem of finding manpower for manual weed control. With the decreasing milk prices expected in the future, a system like the one with fodder beet with a high milk production but also high expenses per ha will suffer more from a price reduction than the system with barley supplement characterized by a lower milk production/income but also lower expenses per ha (Mogensen et al. 2004b paper V).

Type of concentrated feed

The effect of different types of concentrated feed on production per cow is highly dependent on type and amount of roughage. Concentrated feed rich in AAT has minor impact on milk yield per cow if roughage is dominated by high-quality clover-grass silage, and has a greater effect if roughage consists of more whole crop silage. The productivity of a self-supplying system rely on the crop yield of grown concentrated feed. Relative to barley, the yield in rapeseed cake is much lower, yield in lupine may be lower, yield in pea can be similar, and yield in grass pellet higher than in barley. Concentrated feed rich in fatty acids such as rapeseed will increase milk production per cow if the ration does not have a high content of starch, low structure, or a low AAT content combined with a high proportion of whole crop silage. Compared to crop yield in barley crop yield from rapeseed is more uncertain which might have a negative effect on the productivity of the system. Due to high crop production grass pellets and fodder beets will secure the highest milk production per ha, but cost of growing fodder beets is too high. Taking into account that a ration with a high content of cereals may have a negative effect on the cow's health (se next section) a mixed supply of different types of concentrated feed might be preferred.

Initiative 4: Import of manure

According to the Danish organic rules (Anonymous 2004a) manure may be imported as supplement to own production if the total manure available is a maximum of 140 kg N/ha (1.4 LU). Our investigations showed that when a farming system self-supplying with fodder and manure and a livestock density of 0.9 DE/ha imported the maximum amount of manure corresponding to 50 kg N/ha, the available amount of manure for spreading was doubled (Mogensen et al. 2004b paper V). Import of manure has as a result that the average crop yield was increased from 4,120 to 4,500 SFU/ha (Mogensen et al. 2004b paper V). The greater amount of fodder made it possible for livestock density to be increased and milk production per ha was increased from 4,207 to 4,605 kg ECM/ha. Consequently, the average GM from the cattle production was increased, and GM from crop production was increased even when the cost of imported manure was taken into account. The total GM of the farming system was increased by 9%. The cost of manure was 25 DKK/t including spreading. The break-even price for manure was 51.41 DKK/t (11.43 DKK/kg total N) assuming marginal effects on crop yield of 6 SFU/kg total N in clover-grass (Aaes & Kristensen 1994) and 12 SFU/kg total N in cereals (Tersbøl & Kristensen 1997). Import of manure increased the risk of losses to the environment considerably as N surplus was increased from 54 to 95 kg N/ha.

Because of the increased crop yield, import of manure will increase milk production per ha, but it also has significant negative impact on N-surplus. However, the Danish organic growers' organisation (Anonymous 2002b) has as an aim that the use of conventional manure must be phased out before 2011. Furthermore, from an overall organic production perspective, other sectors such as plant production and pig production systems will be able to pay more for the manure.

Additional initiatives

Prolonged lactation

A planned prolongation of the lactation and the calving interval is assumed to decrease the need for feed of dry cows and young stock as well as the need for concentrates as the proportion of cows in peak lactation thus will be reduced (Anonymous 2004c). A great part of all diseases occurs in the period around calving (Ingvartsen et al. 2003a). Therefore, reducing the proportion of cows in peak lactation could be expected to reduce health problems connected to this period (Anonymous 2004c). In Sweden calving intervals of 12 or 18 months combined with a milking frequency of 2 or 3 times a day was compared (Österman & Bertilsson 2003). Extended calving interval did not result in any reduction in the average ECM yield per day from calving to calving, when prolonged calving interval was combined with an increased milking frequency (3 times) (Österman & Bertilsson 2003). Neither did Schneider et al. (1981) find any differences between late or early breeding when daily milk production of the whole calving interval was expressed per day. At the organic research station, Rugballegård, calving intervals of 12 or 18 months were compared (Anonymous 2004c). Preliminary results showed that milk yield of multi-parity cows in the beginning of the lactation were higher for cows with prolonged caving intervals than for cows with normal calving intervals. However, this was only true at a normal feeding level. The opposite was seen when the feeding level was reduced (Anonymous 2004c). An important cause of fertility problems is supposed to be the fact that with a calving interval of 12 months, the cow must be inseminated during a period when she is at the peak of her production. A negative energy balance might lead to a decreased conception rate (Bertilsson et al. 1997). However, there was no significant difference, based on conception rate, in fertility between groups with different calving intervals (Österman & Bertilsson 2003, Anonymous 2004). With prolonged calving intervals there will be a longer interval between generations and, therefore, a lower genetic improvement. There will be fewer calves born per year, and therefore also a lower possibility for replacement and a lower meat production in the herd (Thamsborg et al. 2000).

A prolonged calving interval can be a way to increase the use of roughage and thereby probably also the productivity of a self-supplying farming system. However, the system needs further investigation.

Crop rotation

The most important factors when growing crops organically are to ensure that there are enough nitrogen and to get the weed under control (Tersbøl & Kristensen 1997). Crop rotation, including a mixture of leguminous fertility building crops and cash crops, is the main mechanism for nutrient supply within organic systems. Rotation can also be designed to minimize the spread of weeds, pest, and diseases (Watson et al. 2002). In crops such as clover-grass, which are cut and removed the weed is under control (Tersbøl & Kristensen 1997). Organic rotations are divided into phases that increase the level of soil nitrogen and phases that deplete it. The nitrogen building and depleting phases must be in balance if long-term fertility is to be maintained (Watson et al. 2002). The ratio of time in ley to arable will typically be that two-year clover-grass ley supports two or three years of arable cropping (Halberg & Kristensen 1997, Watson et al. 2002).

In our scenarios used to calculate the effects of different initiatives to obtain self-sufficiency with feed, the crop choice reflects the need for feed more than an optimisation of crop production. However, the area grown with different crops should be within the possibilities and restrictions related to organic crop production. For example the proportion of clover-grass in rotation must be above 20% to secure nitrogen building (Tersbøl & Kristensen 1997) and probably below 60-70% to avoid yield reduction (Kristensen 2004b). In different scenarios the proportion of clover-grass fluctuates between 28 and 55% (Mogensen et al. 2004b paper V), which is within these limits. Furthermore, the analysis of the effect of different types of concentrated feed was limited to the winter period as rapeseed should be grown on more than 30% of the area in rotation if fed both summer and winter, and this is not possible as an intersection of 3-4 years without rapeseed is recommend due to the risk of disease (Anonymous 2004f).

2.3. Animal health and welfare in a system based entirely on home-grown feed

In organic farming, animal health management should be based primarily on disease prevention including, among other things, high-quality feed. The principles of organic farming reflect the belief that the improved 'health' of the soil provides the basis for a healthy crop, which in turn is the basis for healthy nutrition of the animals (Padel et al. 2003).

Generally, herds with organic milk production encounter disease problems similarly to what has been found in conventional herds (Thamsborg et al. 2003). According to a review by Sundrum (2001), no major differences in health aspects, in general, have been identified. Several investigations have addressed the health of dairy cows in organic and conventional farms from the underlying hypothesis that the health of the organic cows might be impaired because of a poorer plan of nutrition as affected by the restrictions on feed used in organic dairy production. However, until now, organic cows have often been supplemented with conventionally grown feedstuffs including vitamins.

Once the dairy cows have to rely entirely on organically produced feed, the farmers' ability to supply the cow with sufficient nutrients to maintain good health may be reduced (Jakobsen & Hermansen 2001, Hermansen 2003, Thamsborg et al. 2003). That nutrient supply in organic herds should be based primarily on home-grown feed may present a higher risk associated with unbalanced diets, especially a shortage of energy combined with an excess of crude protein (Sundrum 2001). It is likely that the requirement of a high proportion of roughage in the ration will be favourable to the rumen environment and result in less metabolic disease. On the other hand, the energy requirements may not be sufficient in some cases (Thamsborg et al. 2003). Furthermore, supplementation with vitamins, trace elements, and minerals is not a routine practice in most organic dairy farms (Krutzinna et al. 1996a) as the EU regulation (1999) does not allow synthetic vitamins to be administrated, and the natural alternatives often are much more expensive.

Mastitis

Mastitis has been recognized as the main animal health problem in organic dairy herds (Krutzinna et al. 1996b, Weller & Cooper 1996). Disease incidence appears to be similar to, and occasionally higher than, conventional production (Hovi & Roderick 1999, Busato et al. 2000, Weller and Bowling 2000). However, in studies from Denmark in 1990-93 was found that the use of antibiotic treatment for mastitis was less frequent in organic dairy herds than in conventional herds (Vaarst & Enevoldsen 1994, Vaarst 1995). A more recent Danish survey showed no difference in mastitis treatments and somatic cell counts between conventional herds and newly converted organic herds (1995 or later), though herds converted before 1990 differed from the other herds by having lower milk production per cow, fewer treatments for mastitis, and lower somatic cell counts (Bennedsgaard et al. 2003). At present the consequences of shortcomings in the diet for mastitis is not known (Thamsborg et al. 2003). In an experiment a high level of barley supplement tended to be associated with higher somatic cell counts than with a supplement of rapeseed cake (Mogensen & Kristensen 2002 paper II), and Barnouin et al. (1995) found in herd studies that high quantities of cereal-based supplement in the diet increased the risk for high somatic cell counts. On that background it is possible that a high proportion of cereals in the ration can increase the risk of mastitis.

Ketosis

Generally, the risk of a severe undersupply of energy will be at a maximum during the first two months of lactation, when the daily milk yield increases considerably faster than feed intake (Nørgaard & Hvelplund 2003). During this time, the cow is balancing the energy deficit by mobilizing adipose tissue. When lipid mobilization exceeds physiologically defined limits, the risk for metabolic disorders increases markedly (INRA 1989, Knaus et al. 2001). Due to the higher proportion of roughage in organic feeding the energy density in the ration in the beginning of the lactation is lower than traditionally (Waldo 1986, Dhiman et al. 1995). This may increase the degree of negative energy balance immediately after calving (Dhiman et al. 1995) and result in an increased mobilization and, subsequently, in a higher concentration of ketone bodies in plasma and milk (Kunz et al. 1985), which is a risk factor for primary ketosis (Enjalbert et al. 2001).

Based on these references the risk of ketosis may be enhanced in organic dairy cows. However, compared with conventional farms several studies found lower incidence of metabolic disorders such as ketosis on organic farms (Ebbevik & Løes 1994, Vaarst & Enevoldsen 1994, Krutzinna et al. 1996a, Hardend & Edge 2001). The lower incidence could be caused by the generally lower production levels in organic livestock farming (Vaarst et al. 1993, Boehncke 1997). On the other hand, the occurrence of ketosis related to the high milk production level is not consistent in literature, and there seems to be best evidence of no effect of the milk production level on the risk of ketosis (Dohoo & Martin 1984, Erb 1987, Gröhn et al. 1989, Gröhn et al. 1995). Another explanation for the lower incidence of ketosis in the organic herds could - according to Strøm & Olesen (1997) - be the result of more variation in the composition of the forage, thereby a more tasty diet and, consequently, a higher feed consumption. In agreement with that Riemann et al. (1985) found a decreased treatment rate of ketosis in Norwegian dairy herds with an increased number of different feedstuffs used.

In an experiment by Mogensen et al. (2004a paper IV) with proportions of roughage between 75 and 93% of SFU, the concentration of metabolites measured in plasma and milk was found to be within the normal physiological range (Enjalbert et al. 2001) indicating no excessive negative energy balance during the first 12 weeks of lactation. Cows offered only 1 kg concentrated feed were expected to have excessive mobilization to meet the physiological needs. This was obviously not the case, as indicated by normal glucose concentrations in plasma. It was concluded that the average cow in the experiment had no increased risk of ketosis, mainly because of an average body condition score (BSC) of 2.5 and a consequent relatively low mobilization of body fat (Mogensen et al. 2004a paper IV).

BCS was frequently registered (on a scale from 1 to 5 points according to Kristensen 1986) on six organic dairy farms where cows were fed entirely organically grown feed (Mogensen 2004a) as well as on six conventional dairy farms. The average BCS of lactating cows was 2.4 and 2.1 points in organic and conventional herds, respectively, and average BCS of dry cows was 2.7 and 3.0 points in organic and conventional herds, respectively. The smaller difference in the average BCS between lactating and dry cows in the organic herds indicates a lower degree of mobilization than in the conventional herds, as, furthermore, there were fewer lactating cows with a score of 1 point in the organic herds (Mogensen 2004a).

The fact that ketosis contrary to the expectations seems not to be a problem in organic herds may be a result of a lower level of mobilization as indicated by a more constant BCS. The lower mobilization may be related to the lower proportion of concentrated feed in the ration as well as to the more equal distribution of the concentrated feed over the lactation.

Ruminal acidosis, liver abscess, and laminitis

Acidosis itself is difficult to diagnose in the field because mild diare and a moderately distended rumen with doughy contents and weak contractions may be the only clinical signs. When acidosis is detected due to laminitis, the acidosis may have developed weeks or months earlier (Nordlund et al. 1995).

Liver abscess is considered a metabolic disease probably caused by dietary acidosis that results in lesions in rumen mucosa and enables bacteria to pass via the bloodstream to the liver. Traditionally, liver abscess has been connected with a high intake of concentrates (Nagaraja & Chengappa 1998, Owens et al. 1998, Andersen 2000). Therefore, with the high proportion of roughage used in organic feed rations, liver abscess has not been regarded as a problem until recently. However, based on registrations from the slaughterhouses, the average incidence of liver abscess was 8% for organic versus 5% for conventional cows (Kjeldsen et al. 2004). A questionnaire survey among 91 organic dairy farms in 2003 showed that between 0 and 30% of the cows slaughtered had liver abscess (Jørgensen et al. 2004a). The incidence was highest in herds fed a high proportion of cereals (> 4.3 SFU/cow/day). Also in herds where summerfeeding was based on a high proportion of fresh clover-grass (> 9.0 SFU/cow/day) and cereals, high incidences of liver abscess were found (Jørgensen et al. 2004a). Furthermore, an experiment with finishing steers at pasture supplied 4 kg barley/day resulted in liver abscesses one year in 4 out of 11 steers (Andersen et al. 2003). When 100% organically grown feed was introduced, beet pellets among other feeds were left out of the ration, and in some herds cows' summerfeeding today is based entirely on clover-grass and cereals. Although clover-grass is regarded as roughage, it has not necessarily enough physical structure to ensure a sufficient chewing time and to stimulate the rumen function properly. When rumination is not optimal, saliva production is not sufficient to neutralize acids from metabolism of cereals (Nørgaard 2003). A high content of sugar in the clover-grass at the beginning of the season (Søegaard et al. 2003) can decrease the pH value further. Consequently, the summer ration has to include for example hay, maize or clover-grass silage, or grass pellets to secure the structure in the ration. Furthermore, high incidence of liver abscess was found to be correlated with great fluctuations in milk and fat content, indicating fluctuation in the feeding (Jørgensen et al. 2004b). Liver abscess is primarily a welfare problem, but if a cow has many and large liver abscesses, production will also be affected, as found for bull calves (Thomas 1986).

Laminitis, like liver abscess, is associated with ruminal acidosis causing aseptic inflammation in the claws (Nocek 1997). Clinical laminitis has been found to be related to type of concentrate given. Livesey & Fleming (1984) and Kelly & Leaver (1990) found that cows fed a starchy diet were more prone to clinical lameness than fibre fed animals. Our results from claw trimming after a 4-month winter period with different concentrated feed, barley or rapeseed cake/barley, showed no difference in claw status (Mogensen & Kristensen 2002 paper II). A surplus supply of protein could also be a risk factor for laminitis though literature shows conflicting results (Vermunt & Greenough 1984, Nocek 1997).

Based on the results presented it seems that supply of a high level of cereals is a risk factor for rumen acidosis and thereby also for liver abscess and laminitis, particularly in combination with a high proportion of fresh clover-grass.

Bloat

The risk of bloat is associated with cows grazing clover-grass fields with a high proportion of clover (Ingvartsen et al. 2003b). The risk is increased if hungry cows are let out in the morning on a dewy newly established clover-grass field. Supply of forage reduced the incidence of bloat (Phillips et al. 1996) as a stable floating layer is created in the rumen and the gaseous production from the microbes thereby is reduced (Ingvartsen et al. 2003b). The gaseous production can be reduced further by a limited supply of starch, sugar, and easily digestible cell walls (Ingvartsen et al. 2003b). Finally, use of plants with a high content of tannins may probably reduce the risk of bloats (Underwood & Suttle 1999).

In organic dairy farms in Denmark an average clover volume content of 44% was found (Mogensen et al. 1999). Based on this information the risk of bloat is supposed to be increased on organic farms with a high proportion of fresh clover-grass in the ration. However, results from a questionnaire survey among 91 organic dairy farms showed that only 1% of the herds often have cases of bloat, whereas the other herds seldom or never have problems with bloat (Jørgensen et al. 2004a). Therefore, bloat does not seem to be considered as a particular problem in organic farming, in general.

Parasites

According to a questionnaire survey, gastro-intestinal worms and/or lungworm were diagnosed during the grazing season 2002 on 42% of the organic dairy farms in Denmark (Weinreich & Pedersen 2004). On 10% of the organic dairy farms worms were diagnosed for five successive years (Weinreich & Pedersen 2004). Nutrition plays a major role for the susceptibility of grazing young livestock to parasitic infections (Younie et al. 2003) as supplementation resulted in lower ingestion of infected grass and thereby a dilution of the parasite burden (Jørgensen et al. 1992). The natural choice of parasite control is grassland management (Younie et al. 2003), including turning out at "clean" fields, and a low livestock density. However, there can be a conflict here with the aim of a high crop yield per ha (Weinreich & Pedersen 2004). Another element in natural helminth control is the use of plants with a high content of condensed tannins (Thamsborg et al. 1999) as such plant species in some cases have been shown to reduce the parasite burden in young animals.

There seems to be greater problems with parasites in organic dairy herds than indicated by number of treatments registered by veterinaries. Therefore preventive parasite control by grassland management needs high priority when planning the feeding in the organic farming system.

Welfare

The welfare status of the animals has always been an important goal for organic husbandry (Vaarst et al. 2003a) and there is more to welfare than ensuring proper health (Rollin 1996), as discussed above, although freedom of disease is an important component. The higher level of minimal standards used in organic livestock farming and their regular check provide several preconditions for good living conditions of farm animals (Sundrum 2001). This reflects a clear improvement compared to the conventional situation. However, those minimal standards are not necessarily a guarantee for appropriate housing conditions (Sundrum 2001) and beside the housing conditions, the quality of stockmanship and management, the patterns of feeding, climatic factors, and the hygienic situation all have significant influence on animal health and welfare (Rushen & De Passillé 1992, Bergsten 1994) and these factors are not part of the EU regulation (1999).

Furthermore, animal welfare is just one of many interests that must be considered on an organic farm, and it may compete with others, such as environmental protection, human safety, and adequate production. One possible interest conflict area identified in Danish organic dairy herds by vets, agricultural advisors, and organic farmers (Vaarst et al. 2001) was the rearing of calves, particularly the grazing of young animals from, at that time, an age of 3 months. An important argument for letting young calves stay outdoor on grass is that it enables the calf to fully express its natural behaviour, but it must be supported by the appropriate activities of the caregiver. Otherwise the health, and hence the welfare, of the calves may be put into jeopardy (Vaarst et al. 2001). Another possible conflict area is 100% organically grown feed (Vaarst et al. 2001). The goal of providing livestock with only organically grown feeds must be met in a manner that allows the animals' needs to be met without jeopardizing sustainability while also being financially feasible for the farmer (Zollitsch et al. 2003). It is obvious that severe undernutrition impairs animal welfare and health, but the question remains whether animal welfare may also be harmed if high yields are to be reached by maximum nutrient supply. Moderate underfeeding accompanied by a reduction in yield may help the animal tolerate certain nutritional imbalances better (Zollitsch et al. 2003).

2.4. Conclusion and future perspectives

To what extent organic milk production will be based on home-grown feed in the future – if it does not become a requirement by the standards – will depend on the sustainability of the system. That includes that it must be possible for the farmer to make a living from the production system. With the preset pricing of milk and concentrate mixtures a system based on home-grown feed can be financially more attractive than a system based on bought-in feed. This, even though productivity: crop yield and milk production per ha can be higher in the system based on feed import. Furthermore, the reduction on prices of milk expected in the future will have a greater negative effect on the system based on fodder import than on the self-supplying system.

The area per cow needed to grow the ration in an organic farming system self-supplying with feed and manure is about 1.7 ha with a variation from 1.4 to 2.0 ha depending on feeding level and type of concentrated feed and roughage, and thereby different types of crop grown with different yield potential. Only 10% of the present organic dairy farms in Denmark have more than 1.70 ha per cow. In an existing production system, it is probably not profitable to reduce the herd size because of fixed capacity costs of the stable, whereas it may be profitable to rent more land or cooperate with a plant farmer.

In a self-supplying organic dairy farming system focus on roughage – quantity and quality – will increase even more and become one of the most important factors in the system. Increased feeding level caused by increased roughage quality will pay off. In the future, the proportion of clover-grass silage is supposed to increase and proportion of whole crop to decrease. With the change in the EU support, clover-grass and whole crop will be ranked equally, and the higher quality and yield in clover-grass compared to whole crop will dominate. Furthermore, the use of clover-grass for grazing, the least expensive feed units of all, has to find a compromise between inexpensive feed units and keeping the manure at stable for later spreading.

Whether a decreased feeding level caused by a decreased level of concentrated feed will be financially attractive depends on the marginal feed efficiency in the herd. If the marginal feed efficiency is high it will not be financially attractive to reduce the feeding level. The marginal feed efficiency is higher at a high feed efficiency and with high-quality roughage.

There will only be a small variation in the financial output from the farm dependent on type of concentrated feed used. Therefore, which type of concentrated feed to choose should depend on crop yield. However, taking into account that a ration with a high content of cereals may have a negative effect on the cow’s health a mixed supply of different types of concentrated feed might be preferred.

- Discussion -

3. References

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