Sustainability of living systems within milk production in need of resources and regulation

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Abstract: Sustainability is the capacity of living systems to endure and survive. This applies for agro-ecosystems such as dairy farms as well as farm animals as sub-systems. To deal with the complexity of production processes when analysing sustainability, the concept of living systems as autopoietic and self-referential systems, organised within a hierarchical structure of different orders is outlined. In a highly competitive environment outside and within farm systems sustainability requires resources and capacities to adapt to ongoing changes in the environment. While self-regulation and adaptation processes within farm animals follow physiological principles, they largely depend on the ability of the farm management to provide appropriate resources in terms of energy and nutrients suited to meet the individual requirements at the various life stages.

In a survey, data from dairy farms deriving from the Bavarian State Control Association regarding results from milk control records as well as economic parameters were evaluated with respect to conclusions in relation to the appropriateness of nutrient supply, and udder health status. Availability of resources differed widely between the dairy farms. The results suggest that a considerable proportion of the dairy cows were not fed according to their specific requirements in the lactation course and were at risk for metabolic disturbances. Udder health status, assessed by somatic cell counts on the cow level, was insufficient on many dairy farms and showed considerable potential for optimisation. While in average about 50% of the profit derived from official direct payments, full costs of dairy farming were covered only by few farms. The majority of the farms was not able to accumulate the required own capital for substitute investments.

The results indicate that sustainability is a result of successful interactions of influencing factors on the base of appropriate resources. The concept of autopoietic systems is suited to structure the complexity within agro-ecosystems and to provide orientation for the implementation of sustainability by the approach of self-referentiality of living systems. However, due to the conflicting areas between competition and sustainability a modification of the market conditions is necessary, supportive in finding a balance between both crucial driving forces in dairy farming.

Keywords: autopoiesis, requirements, animal health, economics, dairy cows, sustainability

Introduction

Through a consistent process of intensification, dairy production has realised enormous improvements in the efficiencies of dairy production. These achievements are based on increasing inputs of external resources, e.g. high quality feed and technological equipment. Unfortunately, these developments go along with severe negative side effects. According to a FAO report, the livestock sector is emerging as one of the most significant contributors to serious environmental problems, locally and globally (FAO, 2009). It marginalises small holders, increases waste, affects animal health and welfare, and food safety. Increasing disadvantages of the intensification processes and conflicts with the interests of other stakeholders call for a critical assessment of the sustainability of dairy production (Keyserlingk et al., 2013).

Striving for sustainability requires resources. As the availability of qualitative resources is generally limited, competition has developed as an evolutionary concept occurring between living unities on all scales. On the farm level, different agricultural areas are in need of labour efforts and investments, provoking conflicting areas for the farm management (Sundrum, 2007). The farmer himself is fighting for the survivability of the farm in a free market, where all dairy farmers produce the same commodity. While farmers have to consider changes in the availability of resources, prices and markets, they can no longer ignore consumer concerns about animal health and welfare, food safety, and environmental pollution. However, market prices and consumer preferences are dominated by forces beyond the farmers' control.

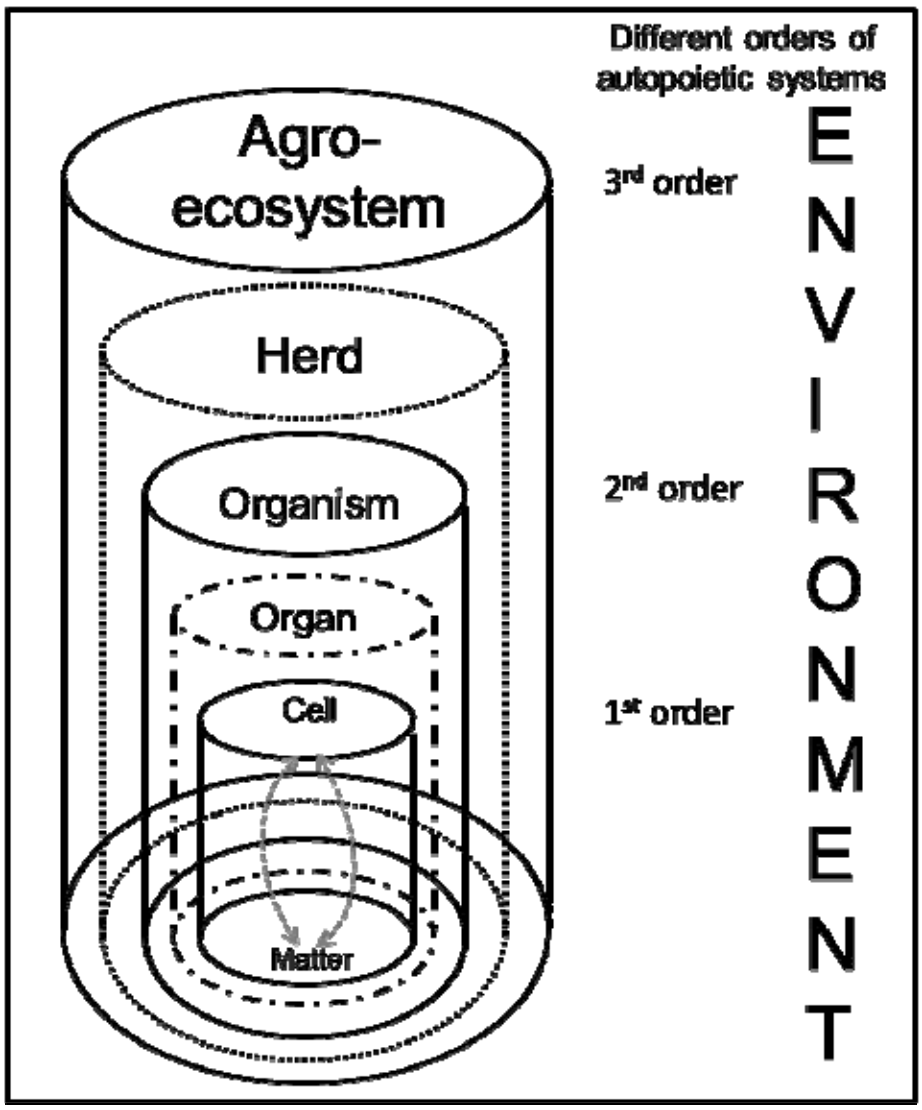
Agricultural systems are human-run systems, so what is sustainable is subject to possible change and regulation. Farm managers are not only agents of control but are components of the system itself. They follow various rituals, world views, economic incentives, or specific objectives. Facing a huge complexity, the crucial question is what may provide orientation and which reference values might be supportive when trying to improve the sustainability of livestock farms and distinguish processes which are supporting systems with respect to sustainability or weaken them.

In the literature, often only single aspects concerning general features of sustainability are addressed. As a consequence, it is difficult to draw an overall picture of the situation in different farming systems. In contrast, a multiple criteria approach to farm performance evaluation offers a more comprehensive picture (Andreoli & Tellarini, 2000). However, further challenges arise when there is a need to decide which of the various criteria is more relevant than others. This is aggravated by the fact that priorities are expected to change considerably between different livestock production systems. In the following, a conceptual framework is explained referring to the self-referentiality of living systems as references to assess sustainability of farms systems. The concept will be related to empirical results gained by a comprehensive survey on dairy farms to show options and limitations of the concept to analyse sustainability in dairy production.

Sustainability of autopoietic systems

From a physical point of view, a body is a material entity, composed of different sub-parts and sub-processes. From a biological-systemic perspective, an organism is an integral and functional system in processes of exchange with the environment. It represents an entity with a functional integrity (Thompson, 1997). Maintenance of the entity is an active process of self-organisation.

Figure 1: Hierarchical structure of autopoietic living systems of different orders within an agro-ecosystem



Based on considerations by Maturana (1980) concerning the characteristics of self-organising autopoietic systems, the vertical structure of living systems in agricultural livestock systems can be described as a hierarchy of scales, with (1) the agro-eco-system (farm) as the superior level, the herd as an intermediary level (2) between the agro-eco-system and the whole organism (3), here the dairy cow, with organs (4) as sub-systems and the basic level of cells (5), interacting with material elements (see figure 1). The living organism as a whole is the precondition of its part insofar as it enables in the first place the existence and the sustainability of the cells and the organs. According to Varela (1997), an autopoietic system is defined as a system that continuously produces by itself the components, which constitute it, while these components steadily sustain and regenerate the whole system.

In striving for maintenance, external material is brought to heel by the living organism according to their own principles and purposes, while integrating and transforming the material. By the dynamic self-organisation the organism demarcates itself from the environment and achieves a kind of autonomy. Thus, processes are not primarily determined from the outside but are depending on basic dispositions und structures, and by current conditions (e.g. deficits or saturation, anabolic or katabolic metabolism, performance level). The organisation of the living systems is in complementary relation to the species-specific environment. It selects the appropriate components from the environment and gives them a meaning of incentives, objects of perception and interests. Correspondingly, autopoietic systems exhibit both a self-referentiality and a relationship to the envi-

ronment. They are not determined by the physical impacts from the environment but react on perceived stimuli through the configuration of the whole system. They interact on a horizontal level with the environment and in a vertical structure within the living system. On animal level, the brain functions as an organ of intermediation in both functional circuits: of the organism and the environment and of the whole and the sub-parts within the organism. On farm level, the farmer organises the exchanges with the environment, the structure of the farm systems as well as the distribution of resources to the sub-systems. On the horizontal level, decreasing availabilities of resources provoke increasing conflicts between competing systems. Limitations in the availability affect not only the competitiveness of living systems on the same level but have also severe impacts on the sub-systems along the hierarchical structure.

A dairy herd is a composite unit in which the single animals are its components. An animal treated as an organism is a composite unity in which its organs are its components, while the organs are composed as a multicellular system. It follows that a herd treated as a multi-animal system, and a herd treated as a simple unity, are two different kinds of unities because they are defined through different operations. A simple unity is only characterised by the properties assigned to it by the operation of distinction through which an observer distinguishes it from the background. A composite unity, however, is characterised by the organisation that integrated its components into a whole, determining its identity as a composite unity of a particular kind and its properties as a simple unity when distinguished as such (Maturana, 1980).

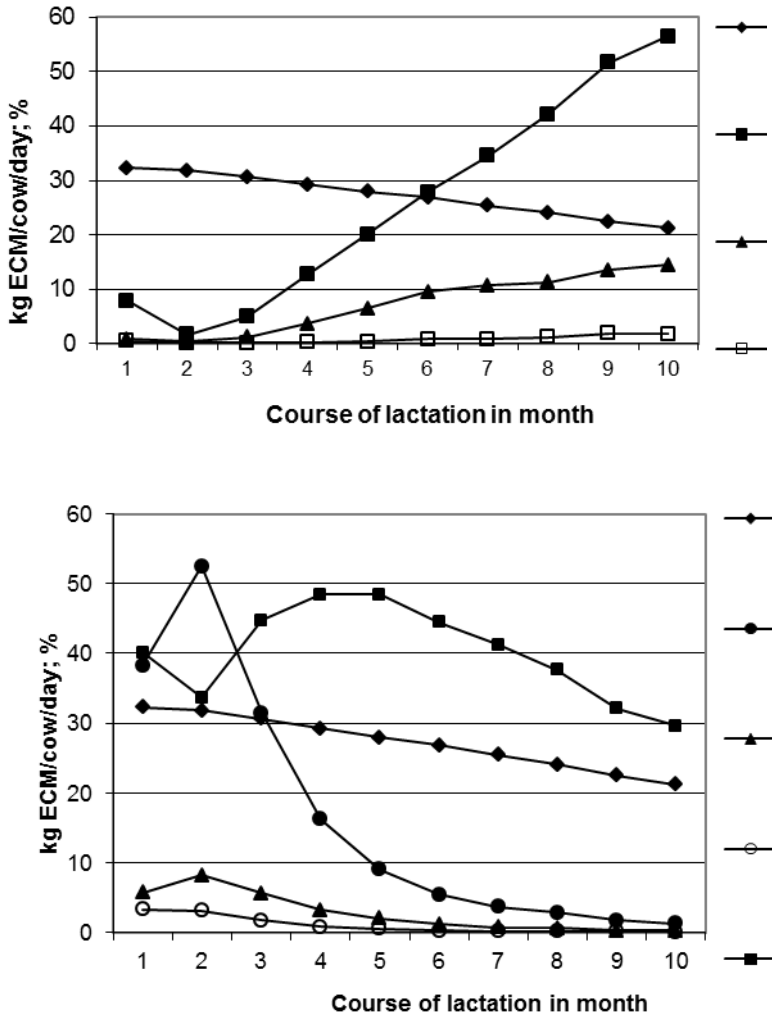
Features of sustainability in dairy farms

In a survey study, data from dairy farms deriving from the Bavarian State Control Association regarding results from milk control records as well as economic parameters were evaluated with respect to conclusions in relation to the appropriateness of nutrient supply, and udder health status. Based on a comprehensive data set, the data used here were restricted to those from 499 farms in 2006. For further details see Haerle (2010) and Haerle and Sundrum (2013a, b).

Nutrient supply

Milk performance based on home-grown feed without concentrates averaged 2,519 kg energy corrected milk (ECM) per cow and year, showing a large variation between the dairy farms. From the fifth month of lactation more than 20% yielded milk protein contents above 3.8%, indicating an oversupply of energy (see figure 2). After birth, > 50% had protein values < 3.2% in the milk which points out deficits in the availability of energy. At the beginning of lactation, about 40 % of the dairy cows showed deviations in fat-protein-quotients (FEQ) from the reference levels (<1.1 - >1.5). The percentage of dairy cows with an FEQ > 1.5, indicating an increased risk for the occurrence of ketosis decreased from the second month of lactation, whereas the percentage of cows with an FEQ < 1.1, indicating the risk of acidosis increased up to the fifth month of lactation to over 40% and stagnated on a high level. A nutrient supply, balanced according to the reference levels, was only attained in the middle of lactation by 39% of the cows. The results suggest that a considerable proportion of the dairy cows were not fed according to their specific requirements in the lactation course and were at risk for metabolic disturbances.

Figure 2: Milk yield and proportion of cows in different categories, characteristic for the supply with energy and crude protein over the course of lactation 2005/06 (n = 3,888 cows)



Udder health

Somatic milk cell counts on the cow level diversified considerably within and between the farms. The breakdown of the data according to the milk cell count classification and the comparison with references showed that the udder health status on many dairy farms was insufficient and showed considerable potential for optimisation, respectively. Over half of the cows fell short of the threshold < 100 tsd. cells/ml milk; indicating a healthy udder. On average, 11.6% of the cows per farm exceeded the cell count of 400 tsd. cells on a variation of 1–34.5% of the percentage of the cows in this class. Nevertheless, the Bavarian dairy farms came up with comparable lower milk cell counts on corporate level in relation to other federal states and other milk-exporting nations.

Economic parameters

Based on comprehensive economic data on the same farms, full costs ranged between 34.5 and 70.0 cent per kg ECM (Haerle, 2010). Remarkable was the high proportion of feed costs with an average of 24.9 and a wages rate of 10.7 cent per kg ECM. The majority of the farms increased milk performance based on the same labour capacity. However, the full costs were covered only by few farms. Under the precondition that all factors apart from the labour were remunerated, an average wage rate of 5.40 € per hour was calculated. While some farms were not able to earn enough money to cover any wages, others earned more than 15 € per hour. About 50% of the

profit derived from official direct payments. Correspondingly, the majority of the farms could not sustain without the transfer payments and was not able to accumulate the required own capital for substitute investments. On the other hand, the calculations of the farms showed that apart from increasing milk performance there were other options to manage a farm profitable.

Discussion

Following the concept of living systems as autopoietic systems, organised within a hierarchical structure of different orders, sustainability of dairy cows within a herd depends on the degree in which the requirements of the individual cows are met through the structure and organisation of the farm system as a whole. In general, dairy cows differ considerably in their requirements in relation to individual peculiarities and with respect to the specific performance within the lactation course. Correspondingly, nutrient requirements of farm animals are self-referential and are not represented by average herd figures. It is a challenge for the farm management to provide enough energy and an appropriate nutrient supply. To fulfil these demands, the farm system is itself in need of appropriate resources (high quality feed, investments, labour capacity, knowledge, etc.). What is needed on individual farms cannot be generalised but is also self-referential.

Market conditions which do not provide enough farmers' income and do not fully cover the expenditures threaten not only the sustainability of the farm systems but also those of the dairy cows and their functional integrity of organs and tissues. Consequently, dairy cows have difficulties to sustain their health status. Animal health is an emergent property of the organism as a living system that represents the capacity to sustain within an environment that can be defined itself as a superordinate agro-ecosystem (Sundrum, 2012). Thus, talking about animal health and welfare as a relevant feature of sustainability requires taking into account the number of animals that deviate from reference values, enabling a distinction between diseased and healthy animals. When striving for sustainability, it makes a difference whether the milk yield derives from a herd with a high or a low proportion of dairy cows facing production diseases.

Availability of energy and nutrient resources

The presented data concerning the energy and nutrient supply of dairy cows show considerable deviations between current and target states. Data are representative insofar as a negative energy balance at the beginning and an over-supply with energy at the end of lactation belongs to a general picture reflecting the difficulties of any feeding regime to provide a diet that corresponds with the course of the requirements during lactation. The preparedness of the dairy cow to deliver itself to a negative energy balance at the onset of the lactation period and to mobilise nutrients from the body tissues is an essential precondition for a high milk performance in the total lactation period. The dairy cow is prepared to mobilise reserves, even beyond borders which put animal health and life of the dams at risk. In the case of undersupply, dairy cows do not possess an effective brake that prevents further depletion of body reserves. Correspondingly, it is in the responsibility of the farm management and left to the organisational skills and to the availability of resources to avoid an overstretched gap between demand and supply. The crucial question is when are borders crossed which endanger the conditions of the individual animals to sustain and reproduce themselves. From the perspective of the explained concept, such thresholds cannot be generalised but are self-referential according to the corresponding order of autopoietic systems.

On the other hand, the most efficient use of nutrient resources is generally achieved when each animal is supplied with energy and nutrients according to their specific requirements. Both, under-nutrition and exceeding supply is not only inefficient but requires additional resources of regulation to keep the internal processes within a certain range of homeostatic conditions. Thus,

feeding farm animals according to their current requirements provides the best orientation for the farmer to gain both, a high efficiency in the use of nutrients while simultaneously reducing the risks of metabolic disturbances and providing optimal preconditions for the farm animals to sustain themselves and to gain longevity. However, the data give reason for the assumption that farm management in dairy production is very often lacking resources in terms of high quality feed, labour capacities, financial resources, and knowledge to compensate for obvious deficits.

Status of udder health

Herd management on dairy farms is often focused solely on the monthly bulk milk cell count. This however is an indicator of minor meaningfulness as data from the farm survey showed that the status of udder health on the animal level is in general far away from the thresholds defined by veterinary associations as indicators for a healthy udder or a high status of udder health on the farm level (Sundrum, 2010). Thus, it makes a difference, if animal health status of the herd is seen as a performance of the total herd or as the sum of the performances of the individual animals, providing by far more profound information. Although milk containing high somatic cell counts deriving from diseased udders is not a direct threat in relation to food security, somatic cell counts are a valid indicator for milk quality. While the somatic cell counts and the milk quality vary considerably between cows and between farms, farmers receive more or less the same price.

Competition, marketing and pricing

Livestock production is characterised by competition on different scales. The farm manager, always facing limitations of resources in terms of time, nutrients or investments, has to decide in which sub-system and over which time period the limited resources should be distributed. On the other hand, each farm is in competition not only with the neighbouring farms but on a global market. While market prices in general do not markedly differ between production units in the same country, those farms that can produce the products with the lowest production costs gain advantages towards the other farms. As price takers, farmers produce as much as possible against the going price. As a result there is a constant downward pressure on prices. This model, also known as the 'agricultural treadmill', characterises the predominant economic model and the basis for the European Common Agricultural Policy (Röling, 2009). Correspondingly, those farms able to produce with lower production costs have an advantage in relation to those with higher productions costs per product unit.

Within these framework conditions, competition depends to a high degree on the availability of internal resources, prices for external resources, and last but not least on the skills of the farm management to make the most efficient use of both. On the other hand, a competitive advantage is also given when the negative side effects of the production processes are externalised, without affecting the production costs (e.g. higher milk performance on the expense of animal health, longevity of dairy cows, or nutrient losses into the environment). From the perspective of sustainability, this adds to the fact of unfair competition. This is the case when producers striving for common goods such as a high status of animal health and milk quality by using appropriate management concepts and encountering higher production costs are competing with their products on the same markets as those who widely make use of the absence of minimum standards and produce on a low cost base. Thus, the current conditions on the food market contribute to a situation in which the existing potential for the production of a high level of milk quality is not realised and further developments of quality production are hampered by unfair competition (Sundrum, 2009). Currently, negative side effects of the production processes are widely ignored. While intensification offers some potential to decrease production costs, the data from Bavarian dairy farms showed that there is always more than one strategy to increase farmers' income. It can be assumed that the inclusion of negative side effects in any assessment of sustainability would be able to modify considerably the previous framework of competition.

Conclusion

Sustainability requires appropriate resources for the living systems at the various scales within the hierarchical structure that enable them to sustain. In addition, those who are in charge of organising balanced environmental conditions for living systems on the different scales are in need of reference values for orientation and decision making. While a multiple criteria approach to assess sustainability leaves the prioritisation of criteria to the perspective and preferences of the assessors, the implementation of the concept of autopoiesis and self-referentiality provides a clear orientation on how to provide appropriate conditions for living systems to sustain. The self-referentiality of living systems on the horizontal level and within the vertical structure regarding their specific requirements corresponds with the large variation found in farm practice. This approach differs considerably from a practice of generalising data on a high aggregation level.

On all scales living systems are facing competition for relevant resources, which are essential to hold their ground. Within the dairy cow, partitioning of energy and nutrients is regulated primarily by the endocrine system. On the level of agro-ecosystems, the farm management is responsible for the assignment of resources and for ensuring that the requirements of each animal are met appropriately. Data from dairy farms in Bavaria show that in general the farm managers are far from realising an appropriate nutrient supply. They themselves depend on resources in terms of adequate incomes, which often are not given. Thus, a modification of framework conditions is necessary to reduce unfair competition and to support farms that go for common goods instead of exploration of subsystems. There is a need to find a balance between competition and sustainability by regulating conditions enabling living systems to sustain themselves.

By keeping the public unaware of common practices, some controversy might be avoided in the short term. However, a lack of sustained engagement provides no feedback mechanism to ensure that any changes in practice are in harmony with public expectations. A competition that is almost exclusively based on the reduction of production costs is not compatible with the aim of sustainability. It leads to a shortage in relevant resources and overstrains the capacity of living systems to organise and regulate the processes of self-production and reproduction on the different scales. Thus, a counterforce is required which counters a one-way exploration and provides a balance in relation to the availability of resources as precondition of sustainability.

A counterforce cannot emerge from within the agro-ecosystems but has to be developed especially by consumer organisation and politicians. They could demand a change in the requirements profile of products of animals' origin, for example in terms of higher milk quality and a higher status of animal health while defining clear objectives, e.g. with respect to the prevalence rates of production diseases in dairy farms or thresholds concerning an acceptable somatic cell count on the cow level. In view of the fact that farmers' income derives to a high degree from official direct payments, consumer organisations and politicians are entitled to demand a higher level of product and process quality that should be oriented towards the realisation of common goods. The concept of autopoietic systems is suited to structure the complexity within agro-ecosystems and to provide orientation for the implementation of sustainability in agro-ecosystems by the concept of self-referentiality of living systems.

While a significant portion of the agricultural research undertaken is typically focused on measures of immediate economic interest or performed on the proviso that the productions costs should not increase, it leaves an important gap in the funding of research that addresses the growing public concerns about the impacts of production processes in dairy farming on common goods. Progress in sustainability science will require problem-driven, interdisciplinary research; creating coherent systems of research planning. Research will have to integrate the effects of key processes across the full range of scales from cells to farm systems, and have to address the behaviour of complex self-organising systems like farm animals and agro-ecosystems.

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