Merits of full grazing systems as a sustainable and efficient milk production strategy

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Abstract

The continuation of high input dairy production systems in areas and on farms where grazing is possible is becoming increasingly questionable in terms of sustainability. Areas north of the central European Alps are ideal grassland areas, with adequate temperature and rainfall which result in a high per-hectare pasture productivity. The multi-faceted merits of milk production from grassland have been overlooked in the quest for prestigious high per-cow performance. However, it is the authors' opinion that there should be prestige in achieving sustainability, profitability and efficiency, and in encouraging a positive image for dairying. By employing the use of a full grazing system these attributes are obtainable. In addition, these cows that have a high proportion of grassland-based feed, produce milk and dairy products of improved nutritional and sensory qualities over their predominantly concentrate-fed contemporaries. Although a grazing system is considered to be low input, this system type should not be associated with low managerial competence. Moreover, an increased quality of technical knowledge and support to full-grazing farmers from consultancy and research levels is needed. Redefining what constitutes an efficient and productive cow in a grazing system, and the appropriate selection tools to identify her, is also required. The qualities, nuances and the challenges of the implementation of a full grazing system are further developed in the body of the text.

Keywords: milk production system, milk quality, dairy cows, feed conversion efficiency

1. Introduction

Dairy production systems in Europe and North America have seen changes towards a total milk-output orientated cow (Holsteinisation) and feed-lot, stall-feeding systems, which utilise optimised total mixed rations (TMR), with the major components being maize and grass silage and concentrates. There are still grassland-based milk production systems in countries with alpine foothills, but the reputation and status of these systems have waned. However, this could change quickly in the near future because of the sharp decline of prized arable land availability. This is due in part to urbanization, industrialization and the corresponding expanding infrastructure, and increased demands on feed-grain production as a consequence of the rising meat consumption of emerging countries such as China. Also, the nuclear disaster in Fukushima will impact the demand for energy-producing land areas. In the light of these developments, the practice of high per-cow concentrate usage to achieve high annual per-cow production is increasingly questionable. Therefore, pastoral land and pasture-based milk production (especially in areas where pasture is a best-case land use) will become more economically relevant and will regain some of its current lost status and reputation. The role of grasslands from the perspective of global food production will become increasingly important, especially if the availability of prerequisite resources for long-term additional food production is uncertain, and combined with growing global food demand (Spiertz and Ewert, 2009; Nösberger, 2010). The core task of sustainable milk production lies in the pathway of the conversion of forage to a food that is of nutritive value for humans in the form of milk, dairy products and, to a lesser extent, meat. This is particularly relevant for regions such as the Alps and alpine foothills, where permanent pasture is the primary input resource. If we assume that the careful and efficient use of resources is becoming increasingly important, and furthermore that the era of extravagance is over, it is right that we, at this year's EGF Symposium can revert back to and employ the strengths of grassland-based milk production and show how these adaptations can be successfully implemented.

In recent decades, dairy farmers in the grassland areas sought huge increases in performance through advancements in breeding and feeding with maize and concentrates. They succeeded, yet it left dairy production systems stressed. However, it was viable - even on marginal land within mountain regions - to have high yielding cows and a high proportion of cheap concentrate in the cow's annual diet. But in terms of sustainability and resource efficiency, it is a moot point whether to continue with this system or not. To survive in the long term, milk producers in the grassland areas should shift their focus to using their own resources and realizing the potential of pastoral-based dairy production. To this point, the presentations at the EGF General Meeting in Kiel 2010 showed that efficient, region-specific usage and combinations of resources should be employed for herd and grassland management. This new grassland management model will incorporate the critical role of legumes, namely white clover, and its positive impact on intake from livestock (Peyraud *et al*., 2010). Moreover, not only should pasture be the main input resource for ruminants, but the awakening societal awareness of the exogenous advantages of grassland must be considered (Sanderson and Wätzold, 2010).

This paper aims to show primarily that the development and promotion of milk production in grassland areas requires a paradigm shift, particularly in countries and areas situated north of the central European Alps. Annual milk yield per cow as a key performance indicator is misleading and should be neither coveted nor necessary to achieve sustainability. It will also be shown that milk and dairy products produced from pasture have a unique composition with beneficial nutritive values (fatty acids), sensory properties and physical characteristics, which should be conveyed to the consumer.

2. The search for sustainability and social recognition

2.1. The value of milk production in small and mid-sized family dairy farms

In many regions north of the Alps, the topography and climate is not suitable for arable crops and the landscape is dominated by grassland. Where there is relatively even distribution of rainfall throughout the year and/or mild temperatures during the winter, the climatic conditions are favourable for grass growth, and the annual dry matter production can reach 15 t DM ha^{-1} y^{-1} (Jeangros and Thomet, 2004). Mountainous regions, in contrast have a shorter grazing period (5-7 months), and DM yields are lower. However those areas often benefit from frequent summer rainfall, allowing grass growth above 40 kg DM ha^{-1} d^{-1} whereas growth is nearly stopped in plains and hill regions, as observed in Franche-Comté in France

Table 1. Average data from dairy farms in 4 countries/regions: Bayern (D), Baden-Württemberg BW (D), Switzerland (CH) and Austria (A)

	D - Bayern	D - Baden-W.	CH	A
Agricultural effective area (Million ha)	3.22	1.43	1.09	3.19
Proportion grassland (%)	35	38	75	62
Proportion maize whole plant (%)	11.0	7.6	4.1	11.0
Size of herd (Cows.dairy farm^{-1})	37.2	32.2	18.5	11.2
Milk yield (kg ECM.cow^{-1})	7638	6198	6773	6828
Concentrates (kg cow^{-1}.yr^{-1})	2370	2079	883	1300

[1] Only milk controlled cows

(Delaby *et al.*, 2010a). This grass growth potential contributes to the construction of a “green landscape”. The aesthetic value of the pastoral landscape is especially important for tourism, and the farms’ integral role at a societal level is recognised by the government via guaranteed direct payments. Permanent grassland-based milk production systems are indispensable for maintaining the typical landscape in these regions, ensuring biodiversity and fulfilling the various multifunctional tasks (Lobsiger *et al.*, 2010). Thus it is important to communicate the positive image of grassland-based milk production systems. However, the figures in Table 1 show relatively small farms (in grassland areas) but using high amounts of concentrates, which is problematic if sustainability is considered.

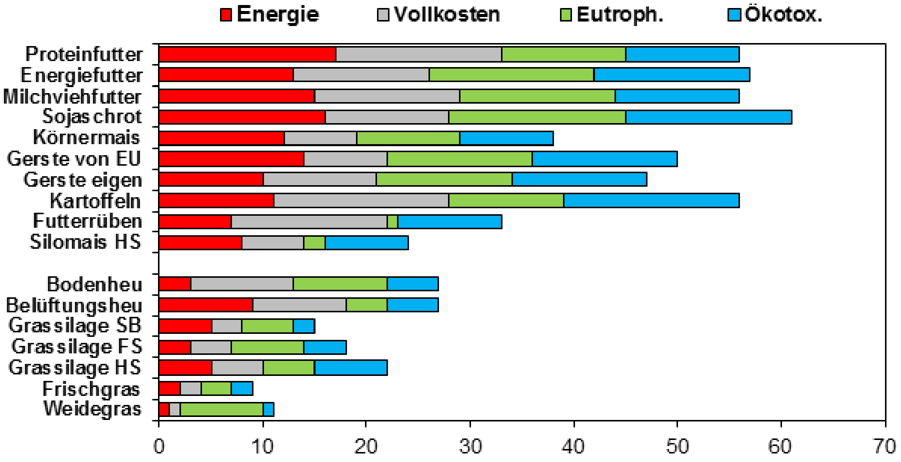

Figure 1. Ranking of the impact of 17 various dairy cattle feeds on full costs, energy efficiency, eutrophication risk and eco-toxicity risk (Zimmermann, 2006)

Figure 1 shows the various impacts of dairy cattle feeds, both economically and environmentally, under average production conditions. Unprocessed, freshly cut and fed feeds were the least expensive. The environmental effects of roughages are generally lower than those of concentrates, especially if the concentrate is dried and processed, or transported over long distances (Zimmermann, 2006). Basset-Mens *et al.* (2009) also support these findings of the decreased environmental impact by grazing mixed-type pasture sward systems. Moreover, grazing has positive effects through decreased labour demand and on improved animal welfare. However, a successful grazing operation places high demands on management and personnel competence.

2.2. Optimising the conversion of grassland biomass to food

In grassland-based dairy production, the cow's four-part stomach system (ruminant) enables it to be utilised as a bioreactor, in which cellulose energy (indigestible to humans) is unlocked to generate a food source digestible for humans. The cow does not suffer from decreased concentrate content in her diet, as pasture in itself is a natural total mixed ration. The timing of plant canopy harvest, the conservation system and the botanical composition of grassland swards determine milk production potential. The age of the plants is the main factor influencing their nutritive value (age effect): early utilization is necessary to obtain feed suited to the high requirements of dairy cows. Rapidly grown spring pasture has by far the highest nutritional value, both in terms of energy and protein supply. During this period, milk yields of 30 kg energy corrected milk (ECM) cow^{-1} day^{-1} are possible solely from forage. As the year progresses, the digestibility and energy concentration falls. However, the crude protein content remains and increases steadily. Therefore, spring production of milk from grazed pasture is the most lucrative, as values of feed conversion efficiency are over 1.5 kg ECM kg DM^{-1}. In the cut-and-carry regime, the forage is mostly older and therefore of lower energy content, but voluntary DMI could be increased through shorter and more evenly spaced ingestion and rumination sequences (Boudon *et al*., 2009). The age effect is less pronounced for legumes and forbs than for grasses. Therefore the presence of legumes in the pasture sward provides year-round ration-energy optimisation. Also, pasture utilisation is increased when feeds, high in legume content, are offered, in all forms (fresh, silage, hay) rather than pure grass monocultures, which also increases the milk production potential and feed-conversion efficiencies (Peyraud *et al*., 2010). The stall-feeding system with an optimized TMR has a distinct advantage in voluntary intake. With similar energy concentrations of the diet, the DM intake is higher in a TMR system than in a grazing system, primarily due to the faster rate of intake, thus allowing for annual milk yields of 10,000 ECM cow^{-1} or more, whilst full grazing systems achieved levels of 6,500 ECM cow^{-1} (Kolver and Muller, 1998). However, the economic result is strongly dependent on the cost of the feeds used.

3. Quality differentiation of grassland-based milk

3.1. Distinction between milk produced from either mainly grass-based feed or from TMR

Many studies have investigated the influence of farm feeding practices on the composition of cow milk in different production systems. The composition of the milk fatty acids (FA) is largely influenced by the cow's diet.

It was shown that an increased proportion of grass-based feed in the diet decreases the amount of saturated fatty acids (SFA) and especially the sum of C12, C14 and C16 (Leiber *et al*., 2005; Couvreur *et al*., 2006; Ferlay *et al*., 2008; Bisig *et al*., 2008; Collomb *et al*., 2008). The levels of mono-unsaturated fatty acids (MUFA) (Leiber *et al*., 2005 [at 2000 m]; Couvreur *et al*., 2006; Bisig *et al*., 2008; Collomb *et al*., 2008) and polyunsaturated fatty acids (PUFA) in milk fat increase with increased proportions of grass-based feed (Leiber *et al*., 2005; Couvreur *et al*., 2006; Bisig *et al*., 2008; Collomb *et al*., 2008).

For the n-3 PUFA, at least 9 studies showed an increase of between 51 and 330% with grass-based feed only, compared to the standard mixed diet in the respective studies (Table 2). The highest increase was observed when 100% grazing was compared to 100% maize silage rations. Another portion of the PUFA, the conjugated linoleic acids (CLA) are of important interest. At least 8 studies found an increase of CLA content between 77 and 244% with grass-based feed mainly, compared to the standard mixed diet (Table 2). The CLA-enriching effect of pasture

Table 2. Fatty acid content in milk of grass-based fed cows compared to milk of cows fed a mixed diet with high levels of concentrate and whole-crop maize silage

		n-3		CLA		Reference, remarks
Region	Diet composition	g/100 g fat	up %	g/100 g fat	up %	
Zug, Switzerland, 400 m above sea l.	Hay, grass silage, maize silage 10:60:30	0.81		0.661		Leiber *et al*., 2005 per 100 g FAME
	Grass only (barn, pasture)	1.375	70	1.789	171	∑ CLA
Grisons, Switzerland, 2000 m above sea level	Hay, grass silage, maize silage 10:60:30	0.85		0.689		Leiber *et al*., 2005 per 100 g FAME
	Grass only (barn, pasture)	1.810	113	1.539	123	∑ CLA
Engadin, Rhinewald, Emmental, Lucernese-Willisau, Toggenbourg	about 75% feed grasses (winter: grass silage, hay), 2% (s_x= 2) maize silage, 12.5% (s_x = 3.3) concentrate	1.19		0.72		Bisig at al., 2008, Collomb *et al*., 2008 ∑ CLA
	Grass based feed only	1.89	59	2.03	182	
Wisconsin, USA	33% pasture, 25% alfalfa hay, 48.3% ear maize, 6% roasted soybean	0.81		0.89		Dhiman *et al*., 1999 per 100 g FAME CLA c9, t11
	66% pasture	1.46	80	1.43	61	n-3: C18:3
	100% pasture	2.02	149	2.21	148	
South Wales	Up to 50% concentrate, grass silage	0.54		0.75		Butler *et al*., 2009 ∑ CLA
	Low input not organic cert. (no or low levels of concentrate)	0.94	74	1.82	143	n-3: ALA
	Low Input organic (no or low levels of concentrate)	1.03	91	1.33	77	
Haute-Loire (Massif central), France	33% Maize silage, 66% grassland, 3.7 kg/d concentrate	0.65		0.73		Ferlay *et al*., 2008
	99% grassland, 1% maize silage, 2.6 kg/d concentrate	0.98	51	1.58	117	
Rennes, Bretagne, France	0% grass: maize silage, 3 kg soybean-concentrate	0.29		0.48		Couvreur *et al*., 2006 CLA c9, t11
	30% grass: maize silage, 2 kg soybean-c, 1 kg cereal concentrate	0.43	49	0.54	13	
	60% grass+1 kg soybean-c, 2 kg cereal concentrate	0.60	108	1.21	152	
	100% grass+3 kg cereal concentrate	0.73	153	1.65	244	
Six regions in France (Bretagne, Picardie, Lorraine, Franche-Comté, Auvergne, Aquitaine)	100% Maize silage	0.20		0.33		Hurtaud *et al*., 2010
	100% Grazing	0.86	330	1.10	233	
Southern Germany	50% Maize silage, other preserved forage	0.5				Weiss *et al*., 2005
	Grass silage, hay, little concentrate	1.1	120			
	Pasture only	1.3	160			

has been explained by the effects on biohydrogenation and the provision of α-linolenic acid as a lipid substrate for the formation of trans-vaccenic acid (C18:1 trans-11) in the rumen and its subsequent desaturation to CLA C18:2 cis-9,trans-11, the main CLA isomer in milk, in the mammary gland (Collomb *et al*., 2006).

3.2. Potential of quality differentiation of grass-based milk

The decreased SFA-C12, -C14 and -C16-content and the increased MUFA, PUFA, n-3 FA and CLA are nutritional benefits of grass-based milk. Of the SFA only C12, C14 and C16 adversely affect low-density-lipoprotein level (LDL) in human plasma. LDL is a risk factor for cardiovascular disease. In higher concentrations n-3 FA can lead to nutritional claims or even health claims. The European Food Safety Authority (EFSA) published their positive scientific opinion on a health claim related to the n-3 FA α-linolenic acid (ALA) for infants and children up to three years with the following wording: "Alpha-linolenic acid, an essential fatty acid, contributes to brain and nerve tissue development." and previously a positive opinion on ALA for normal growth and development of children (EFSA, 2011). To be able to make such nutritional or health claims, conditions of their concentration have to be met.

CLA were discovered by Pariza *et al*. (1979) as an anticarcinogen. Also in animal models, other effects such as a body fat lowering effect associated with an increase of lean body mass, an antidiabetic effect, antiatherogenicity, a positive modification of the immune system and influence on bone metabolism were found. Human studies are often contradictory. Recently EFSA published a negative opinion on several health claims for CLA (EFSA, 2010).

Branched chain fatty acids (BCFA) content in milk is positively correlated to the proportion of grass-based feed (Couvreur *et al*., 2007; Collomb *et al*., 2008; Hurtaud *et al*., 2010). BCFA have an anticarcinogenic effect on cancer cells (Vlaeminck *et al*., 2006).

It is still unsure whether trans fatty acids (TFA) of ruminant origin are neutral, positive or negative from a nutritional point of view. In Denmark and Switzerland maximum levels of 2 g/100 g fat for TFA are set. TFA of animal origin are excluded (EDI, 2008). CLA are mainly TFA and have the positive potential previously shown. An increase of TFA with increased proportions of GBF could be observed (Ferlay *et al*., 2008: from 3.96 to 6.94 g/100 g FA; Collomb *et al*., 2008).

The conclusion is that grass-based milk has positive nutritional benefits but none can be labelled and communicated on the product due to current EU regulations. However, it should be possible to communicate other non-nutritional values on the products.

3.3. Sensory changes with grass-based feed

The softness and spreadability of butter is improved when made from milk with increased grass-based feed (Couvreur *et al*., 2006; Mallia 2008). A softer cheese body texture is also observed, especially with fresh grass in the cow's diet (Bisig, own observations; Martin *et al*., 2009). Butter made of milk produced with more grass-based feed was less rancid than butter made with milk produced with maize silage (Couvreur *et al*., 2006). Other odour and flavour attributes were unchanged (Couvreur *et al*., 2006) or were creamier (Mallia, 2008). Maize silage feeding results in whiter and less appreciated cheese and butter (Martin *et al*., 2009). Even a small proportion of fresh grass (15% of the diet) led to cheeses which were judged more yellow, less firm and with a more intense and partly more grassy and flowery aroma (Martin *et al*., 2009).

4. A cow to suit the system

4.1. Defining the cow's efficiency: from the cow to the system

In many countries, selection pressure was placed on total milk production per cow per year. We must admit that this selection increased the cows' ability to transform feed into milk, for example: gross feed conversion efficiency (kgECM per kgDMI). Cows also became larger; small efficient cows being predictably discarded. More worrying was the fact that other total farm-profit drivers, such as health and reproduction, were left unchecked and declined, owing to antagonistic genetic correlations with milk yield (Windig *et al*., 2006). This reminded us that the evaluation of a dairy cow's efficiency depends certainly on the ratio of output (quantity and quality of milk) per input (quantity and environmental cost of feed), but also on the time scale we use (lactation or life length) and the constraints of the system (feed quality and availability, seasonal pattern). A cow which is best suited to a grazing system must not only possess a high forage conversion efficiency of kg DM consumed to saleable product (including quality) but must also have high fertility, longevity, robustness, intake capacity and willingness to graze. A compact calving pattern further strengthens the importance of the reproductive process, namely cyclicity, oestrus and fertility.

4.2. Genotype × environment interactions: which cow for low input grazing systems?

Efficient cows in one system are not necessarily efficient in another. Indeed, interactions between feeding system and cow type have been reported for both production and reproduction traits (Fulkerson *et al*., 2001; Kolver *et al*., 2002; Horan *et al*., 2004; Beerda *et al*., 2007; Delaby *et al*., 2009; Cutullic *et al*., 2011). Although Delaby *et al*. (2010b) suggested that high genetic merit dairy cows are compatible with low input systems, it is clear that the widespread North-American Holstein type cow currently has a suboptimal reproductive performance, which renders it unsuited to a pastoral compact calving system. However, the recent results of Coyral-Castel *et al*. (2009) and Coleman *et al*. (2010) suggest that selection for both high milk yield efficiency and fertility is possible, as successfully done in New Zealand and Irish dairy breeding programmes. In a recent study conducted on Swiss commercial pastoral, seasonal calving farms, New Zealand-type Holstein cows were not only as efficient as Swiss Holstein cows for milk production, but had improved reproductive performance and thus appeared more suitable for the system (Figure 2; Piccand *et al*., 2011, in these procee-

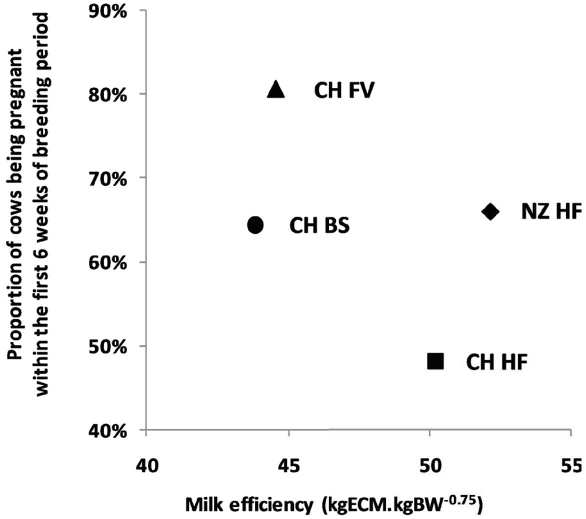

Figure 2. Average milk efficiency over 270 days of lactation and average proportion of pregnant cows within 6 weeks of the breeding season for New Zealand Holstein Friesian (NZ HF; n = 131 lactations), Swiss Holstein (CH HF; n = 40), Swiss Fleckvieh (CH FV; n = 43) and Swiss Brown Swiss (CH BS; n = 45) dairy cows managed in seasonal-calving pasture-based systems (from Piccand *et al*., 2011, in these proceedings).

dings). Between New Zealand type Holstein cows and Fleckvieh cows, we may wonder which type is the more appropriate, since, on the one hand, Fleckvieh cows produced less milk but on the other hand produced more meat and had better reproductive performance.

4.3. Selecting and breeding for the future

In addition to the previously mentioned classical breeding traits (milk production efficiency, reproductive performance, health, meat production), other traits should retain attention, for example: milk composition. If the main final product is cheese, especially high added-value cheese as in many Alpine regions, milk processing characteristics should be considered. Flexibility, i.e. capacity of the cow to switch from one system to another, should also be of increasing importance: either in a context of fluctuating milk prices to quickly produce more milk efficiently through increased concentrate usage when milk price is high, as suggested by Peyraud *et al*. (2010) - although this may be questionable in the context of sustainability. Or, flexibility could also encompass the cow's ability to adapt to temporary feed restriction or high temperatures in the climate change context (Hayes *et al*. 2009). Behavioural components of efficiency may also be emerging criteria (Prendiville *et al*., 2010; Kunz *et al*., 2010). The incorporation of genomic selection will aid in this holistic approach, through increased reliabilities and decreased generation interval, with an increased confidence to include any one trait in any given decision. The main difficulty now relies on the definition of pertinent criteria, each defined according to the production system objectives.

5. The search for the optimal full grazing system

5.1. Learnings from on-farm grazing research projects

The culture of full-time grazing is missing in Switzerland, southern Germany and Austria. Yet a pioneering effort of likeminded farmers with the support from research institutes was formed. The goal was to completely abandon confinement feeding and convert their farms to a full-time grazing system. Table 3 shows which research institutes, and with how many farms carried out this initiative.

Table 3. On farm research projects with full grazing systems in the four areas of Bayern, Baden-Württemberg, Switzerland and Austria

	D - Bayern[1]	D - Baden-W.[2]	CH[3]	A[4]
Number of full grazing farms (≤ 10% Supplementary feed during vegetative period)	6	7	10	4
Of those: organic farms	3	6	2	4
Of those: mountainous zoned farms	-	5	1	4
Project duration	2006-10	2005-07	2001-03	2006-08
Produced milk per farm (kg ECM dairy farm^{-1})	220000	307164	134330	161272
Proportion grazing of annual feed ration (%)	50	36	59	50
Concentrates (kg cow^{-1} yr^{-1})	950	823	504	581
Milk yield (kg ECM cow^{-1} yr^{-1})	6200	6312	6032	5539

[1] Steinberger (2011), [2] Elsässer (2010); [3] Blättler *et al*. (2004); [4] Steinwidder *et al*. (2009, 2010)

The results of these projects show that full grazing systems in the alpine foothills can be implemented with success. In summation, the following statements can be made:

1. The health and fertility of the cows was as good, but in most cases better than those of typical farms.
2. Depending on the duration of the growing season, farm structure and planned start of calving, pasture made up 40-70% of total feed ration.
3. The proportion of concentrates in the annual ration was reduced by up to 70%..
4. The continuous grazing system (set stocking) was found to be suitable for the initiation of farmers to full-time summer pasture feeding. It also resulted in optimal per-area productivity, per-cow yield, labour efficiency and pasture sward performance
5. A complete conversion to a full-time grazing system resulted in decreased labour input, and consequently, the farmer's lifestyle was dramatically improved.
6. The financial results are difficult to compare due to the different direct payment systems, although the annual milk yield per cow of full grazing was much lower. In all four areas, farm management personnel agreed that the final economic outcome had improved.
7. Grassland helped to cultivate a positive image for agriculture amongst the general population.
8. Problems for the dissemination and application of the full grazing systems:
   - Lack of knowledge, competence and empathy for successful grazing management at research, consultancy and farm levels.
   - Land availability: farm growth is hindered because additional area immediately surrounding existing farm infrastructure is very difficult to acquire.
   - There are still entrenched attitudes solely orientated toward high cow performance.
   - Unavailability of best suited dairy cattle genotypes and a lack of relevant breeding indices as selection tools.

5.2. Should seasonality be the rule?

Synchronisation of feed demand with feed supply is the backbone of the seasonal calving pastoral-based system. In Figure 4, it can be seen that pasture growth increases rapidly in spring in all regions, although the timing of growth rate incline is region-specific. As the farmer has

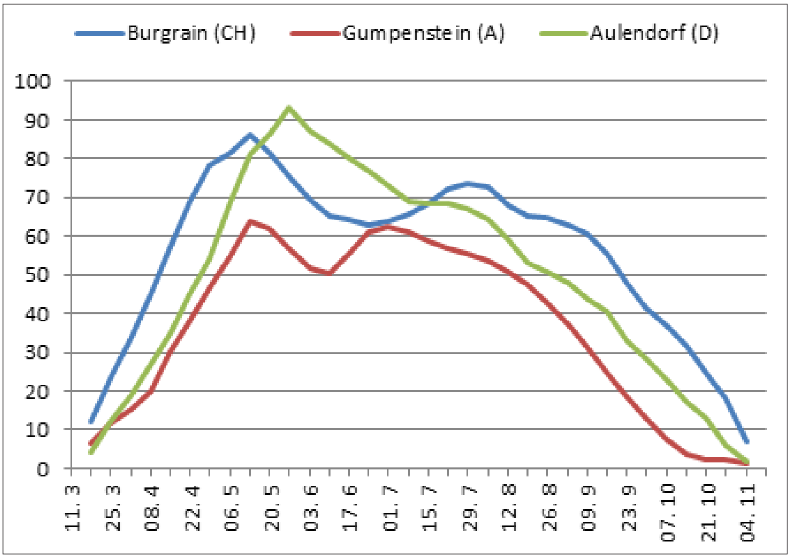

Figure 3. Grass growth at different sites (averages from at least 3 years, measured after the method Corrall and Fenlon, 1978)

no bearing on the onset of spring, the feed demand can be manipulated to meet supply and this will dictate the onset of calving. This ensures a best-case scenario of feed cost minimisation to the farmer, since milk is mainly produced through cheap grazed grass and because peak energy content of grass corresponds to cows' peak energy demand. However, to minimise cow wastage, high reproductive performance (as described in section 4) is imperative to ensure continued synchronicity in successive years (cows which fall out of the seasonal rhythm).

To optimize the system further, other classical management tools of grazing systems can be used, such as stocking rate or grazing pressure. In a grazing system, output must be considered at the herd level, not at the individual cow level. Indeed, an increase in stocking rate decreases individual cow performance but strongly increases biomass utilisation and milk output per hectare (Delagarde *et al*., 2001; McCarthy *et al*., 2011). Milk production per hectare will only decrease once optimal stocking rates are exceeded (King and Stockdale, 1980).

In the future, the dairy industry should take advantage of higher milk production potential during grass growth peaks, instead of imposing disincentives via decreased milk prices. As discussed in section 3, this milk is the best quality milk a cow can produce, from which high quality products can be derived. Originally, the purpose of hard cheese production was to store superfluous milk and enable year-round dairy product consumption. Why now should the farmer store feed to produce milk all year round? How and why has this apparent regression occurred? However, we consider it relevant and sustainable to ensure basal winter milk production. Although, if farmers intentionally produce surplus winter milk (provocatively said, is it not the same as producing tomatoes in winter?), it is clear that complementary systems to seasonal calving pastoral-based systems are also needed. However, research is still required to evaluate the performance of those low-input grass-based winter producing systems.

6. Conclusions

The success of a grazing system is reliant on its simplicity, meeting feed demand with feed supply, and coordinating peak demand with peak nutritional value. Grazing systems are generally considered 'low input'. However, this term is not synonymous with 'low competence'. Although simple in its founding principles, whether seasonally calving or not, a successful system relies on a high degree of managerial competence.

Expertise in this area has diminished and should be rectified. With improved consultancy and on-going research, farmers willing to convert existing confinement TMR systems can improve their economic outcome whilst also fostering a positive image for agriculture. However, not only should human proficiency be improved to meet the demands of a grazing system, but the animal must also be best suited. This should include the establishment and measurement of relevant performance indicators and will include improved selection tools to help identify optimal genotypes. Animal breeding programmes should relinquish per cow production as the primary selection objective and should consider other key profit drivers for farmers (fertility, longevity and kg ECM per kg metabolic BW). The lower per cow yield in a low input system does not mean low output, as it has been shown that there is high per-area productivity (kg ECM ha^{-1} grassland) in grazing systems, whilst also decreasing environmental impact and improving sustainability.

Nutritionally positive differences of grass-based milk have been demonstrated when compared to TMR milk. Although health-benefit claims cannot be made via labelling due to EU regulations, potential differentiating factors can still be communicated to both the public consuming dairy products and conventional dairy producers.

There is no better vector for change at a production level than clear, unobstructed signals from the consumer. Where possible, the choice of milk production system should be sensitive to market preferences, and in the regions north of the Alpine boundary such systems are possible. Moreover, considering the merits outlined in this paper which positively affect consumer, producer and the environment, a change to a full grazing system is highly justified.

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