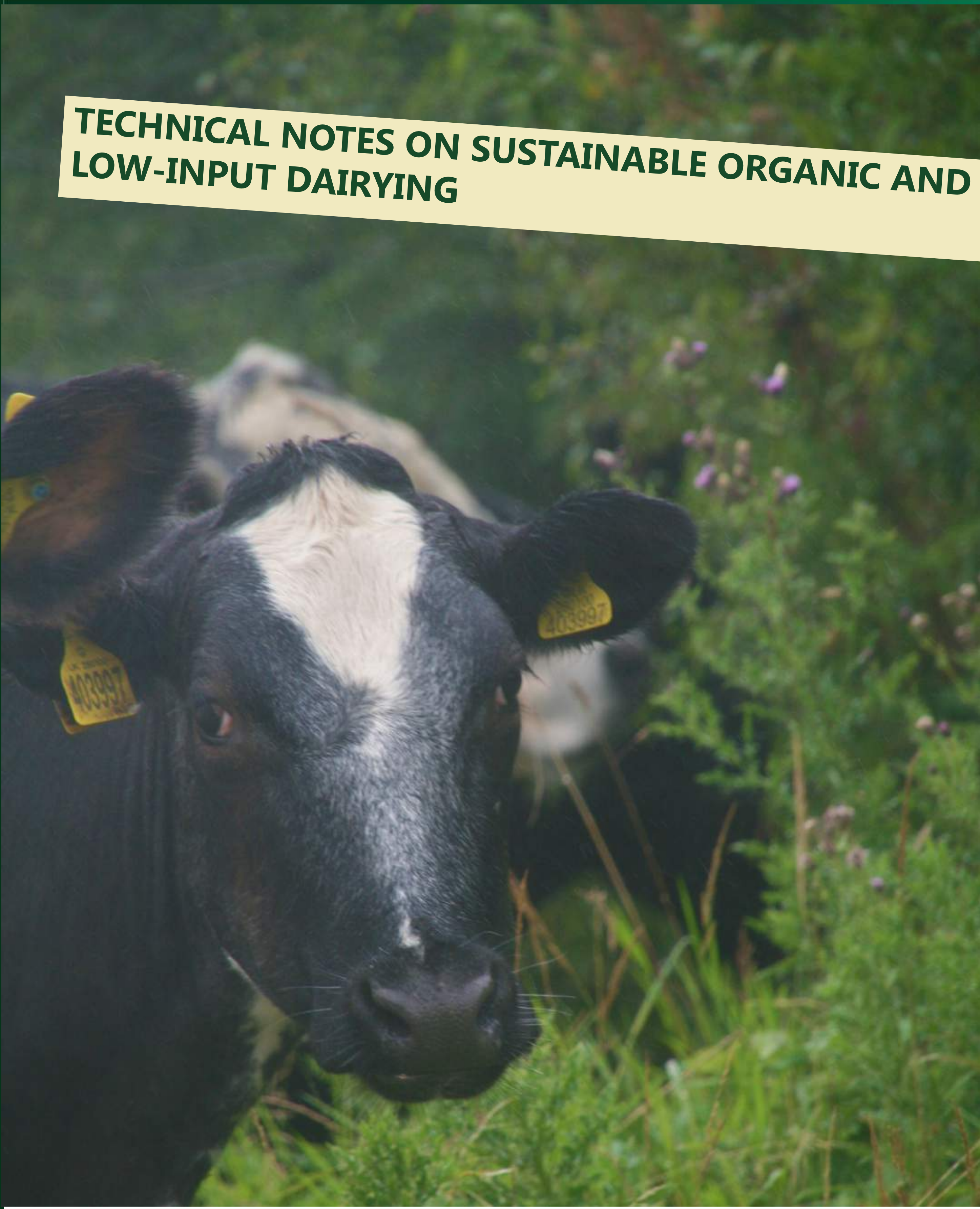
SOLID Sustainable Organic and Low Input Dairying

TECHNICAL NOTES ON SUSTAINABLE ORGANIC AND LOW-INPUT DAIRYING



Farmer Handbook

www.solidairy.eu http://farmadvice.solidairy.eu/

Produced by The Organic Research Centre, UK. 2016

The SOLID Farmer Handbook

Introduction

There is increasing recognition of the ability of organic and low input systems to deliver a variety of benefits, but the same systems are faced with a number of constraints including how to develop appropriate breeding and feeding strategies and deal with health, welfare, financial and environmental challenges, all of which sit within the frame of uncertain policy support and volatile markets. Much of this relates to a lack of knowledge about such systems.

The SME partners and researchers have collaborated closely with farmers in many project activities, ranging from dairy goat producers in Greece and Spain to dairy cow producers with large and small herds, from Romania to Finland.

As an illustration of the great diversity, overall, farms included landless dairy goat farms in Spain and Flanders, goats that ranged over more than 300 ha of common land in Spain and Greece, and dairy cow farms above 200 ha in Denmark and UK. Herd sizes ranged from nine cows (Finland) to over 300 cows (Italy, Denmark, UK) and 22 goats (Spain) to 1150 goats (Flanders), with milk sales for cows both under 3000 l/year (where cheese is also made) and over 10,000 l/year, and for goats between 117 and 900 l/year.

To identify research priorities sustainability assessments were carried out on more than 100 dairy farms (organic/low-input) in nine countries across Europe, followed by workshops where the results were discussed and potential topics for research identified.

The process of the farm sustainability assessment was largely viewed positively by farmers, SME partners and researchers. The output of the tool illustrated differences between countries and between cow and goat enterprises (see box). The most valuable outcome of using such an assessment tool was to encourage discussion about sustainability in its widest sense.

Farmers suggested a range of research topics related to: Feeding, Forage production, Soil and nutrient management, Breeds and breeding, Animal health and welfare, Product differentiation and marketing and Energy use. To identify the final topics of study farmers and researchers worked together to narrow down the questions, identify other research that had been done elsewhere and look for specific farms where any trial could be carried out (see Table 1). Reports of these farmer-led trials can be found at www.solidairy.eu/index.php/participatory-on-farm-research-in-solid/

In this series of technical notes we are presenting a selection of results and recommendations of the work undertaken in SOLID aimed at those working in such industries. The results are derived from the participatory research but also from more traditional scientific experiments carried out as part of the SOLID project. The project has also produced scientific articles, reports, workshops and E-learning materials which are referenced in the notes which can be found at www.solidairy.eu/

Introduction to SOLID

SOLID was a European project on Sustainable Organic and Low Input Dairying, financed by the European Union.

For five years (2011 to 2016) agricultural scientists and farming experts from 25 institutions in ten European countries worked together in order to develop new knowledge and methods to improve the sustainability of the organic and low-input dairying systems in Europe. Nine of the project partners were SMEs working with low-input and organic dairy farmers (including co-operatives, advisory services and one organic certification body). The project was co-ordinated by the Institute of Biological, Environmental and Rural Sciences at Aberystwyth University, UK.

SOLID partners in the UK, Denmark, Austria, Italy, Belgium, Finland, Greece, Spain, Romania, Germany.

Organic/low-input farming

Organic farming is clearly defined through the EU regulations (http://ec.europa.eu/agriculture/organic) for organic production that all organic farmers have to follow.

The term low-input is not clearly defined for dairy farms. In the SOLID project, we used the Farm Accountancy Data Network sources to identify low-input farms. We calculated the total costs of purchased concentrated feed and fodder for grazing livestock, costs for fertilizers crop protection energy and fuel divided by grazing livestock units and considered the 25 % of farms with lowest external input use as low-input in each country (see also Technical Note 10).

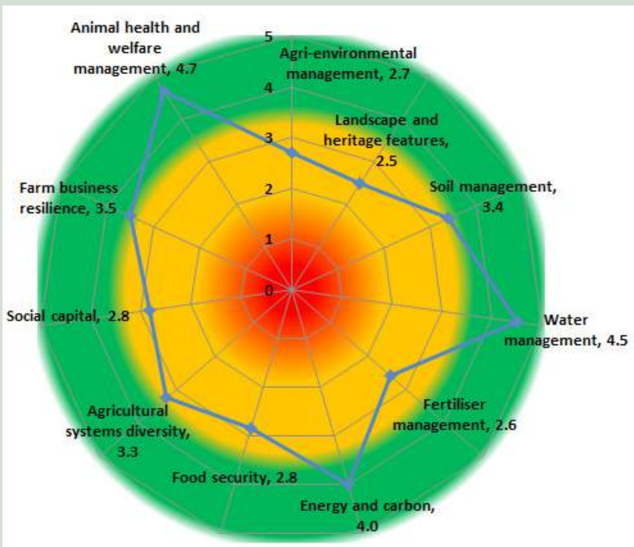
Table 1: Farmer-led research in SOLID

Topic	Approach	Country
Feeding and forage		
Home-grown proteins	On-farm trials	Finland
Use of by-products	On-farm trials	Spain, Romania
Irrigation of pasture	On-farm trials	Greece
Animal management		
Reducing antibiotic use	Moderated discussion group followed by on-farm trials	UK (with Duchy Future Farming Programme)
Herbs in pasture	Comparative case studies	Denmark
Maternal /nurse cow rearing of calves	Farm case study with monitoring of calf growth	UK and Denmark
Impact of farm practices on concentration of iodine in milk	Comparative farm case studies	UK
Natural resource use and environmental impact		
Soil management, pasture productivity and grazing	Farm case study with monitoring of forage production	UK
Responding to climate change	Moderated discussion group and farm case studies	Denmark
Impact of different protein sources on carbon footprint	Case study using LCA (Life Cycle Analysis) method	Italy
Impact of intensification on biodiversity	Comparative farm case studies with assessments and modelling	Austria

Outcome of the sustainability assessment

The sustainability assessments carried out in the SOLID project indicated that the organic/low-input dairy systems studied have their greatest and most consistent strengths in terms of farm business resilience; contributing factors to this strength are diversification (which is not always possible for a dairy farm), and a specialist market for the product. On-farm processing and marketing are beneficial to both organic and low-input dairying, but need more support in most countries. Organic producers have a specifically defined product that requires better marketing and outlets. Low-input producers can use a variety of aspects of their products to market them, but need to be proactive and creative in this respect. Profitability can also be improved by cutting costs and examples of farmers seeking to do this in innovative ways were reported. This includes extending lactations (mainly on goat farms) and moving to once a day milking. Improving energy self-sufficiency was also mentioned. Many farmers clearly have concerns about the economic survival of their businesses. Animal health and welfare appeared from the assessments to be a strength, yet farmers still aspire to greater improvements, being aware of the importance for productivity, consumer image, and the animals themselves.

The weaknesses relevant to sustainability as identified by the tool varied between countries. Water management appeared as a weakness of some systems, both in regions where water is plentiful, and also in some areas dependent on irrigation (e.g. parts of Italy and Romania). This is clearly important in view of the likely increase in extreme weather patterns with climate change. Breeding plant varieties and developing crop management systems for extremely high or low amounts of rainfall were suggested as research topics by farmers. The 'classical' indicators of environmental sustainability, i.e. management of soil, water and nutrients, and energy and carbon resources, all show considerable variation in the majority of countries, indicating that there is the potential for poorer performing farms to improve.



Example farm results: cobweb (0 is poor performance, 5 is good). See http://www.solidairy.eu/index.php/case-farms/

The technical notes

The technical notes cover three thematic areas which we believe are particularly important for organic and low-input farming: feeding of ruminants with forage-based diets and home-grown feeds; animal management for health and welfare; and wider issues of the environment and economics.

Feeding of ruminants with forage-based diets

The principal challenge that organic and low-input farmers face is how to increase milk from forage; this is closely correlated with profitability and yet many producers are not achieving satisfactory performance. Specifically this means increasing forage yields, improving the grassland management and correct ration formulation in order to maximise milk from forage. Given the range of conditions across Europe different solutions will be required to suit individual circumstances including the selection of suitable breeds of animals.

Animal management for health and welfare

There is an expectation that there are some breeds better adapted to organic/low-input conditions, but there is also considerable variability between different organic and low-input systems. There is a need to set specific breeding goals for a specific farm. Many improvements in cow health can be achieved by removing the causes of stress for cows and people. SOLID looked into practices such as suckled calf rearing systems as well as the use of trees to provide shelter.

Wider issues of environment and economics

Dairy farmers are faced with challenges related to the carbon footprint of ruminants, wider issues of sustainability of farming and the supply chain as well as a global collapse of conventional milk prices and the uncertainty of support payments. One advantage of low-input and organic production can be lower inputs costs, but farmers also need to reflect on how the market (including a growing market for organic dairy products in Europe and around the world) and other factors will impact on their economic sustainability.

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Sustainable Organic and Low-Input Dairying

SOLID is a European project on Sustainable Organic and Low Input Dairying financed by the European Union. The project ran from 2011-2016. 25 partners from 10 European countries participated

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Energy requirements and ration planning for low-input dairy cows

Introduction

With milk prices expected to remain volatile in the future, it is important that farmers look for options to reduce the costs of milk production. Feed costs represent one of the most significant costs of milk production on most farms, and as such it is important that cows are rationed correctly.

When rationing dairy cows we need to take account of their energy requirements for milk production, the energy required to maintain the cows' basal body activity ('maintenance'), energy required for pregnancy, and energy required (or released by) body weight change. Research over many years has provided information on the energy required for each of these activities, with energy requirements for milk production the largest of these energy demands. Energy required for milk production is estimated from energy output in milk, which is then divided by the efficiency with which metabolisable energy (ME) is used for milk production (k_l). This 'efficiency factor' (k_l) is required as the process of milk production is not 100% efficient, i.e., some energy is wasted during the process. The second major energy demand is for maintenance of basal body activity, which is quantified as metabolisable energy requirement for maintenance (ME_m). The metabolisable energy requirement for maintenance is normally expressed on a 'metabolic liveweight' basis, i.e., liveweight (kg) to the power 0.75 (liveweight $kg^{0.75}$) – this takes account of cows with different body sizes.

Most energy rationing systems currently adopted across Europe have been developed for the 'average' cow (normally a Holstein cow) offered a 'typical' diet. However, within organic and low input systems the use of breeds other than the Holstein (including crossbred cows) is common, and it is uncertain if existing rationing systems are fully applicable to cows of other breeds. In addition, most existing rationing systems have been developed for cows offered moderate or high levels of concentrates. However, it is unclear if these rationing systems are appropriate for cows offered diets containing very high levels of forages, as is normal within organic and low input systems.

Thus important objectives within the SOLID project were firstly, to examine if there are differences in energy utilisation between Holstein-Friesian cows and cows of other breeds, and secondly, to examine if cows offered diets containing very high levels of forage utilised their energy differently from cows offered diets containing moderate or high levels of concentrates.

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How do we measure the efficiency with which cows utilise their energy?

The energy intake of a cow is calculated by multiplying her feed intake by the energy content of her food. On average, approximately 35% to 40% of energy consumed is lost in faeces, urine and methane gas. The remaining energy (i.e. the metabolisable energy) is then available to support milk production, to maintain the cow's body (maintenance), for pregnancy, and for body weight gain. The energy lost in methane, and the energy lost while maintaining the cow's body, can be determined using respiration calorimeters.

Respiration calorimeters (see photo) are really just small 'rooms' where cows remain for a number of days to allow methane production and heat production to be measured. The Agri-Food and Biosciences Institute (AFBI) in Northern Ireland has two of these chambers, and over the last 20 years these have been used to measure the energy utilisation efficiency of over 1000 dairy cows in over 50 studies. A number of different breeds of cow have been used in these studies, and in addition, cows have been offered a wide range of diets, including diets containing high levels of forage and high levels of concentrate. Data collected from these studies were examined within the SOLID project to identify if cows of different breeds have different energy requirements for maintenance, or if the efficiency of energy use for milk production (k_l) was affected by breed. In addition, the data were used to identify if cows offered diets containing high levels of forage have different energy utilisation efficiencies compared to cows offered diets containing medium or high levels of concentrates.

Respiration calorimeter at AFBI-Hillsborough in Northern Ireland – used to measure energy utilisation in cattle

Do cows of different breeds utilise energy with different efficiencies?

In this part of the project energy utilisation data from a number of 'adapted' dairy cow breeds (Norwegian Red, Norwegian Red × Holstein crossbreds and Jersey × Holstein crossbred cows) were compared with data for the Holstein breed. More details on testing the suitability of these breeds for organic and low-input farming can be found in Technical note 8. An initial test demonstrated that the three alternative breeds did not differ from each other in energy utilisation, and this allowed us to combine their data (categorised as 'non-Holstein' cows), and compare it with data for the pure Holstein cows (see Table 1).

Table 1. Breed of cow has no effect on energy utilisation efficiency

	Holstein	Non-Holstein
Metabolisable energy required for maintenance (ME_m, MJ/kg LWT$^{0.75}$)	0.69	0.68
Efficiency with which metabolisable energy is used for milk production (k_l)	0.64	0.64
Feed required to maintain a 600 kg cow (kg DM/day)	6.9	6.8
Feed required to produce 30 kg milk (kg DM/day)	12.1	12.1

There were no significant differences between Holstein cows and non-Holstein cows in the metabolisable energy required to maintain the cows' basal body activities (ME_m, expressed on a 'metabolic liveweight' basis) or in the efficiency of use of metabolisable energy for producing milk. This result demonstrates that there were no differences between Holstein cows and the 'adapted breeds' in terms of their energy requirements for maintenance or milk production. For example, a 600 kg Holstein cow producing 30 kg milk/day will need to consume a similar amount of dry matter (DM) for maintenance and milk production as a 600 kg cow of an alternative breed producing the same quantity of milk (Table 1). In summary, this research confirms that feed rationing systems which have been developed for Holstein cows are also appropriate for cows of other breeds. However, it should be remembered that some alternative breeds of cows are lighter than Holstein cows, and as such they will have a lower energy requirement for maintenance (MJ/day). In addition, some breeds (such as Jersey crossbred cows) produce milk with a higher fat content, and this will increase their energy requirement for milk production.

Do dairy cows utilise predominantly forage based diets less efficiently?

This part of the project examined the effects of concentrate level in dairy cow diets on metabolisable energy requirements for maintenance, and on the efficiency of utilisation of metabolisable energy for milk production. To facilitate this evaluation, the whole AFBI dataset from the calorimeter chambers was divided into four categories according to the proportion of forage in the diet (on a DM basis), namely cows offered diets containing less than 30% forage, 30-59% forage, 60-99% forage and 100% forage. The efficiency of energy utilisation of cows within each of these four groups was examined, and the results are presented in Table 2.

Table 2: Increasing dietary forage proportion increases maintenance energy requirement of dairy cows

	Forage proportion in the diet (DM basis)			
	Less than 30%	30%–59%	60%–99%	100%
Efficiency with which metabolisable energy is used for milk production (k_l)	0.64	0.64	0.63	0.63
Metabolisable energy required for maintenance (ME_m, MJ/kg $LWT^{0.75}$)	0.61	0.65	0.67	0.68
% increase in metabolisable energy required for maintenance, compared to a diet with less than 30% forage		7%	10%	11%

The proportion of forage in the diet did not alter the efficiency with which diet energy was used for milk production, i.e., k_l was similar for all diets. However, increasing the proportion of forage in the diet significantly increased the metabolisable energy requirement for maintenance (MJ per kg metabolic body weight). When compared with diets containing less than 30% forage, the metabolisable energy requirement for maintenance of cows offered diets containing 30-59% forage, 60-99% forage and 100% forage was increased by 7%, 10% and 11%, respectively. This result indicates that a 600 kg cow consuming a high forage diet (rather than a high concentrate diet), will need to eat approximately 0.7 kg more DM per day to supply its energy requirement for maintenance. The increase in feed intake required would be greater than 0.7 kg DM/day for cows offered diets containing poor quality forages. This is because cows offered high forage diets may require more time and a greater effort to eat, ruminate and digest these bulky forage based diets. This action can increase the basal metabolic rate of their body activities, and this in return requires additional energy (MJ per kg body weight). Thus, when designing rations for cows within low-input and organic systems, the higher maintenance energy requirements of these cows need to be taken into account.

Conclusions and recommendations

The results of this work suggests that cows of adapted breeds (e.g., Norwegian Red and crossbred cows) have similar maintenance energy requirements as Holstein cows, and utilise energy for lactation with a similar efficiency as Holstein cows. Thus existing rationing systems are appropriate for a range of dairy cow breeds. However, the metabolisable energy requirement for maintenance (MJ per kg metabolic body weight) obtained within the SOLID project is much higher than currently adopted in the feed rationing systems used in Germany and France, while similar to the current UK feed rationing system (Feed into Milk models). These differences are illustrated in Figure 1 for a 600 kg cow. Using the data obtained from the SOLID project, this cow would need to consume 7.1 kg DM/day for maintenance, compared to 6.9 kg DM/day in UK, 5.1 kg DM/day in France and 5.0 kg DM/day in Germany.

The results also demonstrate that dairy cows managed under low input or organic farming regimes may require more feed energy for maintenance of their basal body activity than those managed within higher concentrate input systems. Cows offered high forage diets may require more time and a greater effort to eat, ruminate and digest these bulky forage based diets. This issue has not been considered within energy feeding systems for dairy cows in many European countries. Thus many existing systems may underestimate the feed requirements of dairy cows managed within low concentrate input systems.

In summary, in order to improve the economic and environmental sustainability of dairy farming in Europe, there is an urgent need to upgrade current energy rationing systems for low input and organic dairy farming, taking account of the findings of the current work.

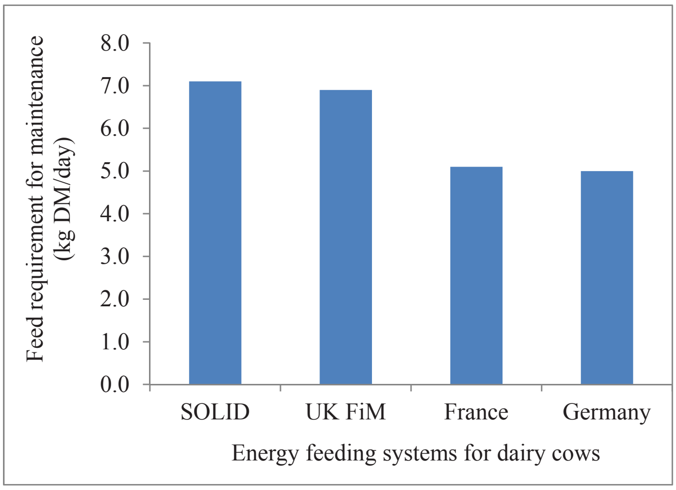

Figure 1: Comparison of feed required (kg DM/day) to maintain a 600 kg dairy cow, when calculated using information from the SOLID project and energy feeding systems currently used in UK, France and Germany.

Cows of different breeds and genotypes were found to utilise energy for milk production with similar efficiencies. However, cows managed on predominantly forage diets have a greater energy requirement for maintenance. This finding should be incorporated into dairy cow rationing systems within Europe.

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Feeding home-grown protein and novel feeds to dairy cows

Introduction

This technical note focuses on the potential of grain legumes and by-products as feeds for dairy cows. We also take a look at a case study from Italy where a diet based on home-grown feed was compared with a diet utilising a commercial protein supplement. Low protein self-sufficiency is a concern at European level (European Parliament 2011) and it is important to find alternatives to feeds based on imported soya beans. Forages also play a crucial role in the protein supply to dairy cows, but this is beyond the scope of this note.

Peas

Grain legumes can replace soya

Grain legumes are annual plants which are well-suited to organic farming practices because they fix nitrogen. Their seeds can easily be incorporated into animal feed. Grain legumes can also be harvested as whole-crop silage or even grazed, in which case the biomass of leaves and stems can also be utilised as feed.

Grain legumes can be cultivated throughout Europe, although in the North the short length of the growing season can be a limiting factor for seed-ripening. Statistics show that the area used for growing grain legumes has decreased during the last few decades, which is mainly due to competition with feeds based on imported soya beans. The challenges for grain legume production remain to obtain a high yield and to minimise the annual variation in yield so that farmers can see an economic incentive to including grain legumes in crop rotations.

Peas (*Pisum sativum*) can be grown as a pure stand or mixed with cereal grains such as wheat. There are many varieties available which are suited for biomass or seed production. The protein concentration of peas is relatively low so that rather large amounts are needed in the diet. Peas contain up to 25% protein and can be considered a 'dual-purpose' feed providing both protein and energy to livestock diets.

Faba beans (*Vicia faba*), also called horse beans, broad beans or field beans, are one of the oldest crops cultivated and they are commonly used globally for both food and feed. Faba beans contain more protein than peas (typically around 30%) but they contain anti-nutritional factors such as tannins and vicin + convicin. The microbial activity in the rumen destroys most anti-nutritional factors, but they must be taken into account when the beans are used for feeding pigs and particularly poultry.

Lupins *(Lupinus spp.)* There are various species e.g. white, blue or narrow-leafed and yellow lupins, which provide seeds with rather high protein and also oil concentration. Native lupins contain alkaloids which prevent their use as feed or food, but breeding of so-called sweet lupin varieties, which are suitable for feed, has allowed their increasing use.

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By-products and novel feeds

There is a wide variation in the properties of novel and underutilised feed resources available for use in organic and low-input dairy systems. The variation is caused by the diversity of raw materials, the variability in their composition, and the impact of the different processing technologies used (Rinne et al. 2014). The variability in feed materials may provide opportunities to find suitable supplements in terms of energy, protein and mineral concentrations, depending on the type of animals and basal feeding.

Not many by-product feeds are labelled organic, but as the organic food and beverage industries develop, more will become available in organic production, where ruminants must be fed a diet with 100% organic ingredients. Increasing the supply of new feed ingredients that are acceptable in organic production would, in many cases, allow for an increase in the supply of organic milk by giving greater flexibility in terms of feeding strategies and overcoming potential periods of feed shortage.

Certain by-products may have a large impact locally: in the vicinity of the processing plant they may provide an important additional feed resource. By-products may also be cheaper than standard feeds. Using by-products as feeds prevents the energy and nutrients they contain from being wasted.

- **Oilseeds.** Meals from oilseeds such as camelina, crambe, safflower and rapeseed provide protein-rich supplements after oil extraction. Their on-farm production could offer a good opportunity to increase supply of oils for human consumption or biodiesel, to produce high quality protein supplements for animals and to improve the farm's finances.
- **High-protein and low-fat distillers' grains** are the result of sophisticated industrial processes to extract as much as possible from the cereals (e.g. oil) and to diversify and add value to by-products in order to meet farmers' requirements (e.g. the case of high-protein distillers' grains). Guidance on suitability for organic diets needs to be obtained from a Control Body before use.
- **Olive leaves and cakes** are by-products from olive oil production and, if adequately supplemented, they may be successfully used in animal diets.
- **Vegetable and fruit industry by-products** such as tomato wastes offer a cheap source of energy and protein with high digestibility; however, the high moisture content makes processing and storage a challenge. This can be overcome e.g. by co-ensiling them with straw.
- **Carbohydrates from wood** are available in large quantities, but because of very low digestibility of intact wood, a great deal of processing is required to improve their digestibility. Currently this is not economically viable.
- **Feed supply from agroforestry systems.** Fast growing trees provide potential for a large quantity of material, but unpredictability and variability is a challenge to their uptake. The use of silvopastoral systems requires a change in the mindset of the farmer. Harvesting, preservation and transportation questions also need to be solved for agroforestry based systems before they can be adopted in wider use (for more information refer to SOLID Technical Note 12).

Case study: Climate friendly organic milk production - Modena, Italy

The study aimed at evaluating the carbon footprint of organic milk produced by cattle on two different diets:

- Control, based on purchased ingredients - crushed maize (7%) and protein (mainly based on sunflower and soya bean) meal (10%) - and on-farm produced ingredients - lucerne hay (60%), crushed barley (13%), crushed sorghum (10%)
- Home-grown feed based almost solely on feed ingredients produced on-farm- lucerne hay (64%), crushed barley (16%), crushed sorghum (19%), with protein meal (1%) as the only purchased feed.

The feeding trial was conducted using 136 dairy cows (Italian Friesians) divided into two homogeneous groups (in terms of parity and days in milk) for 3 months at the Hombre farm in Modena, Italy.

The average daily milk production of the home-grown feed group was 3.9 kg lower than the control group. Milk quality (fat and protein concentration, number of somatic cells) was not affected by the diets. The results obtained for the milk yield have been confirmed by other authors that studied the substitution of soybean with alternative protein plants on a dairy cow ration (Martini et al., 2008; Mordenti et al., 2007).

The impact of the home-grown feed system on global warming, calculated in terms of kg of CO_2-eq per kg of fat and protein corrected milk (FPCM) produced was higher than the control system (Figure 1). This is mainly due to the reduction in milk production in the home-grown feed system. This is in agreement with literature showing that the milk yield per cow is one of the main factors affecting the carbon footprint of dairy farms (Rotz *et al*., 2010; Hermansen & Kristensen, 2011; Opio *et al*., 2011).

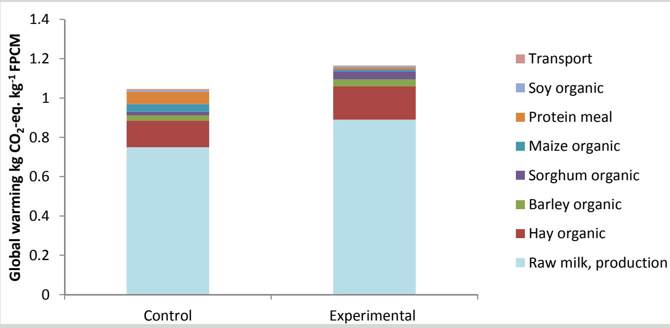

Figure 1 - Global warming potential of control and home-grown feed systems and the contribution from different processes

As with most case study analyses, some aspects of our study (for example crop rotation and herd management) limit the generalisation of the results. Despite these limitations, the results gave useful insights into the choices that a farmer must make before deciding to modify a diet.

Hombre farm, Modena, Italy

First of all, in addition to lucerne hay, we suggest the use of faba beans or peas to improve home-grown protein supply to low input dairy systems. Those sources could be viable alternatives to soya based feeds. Secondly, as well as considering possible effects on milk yield, dairy farmers should also consider the environmental impact. This study demonstrates that lower milk production generates not only a lower profit for the farm, but also a higher environmental impact.

Furthermore, solutions at farm level should be linked to consumers preferences. In particular, consumers are unlikely to be willing to pay more for changes in animal diets. According to a survey of European consumers (Zanoli *et al.*, 2015) changes in animal diet are relevant only if they reduce the risk of GM contamination and can improve the quality of milk, especially in terms of human health.

Faba beans are suitable for ruminant feeding as whole-crop silage or the beans can be used as protein supplement.

Table 1. An overview of various novel and underutilised feedstuffs as supplements in organic and low input dairy production. A minus (-) includes negative and a plus (+) positive effects whereas a question mark (?) indicates lack of knowledge.

Feed	Quantitative availablility	High energy value	High protein value	Effect on milk quality	Effect on animal health	Lack of antinutritive factors	Ease of processing	Ease of preservation	Suitability for organic production	Suitability for low input production
Camelina meal	-	+	++	+	?	+	+	+	++	+
Crambe meal	-	+	++	-	-	-	+	+	+	+
Safflower meal	-	+	+	+	?	?	+	+	++	+
Reduced fat distillers' grains	++	+	+	+	?	+	--	+	?	-
High protein distillers' grains	+	+	++	+	?	+	--	+	?	-
Whole rapeseeds (on-farm)	+	++	++	+	?	-	+	+	+	++
Rapeseed expeller (on-farm)	+	++	++	+	?	-	-	+	+	++
Lupin by-products	-	++	++	+	?	-	+	+	++	++
Pea, bean, chickpea and lentils	+	+	+	+	?	+	+	+	++	+
Buckwheat, mustard, canary seed	-	?	?	?	?	-	?	+	?	+
Olive leaves	++	+	-	+	-	-	+	+	-	++
Olive cake	++	++	-	+	+	-	-	-	-	++
Tomato pomace	++	++	+	++	?	+	-	-	-	++
Wood by-products	-- / ?	-/+	--	-/+	?	+	--	--	--	-
Agroforestry	+	-/+	-	?	?	-	+	-	++	++

Conclusions and recommendations

The amount and quality of feeds offered to animals have significant effects on feed intake and milk production, which largely dictates the economics of production. In addition they may also influence milk quality and the health of the animals. Although ruminants rely mainly on forages and microbial protein synthesis in the rumen for their protein supply, adequate supplemental protein is typically required to obtain better economic performance and environmental efficiency.

In order to maximise the home-grown protein content in the dairy ration, firstly it should be explored whether the protein supply from legume based forages (clovers, lucerne, sainfoin and whole crop silages with pulses) can be increased. It may be possible to increase their contribution to both protein quantity, for example with red clover, and protein quality, for example by using sainfoin with its rumen protected proteins.

There are viable alternatives to imported soya bean based feeds, grain legumes and rapeseed-based feeds being the most obvious. By-products, some traditional and some novel, some home-grown or locally available and some industrial, may also play a role. The developing bio-economy, increased use of bioenergy and development of different bio-refineries provide potential new opportunities to the feed sector in the future.

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See also SOLID workshop on new research and practical experience of feeding dairy cows in Jan 2016 http://tinyurl.com/SOLID-feed

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Sustainable Organic and Low-Input Dairying

SOLID is a European project on Sustainable Organic and Low Input Dairying financed by the European Union. The project ran from 2011-2016. 25 partners from 10 European countries participated.

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SOLID Sustainable Organic and Low Input Dairying

Use of diverse swards and 'mob grazing' for forage production

Introduction

Feeding and nutrition of the dairy cow represents the highest cost in producing a litre of milk and therefore is one of the most important factors in efficient dairy production. Nutrition is a key factor in the overall performance, health and welfare of dairy cattle. In these respects, farmers, particularly within the organic and low-input sectors, must increasingly concern themselves with optimising feed efficiency and nutrition. Given the high reliance of organic and low-input dairy cattle on forage resources and the various environments in which they are maintained, producers may inevitably have to adjust methods for forage production and adopt grazing strategies for better pasture utilisation while broadening the inclusion of alternative feed resources and diverse swards into their system (Zollitsch *et al*., 2004).

There are an increasing number of farmers seeking ways to reduce their costs of production by using less fertiliser and by reducing the amount of purchased feed. In order to achieve this, some farmers, particularly from the organic or low-input sectors, choose to grow diverse swards with high proportions of different legumes, grasses and herbs. Whilst there are many benefits from mixing multiple species in leys, some farmers are not familiar with this practice and have reservations about their use compared to the typical grass leys or grass/white clover mixtures. In addition, innovative grazing strategies can also influence soil organic matter and performance of dairy cows in terms of energy utilisation and milk production. This technical note pinpoints some of the potential benefits of utilising diverse swards for low-input and organic dairy systems and reviews the claimed benefits of a grazing system called 'mob grazing' on soil organic matter and dairy cow productivity.

Benefits of diverse swards

Documented information about the benefits of diverse swards comes from a recently completed project in the UK (LEGLINK; Döring et al., 2012). It was evidenced that species-rich legume-based leys can maximise pasture productivity and other ecosystem services while functionally diverse plant species can be optimised and fine-tuned to farm-specific needs. Diverse swards have increased above-ground biomass and provide greater stability of biomass production compared to monocultures while productivity increases over time. In addition, they have greater resilience to adverse weather, climate and management conditions.

Legumes and herbs, compared with grasses, can provide considerably higher amounts of minerals and protein per kg DM of grazed forage, which is particularly important for the pasture-fed cow on organic or low-input dairy farms (Lindstrom et al. 2013). Micronutrient status of the soil, and variety within plant species, has some effect on the mineral content of legumes and herbs, but the pH of the soil can have an even greater effect on the mineral concentration in the herbage, particularly of manganese and molybdenum. The potential to provide adequate levels of minerals through selection of forage species is considerable. In addition to clover there is scope to include herbs, and there are indications that they will make a significant contribution to total cow needs; however some farms experience difficulties in establishment and maintenance of herbs in a diverse ley, in which case herb strips may be a solution. There is recent interest in the use of browsing shrubs and trees to supply trace minerals but there is a lack of information about species selection and mineral contribution (for more information about minerals on dairy cow nutrition refer to Technical Note no 4 of the handbook).

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Benefits of mixing species

- Diverse mixtures have greater above-ground biomass production and crop cover than simple mixtures
- Productivity increases over time
- Greater stability of biomass production
- Improved soil organic matter
- Mixing species with different properties allows better weed control
- Greater resilience to variable weather, climate and management conditions
- Improved drought tolerance and soil structure due to deeper rooting
- Better N utilisation by subsequent crops; lower costs for N fertilisation
- Diverse mixtures support more pollinators throughout the season
- Diverse mixtures provide a larger food range for other invertebrates ('bird food')
- Mixtures with higher diversity do not compromise wild plant diversity
- Slower decomposing species decrease the risk of nitrogen losses to the environment (leaching, gaseous losses) following incorporation

Commercial performance of diverse swards

In a case-study farm as part of the SOLID project, herbage yield, composition and nutritional value of diverse swards were assessed on a monthly basis from May to September 2014 and compared to those of grass-clover. The diverse sward mixture included 10 different grass species, 6 legumes and 5 herbs. Analysis showed that ME content of the diverse sward averaged about11 MJ (normal values for this type of forage are 11 to 13 MJ of ME per kg DM) CP content was high (21%) and NDF within the expected levels (about 350 g/kg).

From April to September diverse swards produced 10.5 tonnes of herbage per hectare. Of the total production clover accounted for about 46% and grass accounted for 34%; the productivity of other legumes and 'broad leaves' represented 14% of the total production and senescent material was about 6%. Preliminary data collected in 2013 indicated a similar productivity of the diverse sward.

Herbage production of the simple grass-clover ley over the same period (i.e. May to September 2014) was better than those of diverse swards and averaged 12.3 tonnes per hectare. As expected, composition was dominated by grass and clover which accounted for about 44% and 46% respectively, while the productivity of other legumes and 'broad leaves' represented just 4% of the total production (Figure 1). The grass-clover ley had an average of 17.2% DM, 10 MJ of ME and 21.5% of CP indicating a good quality forage.

This study showed that although pasture productivity of the diverse sward was lower than that in the grass-clover ley, the total productivity remained relatively high (above 10 tonnes per ha) suggesting that diverse pastures can serve as a viable alternative to conventional pastures.

Designing a diverse mixture

Mixes with high agronomic productivity should contain at least two **common legumes** (e.g. lucerne and white clover), but performance improves by including a third or fourth legume species. In the UK, multifunctional mixtures that contain lucerne, red clover and black medic (*Medicago lupulina*) were found to have the best performance and resilience, particularly as fertility building crops.

White clover (*Trifolium repens*) consistently performs well in terms of yield and persistence and its creeping habit makes it the legume best adapted to grazing.

Red clover (*Trifolium pratense*) is generally more productive than white clover, but less persistent and less tolerant to high grazing pressure. White clover and red clover have better N utilisation by subsequent crops than black medic or lucerne.

Lucerne (*Medicago sativa*) is a high yielding species that produces high quality feed, dried or ensiled. Although not commonly grazed there are some varieties more tolerant of being grazed provided this is in a rotational grazing situation.

Sainfoin (*Onobrychis viciifolia*) shows marked differences in performance depending on region and soil. It is attractive as a non-bloating, high quality legume on alkaline soils but is less persistent under hard grazing.

Some other legume species such as meadow pea (*Lathyrus pratensis*), winter vetch (*Vicia villosa*) and large birdsfoot trefoil (*Lotus corniculatus*) often show low performance in northern European climates BUT can perform better under other climatic conditions.

Grasses: Depending on the use of the ley and soil type there are a number of grass species that can be combined to complement legumes: perennial and Italian ryegrass (*Lolium perenne* or *multiflorum*) for its high yield and palatability, timothy (*Festuca arundinacea*) for yield, palatability and suitability to wetter conditions, cocksfoot (*Dactylis glomerata*) for yield, rooting and drought resistance, but is less palatable, and meadow fescue (*Phleum pratense*) for palatability and yield but is less competitive. Recently developed festulolium provides a combination of high quality forage with good winter hardiness, persistence and stress tolerance.

Herb species can also be included, such as burnet (*Sanguisorba minor*), chicory (*Cichorium intybus*), ribgrass (*Plantago lanceolata*) and sheeps parsley (*Petroselenium crispum*).

Sainfoin in diverse sward

Grazing strategies for increasing soil organic matter

Farmers are interested in increasing soil organic matter (SOM) because it is well known that it serves as a reservoir of nutrients for crops, provides soil aggregation, increases nutrient exchange, retains moisture, reduces compaction, reduces surface crusting, and increases water infiltration into soil. The potential for carbon sequestration is of increasing interest. The build-up of SOM can be influenced by the way in which the sward is managed (e.g. increasing the return of vegetation to the soil), and also by the plant species in the sward.

A grazing system relatively new to Europe called 'mob grazing' is attracting attention, especially in regards to increasing SOM. Mob grazing is a livestock management grazing strategy that is characterised by high stocking densities of livestock on relatively tall forage. Livestock are moved frequently, i.e. at least one or twice per day, with the aid of electric fences and trample forage into the ground as they graze. The pasture land is then left, ungrazed, until it has fully recovered, giving all plant species present the chance to re-establish in the sward. In this respect, mob grazing tries to simulate the grazing behaviour of the vast herds of wild herbivores found on the American plains, or in the African savannah.

Claimed benefits of 'mob grazing'

It is considered that leaving higher residuals in the paddock can be a strategy for building up SOM, through the contribution of 'liquid carbon' through plant roots (Savory & Butterfield, 1999). Plants with more above ground canopy are able to grow larger root systems than those that are grazed more severely and the long recovery time between grazing allows plants to establish a healthy root system. The roots grow deeper into the soil, bringing up nutrients and making the plant more drought-hardy. The long recovery time also leads to high volumes of above-ground forage, a mixture of leaf, seed and stem. In addition, it is claimed that the high stocking density results in more than 50% of the plant being trampled into the ground by the animals. Uneaten plant stems are trodden onto the soil surface and these stalks act both as mulch and as a food source for soil microorganisms, building new soil in the process (Chapman 2011; Richmond 2011).

It is also claimed that by turning animals out into a fully mature pasture, animal performance is improved as they can select the most nutritious parts of the plants and benefit from grazing the lush tops of the plants, seed-heads and upper leaves that are high in energy and protein.

Mob grazing: it should be noted that there is an inconsistency in the terminology found in the literature. The different perspectives on this grazing system create some confusion and in many cases make it difficult to compare and discuss its claimed benefits. In the case study presented in this leaflet we regarded 'mob grazing' as a short duration, high-density grazing (i.e. 100 t of LW per ha) followed by a recovery period of more than 50 days.

A case study of mob grazing for dairy farm productivity

The claimed benefits of mob grazing for SOM and animal performance have not been studied scientifically in robust experiments/studies and this gap in scientific knowledge is reflected in the literature. In the UK, there is a growing interest in this grazing method also among organic and low-input farmers, but there is some uncertainty about the levels of production that may be achieved, especially on dairy farms.

On the case-study farm, herbage yield and composition of diverse swards were assessed on a monthly basis in the same field which was representative of the type and the age of the swards across the farm. On average 181 milking cows grazed a diverse sward field of total area 12.5 ha for a total of 43 days in monthly rotation intervals. The resting period of the diverse sward between consecutive grazings averaged about 21 days, with 16 and 25 days the shortest and the longest, respectively. These resting periods do not fully coincide with the stated principles of 'mob grazing', where resting periods are of long duration (i.e. more than 50 days) but the stocking density was relatively high (i.e. 115 tonnes of LW per ha). The farmer stated that over the last 7 years he has applied a 40 to 50 days rotation management allowing the pastures to recover for longer.

Over the period the average daily grazed intake per cow was estimated to be 17 ± 1.9 kg DM (based on herbage cuts taken before and after grazing) but it fluctuated from as little

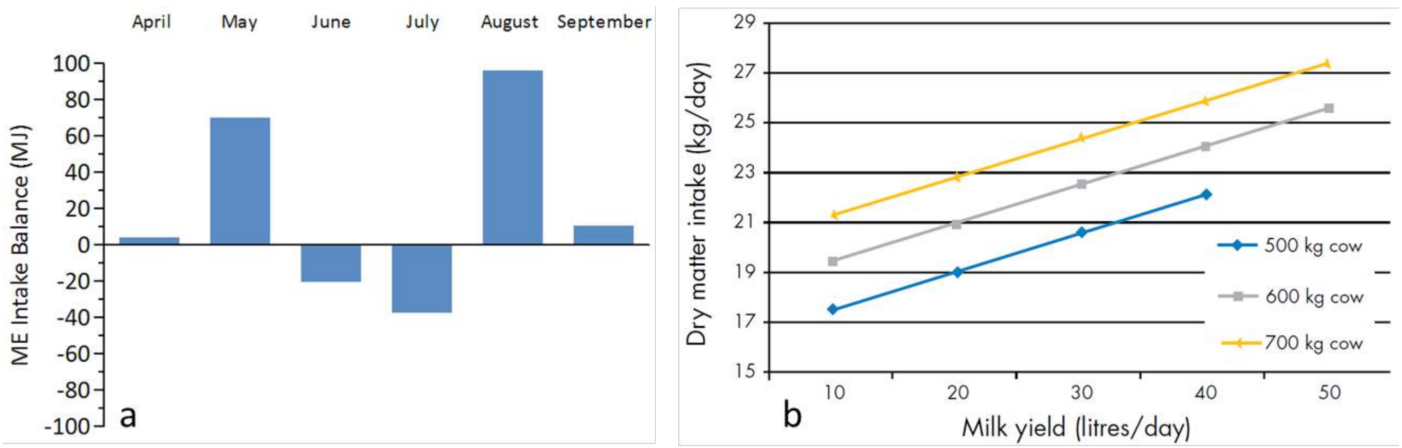

Figure 1. Monthly estimated ME intake balance of the cows from April to September 2014 (Panel a); relationship between dry matter intake and daily milk yield (Panel b; Source: AHDB Dairy 2012)

as 10.9 kg DM in July up to 23.8 kg DM in August. The average daily concentrate supplementation per cow was 2.9 ± 0.29 kg DM, ranging from 4.3 kg DM in April to 2.2 kg DM in September.

Nutritional shortfalls in ME intake during the grazing periods in June and July (Figure 1) may occur because of the relatively low forage DM intake, which is attributed to the low forage availability. Nevertheless milk yield may not be compromised if subsequent grazing in the next field in the rotation allows for better DM intakes. In the case-study farm, over the monitoring period the daily total DM intake per cow averaged 19.6 kg DM while the daily milk yield averaged 22.3 kg. These intake and productivity data are consistent with each other and are in accordance with the predictions postulated by the literature and illustrated in Figure 1.

This case-study illustrated that soil improvement through rotational high stocking grazing of biodiverse pastures can have a positive impact on SOM. The farmer reported SOM increases on fields managed with this strategy: more than doubling in one field (from 4.4 to 9.8% between 2007 and 2015) and increases of more than 40% in two other fields (from 5.3% to 7.8 and from 5.7 to 8% respectively, between 2012 and 2015) (Zaralis 2015). However, further research on the benefits of diverse pasture and different grazing strategies on the performance and productivity of dairy farms is needed to confirm these findings.

Conclusions and recommendations

- Multi-species diverse pastures are sufficiently productive to serve as a viable alternative to conventional pastures (i.e. grass/clover pastures) as they can maintain animal productivity at high levels.
- A period of less than 30 days between two consecutive grazings is rather short over the summer months to allow for an adequate recovery of the pasture and can result in low intakes.
- Under the principles of 'mob grazing', grazing rotation should be long enough to allow for full recovery of the pasture while the residual ungrazed forage should be left relatively tall.
- The monitored farm operating high stocking density and 30 – 50 day rotational grazing of multi-species diverse pastures has experienced a significant build-up of soil organic matter.
- Further research on the benefits of diverse pasture and different grazing strategies on the performance and productivity of dairy farms is needed.

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Technical Note 4

SOLID | Sustainable Organic and Low Input Dairying

Minerals and trace element management for dairy cows

Introduction

Minerals, including macro and trace elements are essential for the health of the dairy cow, notably affecting immunity and growth, production and reproduction while influencing the nutritional quality of the milk supplied to the consumer.

The challenge is to ensure that the cow is able to access and assimilate optimum mineral levels and is neither under-supplied nor over-supplied.

Organic and low-input management, which requires a high forage diet mainly sourced from the farm, is based on the principle that a natural diet of whole and minimally processed feeds will supply the necessary minerals to meet the needs of the cow. Generally milk yields are slightly lower than conventional. Various forms of mineral supplementation are permitted where there is a demonstrable deficiency, which may well happen, for example due to the characteristics of the local soil type and the effect of antagonists on uptake.

Data from individual herds in the UK show that some organic and conventional herds are being under-supplied with minerals and others are being over-supplied. Further, as normally organic milk contains less iodine than conventional milk, it triggers discussions about the factors that can most affect the concentrations of iodine in milk.

This technical leaflet reports on the actual mineral levels of organic milk, reviews the SOLID research on iodine in milk and summarises the management and supplementation options available to organic and low input dairy farmers.

Mineral needs

Maintaining adequate levels of minerals in the cow is clearly critically important; however it is also important to avoid over-supply. Not only is excessive supply expensive but there are real risks of poisoning, notably of copper, selenium and iodine; there are risks of excessive levels in the milk affecting human health and high excretion affecting other livestock, such as copper affecting sheep and environmental pollution, such as phosphorus. Vitamins are often interrelated with trace mineral functioning, e.g. vitamin E with selenium, both of which are critically important for the immune system and mastitis. The principal minerals that are needed for optimum health and production of the cow are summarised in Table 1 along with the main role for each mineral.

Table 1. Principal minerals for cow health and productivity

Mineral	Key roles	Normally tested in:	Dietary recommendations[1]
Macro minerals			(g/kg/DM)
Sodium (Na)	Rumen function		1.2
Potassium (K)	Production, reproduction and immune system	Soil. Forage/feed	4.6
Calcium (Ca)	Skeletal growth. Fertility	Soil. Forage/feed	4.3
Magnesium (Mg)	Grass staggers	Soil. Forage/feed	2.0
Phosphorus (P)	Skeletal growth. fertility	Soil. Forage/feed	4.6
Micro minerals			(mg/kg DM)
Copper (Cu)	Immunity. Mastitis. Growth. Reproduction. Hormones. Feet. Scours and pale hair. Excess causes poisoning.	Soil. Forage/feed, Blood. Biopsy. Milk	10
Cobalt (Co)	Growth. Feed efficiency	Soil. Blood	-
Zinc (Zn)	Mastitis,Immunity. Growth. Production. Reproduction. Hormones. Feet	Milk. Forage/feed	50
Iron (Fe)	Immunity. Hormones. Excess reduces copper availability	Water. Soil	-
Manganese (Mn)	Immunity. Growth. Reproduction	Milk. Forage/feed. Soil	20-25
Selenium (Se)	Immunity. Mastitis. Feet. Reproduction. Toxicity risk	Soil. Blood. Biopsy. Milk. Forage/feed	-
Iodine (I)	Thyroid hormones. Calf vigour	Milk. Urine, Forage/feed	-
Sulphur (S)	Growth. Excess reduces copper availability	Forage/feed	-
Molybdenum (Mo)	Excess reduces copper availability	Soil, Milk	-

[1] AFRC/ARC Values represent the contribution from the diet, water and supplementary sources and are expressed on a g or mg/kg dry matter intake basis.

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Monitoring your minerals

Monitoring is essential to ensuring that optimum minerals are available. Table 1 identifies the role, the appropriate means of monitoring, which varies according to the mineral and the recommended levels in the diet.

The need for monitoring will depend on whether there are indications of a farm deficiency, e.g. poor animal performance, known deficiencies in the region or indications from the farm's milk buyer. Monitoring is essential before any supplementation, normally starting with soil and forage analysis. Subsequently and dependent on those results it may be necessary to monitor drinking water, blood, animal tissue (liver biopsy or of dead animals) and/or urine.

The difficulty of monitoring is complicated by the need to recognise that some minerals act as antagonists, restricting the cows' ability to absorb other minerals; the effect of high soil molybdenum on the availability of copper to the animal is well known, but iron (from water or soil contamination) and sulphur also affect copper absorption. Levels are also influenced by a number of factors such as stage of lactation and age.

Excessive supply of minerals has been reported in the past in conventional herds and recently shown to be a current problem (see box). The results demonstrate that while there is a considerable range in macro and trace minerals supplied, most farms were feeding in excess of recommended dietary concentrations. Even organic herds, with their higher requirements for inspection and regulation, are being over-supplied with minerals in early lactation and the dry period, while other individual herds are being under-supplied and are at deficient levels.

Mineral and trace element requirements of dairy cows *(Sinclair & Atkins 2011)*

A survey of mineral concentrations in the diet of 50 diary farms in England, including 10 organic farms found:

- There was a considerable range in the dietary concentration of macro-minerals, with on average a 67% excess of Ca and 28% excess of P, with one farm feeding 192% excess Ca and 66% excess P. In contrast, some farms were supplying only 82% of Ca and 80% of P requirements.
- There was a considerable range in micro-mineral dietary concentration, with many farms supplying substantially above but some below requirements.
- When accounting for all sources of Cu, 4 farms were supplying above 40 mg/kg DM with a further 10 above 30 mg/kg DM. These levels if fed long term are likely to lead to Cu toxicity. A total of 31 out of 50 were feeding above the recommended Cu allowance of 20 mg/kg DM.
- Based on the dietary Mo concentrations, for the vast majority of farms there was no justification for high dietary Cu concentrations to be fed.

Although the number of organic herds was small, they tended to feed above average levels of Ca and K, similar amounts of Mg and P and lower amounts of Cu and Zn than conventional herds.

Iodine concentrations in forage and milk in organic farms

Although concentrations of iodine in organic milk are well within the optimal levels (i.e. 60 to 300 µg/L), it normally contains less iodine than conventional milk. Research undertaken in the SOLID project investigated the relationship between iodine concentrations in bulk milk samples and in forage. The data show that iodine in urine does reflect cow dietary iodine and that there is wide variation in milk iodine levels between farms. Milk iodine concentrations were 2.3 times higher in the farms that use iodised post-dip teat disinfectants (mean 195 ± 13 µg/L) compared with the farms that don't (mean 85 ± 8.9). This indicates that the use of iodised post-dip teat disinfectant is the most important influencing factor for the iodine concentration in milk. Assessing iodine levels in milk is not an accurate means of identifying shortfalls in dietary iodine intake. Where doubts about the dietary iodine supply to animals exist, urine samples can be used to monitor the cow's iodine status. While average iodine levels in organic milk in the UK and elsewhere are demonstrably within the optimum range for human health, the results do point to the importance of each herd monitoring urine and milk iodine and ensuring that there is neither under nor over supply to the cow, nor excess levels in the milk. Where urine iodine levels are deficient then supplementation through feed, bolus, paint or water is effective.

Soil and water

The role of soil in the supply of minerals is crucial. Certain soil types are well known for causing micro mineral deficiency in livestock; this may be due to inherently low levels of one or more minerals. Soil management is the first step in ensuring mineral supply to the plant and animal. Ensuring good soil structure is likely to enhance rooting and availability of minerals, and maintaining pH between 6 and 7 is essential in order to optimise the availability of most minerals. The use of rock minerals to supply macro elements including phosphate, potassium and magnesium is standard practice, but there is also opportunity to rectify some trace minerals, notably cobalt, by soil application. The application of other trace minerals such as selenium is not common practice in the UK because of potential toxicity risks.

Farms using their own water supply should test for any antagonists to mineral absorption by the cow, such as high iron.

Forage

Organic and low-input farms will, by their nature, include a high proportion of legumes in their sown forage crops. The levels of most trace minerals including cobalt, copper, iron, and zinc are higher in legumes than grasses, but similar for manganese and molybdenum. Red clover is reported to be high; however the presence of cyanogenic glycosides in some white clover varieties may reduce selenium absorption in the rumen. White clover is higher than grass except for sodium, potassium, phosphorus, iron, cobalt and molybdenum. Inclusion of herbs such as chicory and plantain in the forage mix can potentially increase mineral intake (Van Eekeren *et al.*, 2006). In general there is a

Table 2. Mineral composition (per kg DM) of different species

		n	Na	K	Mg	Ca	P	Mn	Zn	Fe	Cu	Co	Se	S	Mo
			g	g	g	g	g	mg	mg	mg	mg	µg	µg	g	mg
	grass	24	1.6	35	2.3	6	4.9	58	40	251	8.9	105	97	3.7	4.0
Trifolium repens	white clover	22	1.4	32	3.4	13	3.7	45	39	156	10.2	97	98	2.5	3.4
Cichorum intibus	chicory	28	3.0	48	3.1	14	5.2	50	97	173	17.0	119	182	4.4	2.4
Plantago lanceolatus	plantain	22	1.3	39	2.8	15	4.7	39	61	137	11.4	110	120	4.0	1.8
Achillea millefolium	yarrow	20	0.5	51	2.8	11	5.5	57	45	289	15.2	146	106	2.5	2.4
Taraxacum officinalis	dandelion	8	1.3	53	2.9	11	5.1	34	53	596	12.8	239	248	4.5	2.7
Daucus carota	wild carrot	2	0.6	46	2.8	13	5.6	103	77	189	9.7	73	67	3.4	3.8

Data from report of the European Advisers Training meeting, May 2014 Belgium, pooling data from Van Eekeren et al., 2006 and http://www.wimgovaertsenco.be/

decline in mineral concentration with the age of the sward and some species (e.g. timothy, whole crop silage and kale) have lower levels of mineral concentration. Chicory stands out as having higher levels of most trace minerals except iron and molybdenum, both antagonists.

Supplementation

The need for further supplementation will depend entirely on the individual farm; some long established herds on fertile soils with cattle bred to suit the conditions are known to be getting sufficient minerals without additional supplementation. Organic farms aim for self-sufficiency in feed, consequently any specific farm deficiencies may be accentuated compared to a farm buying in feed which is likely to originate from a farm with a different soil type and different mineral profile in the feed. Analysis and monitoring is essential and if supplementation is required organic farmers may need to get permission from their control body to do so. The majority of minerals can be supplemented in various ways: in-feed, in-water, free access, bolus, body paint, soil application and injection.

In-feed supplementation

Supplementation in concentrates is routine in conventional farming while in organic farming in the UK it has depended on the compounder. In the past most have not included minerals, but in 2014 there was a change towards all compounders including minerals unless the individual farmer requested that they are excluded. The lack of certainty about the inclusion of minerals in concentrate feeds in the past may be one reason why there has have been both over and under supply of minerals to cows. While this is a reliable means of getting known quantities of a general purpose mineral into the cow the problem is that there is limited scope to tailor the minerals to the particular needs of the farm and the quantity supplied will depend on the quantity of concentrates fed; early lactation cows will be over supplied compared with later lactation cows. It should not form the only means of supplementation. Bespoke minerals meeting the herds individual needs are much more satisfactory, particularly where they are fed in a Total Mixed Ration system as this ensure that each cow gets the correct amount.

Chicory

In-water supplementation

Drinking water can act as a useful carrier for minerals, allowing reasonably accurate allocation to all cows but again there is a risk that high yielding cows will get more than they need. Systems are relatively cheap to operate and include water trough floating dispensers and pumps feeding the main farm water supply.

Table 3: Options for supplementation

		Supplementation options						
Mineral		In-feed	In-water	Free access	Bolus	Body paint	Soil apply	Inject
Macro								
Sodium (Na)		✓		✓			✓	
Potassium (K)		✓		✓			✓	
Calcium (Ca)		✓		✓			✓	
Magnesium (Mg)		✓	✓	✓			✓	
Phosphorus (P)		✓		✓			✓	
Micro minerals								
Copper (Cu)	Toxicity risk	✓	✓	✓	✓		**X**	✓
Cobalt (Co)		✓	✓	✓	✓		✓	
Zinc (Zn)		✓	✓	✓	✓			
Iron (Fe)		✓		✓			**?**	
Manganese (Mn)		✓	✓	✓	✓		✓	
Selenium (Se)	Toxicity risk	✓	✓	✓	✓			
Iodine (I)	Toxicity risk	✓	✓	✓	✓	✓	**X**	
Sulphur (S)		✓						
Molybdenum (Mo)		✓						

Free access

Free access mineral blocks or powder usually control intake by incorporating salt. While they may be tailored to a farm's needs and they are convenient, particularly for young stock, they are imprecise; intake is related to the cow's appetite for salt, not the need for the mineral.

Free access natural rock salt ensures that sufficient sodium is provided, and to a lesser extent potassium, calcium and magnesium, as well as other benefits, including reduction of bloat and encouraging saliva production enhancing digestion. It is a useful supplement which may, however affect the intake of free access general-purpose minerals.

Free access or in-feed seaweed meal offers potential for mineral supplementation and is quite widely used by organic farmers. However the quantities of minerals provided are relatively small.

Mineral bolus

Rumen boluses tailored to meet the farm's needs are a reasonably reliable method of getting the correct trace mineral into the cow. Again it is difficult to ensure the correct level of supply and they are relatively expensive.

Injection

Injection of trace minerals may be necessary in an emergency or if there is a major problem with antagonists, such as the effect of molybdenum on copper availability. The disadvantage is that the rumen is bypassed thereby denying the rumen bacteria potentially important trace minerals.

Form of supplementation

There is some evidence that the form in which minerals are supplied may affect the availability and utilisation by the cow. Selenium supplied as selenate was found to be more effective than selenite and selenium yeast product was more effective than either. There may be benefits from feeding organically bound minerals, such as that found following soil application and plant uptake.

Conclusions

It needs to be recognised that a whole farm systems approach is needed, one that recognises the characteristics of the farm – soil, water, breed of cow etc., ensures that soil, feed and forage is regularly monitored and that any deficiency is remedied, selecting the most appropriate form of mineral supplementation.

Farms should not necessarily be trying to replace all the minerals that go off the farm; many soils are capable of long-term supply, though in some cases our aim should be to improve the availability and utilisation of soil minerals.

Ongoing and regular monitoring is essential to ensure that adequate but not excessive minerals are being accessed by the cow.

It is strongly recommended that there is one specific person on the farm responsible for managing animal minerals and trace elements.

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ORGANIC RESEARCH CENTRE ELM FARM

Sustainable Organic and Low-Input Dairying

SOLID is a European project on Sustainable Organic and Low Input Dairying financed by the European Union. The project ran from 2011-2016. 25 partners from 10 European countries participated

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n°266367

Technical Note 5

Vegetable by-products for feeding dairy goats

Introduction

Nearly 50% of all fruits and vegetables in the European Union go to waste, with losses occurring during agricultural production, processing, distribution to retailers and by the consumers. This represents a significant annual volume of potential feed that can be incorporated into animal diets. The majority of fruit and vegetable wastes are highly fermentable and perishable, mainly because of high moisture (80–90%), total soluble sugars (6–64% in DM) and crude protein (10–24% of DM). During the peak production or processing season, large quantities of these resources are available and cannot be consumed at the same location in which they become available and thus they become surplus and can cause environmental pollution.

Therefore, suitable methods should be adopted to conserve such resources for animal feeding throughout the year or specifically during the period of low green fodder production.

Storage of waste vegetables in processing plant (Motril, Spain)

Nutritional value

Cauliflower and pomegranate pulp showed variability in the chemical composition reflecting the different nature of the materials (Table 1). Some by-products had high protein contents (i.e. cauliflower), others medium (tomato and pomegranate wastes) and some rather low (olive pulp and olive leaves), yet, with high levels of fibre. This variation in nutrients highlighted the differences in the potential of the feeds tested to replace more conventional feedstuffs, depending on their chemical composition. While some would be suitable as forage alternative, others could potentially replace cereal grains in the diet of ruminants. Special attention should be paid to the moisture content, which varies considerably across by-products. This relates to the need to implement appropriate processing and storing practices to ensure sustained feed supply.

Table 1: Nutrient composition of the main vegetable by-products generated in south Spain (DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fibre, EE: ether extract, DMD: DM digestibility)

By-product	DM %	OM %	CP %	NDF %	EE %	DMD %
Tomato surplus	5.6	89.9	10.3	19.1	3.9	91.0
Olive pulp	52.1	88.9	9.9	63.2	3.4	51.2
Olive leaves	61.5	81.9	7.4	54.4	5.6	54.4
Cauliflower	52.2	87.1	25.5	21.2	0.5	81.4
Pomegranate pulp	67.1	94.8	12.1	12.5	10.8	76.0

Ensiling as a solution

There are different options available for preserving high moisture by-products. The most common for use at a farm level are sun drying, artificial forced-drying and ensiling.

Ensiling by-products is a simple and low-cost option, which can preserve feeds that are seasonally abundant for later feeding during periods of feed shortage. Essentially ensiling involves a microbial anaerobic fermentation of carbohydrates and protein that results in the production of acetic, butyric and lactic acid, which lowers pH to around 4.5-3.8. At this pH the silage can be safely stored for months provided it is not exposed to oxygen (Figure 2).

On-farm trials carried out at CSIC in Spain tested the suitability of tomato fruit silage and olive cake silage for dairy goat nutrition. The first silage included tomato fruit and straw in a 80:20 ratio on fresh weight basis and

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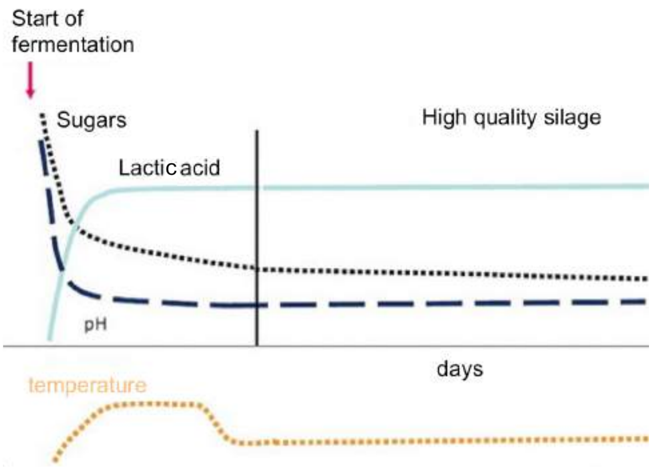

Figure 2. Representation of the ensiling process

was fermented with 0.5 % formic acid. The second silage included olive cake, olive leaves and barley grain in a ratio of 45:45:10 on fresh weight basis. These proportions were selected based on previous observations and intended to balance the dry matter content to ensure successful ensiling. The ingredients were weighed and thoroughly mixed in a feed mixer. The mix was then baled, individually wrapped with four to six layers of 'bale wrap plastic' (25 micrometre stretch film). This was performed with a bale wrapper, using a bale handler with front-loader. The bales had dimensions of 1.5 m x 1.5 m x 1.5 m and weighed around 1,000 kg.

Once opened, the silages appeared fine and were analysed for nutrient composition (Table 2). Tomato and olive silages have been tested as part of a typical diet for dairy goats, replacing oat straw, which represented 20 % of the diet. The goats were in mid lactation and the adaptation period was 30 days.

Table 2: Nutrient composition of tomato and olive silages

Silage	DM %	OM %	CP %	NDF %	pH
Tomato	5.6	89.9	10.3	19.1	3.9
Olive	52.1	88.9	9.91	63.2	3.4

Goat milk production from silage

The inclusion of olive and tomato silage in the diet of dairy goats increased dry matter intake (Figure 3), which shows that these types of silages are highly palatable and the animals accept them very easily. This is particularly important, as the use of silage in feeding dairy goats in south Spain is not common practice. Milk production did not change significantly among diets, although a numerical decrease occurred when olive silage was used (Figure 3). In the case of tomato silage milk yield was similar to the control. Considering that 20 % of the diet (oat straw) was replaced this is a great advantage in terms of reducing feeding costs. Interestingly, the somatic cell count was lower in the milk of goats fed the two silages including olive and tomato by-products (figure 4). If this is further confirmed, including these by-products in the diet of dairy goats would result in a better health status throughout the lactation.

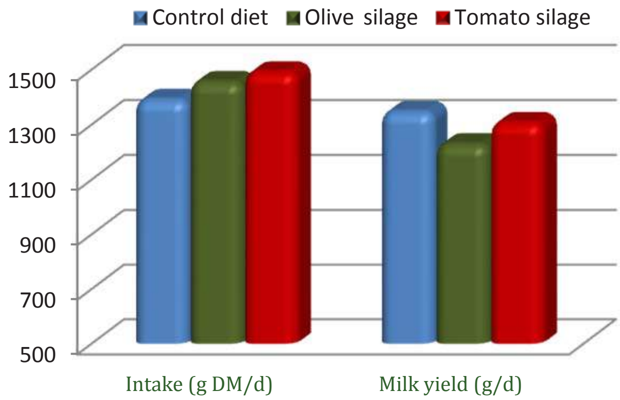

Figure 3: Effect of the diet on intakes and milk yield

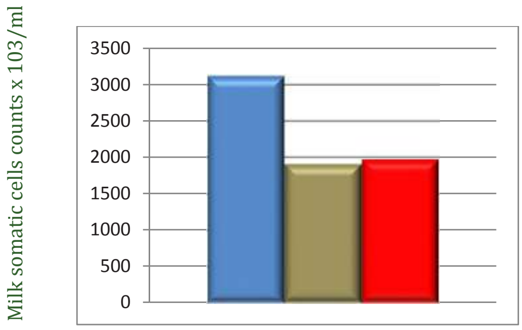

Figure 4: Effect of the diet on somatic cell count in milk

Conclusions

- A wide range of vegetable by-products can provide different nutrient resources, which have potential to be used as replacement of a range of conventional feeds in feeding dairy goats.
- Ensiling tomato and olive derived by-products represents a valid strategy to address the high moisture challenge, maintain their nutritive value and ensure supply of these by-products throughout the year.
- Feeding tomato and olive silages as a replacement for oat straw does not compromise milk yield and has beneficial effect on somatic cell count.
- This strategy can be applied to a number of potential different fruit or vegetable by-products in the future.

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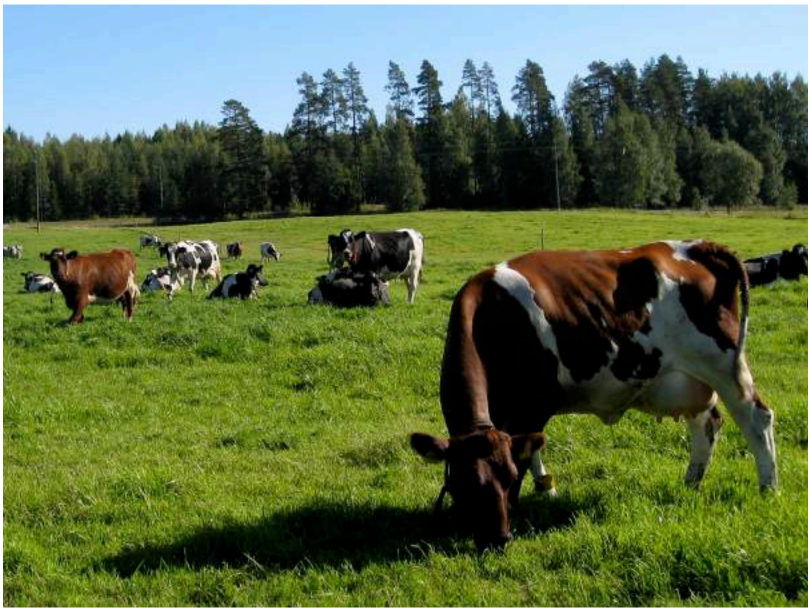
SOLID | Sustainable Organic and Low Input Dairying

Breeding cows suitable for low-input and organic dairy systems

Introduction

Most low-input dairy systems seek to maximise the utilisation of 'home grown' forage, especially pasture, and to operate with low inputs of supplementary concentrates. These principles are reflected in the EU regulations for organic milk production systems, namely basing the system on a maximum use of grazing pasturage and restrictions on the proportion of concentrates in the diet. Thus, a key requirement of an efficient low-input forage-based milk production system is a cow that can consume large quantities of forage per unit bodyweight, efficiently convert this forage into high value milk or milk solids, become pregnant within a defined breeding season, and have a high health status.

Until relatively recently selection programmes within the Holstein-Friesian breed focused primarily on milk yield, resulting in a breed with high milk production potential and high efficiency for milk production. This has led to the dominance of the Holstein breed in many parts of the world. However, these selection programmes largely ignored functional traits, and were often implemented in high concentrate input environments where (grazed) forages were considered relatively unimportant. This, together with the excessive mobilisation of body tissue reserves which is common with high-performing cows, resulted in a decline in fertility, health (metabolic disorders) and longevity within the Holstein population. This has motivated many dairy producers to consider alternative breeds of dairy cattle.



Which cow for which system?

A diverse range of low-input and organic milk production systems exist across Europe. These diverse systems generally require livestock which are adapted to specific conditions within countries and regions, and this means that different breeding approaches may be required to secure appropriate livestock. Farmers, breeding companies and researchers have therefore adopted a number of alternative strategies to overcome the limitations of conventional genotypes within low input or organic systems. These include crossbreeding and selection for robustness and lifetime performance.

A key objective within the SOLID project was to compare the performance of a number of breeds which are commonly used within three diverse dairying regions (Austria, Northern Ireland and Finland) with breeds/genotypes which were perceived as being 'better adapted' to the local systems (Table 1). Each comparison took place at two different concentrate levels. While the results across the different regions and breeds were inconsistent, in general there were no clear overall advantages for the alternative breeds examined. Nevertheless, there was evidence of improved fertility and health traits with some 'adapted' breeds, while the different breeds had different metabolic responses to concentrate feeding. This suggests that it is possible to select breeds which are adapted to the specific low input and organic dairy systems.

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Table 1: Dairy systems and breeds examined in the SOLID-project

Country	Austria		UK (Northern Ireland)		Finland	
Region	Alpine Grassland		Western European Grassland		North European Grassland	
Systems studied	Low (320 kg) vs. moderate (710 kg) concentrate input		Low (850 kg) vs. moderate (2110 kg) concentrate input		Moderate (1440 kg) vs. high (3470 kg) concentrate input	
Milk output from systems	5,600 kg vs. 6,200 kg		6,300 kg vs. 8,000 kg		8,300 kg vs. 9,400 kg	
Breeds studied	Conventional	Adapted	Conventional	Adapted	Conventional	Adapted
	Brown Swiss	Local Holstein (selected for longevity)	Holstein-Friesian	Swedish Red x Jersey x Holstein	Holstein-Friesian	Nordic Red (selected for robustness)
						
Results	The local Holstein cows had: • A lower production response to concentrate supplementation • Higher milk fat and lower milk protein content • Lower body weight • Earlier minimum body condition score		The crossbred cows had: • Lower milk yields • Higher fat and protein content • Improved energy status in early lactation • Lower body weight but higher body condition score • Later minimum body weight • Fewer health disorders		The Nordic Red cows had: • Slightly lower milk yields • Higher milk solids content • Less fat mobilisation in early lactation • Tendency towards less metabolic disorders	

Selecting animals for low-input and organic dairy systems

Breeding decisions have a cumulative impact, meaning that the effects of breeding choices (both good and bad!) can build up over many generations.

For this reason, a clear set of breeding objectives should be established on each farm. While specific objectives may vary greatly from farm to farm, the overall objective on most farms is likely to be improving profitability in the long term. As a first step farmers need to identify the specific strengths and weaknesses of their herd, and indeed individual cows in the herd. Sires which will help overcome these 'weaknesses' and further add to 'strengths' should then be selected.

Traits which are particularly important within organic and low input systems include fitness traits (such as fertility, lifespan and disease resistance), functional type traits (legs and udder) and specific performance traits (such as persistence and lifetime performance). Increasing milk yield is unlikely to be a core selection criterion on most low-input and organic dairy farms. Sire selection decisions are then made by matching the information available from performance testing schemes and breeding indexes (genetic merit) to individual breeding goals.

Genetic indexes and selection decisions

The overall genetic merit of an individual animal is usually calculated from 10 to 20 individual traits (e.g. milk yield, milk fat, milk protein, somatic cell count, fertility, mastitis, lameness etc.) plus a number of auxiliary traits. Each trait is given an economic value, and these traits are then weighted to give the overall genetic merit of the animal. This is normally expressed as a monetary value relative to the breed average. Animals within a breed can then be ranked in terms of their genetic indexes. Most countries publish specific selection indexes which follow very similar concepts, but which do not allow direct comparisons between countries.

The decision on which cow to select and which bull to use for insemination should not be based on the overall genetic merit only, as this value only expresses the overall financial improvement that a breeding animal is, on average, expected to transmit into the next generation. If the offspring are to be managed in a system which is substantially different from the average system, the overall genetic merit may not represent the true breeding value of the animal for that specific production environment. In order to better address the needs of breeders operating within organic and low-input dairy systems, specific indexes (e.g. 'Ecological Total Merit Index' and 'Spring Calving Index') have been designed in a number of countries.

When selecting sires, the overall genetic index provides a first overview of the sires to choose from. The farmer then needs to identify the traits which are most important within the herd, and which need to be improved, and then select sires with a high genetic merit in these traits. As all bulls have strengths and weaknesses, it is important to select a sire which is strong in the traits to be improved but yet not weak in any of the traits of particular importance for the specific herd.

Some traits which may be particularly relevant in low-input and organic systems were mentioned above; it is recommended that a limited number of traits (three to four) should be focused on at any one time. The primary traits for selection should have at least moderate heritability (i.e. the degree to which a trait is passed down to the next generation). If milk production is already at the optimum for the production environment, this offers the opportunity to improve other traits, such as reproduction performance, longevity, somatic cell count, type traits (including optimum cow size), etc.

Crossbreeding: a quick fix?

Crossbreeding is frequently suggested as providing a rapid solution to the problems of declining fertility and health in dairy cows, with the New Zealand dairy industry frequently used as proof that crossbreeding is particularly appropriate for low-input or organic dairy production systems.

There are two main reasons for the adoption of a crossbreeding programme:

- Introduction of desirable genes from another breed, which may be absent or very rare in the recipient breed. Examples are crossbreeding with Jersey in order to improve milk composition and with Scandinavian breeds in order to improve fertility and health.
- Benefiting from hybrid vigour; i.e. the additional performance benefit which can be achieved by crossbreeding, over and above the average of the two parent breeds. The magnitude of this effect varies, depending on the trait and on the degree of genetic differences between the parent breeds; e.g. hybrid vigour may be around 3 to 6 % for milk yield and milk composition, and 6 to 15 % for fertility, health and longevity. Within low-input systems there is clear evidence that crossbred cows may have similar levels of performance as the high-performing parent breed, while having improved fertility, health and longevity. However, hybrid vigour should not be mistaken for long term genetic improvement as it will not be passed on to the next generation.

Points to be considered

Despite the potential benefits, the decision to adopt crossbreeding needs to be made with caution. Crossbreeding will not solve problems caused by poor management or poor nutrition, and hence must not be seen as a substitute for improving poor management. It is also not a 'quick fix' due to the time taken (three years) before crossbred animals enter the milking herd. Additionally, a breeding strategy needs to be developed for the F_1-generation once they reach breeding age. A number of options are available and these need to be considered critically, including 'criss-crossing', 'rotational crossing' or use of progeny tested F_1-sires. The choice of the second (and possibly third) breed is a critical decision within any crossbreeding programme. The breed(s) to be chosen should allow for a minimum loss in milk production and at the same time substantially improve the other traits of interest. The specific requirements of the dairy system need to be carefully considered when making this choice. The chosen breed should have a robust progeny testing scheme and breeding programme in place in order to secure the future availability of high quality sires. In addition, sires used for crossbreeding should be among the top sires from the selected breed.

Experiences from existing crossbreeding programmes for grassland-based dairy systems show that, depending on the parent breeds, while the desired reduction in cow size is realised, this is often accompanied by increased variability in cow size. Herds comprising cows of different sizes create specific management challenges, including optimum cubicle sizes and fitting into milking facilities. Depending on the parent breeds used, crossbreeding may also have an impact on the value of cull cows, (male) calves and youngstock when sold, and this may affect the overall profitability of the dairy system.

Conclusions and recommendations

Low-input production systems require a cow that can consume large quantities of forage per unit body weight, efficiently convert this forage into high value milk or milk solids, become pregnant within a defined breeding season, and has a high health status. Thus, high-yielding dairy cows, which have been selected under high-concentrate input conditions, may not be suitable for low input and organic production systems. While producers are requesting alternative cow types, there is no 'one size fits all' solution.

Given the diversity of low input and organic systems throughout Europe, results from the SOLID project show that within well-managed herds, breeds perceived as being better adapted to low-input and organic systems did not necessarily show clear and substantial advantages over conventional breeds.

However, the 'adapted' breeds examined had specific strengths which may offer particular advantages in certain environments. These breeds, and the principles involved in their development, should be further developed within their breeding programmes.

The large variability in the genetic merit of breeding animals allows for the selection of animals which are suitable for individual herds or farms. A good understanding of the existing strengths and weaknesses of a herd is the first step in defining the traits which need to be improved, and for the choice of the most suitable sire.

While crossbreeding provides an alternative to selection within one breed, it requires strategic planning and should not be seen as a 'quick fix' for management-related problems.

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Low-input antibiotic strategies: improving animal health & welfare

Introduction

Organic principles call for a unique way of viewing animal health, welfare and disease. Animals should be given the opportunity to meet their natural needs – e.g. perform their natural behaviour such as be given opportunity to take care of their offspring – and farmers (or other actors) should intervene quickly and consequently when it is necessary to avoid any pain, stress and frustration. We view the animal as a living sentient being that has the ability to respond to its surroundings in 'clever and resilient ways' to stay healthy. Organic and low-input milk production are not the same in all aspects but also have much in common. At the same time, working with low-input farming inevitably means working with low-input antibiotic use. Farming to organic principles emphasises health, as one of the four principles (ecology, health, fairness and care). Low-input farming clearly aims to optimise the management and use of on-farm resources (internal inputs), minimising at the same time the use of off-farm resources (external inputs), such as purchased fertilisers, pesticides, feed compounds etc. (Parr et al. 1990). With focus on animal health low-input farming systems aim to mitigate the use of antibiotics. However, this does not simply mean denying the use of antibiotics to sick animals but it implies a more cautious and targeted use and making use of all various strategies to prevent health problems and diseases from taking hold in the herd. Actually, health can be thought of as 'resilience': the living animal's ability to withstand

and absorb shocks and changes in its surroundings. This leaves the humans with a responsibility to take care of the animal among others by creating an environment which can support the animal and minimise shocks and disturbances. For example, we can provide animals with good indoor environments where they can move around peacefully, and give them possibilities to meet their natural needs as much as possible, and timely, appropriate intervention when needed. In the SOLID project (WP2; http://www.solidairy.eu/index.php/category/wp2/page/2/ & http://www.solidairy.eu/wp-content/uploads/Welfare-state-of-dairy-cows-in-three-European-low-input-and-organic-systems.pdf), animal welfare assessments were undertaken in 30 herds in 3 countries and showed that animal health and welfare could be good and excellent in organic and low-input farming. There was a huge variation between farms and countries, and in specific cases, major challenges were seen in some farms, such as injuries, lesions and swellings due to poor lying-down facilities, mutilations, poor human-animal relations and even insufficient water supply could be challenging.

The question is: how do we improve animal health and welfare in practice? This technical note gives three examples of approaches to improve the herd, and of course a good animal health condition, good animal welfare and 'natural needs' can be met in multiple ways and by combinations of actions and management routines. There will be as many ways to answer this question as there are farms and herds. There is not a one-size-fits-all strategy, and our very different case studies in the SOLID project demonstrate very different approaches of attempting to meet natural needs of cow and calf around birth, feeding with herbs for health promotion, teat dip with iodine and working together in farmer groups.

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Farmer-led studies in the SOLID project related to health and welfare

In the SOLID project, a total of 18 smaller projects were conducted by farmers working closely with researchers. This technical note summarises the results of three projects that were all aimed at improving animal health and welfare, and they took widely different approaches:

1. Using herbs in grass – for grazing, hay or silage (Denmark);
2. Farmer Field Labs and farmer groups for improving the animal and herd health (UK);
3. Improving udder health and reducing somatic cell counts (UK).

Other SOLID farmer-led projects are also relevant to animal health and welfare for example, two studies were carried out in Denmark and UK about rearing calves on cows (see Technical Note 8: Rearing calves on milking cows).

Photo: Karen Søegaard

Herbs in pasture

Using herbs in grass – for grazing, hay or silage

There are an increasing number of farmers interested in growing herbs in pastures because of the health and production benefits to the animals and to the soil. In addition, herbs have a positive influence on milk quality and contribute to the variety and 'naturalness' of the pasture, among others by offering the cows a variety of different tastes and additional micro-minerals and other substances.

As part of the SOLID activities, we followed seven organic farmers who had established herbs for a number of years i.e. four of them had included herbs in their pastures for 15-18 years. Several farmers experimented with keeping their herb/grass pastures for more years before ploughing. The oldest pasture was 6 years old. Most of them either bought seed mixtures including herbs or mixed herb seeds with grass and clover seeds before sowing. Almost all farmers interviewed used herbs in all of their grass-fields, for grazing and for silage production. One common problem was the survival of herbs in the swards, where they were out-competed by grasses and other plants or failed to survive droughts, hard winters or ensiling/ harvesting methods. Herb seeds are often very expensive, and then it is discouraging to see them being out-competed by grasses. Plant cover analysis indeed revealed that a lot of the herbs were out-competed, and some were better survivors than others. This is very specific for the location, and local knowledge should guide the seed mixtures and which herbs to favour. One farmer was sowing the herbs in 30 cm broad strips for every 4th metre. He had observed that this improved the survival chances of the herbs and decreased the competitive pressure from grasses and clover. Other farmers had increased the amount of herb seeds per hectare. Most farmers considered following the experiments of the farmers sowing herbs in strips, and planned regular strips all over the field, while other farmers planned broad strips at the edge of the field.

All farmers reported that their cows were happy to eat both fresh herbs when grazing (except the old tough stems of chicory) and silage made from herb-grass fields. Only the silage including woody chicory and soil was disliked by the cows. Some farmers had the impression that especially in the springtime, their cows preferred herbs and leaves from bushes and trees in hedgerows more than grass (see Technical Note 12: Agroforestry). The farmer who established strips of herbs on the pasture described how the animals could stand in these rows grazing primarily there. This supports a major argument for using herbs to promote animal welfare: the cows really liked it.

Farmer field labs and farmer groups for improving animal and herd health

Treatment of mastitis incidences in dairy farms relies largely on antibiotic use and with particular emphasis to organic production the EU Regulation (EC/834/2007) postulates that "homeopathic and phytotherapeutic remedies shall be used in preference, provided that their therapeutic effect is effective for the species of animal and the condition for which the treatment is intended". Under the SOLID project and in collaboration with the Field Lab programme "Duchy Originals Future Farming Programme" the Organic Research Centre (ORC) undertook a study that aimed to help farmers to improve current on-farm practices in reducing the use of antibiotics in their farms. The study was initiated as a discussion group amongst a number of farmers that were keen to improve the health of dairy cows and in this way cut down on antibiotic use. The group met eight times, and four of the farmers conducted a trial which is summarised below.

Liniment commercial cream containing mint oil reduces somatic cell counts in dairy cows

To mitigate the use of antibiotic treatments for controlling mastitis in dairy cows, many farmers use a commercial product that is specially formulated liniment cream containing 35% mint oil. The cream is designed for massage and absorption into the udder and it is used for softening swollen and inflamed udders as well as being used as an oedema preventative at calving time on organic farms. Somatic cell counts (SCC) in milk increase as a result of an immune response to a mastitis-causing pathogen. Mint oil is known to improve blood flow by dilation of the capillaries and it is likely that application of the mint oil cream can enhance the transportation of white blood cells to the udder and thus can act as a prophylactic measure to prevent mastitis. Here we present results from a participatory research trial which tested the effect of the cream on SCC.

Four farmers participated in an on-farm trial, following a common experimental protocol in which every second newly-calved cow was treated for 4 consecutive days with the mint oil cream. The farmers massaged the udders of newly calved cows for minimum of 2 minutes with 5 ml of the liniment cream before the morning milking. SCC data from the National Milk Records of these cows were compared with data from untreated cows (control).

The results show that on average, SCC in the untreated cows remained relatively constant and above the critical threshold of 200,000. In all recording months, the SCC of the treated cows were lower than in the untreated cows but a statistically significant difference was noted only in the 3rd milk recording (Figure 1a). Combined farm data across the recordings showed that the overall SCC of the treated cows were significantly lower (P=0.04) compared to those of the untreated control cows (Figure 1b). The results also showed that mean SCC were not affected by the year of lactation, or by calving month.

This study showed that treatment of the newly calved cows with a liniment mint oil cream could act as a complementary practice to reduce mastitis incidences as indicated by its effect on cows' SCC, but future studies will be needed to determine the mode of action of the cream as well as the optimum volume and massage duration for an effective treatment and to assess wider impacts, e.g. the costs of the treatment.

Applying liniment mint oil cream at milking time

The general experience, based on participation, observation and reports from the group meetings is that there is a great power and pool of knowledge in farmer groups. This is demonstrated in this field lab group, and confirms what other studies of other types of farmer groups have also shown, e.g. the Danish so-called stable schools. The creation of ownership among the farmers is paramount for taking action, and the framework has to enable this ownership by every participant.

Farmers that participated in this study have commented that although they considered their management prior to this discussion group and the on-farm trial was quite good, they have benefited from the process of coming together to discuss the various methodologies the other farmers employed.

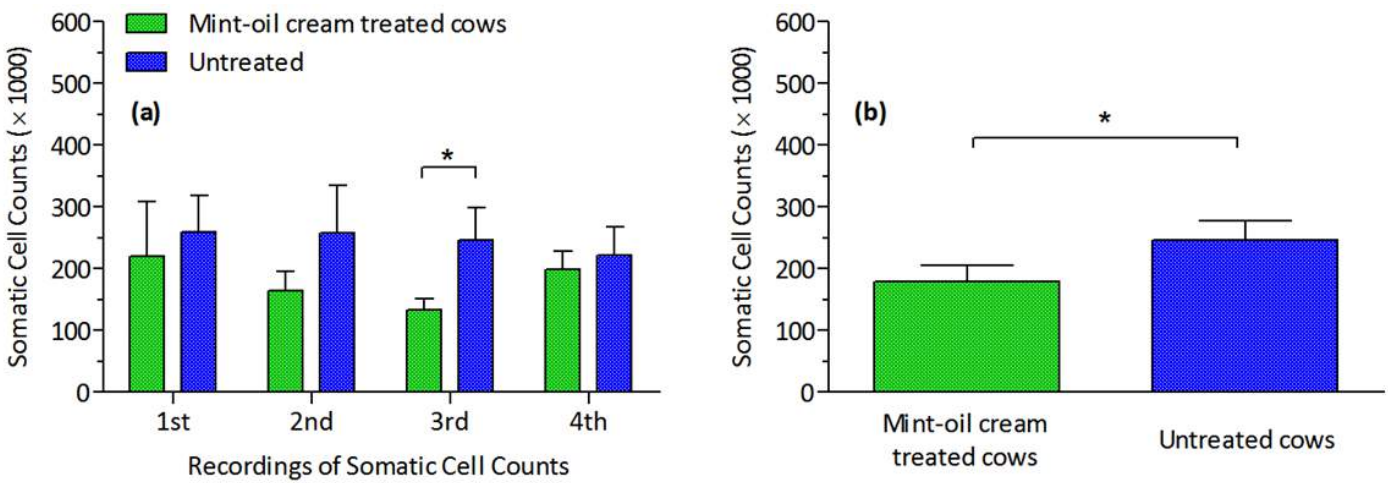

*Figure 1: Average SCC in each recording month combined across the participating farms [panel (a)] and average SCC combined over the recording periods and over farms [panel (b)] (in each panel, means marked with * indicate statistically significant differences).*

Conclusions and recommendations

The reduced use of antibiotics is an important characteristic of low-input and organic farming and the management of such farms should be oriented towards health, which is more than the absence of disease. This practice enhances animal welfare and farm profitability as well as contributing to efforts to preserve antibiotics for life or death situations.

Humans have the responsibility to take care of the health of the animal by creating an environment which can support the animal resilience and by minimising various shocks and disturbances. Also see Technical Note 8: Rearing calves on milking cows.

Working together in a discussion group can be an excellent way to further develop approaches to reducing antibiotic use if such groups share common understanding of working towards a shared goal and show mutual respect for each other in working together in finding practical solutions for the participating farms.

There is a need to further explore the use of complementary therapies in health management. The example of a trial of using a liniment mint oil cream for the treatment of the newly calved cows on four practical farms has shown the potential of one of those practices for reducing mastitis incidences.

Cows and other ruminants like a variety of plants in their diet. Danish farmers have reported that the cows like herbs in their feed, both grazed and as silage. This gives them different tastes and potentially micro-nutrients and minerals, even if the direct benefit on animal health is difficult to prove experimentally. It is in accordance with organic principles to provide ruminants with a broad variety of plants instead of monocultural grass fields, and also giving them different tastes and potential micro-nutrients and minerals.

Herbs in the grass field contribute to an attractive environment for different types of beneficial insects and enhance biodiversity.

Some herbs are very vulnerable and not good survivors, and it is important to exchange experiences and learn from other farmers for each geographical location, to choose the most robust herbs. Sowing herbs in strips seems a viable strategy, making it easier to re-establish in a long-term grass field. In Danish and similar conditions, making silage rather than hay seems to be a better option for herbs. In many cases it might be better to focus on increasing wild herbs which naturally grow in fields rather than introducing herbs in expensive seed mixtures, which may have problems competing or surviving. For more information about enhancing forage production of diverse swards please refer to Technical Note 3.

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The work behind this leaflet is compiled with contributions to the herb studies from Anne B. Kudahl, Emmanouela Karydi, and a summary of research in the field of herb use in pasture is based on research conducted by colleagues mainly at Aarhus University. The work on Farmer Field Labs also refer to other European experiences with farmer owned farmer groups.

Editing and design: Phil Sumption (ORC)

Sustainable Organic and Low-Input Dairying

SOLID is a European project on Sustainable Organic and Low Input Dairying financed by the European Union. The project ran from 2011-2016. 25 partners from 10 European countries participated

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement n°266367

Technical Note 8

SOLID Sustainable Organic and Low Input Dairying

Rearing calves on milking cows: key points to consider

Introduction

Organic agriculture has the aim of letting animals perform their natural behaviour, such as letting them take care of their offspring. Mothers and their new-born calves have a strong natural need to be together. When keeping cows for milk production, cows and calves are usually separated early after calving. Keeping calves with their mothers is the rearing system which allows cow-calf interaction and most likely meets the natural needs of both cow and calves. It is rarely practised under European production conditions, for different reasons: it can be practically difficult to manage, and it will probably reduce the milk for sale quite significantly. As part of the SOLID project, some farmers were curious how keeping cows and calves together could be practised because they acknowledge its potentials to meet animals' needs as it is emphasised in the organic principles. However, many other farmers are very sceptical about the idea because of the milk loss and the difficulties in managing the separation of cows and calves if a strong bond has been established and perceived risks of damaging the calves. We therefore took up this topic as a farmer led innovation to explore the practicalities of rearing calves on milking cows.

Learning from experience in different types of systems

We learned about maternal suckling from three different 'cases':

1. A Danish farmer who had for 20 years practised a system with seasonal calving and calves kept mainly with their mothers and some of them with suckler aunts;
2. A British farmer with all year round calving who tried for the first time keeping calves with their mothers inside their cubicle housing system; and
3. A study tour to The Netherlands visiting 6 different farmers who have practised rearing calves this way for several years.

Produced by The Organic Research Centre, UK. 2016

The Danish dairy farm

A good sign of bonding between a cow and a calf: reverse parallel position

The Danish farm had about 50 crossbred cows. The farm is autumn calving from August to November and sold about 6500 kg milk per cow. Milking cows and heifers had access to outdoor areas. Calves were fattened until slaughter on the farm. The farm had a strategy of extensive farming and was also working actively on health improvements and on phasing out of antibiotics. A case study observing the cow-calf rearing was carried out in 2013.

The cows give birth in a common calving area, outdoor or indoor. Cow and calf are transferred to a separate box to bond, and machine milking happens from the second day. Together, they will typically be first included in a smaller group of cows and calves, and then a bigger group, where cows and calves are together between morning milking and until after evening milking (of the others without suckling calves). All suckling cows are milked in the morning, and not in evening when they have been with their calves during the whole day. Cows produce more milk than what their own calf can drink, and therefore the numbers of calves and cows are balanced so that there is no milk left for evening milking. This means that not every calf had his/her mother in the cow-calf-area. The 'best suited' cows are gradually selected to become suckler aunts for the calves without their own mothers. Approximately 20 calves stay with 12 cows per area. By the end of December, the cows and calves – now between 1 to 4 months of age – are separated abruptly: the cows do not go back to the calves after morning milking. In 2013, fence line separation was tried out and proved to be successful. Bull calves often stay longer with suckler aunts.

What did we observe in the Danish herd?

In the period with suckling, an observing person stayed in the herd for a full day every fortnight. There were no stillborn or dead calves in 2013, no assisted calvings and no peri-partum complications (retained placenta or milk fever). The bulk tank SCC was 327,000 during the study period. The calves had an average birth weight of 35.3 kg. There were no treated diseases among cows or calves during the study period observed or reported by the farmer, but traces of liver flukes in slaughtered animals. All calves followed a weight curve above the standard average, except one Jersey bull. The weight gains were generally a bit lower (not significant) among the youngest calves, compared to the first born. The calves which had their own mother during the whole period generally grew bigger than the calves which partly suckled 'aunts'. The calves were observed eating roughage within the first weeks of life, often together with their mother or other grown-up cows.

Farmer time spent at the cow-calf system was observed through one day, and on that day, 80 minutes were spent with cows and calves in the system, and of them, 28 minutes were used for talking and patting. These 'talking and patting' periods observed happened often while talking on the mobile phone or waiting for the water troughs to be filled. Fear tests were performed on 14 one-year old heifers in a group, to see if they seemed wilder than 'normal heifers', and they were absolutely not: they let the owner get close.

Cows and calves were observed during two full days, and a wealth of detailed info was recorded, all giving witness of a highly complex dynamic pattern between cows and calves. These observations informed the following recommendations:

- A useful sign of a good relationship is when calves suckle their mother or 'aunts' in a 'reverse parallel position' typically seen for calves having their mothers with them, and for small calves suckling aunts. Generally, calves suckled aunts in a 'stealing position' between their hind legs, with few exceptions; e.g. one cow seemed to be a favourite cow for many calves. Young calves generally only suckled their mothers; slightly older calves could occasionally cross-suckle also when their own mother was present.
- Young calves rested closer to their mother, whereas older calves went into a calf group and slept together as a group. Mothers of young calves often seem more protective towards them and attempt to keep their calves closer.
- The calves started suckling in the Danish system, when 'feeding and milking sounds' started, because they knew that now their mothers/aunts would leave soon. Similar patterns were observed in Dutch herds.
- The calves seemed to enjoy when the mothers/aunts left in the evening, because it gave them the space for running and playing. The cows seemed happy having a bit of evening concentrate and being able to be with the other cows and have outdoor access. In the morning, both groups seemed to enjoy getting back together.

The British dairy farm

In the British case-study farm cows and calves were housed in a cubicle housing system with concrete floor, and calves were allowed to be with their mothers throughout the day in the cubicle area. The design allowed cows to lie in a variety of positions, including diagonally across the cubicle space, and even parallel to the dung passage, underneath the cubicle divisions.

Calves resting together with their mothers in the cubicle area

What did we observe in the British herd?

The overall saleable milk per cow per day averaged 4 to 5 litres, which was disappointingly low for the farmer. Therefore restricted suckling was introduced, where calves were kept separated from their mothers during the day and were allowed unrestricted access to their mothers from after the afternoon milking onwards. During the day, the cows and calves could still see each other and interact through gates. The overall milk yield remained below the expected level (Figure 1), which caused a significant impact on the farm's profitability.

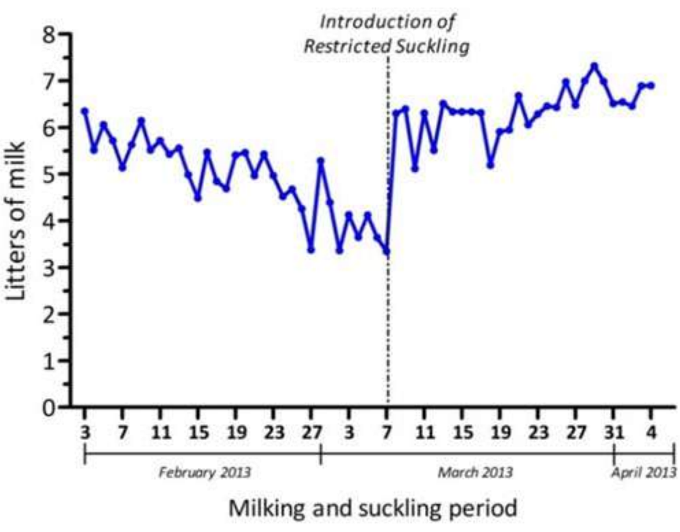

Figure 1: Daily milk production retrieved at the parlour of cows that were suckled by their calves during the period 1 February 2012 to 4 April 2012

Suckled calves were slaughtered 193 days earlier than bucket reared calves. Suckled calves achieved a daily live weight gain of 0.9 kg/day compared to 0.65 kg/day of the bucket fed calves.

Slightly rough and very rough teats in terms of dryness were more prevalent in the group of cows suckling calves than in the lactated cows not suckled by calves. In contrast, occurrences of warts were less common in the teats of the suckled cows compared to those of the non-suckled cows but suckling seemed to result in dryer skin in the suckling cows.

The collected data indicate that restricting the amount of milk taken by calves is necessary to retain an economic level of milk for sale. Further adaptation of the management system is necessary to achieve a financially viable way of producing milk for sale while rearing calves naturally on their dams. One alternative system would be using multiple suckling, which can be considered a compromise between increased 'natural living' and practical and economic implications.

Summary of interviews and study trip to The Netherlands

Two researchers from Aarhus University visited one farm where cows and calves were together 1½-2 hrs after each milking, and five farms where the calves were part of the milking herd night and day. In some herds, the calves were kept inside when the cows went out to pasture, for security reasons (e.g. a motorway close to the farm). In most farms, the bull calves were sold off at an age of 3 weeks. Heifer calves were normally kept with their mothers until an age of about 2-3 months. The following recommendations were drawn from this study trip, based on the Dutch farmers' experience:

- Bonding should be ensured from the beginning. Some farms had the cows and calves isolated in a calving box for a few days, before they were let into the main herd; others just kept a close eye on them. It was normally uncomplicated, although some had to be helped at the start. It was paramount to ensure that it worked well within the first day or two, no matter which system was applied, before the cow and calf went into the herd, where many more disturbances challenged them.
- The major challenge was the process of de-bonding. One farmer let the calf stay with its mother but with a 'nose-ring' that hindered suckling. Others made various versions of fence-line weaning, meaning that the calf had to suckle through a fence, which limited it and made the calf more aware of presence of humans – who then should make positive contact to the calf and feed and pat it, and of other calves. It would be an advantage to have several calves together.
- Most herds had an all-year-round calving pattern. This can be a challenge for the 'peace' of the herd – both in the calf group and the cow group, and with regard to behaviour as well as hygiene issues. However, calf-cow systems for block calving would require quite a lot of extra space used only during one period of the year.

- The design of the housing system needs to be considered carefully: minimum metal bars, corners, narrow places and blind ends, and maximum overview, space to move and equipment for the calves like lower water troughs and feeding tables which they can reach.
- A special area for calves, unreachable for cows, could be useful, but only very few of the visited farms had it.
- The very young calves preferred often to stay with their mothers – sometimes they walked with them to the slatted floor areas and lay there while their mother was eating. Solutions to this such as to offer mothers of young calves feeding in a more 'calf friendly' area were not really developed.
- Calves normally preferred to eat the same feed as their mothers. The farmers would offer calves special calf concentrate, but the calves preferred the cow feed.
- The calves could have diarrhoea caused by 'overdrinking'; this was seen occasionally but was not regarded as life threatening.
- All farmers had experienced having a calf that was injured or had died, but it was very rare. In response, one farmer took out cows in heat from the herd, and others emphasised the design of the housing system.

Conclusions and recommendations

In addition to lessons learned from the examples presented in this leaflet, the following overall conclusions can be drawn:

- All examples show that calves that are allowed to suckle a cow drink more milk compared to those restricted to a twice-a-day-milk-feeding programme. This leads to healthier calves and improved weight gains but also less milk in the tank.
- A farmer from Finland summed up her experience with rearing calves on cows as follows: "Every litre of milk invested in the calf is returned in the form of higher milk production by the cow she grows into".
- Skill and adaptation to the herd conditions is paramount for the success of rearing of calves on cows. It requires observation and knowledge of cow and calf behaviour, as well as quick action and reaction to all observations made. The Danish farmer had developed his system over a 20 year period, whereas the British farmer who did not have much prior experience ran into a lot of challenges. All the interviewed farmers in The Netherlands also supported this. So: start carefully and make sure that there is time for observation, actions and interactions, and room for constant adjustments.
- All farmers emphasised that calves learn from grown-up cows when they are allowed to be together. Farmers' observed that such calves were much better equipped to join the herd when they grew up. They ate roughage and had social contact with fellow calves and grown-ups, which also gave them a good start as ruminants and as social animals.
- The people taking care of the herd should be highly attentive and ready to interact! It is a wrong assumption that humans do not need to do much because 'the cows will now take care of the calves'.
- The biggest challenge in the cow-calf system is clearly the de-bonding process, and to a lesser extent also the bonding.

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Authors: Mette Vaarst (Aarhus University), Konstantinos Zaralis and Susanne Padel (ORC)

Editing and design: Phil Sumption (ORC)

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Sustainable Organic and Low-Input Dairying

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Carbon footprint and biodiversity assessment in dairy production

Introduction

While the main focus of dairy farms is on milk production, they also have an impact on the environment. Cows emit methane; tractors produce carbon dioxide; manure releases nitrous oxide and ammonia; and nitrates are leached from fields. These emissions contribute to climate change and undesirable nutrient enrichment of water courses. Insects, plants and other biodiversity are also affected depending on, amongst other factors, the proportion of maize to grassland on the dairy farms. Grasslands are better for biodiversity, and also increase carbon levels in the soil – thereby contributing to the mitigation of climate change.

Fields of organically managed farms generally have higher biodiversity compared to comparable fields of conventional farms (Tuck *et al.*, 2014). In addition, organic farms generally have greater carbon sequestration in their soils (Gattinger *et al.*, 2012). These are the most important differences between organic and conventional farms.

When the environmental impact of milk production is assessed using Life Cycle Assessment (LCA), all important factors should be included in the calculations. However, up until now, when the environmental impact of organic and conventional milk has been compared biodiversity and carbon sequestration have generally not been included in the calculations. Given the differences between the two production systems, this is of course problematic. The actual effect of including these two factors is not straightforward. The environmental impacts in LCAs are given per litre of milk, and the milk yield is often slightly lower for organic dairy farms – which has an impact on the carbon footprint. It is therefore essential to examine the effect of different kinds of dairy farms on soil carbon sequestration and biodiversity.

During the SOLID project we have worked on developing methods in LCA so that soil carbon sequestration and biodiversity can be included in the calculations. This is especially relevant when assessing the environmental impact of organic milk. In the following text, we will show the results – specifically the effect of including these environmental parameters within LCA calculations.

Produced by The Organic Research Centre, UK. 2016

Carbon footprint

The impact of milk production on climate change can be calculated as a 'Carbon footprint of a litre of milk'. The carbon footprint is the sum of all greenhouse gas emissions (methane, carbon dioxide and nitrous oxide) from the dairy farm and other related upstream processes, expressed as CO_2 equivalents, divided by the amount of milk produced on the farm. Currently, calculations for carbon footprints do not normally include soil carbon sequestration . Firstly, we followed a standard LCA procedure and calculated the carbon footprint for 23 organic dairy farms from the UK, Denmark and Finland without including soil carbon sequestration. The carbon footprint was also calculated for conventional dairy production as a comparison (see Figure 1). The carbon footprint of milk was found to be around 1 kg CO_2 eq. per litre of milk (ECM - energy corrected milk). The results also show that the carbon footprint of organic milk varies among farms, shows no clear differences between countries, and is comparable to the carbon footprint of milk produced by a typical, conventionally managed dairy farm in Denmark.

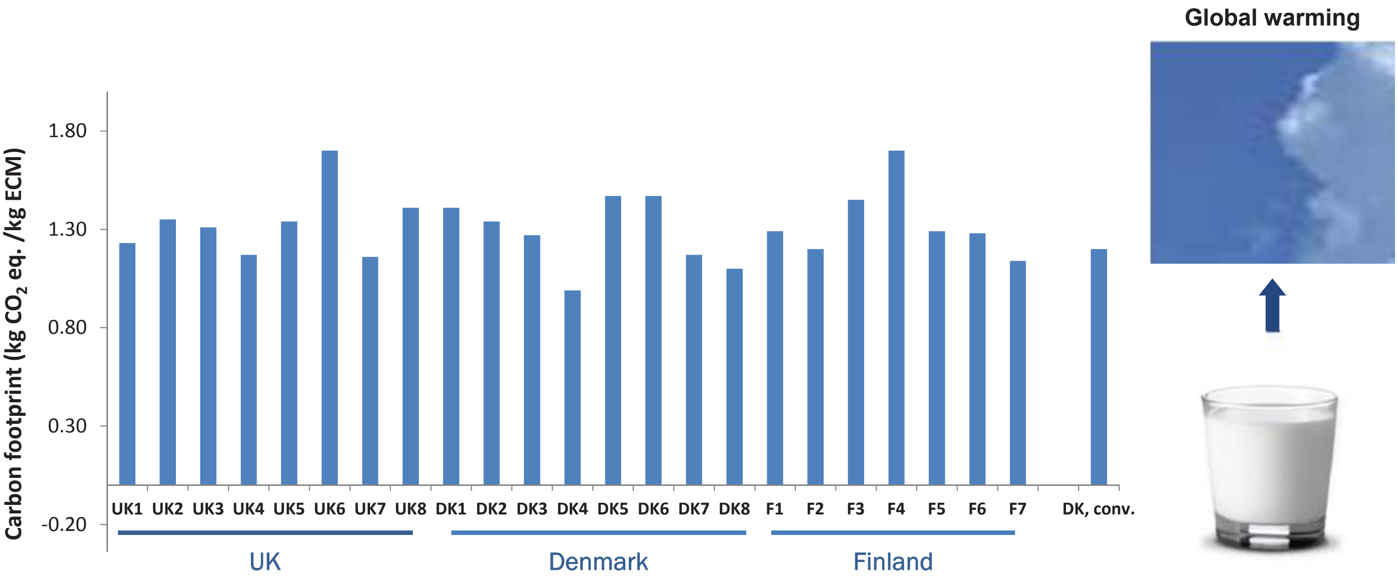

Figure 1: Carbon footprint of milk from 23 farms

As a second step, we then included the soil carbon sequestration in the calculations. In short, the methodology developed to include soil carbon sequestration in the LCA is based on the amount of carbon added to the soil through crop residues, roots, manure etc. and a certain percentage of this carbon will ultimately be sequestered in the soil (Petersen *et al.*, 2013; Mogensen *et al.*, 2014). The results (Figure 2) show that for all the organic farms, the carbon footprint is reduced when soil carbon sequestration is included in the calculations (green bars). The carbon footprint of conventional milk is not significantly affected. The main reason is that organic farms generally have a higher share of grassland relative to cereals/maize on their farms. The grasslands increase the carbon pool in the soil, whilst maize reduces it. Since a higher level of soil carbon is one of the main features of organic farming, it is crucial to include sequestration for accurate carbon footprint calculations.

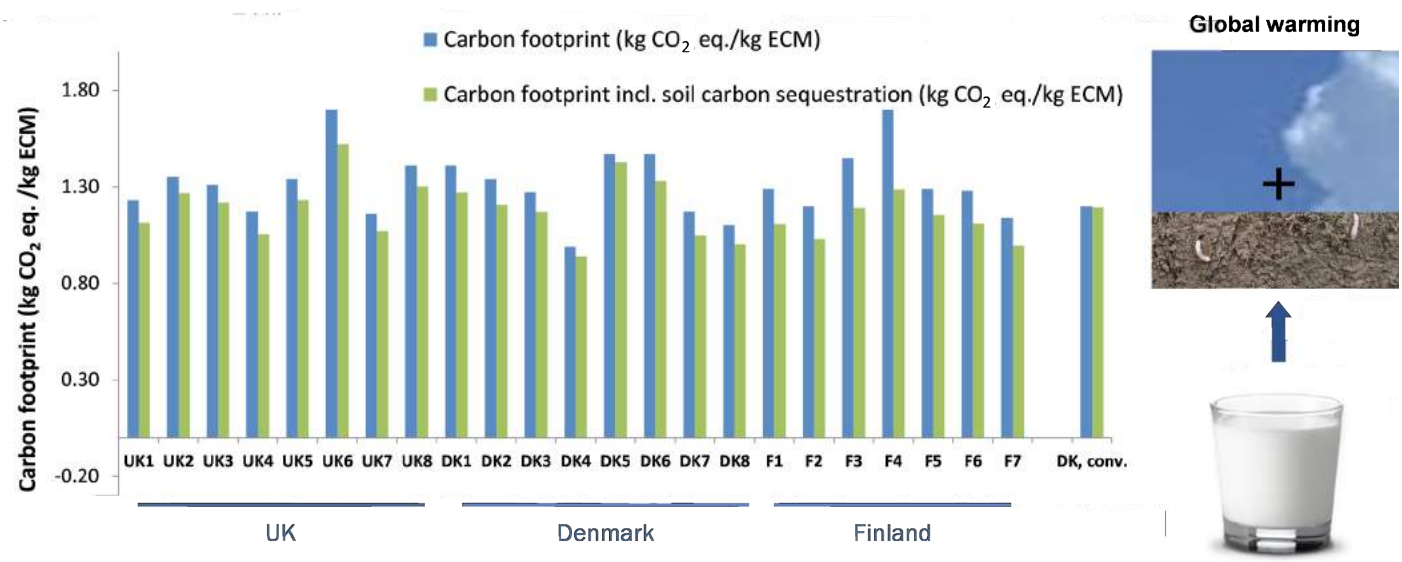

Figure 2: Carbon footprint of milk from 23 farms - including soil carbon sequestration

Biodiversity

Another key difference between organic and conventional farms is a higher biodiversity at the field level on organic farms. However, the impact on biodiversity is also not normally included in environmental LCAs due to methodological challenges. In this project, we have used biodiversity data from the EU funded BioBio project, which collected plant species data in more than seven European countries. We have used these data to develop and refine a method to include biodiversity assessment in environmental LCAs.

The method is based on the potential loss of plant species in a field as compared to natural vegetation (semi-natural forest). In a forest you might find 20 different plant species per 100 m^2 – whereas in a conventional cereal field you might only find six different species. The number of plant species is then used as an indicator of biodiversity, recognising that although this is not a fully comprehensive indicator of overall biodiversity, is a significant contributor. The potential disappeared fraction of biodiversity in, for example, a conventional cereal field compared to natural vegetation is then calculated. A loss from 20 to six plant species per 100 m^2 corresponds to a potential disappeared fraction of approximately 0.70 or 70% in conventional cereal fields. In organic cereal fields the loss is only approximately 0.20 or 20% and in conventional grasslands the loss is only approximately 0.10 or 10%. In organic grasslands you actually find a higher number of plant species than in the natural vegetation (semi-natural forest); so here the loss is approximately -0.30, meaning that you actually gain 30% more plant species compared to natural vegetation.

The calculated biodiversity losses for each crop type are based on registrations of plant species on different crops across Europe. The calculated numbers for each crop type are then used to calculate a Biodiversity Damage Potential for the milk production of the 23 farms in the UK, Finland and Denmark – depending on the share of grass, cereals and maize in the cows' feed rations. The Biodiversity Damage Potentials for each farm are shown with red dots (Figure 3). You can see that many of the organic farms have negative Biodiversity Damage Potential, which means that there is an overall increase in biodiversity. In comparison, the average Danish conventional milk production has a Biodiversity Damage Potential of approximately 0.40 per litre of milk. From the figure, it is also visible that for a farm, like the Finnish farm F4, that has a share of 84% grass in the feed ration (as compared to 37% in the Danish conventional), it is very important to include soil carbon sequestration and biodiversity in the environmental LCAs – in order to show the actual impact of the farm's milk production.

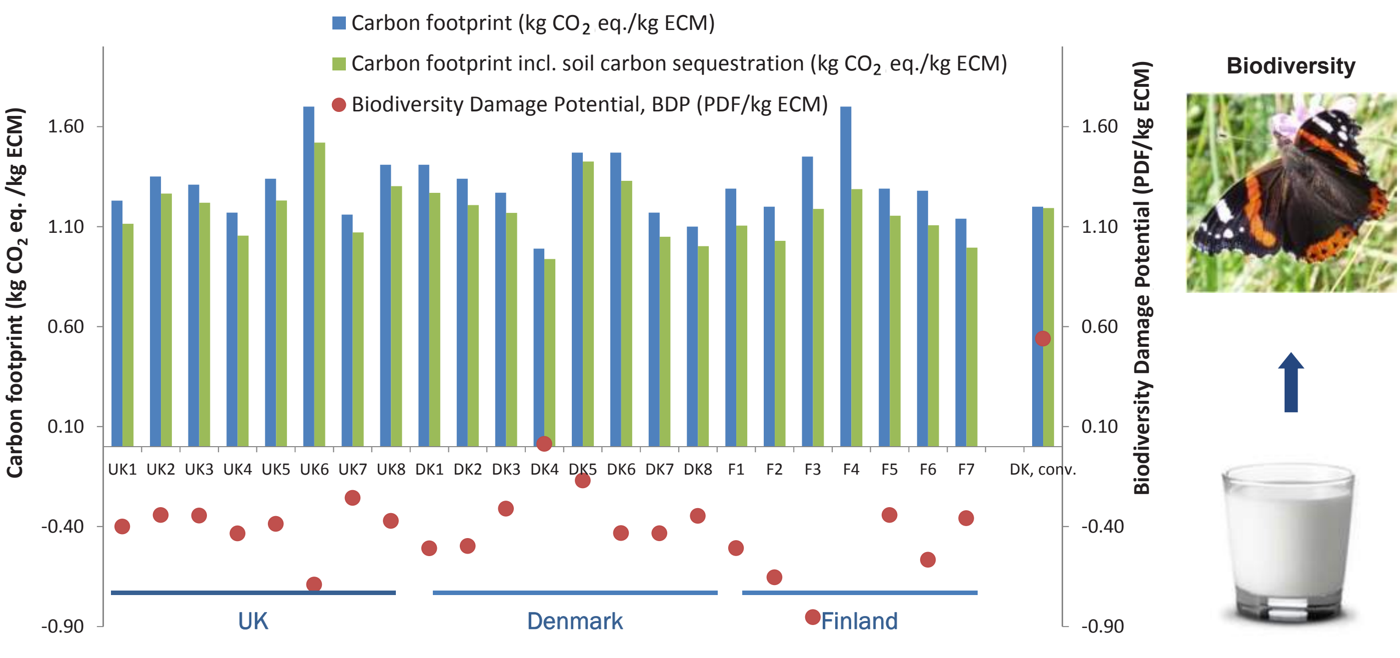

Figure 3: Biodiversity impacts of milk from 23 farms

Conclusions and recommendations

Organic farms generally have higher soil carbon sequestration, due to a higher proportion of grassland and greater use of manures, instead of synthetic fertilisers. Likewise, organically managed fields generally have higher biodiversity compared to conventional. These two factors – soil carbon and biodiversity – are not normally included in the environmental LCA of milk, resulting in a biased comparison of organic and conventional milk.

- In the SOLID project, a methodology has been developed to include soil carbon sequestration and biodiversity in the environmental LCA of milk. This will result in more comprehensive and less biased results in the assessment of the environmental impact of milk.
- The carbon footprint of organic milk is reduced when soil carbon sequestration is included in the assessment. The footprint of conventional milk remains unchanged.
- A higher proportion of grass in the cows' feed ration increases soil carbon sequestration and can also increase biodiversity, depending on the duration of the grassland and the structural characteristics of the grass sward.
- A method has been developed to distinguish biodiversity between organic and conventional fields and to include biodiversity in the life cycle assessment of milk through an indicator of biodiversity damage.
- Generally, milk from organic farms causes less biodiversity damage compared to milk from conventional systems.
- It is recommended that soil carbon sequestration and biodiversity is in future always included in environmental LCA of agricultural products.
- From an environmental point of view, it is recommended to include more grass in the feed rations of dairy cattle.

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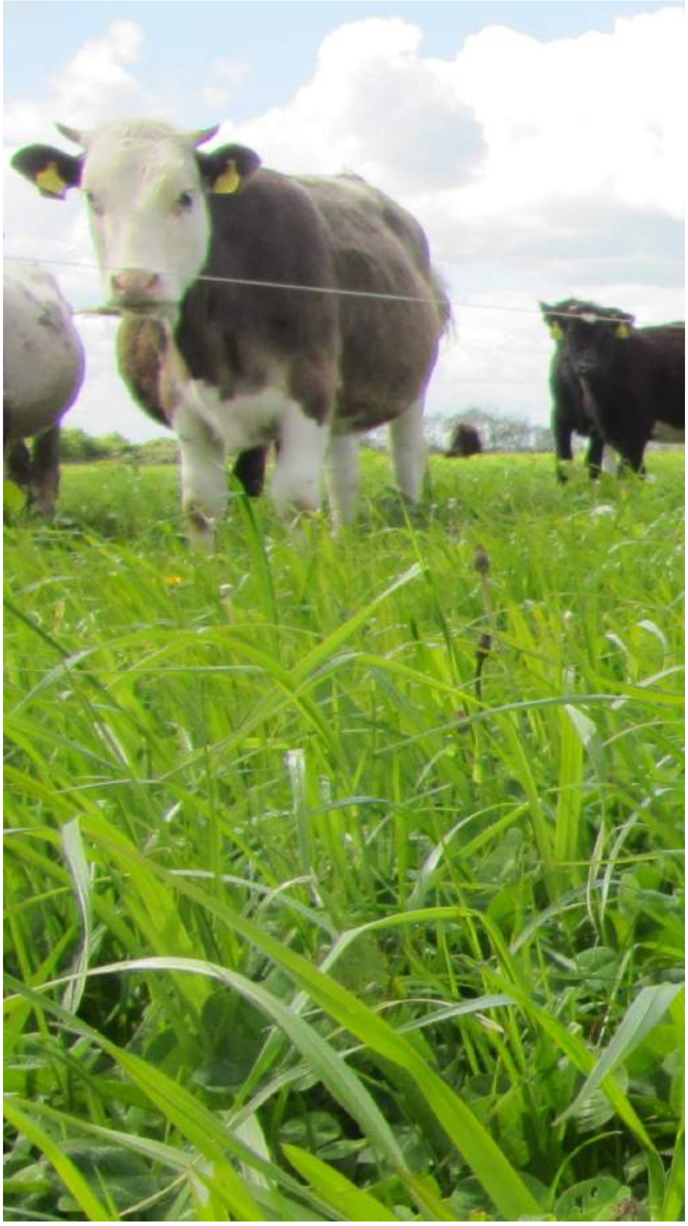

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Sustainable Organic and Low-Input Dairying

SOLID is a European project on Sustainable Organic and Low Input Dairying financed by the European Union. The project ran from 2011-2016. 25 partners from 10 European countries participated.

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SOLID Sustainable Organic and Low Input Dairying

Technical Note 10

Profit on low-input and organic dairy farms

Introduction

Conventional dairy farms increasingly use so-called external inputs like concentrates, fertiliser or crop protection products. Higher productivity resulting in better economic performance is the main incentive for applying this high input (HI) production method. However, abundant input use also results in environmental problems like nutrient imbalances, water and air pollution and biodiversity losses. Farming systems with a lower external input (LI) use and organic farming (ORG) can cope with these problems. It is, however, not always clear whether they are sufficiently profitable to compete with the HI production method.

This leaflet aims at examining the main drivers for competitiveness of HI, LI and ORG dairy farming. Organic farming is clearly defined through the EU regulation 834/2007 and the various implementing rules that all organic farmers have to follow, whereas no clear definition exists for LI farming. Therefore, this leaflet first describes how we defined LI dairy systems throughout Europe. We will then illustrate what these farms look like, what they produce and how they use their production factors based on the information we can extract from the European Farm Accountancy Network. Profit evaluation of these types of dairy farms is illustrated for three countries.

What is low-input dairy farming?

Contrary to organic farming, LI dairy farms are not defined by a legal definition in the European legislation, and in official farm business monitoring carried out throughout Europe such farms remain hidden in the group of conventional dairy farms. Different approaches exist as to how to look into LI dairy farming, by looking at low levels of external input use, at farms adopting production strategies with a high nature value (e.g. based on permanent grasslands) or at farms that use their inputs in such an efficient way trying to maximize the produced outputs.

In the SOLID project, we analysed the profitability of dairy farms throughout Europe. The European Farm Accountancy Data Network makes this evaluation possible. A disadvantage of FADN however is that there is a delay before the data can be used and the dataset consists of whole farm economic data. As such, the data set contains very few enterprise specific data and technical data. Based on an exploratory analysis and a literature review, we decided to define LI farms based on an indicator that relates external inputs used, relative to the grazing livestock units on the farm (see Table 1). At the country level, we considered the 25% of farms with lowest input use as LI farms and the 25% of farms with the highest input use as HI farms. Organic (ORG) farms were examined as a separate group.

In this leaflet we have focused on the results of an analysis in three countries and compared them with a European wide analysis (27 countries) of which the results are not presented here. These three countries are: Finland, Spain (except organic) and United Kingdom.

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Farm structure information

In Table 1, some farm structure variables for Spain, Finland and UK are discussed for the accounting year 2011. The accounting year 2011 was chosen because it was considered to be best most representative year considering the accounting years 2004 to 2012; later data were not available EU wide when the analysis was done. The country results are discussed in more detail and compared with some general conclusions from the European level analysis (not presented here, see Hamerlink *et al.*, 2014). All differences discussed in this technical note are statistically proven.

Table 1: Whole farm structural data from 2011 for Spain, Finland and United Kingdom (EU-FADN – DG AGRI)

		Spain		Finland			United Kingdom		
Variable	Unit	LI	HI	LI	HI	ORG	LI	HI	ORG
SOLID indicator [1]	€/GLU	481	1,339	680	1,369	839	413	922	579
Number of dairy cows		62	72	34	32	39	71	160	144
Utilisable agricultural area (UAA)	ha	27	36	64	65	83	86	130	173
Stocking rates	GLU/ha	4.82	3.15	1.33	0.94	0.98	1.83	2.32	1.58
Milk production per cow	kg/cow	5,274	8,772	8,237	9,479	8,056	5,806	8,671	6,661
Milk price	€/tonne	297	324	416	411	433	303	309	354
% milk output in total output	%	78	90	80	84	80	67	78	75
% meat output in total output	%	12	5	7	6	9	15	10	11
% forage on total UAA	%	99%	98%	67%	81%	78%	99%	88%	94%
% fodder maize on total ha forage	%	18%	10%	0%	0%	0%	1%	8%	0%
% temporary grass on total ha forage	%	20%	5%	91%	94%	92%	13%	27%	33%
% permanent pasture on total ha forage	%	49%	70%	1%	2%	2%	82%	59%	56%
% rough grazing on total ha forage	%	11%	6%	7%	5%	4%	5%	2%	5%
% other forage crops on total ha forage	%	2%	9%	1%	0%	2%	1%	4%	5%
Purchased concentrates/dairy cow	€/cow	591	1,322	554	1,222	862	518	947	692
Purchased fodder/dairy cow	€/cow	24	325	6	38	29	25	81	75
Purchased fertiliser/ha	€/ha	55	53	158	176	24	144	238	16
Annual working units on the farm		2.1	2.3	2.0	2.1	2.3	1.9	3.1	3.1
% family labour of total labour	%	96	86	88	89	82	88	57	53

[1] SOLID indicator: the sum of economic costs of purchased concentrated feed and fodder for grazing livestock, costs for fertilisers, crop protection, energy and fuel divided by grazing livestock units (GLU).

Farm scale

When we compare LI, HI and ORG dairy farms throughout Europe, we observe that the number of dairy cows and utilisable agricultural area (UAA) on the farm are lowest for LI dairy farms. This implies that LI dairy farms are small farms. The number of dairy cows is similar for HI and ORG dairy farms, but the amount of UAA is lower for HI farms in comparison with ORG dairy farms, indicating that these farms have a more intensive farming system than the two other farm types. At country level, these results differ: in Spain and Finland, there were no differences in the number of dairy cows when comparing LI, HI (and ORG). In the United Kingdom, HI and ORG farms have more dairy cows. In Spain and the UK, LI dairy farms also have less UAA than HI and ORG while in Finland there is statistically no difference between LI, HI and ORG dairy farms. This indicates that the three different farming systems in Finland do not differ in farm structure.

Production and financial output

In Europe, milk production per dairy cow is lowest on LI dairy farms and highest on HI dairy farms; ORG dairy farms are situated in between. Milk price is highest on ORG farms and lowest on LI farms. The percentage of milk output as part of total financial output is lowest for LI and ORG dairy farms. This result can be interpreted in two different ways: on the one hand, the higher milk production of HI farms can result in a higher total output from milk on HI farms. On the other hand, LI and ORG dairy farms have the option to gain output from other activities on the farm. The share of financial output from meat as part of the total output confirms this interpretation: LI and ORG farms acquire more output from meat output than HI dairy farms, indicating that these farms also have meat finishing enterprises on the farms.

These European conclusions are partially confirmed when comparing the variables in the different countries, where milk production per cow is lower for LI farms compared with HI dairy farms. In Finland, the organic milk production per dairy cow is comparable to LI dairy farms; in the UK the organic farms are in between the two other systems. There are no differences in milk prices in Finland. In UK, the milk price is the same for LI and HI dairy farms but higher for ORG dairy farms. In Spain, the milk price is the highest for HI dairy farms. Again in Finland, there are no differences in percentage milk and meat output on total output, indicating that we did compare farms with a similar enterprise mix.

Land use – Feed production

The percentage of land used for forage production in Europe differs significantly between LI, HI and ORG dairy farms, being the lowest for HI and highest for LI dairy farms. ORG dairy farms are closer to HI dairy farms, but have different cropping patterns than HI dairy farms. This supports the conclusion that land use on HI dairy farms is more intensive than on organic and LI farms. This is also confirmed by the fact that these HI farms purchase more concentrates and fodder crops per dairy cow and have a higher percentage of fodder maize in their rotation. LI and ORG dairy farms have more permanent pasture and rough grazing. ORG dairy farms also grow other forage crops like lucerne.

At the country level, the following conclusions apply. In the United Kingdom, LI dairy farms use more land for their forage production than HI farms. The percentage forage production on ORG farms is situated in between. In Spain, the share for forage production is the same for LI and HI dairy farms. The Spanish results show that HI farms use more land to produce forage for the same number of animals. Expressed per cow, HI farms also purchase more concentrates and fodder for their animals. In Finland, LI dairy farms use a lower percentage of their land for forage production. This indicates that Finnish LI dairy farms produce forage more intensively and also grow other crops on their land. This is confirmed by the fact that Finnish dairy farms do not differ for number of dairy cows and UAA. Moreover HI dairy farms in Finland also have higher purchase costs for concentrates per dairy cow, indicating that they are more specialised in dairy production.

Labour

Throughout Europe, LI dairy farms have fewer workers (expressed in annual working units (AWU) per farm) on their farm than the other groups. ORG dairy farms are situated between LI and HI dairy farms. LI farms have the highest percentage of family labour followed by ORG and HI farms. The Finnish results do not confirm this, as these dairy farms employ the same amount of labour and the same percentage of family labour. In UK, ORG and HI farms have more AWU per farm and this includes a higher share of paid labour in comparison with LI farms. Finally in Spain, LI and HI farms use the same amount of labour, but HI dairy farms employ less family labour.

Financial implications

The data helps to explain some profitability indicators presented in Table 2. The different variables are expressed in euro per annual working unit (AWU).

Total output

Total financial output on dairy farms includes sales value of milk and meat and farmhouse consumption. The value also includes purchase and sales of breeding stock for the accounting year and the changes in the valuation of the livestock. If farms have other smaller enterprises, like cash crop production, the output from these is also added to the total output. Throughout Europe, the total output of the different groups differs significantly: LI farms have the lowest total economic output, HI farms have the highest and the ORG farms lie in between.

At country level, these results are confirmed in Spain and the United Kingdom. In Finland, however, no significant differences were found between the different groups. The results can be explained by some structural data (see Table 1): HI farms have more dairy cows (UK), a higher milk price (Spain) and higher milk production per dairy cow (Spain, Finland, UK) and use land for the production of cash crops (UK). Finland is an exception as LI farms use less land to produce forage and also have the possibility to produce cash crops. The output of this cash crop production will minimise the difference in total output.

Table 2: Whole farm accountancy data of 2011 for Spain, Finland and United Kingdom (EU-FADN - DG AGRI)

	Spain		Finland			United Kingdom		
Variable (€/AWU)	LI	HI	LI	HI	ORG	LI	HI	ORG
Total output	**62117**	**105471**	**77158**	**71472**	**70766**	**104528**	**196237**	**143264**
- Direct costs (such as seeds, fertilisers)	36057	87250	58662	65668	60915	67581	141150	94240
+ Balance: Subsidies and taxes	8141	12404	35875	36273	43207	12527	13172	16853
= Gross farm income	**34202**	**30625**	**54371**	**42076**	**53058**	**49475**	**68260**	**65877**
- Depreciation	2926	10742	18122	19281	19472	13475	15074	12425
= Farm Net Value Added	**31276**	**19883**	**36249**	**22795**	**33586**	**36000**	**53185**	**53452**
- Total overhead costs (hired labour, rented land, interest on loans)	1427	4002	6847	6370	10277	7769	20036	19707
+ Balance: investment, subsidies and taxes	-41	1204	935	348	885	1439	318	280
= Farm Net Income	29808	17086	30336	16773	24193	29669	33467	34024
- Unpaid family factor costs	132360	144367	35995	37083	33540	48572	36533	31918
= Net Economic Profit	**-102552**	**-127281**	**-5659**	**-20310**	**-9347**	**-18903**	**-3066**	**2106**

Farm net income and net economic profit

A range of indicators for whole farm results are used in the European Farm accountancy system FADN (see Table 2). Farm Net Income is an indicator of the profit before unpaid family factor. To calculate Farm Net Economic Profit further non-cash costs are taken into account, such as remuneration for family labour, own land and own capital. For example, the own land cost can be estimated as rent which the owner would have to pay if the land were rented instead of owned.

At European level, the farm net income of ORG dairy farms is higher than HI and LI dairy farms. The big differences in total output are reduced significantly, indicating that HI and ORG farms have higher production costs than LI dairy farms. Economic profit is lower for LI and ORG farms than for HI dairy farms. At European level, economic profit is negative for all types of dairy farms. This shows that there is not enough output to remunerate the unpaid family production factors.

Farm net income and economic profit vary between countries and between the different groups at country level. In Spain, the difference between LI and HI at the level of total output disappears when comparing gross farm income. This indicates that the operational (direct) costs of HI dairy farms are much higher than for LI farms. The cost of purchased concentrated feed per dairy cow and the SOLID indicator in Table 1 give already an indication of these differences. Farm net income is higher for LI dairy farms in comparison with HI dairy farms as HI farms have higher depreciation costs, indicating that these farms have more investment costs. The economic profit is lower for HI farms than LI farms. For HI farms, the economic profit is negative, which indicates that HI farms are not able to remunerate their own factor costs.

In Finland, the farm net income differs much between LI and HI dairy farms, but not at a statistically significant level. The economic profit is recognised as significantly different, making LI and ORG dairy farms more profitable than HI dairy farms. This validates the results in Table 1, where it was difficult to separate LI from HI dairy farms. Finally, the profitability indicators of the type of farms in the United Kingdom are significantly different for LI and HI dairy farms, with LI less profitable than HI dairy farms. ORG dairy farms have about the same profitability as HI dairy farms. This is primarily explained by the higher output HI dairy farms gained by keeping more animals and producing more milk per dairy cow.

Conclusions and recommendations

In SOLID, we distinguished low-input dairy farms based on their input use (compared to the national average for dairy farms) and compared them to high-input and organic farms at country (Spain, Finland and UK) across Europe and in three countries at national level.

In some countries, low-input and high-input dairy farms represent two clearly different farming strategies, whereas in others the differences are not so clear. However, the examples illustrate that low-input farms can be more efficient and gain a better profit.

Organic dairy farms need to be seen as a separate group and show different results in different countries. In some countries organic dairy farms are structurally more similar to the low-input systems (e.g. Finland), whereas in the UK they are structurally more similar to high-input farms (e.g. United Kingdom).

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EU-FADN DG-AGRI, 2011

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Sustainable Organic and Low-Input Dairying

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Strategies to increase sustainability for the supply chain & consumers

Introduction

In order to enhance the competiveness and sustainability of the organic and low-input dairy sector, the views of stakeholders and consumers were studied. Improving the dairy supply chain's competitiveness and sustainability is linked to the identification of innovative practices that could be adopted by the whole supply chain. Different actors in the supply chain and consumers may have differing views depending on how a new strategy is perceived to affect their business or themselves. Other innovations within the supply chain may require investment and firms may be reluctant to incorporate new practices until the risks can be alleviated and clear benefits identified.

This note presents results of several surveys evaluating the acceptability of a range of innovations to various members of the supply chain from the farmers to the consumers. At first a broad set of statements was presented to groups of farmers, consumers and other supply chain actors, who were asked to rank the statements according to acceptability. At the next stage three specific innovative production strategies were evaluated in more detail in two separate surveys with supply chain actors including farmers and consumers.

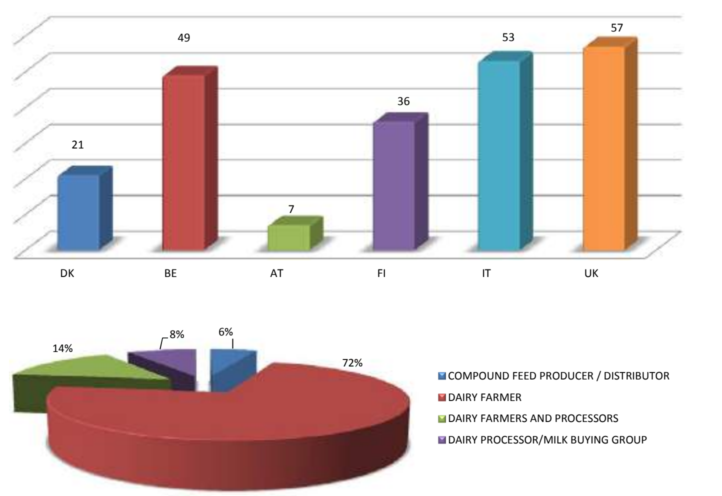

Figure 1: Respondents' profile per country and per sector for the supply chain questionnaire

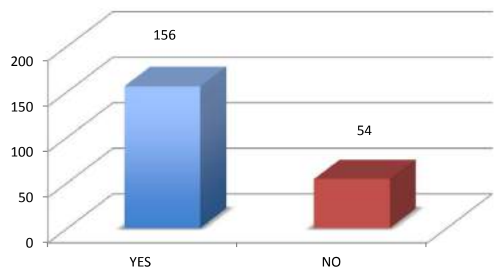

Figure 2: Proportion of respondents from certified organic supply chains

Acceptability of different innovations

All stakeholders within dairy supply chains (farmers, retailers, processors and consumers) in the UK, Italy, Finland and Belgium were asked to evaluate 34 innovative production strategies using a qualitative approach called Q method (Eden et al. 2008). The statements fell into three main categories of innovation: items relating to breeds (9), feeds (11) and management (14), as well as practices relevant to organic, low-input and conventional farming. Participants were asked to identify those innovations which were deemed acceptable for the whole supply chain.

There was consensus across all countries as to which innovations were deemed to be unacceptable in organic and low-input dairy systems.

These included innovations involving GM plant breeding techniques, using transgenic animals or genetic transformation of products, genetic selection, and using 100% housed dairy systems to improve animal welfare. This preliminary study highlighted the importance for the entire supply chain of a 'more natural' feeding process for better quality products and, of course, improved human health.

Three novel production strategies were chosen for further investigation:

- **Agroforestry:** integration of animals (cows, sheep) and trees on the same plot of land.
- **Alternative Protein Source:** Use of home-grown protein crops, such as lupins, beans and peas, as animal feed.
- **Prolonged Maternal Feeding:** The calves and lambs can suckle directly from their mothers (or a foster mother) for the first 3-5 months after they are born.

Produced by The Organic Research Centre, UK. 2016

Survey of supply chain partners

Results of a supply-chain analysis indicated that the most widely favoured strategy, across all countries, was that of soy substitution by using 'alternative protein sources'. Many farmers interviewed confirmed that they have already adopted this strategy, whereas others felt more confident in being followers of a tried and tested technique. In other words many individual farmers consider it more useful and are more likely to adopt those innovations that receive broader consensus among their peers, their advisers and society in general.

Lack of home-grown or locally available protein is one of the greatest barriers to the truly sustainable development of organic and low-input dairy systems. Given that many alternative protein sources have implications for farm productivity and profitability as well as for milk quality, the success of this strategy hinges upon increased collaboration among the various supply chain actors.

The least popular innovation among those who took part in the survey was 'prolonged maternal feeding'. To be applied successfully an increased level of information from farm to fork is necessary to ensure consumer recognition of associated higher welfare standards. Without this the strategy is likely to lead to higher costs on farms with no additional rewards.

Consumer survey

A consumer survey was conducted in 6 countries with nearly 5500 consumers (around 900 each in Austria, Denmark, Italy and the UK) to assess the acceptability of the three novel production strategies. The consumers were asked to rank them according to importance.

'Prolonged maternal feeding' was ranked first by 42% of respondents. 'Agroforestry' was slightly less favoured (33%), but some variations between countries existed. 'Alternative protein source' was generally the strategy preferred least by consumers (only 25% ranked it first). These results differ from those reported for dairy supply chain members, who preferred the 'alternative protein sources' innovation strategy.

The 'alternative protein sources' strategy appears not to be fully understood or appreciated by consumers. Regarding the reduction of risk of GM contamination in feed – it may be that consumers feel sufficiently protected by current regulations (especially for organic dairy products), are not aware of the risks or believe that contamination is already happening and unlikely to be stopped by feed substitution in the dairy chain.

Results indicated that consumers preferred those solutions linked to the reduction of the risk of GM contamination in feed.

The 'prolonged maternal feeding' innovation was the most accepted strategy by consumers, but it clearly increases the production cost for dairy farmers by limiting milk yield and the responses in the supply chain indicate that farmers do not see the benefit of adopting this. However, it may be a viable solution if farmers were to be adequately compensated for potential losses.

In terms of paying more for 'prolonged maternal feeding' our results were not encouraging: the average willingness to pay a premium never exceeded 60% of the current milk price in Austria, Belgium, Italy and the UK (not enough to cover the increased cost of production), and Danish and Finnish consumers were not willing to pay a cent more. There are likely to be some consumers willing to pay more for such milk, but the number will be small.

Ranking of 34 innovation statements

Conclusions and recommendations

Our Q-study on the acceptability of innovations in low-input and organic dairy farm management and supply chain practices revealed that substantial similarity of viewpoints exists across countries.

Consumers tended to agree more with statements that referred to high animal welfare. Animal welfare is an issue of considerable significance for European consumers. At the same time, the retailers and producers are increasingly recognising that efforts to meet consumer concerns in animal welfare actually represent a business opportunity.

Producers and retailers/processors are more interested in innovation related to feed efficiency and feed quality, and efficiency of production, but improving animal welfare was also important to this group.

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Agroforestry for livestock systems

Introduction

Agroforestry combines agriculture and trees, hedgerows or shrubs into production systems that can deliver, in addition to agriculture, a wide range of products including food, fuel, fodder and forage, fibre, timber, gums, resins and medicinal products. It also supports a range of ecological services such as soil and water protection, biodiversity support and climate change mitigation.

Silvopastoral systems that combine livestock and trees offer two main advantages for the animals. Trees modify temperature, water vapour content or partial pressure, and wind speed, which can have beneficial effects on pasture growth and animal welfare (Jose *et al*. 2004). Trees also provide alternative feed resources during periods of low forage availability, particularly in climates with seasonal droughts such as the Mediterranean (Papanastasis *et al*. 2008). This may become widely relevant in a changing climate.

There is increasing evidence that supports the promotion of agroforestry in temperate developed countries as a sustainable alternative to industrialised agriculture with high reliance on external inputs with its associated negative environmental externalities. However, evidence on the performance of such systems in the context of European low-input production systems is still lacking. This technical note highlights some of the potential benefits and impacts of utilising an agroforestry system for low-input and organic dairy systems.

Aberdeen Angus in among the trees, Fife, Scotland

Photo: Jo Smith/ORC

Silvopastoral systems

Trees have traditionally been important elements of temperate agricultural systems around the world, evolving from systems of shifting cultivation towards more settled systems involving agriculture, woodland grazing and silvopasture (trees and livestock). Modern silvopastoral systems that cultivate trees specifically for fodder include fodder banks, where trees and shrubs are planted at high densities and pruned regularly to maximise productivity, and alley pasture systems with rows of trees and shrubs separated by alleys of pasture, with perceived benefits to enhanced nutrient cycling and improved animal welfare.

Agroforestry research at the Organic Research Centre

As part of the SOLID project, the Organic Research Centre evaluated an established willow agroforestry system (Wakelyns Agroforestry) in terms of productivity, microclimate modification and carbon storage, as well as investigating the establishment phase of a new organic agroforestry system at Elm Farm in Berkshire to provide economic and environmental (microclimate) data on establishing and managing a system.

In the Elm Farm trial, willow (*Salix viminalis*) was chosen as it has a dual value as both a bioenergy source and a livestock fodder. Common alder (*Alnus cordata*) was chosen as a second species to trial; its value as a fodder crop was unknown, and while it coppices well, it is not a common species for short rotation coppice (SRC). However, it fixes nitrogen, and so is of interest in an organic system. Trees were planted in double rows with a 24 m pasture alley between rows.

We have summarised some key results from this work on the following pages. Also see SOLID report (Smith et al., 2014).

Produced by The Organic Research Centre, UK. 2016

Tree fodder and browsing

Browse from trees and shrubs plays an important role in feeding ruminants in many parts of the world and there has been considerable research into the nutritional properties of many tropical fodder species. However, while there is growing interest in exploiting tree fodder as an extra resource from trees planted for other purposes, comparatively little is known about the potential of temperate browse species, the preference for browsing particular tree species or the impact of browsing on the trees.

As part of the SOLID project, an on-line survey of UK farmers found that browsing appeared to be a common behaviour in cattle, with most responses suggesting that cattle browsed most days, frequently, or at least once a week, and at any time of day, and a wide range of woody species were selected, including willow, hazel, oak, ash, sycamore, blackthorn and alder.

The composition of tree fodder varies depending on a range of factors including tree species and cultivars, season, age of growth, climate, and plant part utilized (leaf vs. stem). A literature review (Luske & Van Eekeren 2014) that collated nutritional information from a range of tree species into a database (Table 1) concluded that while the in-vitro organic matter digestibility of tree leaves is relatively low compared to grass, crude protein and mineral levels of some species are relatively high, showing the potential value of tree leaves as an additional feed source. There was a considerable range in feeding values for the same tree species, likely to be due to seasonal differences, local soil conditions and the ability of tree species to adapt to these. The presence of tannins and other phenolic compounds may reduce digestibility and availability of protein, and palatability and intake. However, at low concentrations, some condensed tannins (CT) can have a beneficial influence, by reducing protein degradation in the rumen and increasing the flow of protein and essential amino acids to the intestine (Rogosic *et al*. 2006).

Table 1. In vitro organic matter digestibility (OMD), crude protein (CP) and copper (Cu) levels in tree leaves, taken from a literature review (adapted from Luske & Van Eekeren 2014). Average (minimum – maximum) and number of records (n) found in the literature.

Species	OMD %	CP % of DM	Cu Mg kg^{-1} DM
Alnus glutinosa Alder	48.1 (10.4-69.1) n=6	19.2 (14.1-26.2) n=6	12.3 (6.0-20.0) n=4
Betulus pendula Birch	37.6 (5.9-63) n=3	17.5 (14.0-22.9) n=5	10.0 n=1
Corylus avellana Hazel	47.7 (46.4-50.0) n=3	16.1 (14.1-20.4) n=7	13.1 (8.5-18.0) n=4
Fagus sylvatica Beech	30.7 (7.4-59.0) n=5	18.0 (14.3-23.3) n=18	15.3 (6.5-24.0) n=2
Fraxinus excelsior Ash	34.1 (12.8-55.3) n=2	15.7 (5.9-26.8) n=8	10.0 n=1
Robinia pseudoacacia Robinia	56.7 (37.3-77.4) n=7	20.4 (11.6-27.0) n=16	7.7 (7.0-8.3) n=2
Salix spp. Willow	57.8 (4.5-70.5) n=5	15.9 (9.8-23.10) n=10	8.3 (5.5-12.9) n=5
Tilia platyphyllos Large-leaved Lime	30.6 (15-46.2) n=2	21.4 (15.3-28.0) n=13	8.0 n=1
Lolium perenne Perennial Rye Grass	79.0	16.5	8.9

Productivity

Agroforestry systems are usually considered as increasing overall productivity due to the complementarity of trees and the agricultural component. However, there are concerns within the farming community that integrating trees within pasture will negatively impact on pasture productivity and quality. Within northern temperate regions, the main limiting resource for plants is usually light and studies have shown that shading has reduced yields in temperate silvopastoral systems. However, during the early years following tree establishment, it has been shown that trees have few effects on pasture as tree crowns are small, although this will depend also on growth rates and spacing.

Sward production within the newly established silvopastoral system at ORC was monitored over the first five years. There were no statistically significant differences in pasture productivity and species composition between the different treatments, indicating that for the first five years, the impacts of tree planting on the pasture were minimal.

At Wakelyns Agroforestry, a 15 year old SRC agroforestry system, we found evidence of competition between the trees and plants at the edge of the alleys, although the extent of this competition appeared to vary depending on weather conditions and stage of rotation of the tree component. This would suggest that wider alleys that minimise ‘edge’ would be better than the narrow alleys used in this system (10 m wide). The sward in the alley developed into a shade-tolerant grass-dominated community while the sward in the no-tree control field remained dominated by clovers. This shows that the selection of shade-tolerant species appropriate for agroforestry systems is important.

Microclimate

One of the main perceived advantages of integrating trees into livestock production systems is that trees modify microclimatic conditions including temperature, water vapour content or partial pressure, and wind speed. These modifications can have beneficial effects on pasture growth and on animal welfare. Studies have found that trees can reduce wind speeds in the protected area, with wind speed reductions extending up to 30 times the height of the windbreak on the leeward side, (Tamang *et al*. 2010). Providing shelter for livestock during the winter months has been found to lead to better survival rates, increased milk production and significant savings in feed costs (Brandle *et al*. 2004). In addition, the provision of shade in hot summers is an important factor for animal welfare.

At Wakelyns Agroforestry, the microclimate was significantly different in the agroforestry when compared with a neighbouring field without trees. Wind speeds recorded using a detector at a height of 1.5 m were significantly higher in the open field every month with speeds on average of 2.7 mph and up to 6.5 mph stronger than in the agroforestry. Combined with point measurements of air temperature at 1.5 m, the resulting wind chill was significantly greater in the control plots during the winter months with a noticeable difference of 1 to 4°C during the cooler months. In the newly-planted silvopastoral system at Elm Farm, there were no noticeable effects of trees on the microclimate in the first 5 years, and other studies have found a significant impact only when the trees reach a height of 3 m.

A browsing trial within the ORC bioenergy silvopastoral system also found increased acceptability of fodder, with cattle initially preferring willow, and then over time adapting to browsing alder trees too.

Establishing agroforestry

Silvopastoral systems that meet the farmer's objectives need careful planning. The selection of tree and livestock species for an agroforestry system is influenced by a number of factors, including the desired outputs (food, fuel, fibre), site conditions and climate, species properties (canopy size, root characteristics, shading tolerance etc.), species interactions, and agronomic factors such as harvest times and rotations. Government regulations regarding maximum tree densities and eligibility for basic farm payments and agri-environment schemes must also be considered.

The establishment of agroforestry under organic conditions presents particular challenges as regards weed and pest control. As chemical controls aren't allowed, alternative methods of weed and pest control must be considered and the effectiveness and cost-benefit ratio investigated.

Trials of different weed control approaches at Elm Farm showed that while tree survival rates in plots with fabric mulches were similar to those using woodchip mulch, as the woodchip was sourced for free from local tree surgeons, it provides a good approach to weed control in newly planted agroforestry systems.

Economic studies of agroforestry systems have shown that financial benefits are a consequence of increasing the diversity and productivity of the systems, influenced by market and price fluctuations of timber, livestock and crops. An assessment of establishment costs of forestry, agriculture and agroforestry found that establishing agroforestry required higher initial investment than the agricultural and forestry systems due to higher initial inputs, but over a 30 year period, profitability per hectare was higher in the agroforestry system than in the exclusively livestock (17%) or forestry (53%) systems (Rigueiro-Rodríguez et al. 2008). When environmental and ecological benefits were included in the evaluation, the profitability of the agroforestry system was even higher.

Establishment and maintenance costs of the new silvopastoral system at Elm Farm were collated, and showed that labour costs account for over 50% of total costs. Net present value calculations (NPV) showed that while overall the NPV is positive, the initial establishment is a large cash outflow that is not repaid, in this system, until 5 years after establishment; this may prove a barrier to many farmers contemplating agroforestry and suggests that support (e.g. from Rural Development programmes (RDP)) to cover establishment costs may be needed if uptake of agroforestry is to be encouraged. There may be scope for including these types of novel systems in RDP agri-environment schemes in recognition of the benefits to wider ecosystem services such as water regulation, biodiversity and soil protection, which would enhance overall profitability.

Conclusions and recommendations

- Agroforestry has been identified as a 'win-win' multifunctional land use approach that balances the production of commodities with non-commodity outputs such as environmental protection and cultural and landscape amenities.
- Designing a new system must consider the desired outputs (food, fuel, fibre), site conditions and climate, species properties (canopy size, root characteristics, shading tolerance etc.), species interactions, agronomic factors as well as government regulations.
- Controlling competition from weeds and grasses is essential for promoting better tree establishment.
- Tree fodder may offer nutritional benefits to livestock, although values vary depending on tree and animal species, as well as seasonal and bio-geographical factors. Fencing is essential to protect the trees from livestock and control the impact of browsing.
- Providing shelter for livestock during the winter months can lead to better survival rates, increased milk production and significant savings in feed costs. The provision of shade in hot summers is an important factor for animal welfare.

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Silvo-pastoral browsing trial at ORC, Elm Farm

Photos: ORC

Short rotation coppice willow agroforestry system at Wakelyns Agroforestry

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