Contribution of Holstein Cows to Sustainability of Dairy Systems in Brazil

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ABSTRACT

This study presents an overview of the contribution of the Holsteins to the sustainable development of dairy system in Brazil. The indication of Holstein as the best dairy breed choice for dairy farming is evaluated, to understand constraints and opportunities of dairy farming in Brazil. The studies presented in this thesis evaluate systems' sustainability at society and at system level. Focus is given to a systems approach to explain and explore the function of dairy systems and their contribution to sustainable development. Starting with a view of production systems in relation to their economic, social and ecological context, then studies in-depth specific system components at animal level. Focus is given on cow's health and reproductive performance and their mutual relations regarding biological problems and metabolic events in lifetime. Genetic selection has resulted in considerable increases in production levels of the Holstein breed, but associated with this favourable development, animals selected for high production efficiency seem to be more at risk for behavioural, physiological and immunological problems. Finally, by integrating public concern at society level and productivity aspects at production system level, a general framework for monitoring sustainability is proposed within the context of the dairy systems. Important indicators for on-farm sustainability evaluation are identified and discussed.

Keywords: sustainability, Holstein cows, Brazil

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Beatriz

in memory of my father,
friend and great scientist
Dimas Waltrick
(1930 – 2000)

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Chapter 1

CHAPTER 1

GENERAL INTRODUCTION

1. Sustainability Assessment

Sustainability is one of the buzzwords of our time; it is often used as adjective to express the aim of a certain activity, such as sustainable agriculture and sustainable development (SD). Agricultural sustainability refers to production of agriculture over time. As the word sustainability is used abundantly, its perception is likely to differ among agricultural production systems and stakeholders, such as farmers, nature conservationists, policy makers, researchers, consumers, etc. However, all stakeholders agree on the importance of ensuring that agriculture production systems should be sustainable, expressing the concern about sufficient capacity of adapting to current and future demands, within a time horizon, aiming at sustainable agricultural development.

The development of agricultural systems in the last century has been towards intensification of resource use, eventually giving rise to concerns with respect to environmental, social and economic impacts of such activities in the short and long term. Within the Brazilian agricultural sector, the dairy system is an important production system. In dairy systems, sales of animals and dairy products such as milk, cheese and yoghurt are the main revenue-generating activities of the farm, however, crops, pastures and forage are also produced, to feed the dairy cows and/or for extra farm income.

2. Problem definition

In South America, as everywhere, dairy production systems are continuously developing under the influence of external and internal forces, and among the suggested improvements is the use of the Holstein breed, based on its high capacity for milk production. The use of exotic European breeds with a high production potential in a tropical country such as Brazil, is very management-demanding and can be problematic, if environmental conditions can not be controlled and management and nutrition of the animals are sub-optimal. Therefore, most Holstein dairy farms in Brazil are semi-intensive or intensive production systems, characterised by high levels of external inputs and controlled environments. These dairy production systems are developing towards high production levels, associated with use of high input levels and advanced technology as the only way of maintaining technical efficiency. . However, the associated high production costs appeared economically non-sustainable in Brazil, a country with weak agricultural policies, where subsidies are very limited and economic crises occur regularly.

Holstein dairy systems in Brazil have been studied extensively, and many positive and negative aspects have been reported separately, but an integrated study, dealing with the various facets of sustainability is lacking. Especially economic and nutritional aspects have been exhaustively reported, but no evaluation has been found dealing with the question whether activities and choices in these dairy farming systems contribute to their sustainable development.

Genetic selection has resulted in considerable increases in production levels of the Holstein breed, but associated with this favourable development, animals selected for high production efficiency seem to be more at risk for behavioural, physiological and immunological problems. These seem to be undesirable (co)related side effects of selection for high production efficiency, with respect to metabolic, reproduction and health traits. Knowledge of biological backgrounds and the effects of management will offer the opportunity to understand, anticipate and prevent undesirable problems related to the Holstein breed and its dairy system.

This thesis contributes to development of a framework to evaluate the sustainable development of the dairy production system in Brazil, based on the contribution of Holstein cows, by integrating public concern at society level and productivity aspects at production system level. Such a framework may serve as a tool for supporting decision making for different stakeholders. Different dairy production systems will be discussed to identify relevant sustainability indicators to measure the contribution of Holsteins to system SD, among others in terms of breed choice, i.e. pure-bred or crossbred.

This study starts by defining the context of dairy production systems with a system behaviour analysis and its important characteristics, and then focuses on the Holstein breed contribution and its characteristics in the production system, analysing mainly at animal level.

3. Objectives and research questions

Dairy production systems in Brazil are constantly developing and innovating . It is important to ensure that the proposed innovations are positively contributing to sustainable system development. The intensification of resource use increases concerns about sufficient capacity of adapting to current and future demands and about environmental, social and economic impacts. The Holstein breed is often selected as the best choice for dairying, because of its high capacity for milk production, but they are relatively ‘fragile’ animals, that are very demanding in terms of management, which implicitly requires farm adaptations, and for most Brazilian dairy farms it has some constraints.

The challenge is to understand the development of dairy farming systems and monitor their sustainability, from a multidimensional perspective, i.e. considering Ecology, Economy and Society (EES issues). By monitoring the developments, useful information may be provided to support farmer’s decision making. The study should yield prospects and constraints for Holstein dairy farming and their implications for the Brazilian dairy system as a whole, at society level and at production system level.

3.1 Research questions

The research questions formulated on the basis of the objectives were:

- How does the Brazilian dairy system perform, what are its characteristics, structure and development in time?
- Are high-yielding cows more likely to be culled for health and reproduction problems? Is it possible to identify these cows to prevent problems in early stages to reduce involuntary culling and increase longevity?
- Does genetic selection for early and high production affect the age at maximum production in the animals' life? Does it affect reproduction performance?
- How can we evaluate the effect of activities at production system level on the system's sustainable development? Would the impact be the same in different production systems (scenarios)?
- What are the major strong EES points of and the constraints for Holstein dairy systems in Brazil?
- How can we measure sustainability of dairy systems in Brazil from a large range of existing systems? How can we provide useful information for decision making for farmers in Brazil with respect to system sustainability?

Derived from the broad objective as starting point, other specific objectives of a more practical nature related to the dairy system and the use of Holstein cows have been formulated. Therefore this research will investigate the contribution of Holstein cows to sustainable development of dairy systems in Brazil.

3.2 Objectives:

1-To analyse the Brazilian dairy production system, focusing on system behaviour and its characteristics, evaluating system sustainability during crisis time.

2-To identify culling factors and to analyse the relation of culling with level of milk production. Evaluation of the incidence of problems at animal level, such as reproduction and health problems, in relation to intensity of milk production.

3- To analyse the effects of genetic selection for early and high production on the age at maximum production in the animal's life. With focus on effects of increasing genetic production potential on lifetime milk production and reproduction in Holstein dairy systems in Brazil, the objective is to identify age at maximum milk production and number of services needed per conception, in relation to genetic production potential.

4-To define a general framework for sustainability analysis for different dairy farming systems in Brazil, by identifying the major strong EES points and constraints. The integrated social, economic and environmental methodology should provide information in support of decision making for dairy farmers regarding SD. The general framework will refer to a grazing dairy system. Furthermore, the possible use of the framework to different scenarios will be discussed by evaluating the impacts of changes in activities on the sustainability indicators proposed.

4. Scope and organisation

Although focused on the Holstein dairy breed, this thesis is fundamentally concerned with understanding the development of dairy farming systems in Brazil. Specifically, monitoring their sustainability, using the contribution of Holsteins to exemplify the effect of changes on sustainability indicators, provides useful information in support of farmer's decision making for the complete range of existing dairy systems, based on the major strong EES points.

The core chapters were developed to integrate information from different levels, i.e. society level, production system and animal level, through the use of relevant indicators.

This thesis is organised in seven chapters. Most of these individual chapters provide an extensive literature review on the subject. The following paragraphs provide a short overview of all chapters, and a schematic outline of the steps carried out in this study.

Chapter 1: Starts with a description of the sustainability assessment and the problems identified for Brazilian dairy systems, followed by the definition of objectives and research questions. The chapter ends with an outline of the thesis contents.

Chapter 2: Brings a detailed description of dairy production systems in Brazil and the dairy sector in relation to sustainable development, with emphasis on Holstein production systems.

Chapter 3: Presents the development of the Holstein dairy system in Brazil, evaluating system sustainability during crisis time, based on changes in system aspects such as productivity, stability and resilience, and equity. Sustainability indicators are used to describe aspect changes during crisis.

Chapter 4: Explores culling factors in relation to milk production of the first lactation, focusing on factors and problems that influence longevity of Holstein dairy cows in Brazilian herds. Because culling is a subjective decision, mainly based on farmer’s perceptions, culling reasons were identified and classified into culling factors. Models have been developed to predict culling risk variation in time, that can be applied in support of herd management and culling decision planning.

Chapter 5: Introduces the theory on lifetime milk production and the peak or maximum. Peak milk production is expected at maturity, however, most high yielding cows show peak production before the cow reaches maturity. Increased milk production as a result of genetic selection and the correlated negative (side) effects, such as biological changes, behaviour, health and reproduction problems are discussed.

Chapter 6: Presents a framework for sustainable development evaluation for Brazilian dairy farming systems. This framework is a tool to evaluate sustainable development and to provide information to support decision-making in existing dairy systems. An integrated social, economic and environmental accounting framework is proposed that can be applied to different scenarios to evaluate impacts of activities on sustainability indicators.

Chapter 7: Evaluates the main conclusions of each chapter and of the thesis as a whole. It provides answers to the research questions as well as recommendations.

Chapter 2

CHAPTER 2

SUSTAINABILITY AND SYSTEM CHARACTERISATION: THE BRAZILIAN DAIRY SYSTEMS

1. Sustainable development (SD)

Defined in terms of a systems approach (Dillon, 1992), a production system is a result of the relationship between inputs, management and technologies used on a particular resource base to produce outputs within a given socio-economic context. This dynamic character of production systems requires proper monitoring of its development over time, by using informative measurements within the context.

Practically, when monitoring sustainable development (SD) of production systems we are facing a complex dynamic evaluation, which makes a one-sided approach, only based on individual indicators without the context of development, irrelevant.. It is important to integrate the information within the context. The definition of sustainability used in this thesis is based on the World Commission on Environment and Development report (Brundtland, 1987):

“*…a sustainable development meets the needs of the present without compromising the needs of future generations…*”

Implicit in this concept of sustainable development we find not only the need to develop a quantitative measure of sustainability, but also the need to monitor it over time. Because sustainability is a concept too elusive to be measured directly, it is necessary to evaluate indicators and monitor their multidimensional development over time. The multidimensional character refers to the three main sustainability dimensions, which are: Ecology, Economy and Society (EES issues) (Brundtland, 1987; Becker, 1997; Cornelissen et al., 2001). Within each dimension, issues of concern are being discussed at society and production system level. Many issues for dairy production systems have been identified already by stakeholders and discussed in the literature (Becker, 1997; Dore, 1997; Gomes, 1999).

Based on the three dimensions of concern, three essential criteria have been established for sustainable agriculture: it should be ecologically sound, economically viable and socially just. The question is now how to determine whether a certain production system is fulfilling the criteria from a sustainability perspective. That requires collecting all possible information that, integrated, would allow evaluation of the degree of sustainability of a system . The necessary information can be derived from indicative measures or "indicators", which will give objective information about the issues of the dimensions of concern.

2. The choice of Sustainability Indicators (SI)

The assessment of sustainability indicators is a very important step towards quantification of sustainability. Criteria for translating sustainability issues into measurable indicators have been proposed in many studies (Hansen & Jones, 1996; Becker, 1997; Dore, 1997; Cornelissen et al., 2001).

In dairy production systems, measurable indicators are phenomena occurring in the production system that should describe the performance of each production system in its specific context, measured over time horizons and thereby cover the three EES dimensions. Each individual SI can become more informative when it is placed in the whole context of the farming system. Important indicators at dairy production system level will be studied in detail in this thesis. In the future, the results of this thesis could be applied in the assessment of the contribution of each SI to the overall process of sustainable development. Analysing overall SD is important at society level for policy makers in support of decision making. However, analysing overall SD is not part of this thesis. The study described in this thesis focuses on indicators at dairy production system level and the related issues of system contribution to sustainable development. By monitoring dairy production systems, SIs can become very informative tools in supporting farm decision making. This subject will be deeply discussed in Chapter 6 of this thesis.

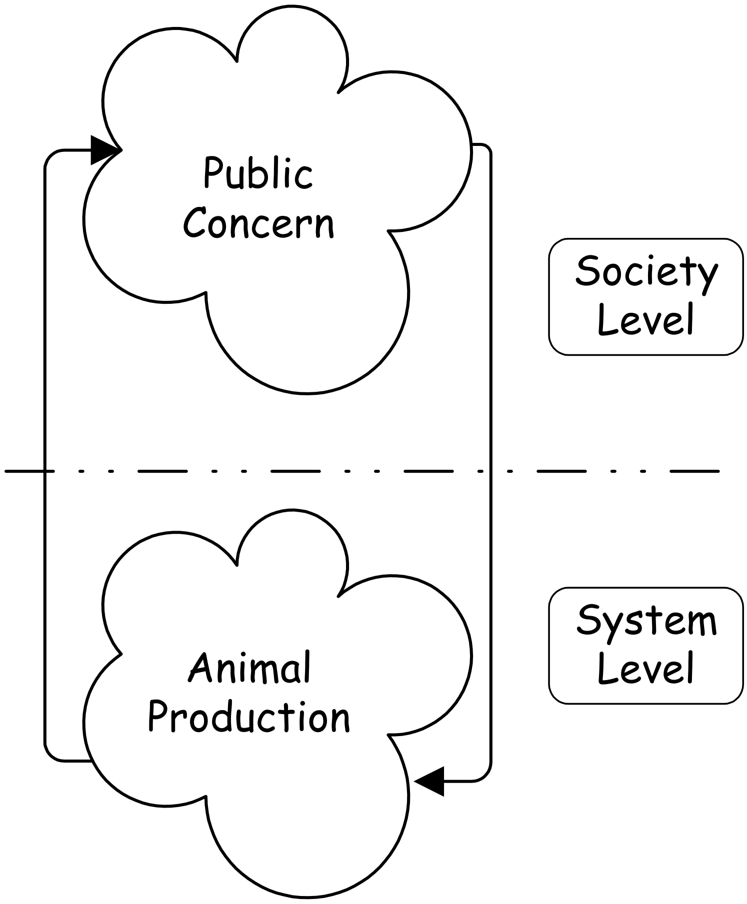
3. Sustainability characterisation

It is very important to sustainable development to understand the impact of activities at the farm level to the sustainability of a production system. It leads to the need for developing appropriate methods to measure and evaluate sustainability, through the assessment of relevant sustainability indicators. The evaluation of indicators provides important insights in the performance of system activities regarding social, economic and environmental issues (EES issues), thus contributing to characterisation of system sustainability.

Various sustainability indicators (SI) have been proposed to monitor and evaluate resources of production systems, with a bias, however, towards economic indicators. In practice, limited information is available for Brazilian dairy production systems on environmental and social issues. Therefore, the urgent need for overall sustainability characterisation as a useful tool in support of decision-making at production system level, as well as information at society level.

The term sustainability is elusive and the stakeholders, either those *influencing the functioning* of the production system or those *depending* on its functioning, have different perceptions about sustainability. Thus, sustainability may have different meanings at different levels. Public concern about activities at animal production system level promotes changes at farming system level, thus becoming a farm concern. The farm concern deals with the question how to keep the system running based on more sustainable activities as proposed by the public concern. When farmers change activities at farming system level, there will be an impact on sustainability as perceived at society level, completing the cycle (Figure 1). Therefore, it is postulated that sustainability is a soft issue, however it is linked to hard measurements, like pollution, erosion, use of resources, etc.

Figure 1. The sustainability situation (Cornelissen, 2003)



When sustainability of a particular system is characterised, potential benefits of applying the concept of agricultural sustainability arise. This provides feedback about future impacts of current decisions, and focuses on research and intervention by identifying constraints. Characterisation includes both quantification and diagnosis of constraints (Hansen & Jones, 1996).

Generally, evaluation of indicators is informative, but monitoring them over time is desired. However, evaluation of indicators may lead to adaptive changes in the production system, which in turn can affect the indicator, thus making monitoring over time very complicated if indicators are dynamic.

Furthermore, especially in Brazil, where a variety of dairy production systems can be recognised, their variability is proportional to the size of the country, associated with differences in cultural traditions and climate conditions. Farming systems evaluation in Brazil within this variety in production systems must be considered an important aspect of sustainability assessment. The Brazilian dairy farms range from low-input production systems with high-Zebu grade herds under extensive grazing on tropical pastures to capital-intensive confinement systems with purebred Holstein herds.

The challenge is to develop a methodology for characterisation of sustainability that applies to most Brazilian dairy production systems, not only evaluating and monitoring sustainable development, but providing information for decision making, on the basis of identification of the major strong EES points of each system and their constraints. Such a framework is presented in Chapter 6. The availability of data and the relative importance of the Holstein breed in the Brazilian dairy sector make it important to examine their contribution to sustainable development. An integrated social, economic and environmental accounting framework is applied to different scenarios to evaluate the impacts of changes in activities on the sustainability indicators presented.

4. General analysis of production systems

A production system is defined here as a population of individual farms that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate. Depending on the scale of the analysis, a production system can comprise a few dozen or many millions of households. The classification of production systems of developing regions according to FAO (FAO, 2003) has been based on the following two criteria:

available natural resource base, including water, land, grazing areas and forest; climate, of which altitude is an important determinant; landscape, including slope; farm size, tenure and organisation; and

dominant pattern of farm activities and household livelihoods, including field crops, livestock, trees, aquaculture, hunting and gathering, processing and off-farm activities; and taking into account the main technologies used, which determine the intensity of production and integration of crops, livestock and other activities.

4.1 The Brazilian dairy production systems

The dairy production systems in Brazil can be classified in *Intensive* and *Extensive* systems. In *Extensive Systems* animals are kept continuously on pasture, at a low livestock density. These extensive systems are prevalent where large areas of natural and/or cultivated pastures are available; therefore, seasonality plays an important role affecting the productivity of the pasture and hence milk production in the course of the year.

Within the *Intensive Systems*, three different systems can be distinguished: *Confined, Semi-Confined* and *Intensive Grazing*.

- *Confined*: animals are kept indoors with no grazing, and fed a total mix ration (TMR). This system is also called “free-stable”, “free-stall” or “zero-grazing”.

- *Semi-Confined:* according to farm characteristics and pasture availability, the animals are kept alternately in the stable and on pasture. Milking takes place in the stable, after which the milked cows are released in the pasture for grazing (if available), ruminating and resting, which can be during day or night.

- *Intensive Grazing*: animals are kept continuously on pasture and more than 50% of dry matter intake (DMI) comes from grazing. Intensive grazing requires high quality pasture management. This system is often referred to in the literature as MIG (Management Intensive Grazing). In the MIG system, animals at a high stocking rate are rotated through several paddocks at short time intervals (12–24h, in some cases one to three days), so that animal performance is maximised and the pasture has time to recuperate between grazing periods.

4.2 Dairy Breeds

Crossbreds produce more than 80% of the total milk produced in Brazil. Mostly common crossbreds are the different crossbreeding levels of Holstein and Zebu breeds, such as Gir and Guzerá. Crossbreeding between Zebu and Holstein cattle is popular due to the dual production purpose - milk and beef - and the better adaptation of the crossbred offspring to tropical conditions, compared to their Holstein parents (EMBRAPA, 2003). The genotypic preference is strongly associated with the levels of farm management, capital investment and expected productivity of labour and capital. About 50% of the total milk in Brazil is produced on farms with a production level below 200 kg milk per day, representing 90% of the total number of dairy farms. Average milk yields are 47 liters per farm/d and 950 kg per cow/year, which is substantially below the average production in the neighbouring country Argentina (4500 kg milk per cow per year) (Ostrowski & Deblitz, 2001; EMBRAPA, 2002c).

4.3 Dairy crisis in 1990

Since 1986, the Brazilian government policy has focused on increasing milk production and programs for research on more intensive dairy systems have been started. The National Dairy Cattle Archive reported an increasing number of registered animals. Unfortunately, in that same period Brazil entered a dramatic economic crisis, that reached its deepest point in 1990, following several plans from the government to stop inflation. The effect of this crisis and the new policy on the sustainability of the Brazilian Holstein dairy system was never analysed with the perspective of future developments of the Holsteins in Brazil. To understand and support this development, the effect of the economic crisis on the sustainability of the Holstein dairy system in Brazil will be analysed and presented in Chapter 3, on the basis of system properties such as productivity, stability/resilience and equity, using a Holstein data set of the National Dairy Cattle Archive.

Table 1. Milk production in 1998 in Brazil per state, ranked according to volume.

State rank	Volume (klyear)	%of Total	cumulative (Cum %)	area (km2)	Productivity per area(1)(2) (liters/Km2)	(liters per cow/year)(3)
1º Minas Gerais	5,700,987	28.4	28.4	587,172	9,709	1,386
2º Goiás	2,377,681	11.8	40.2	355,386	6,690	1,049
3º São Paulo	2,208,731	11.0	51.2	247,898	8,910	973
4º Rio Grande sul	2,194,992	10.9	62.1	282,184	7,779	1,737
5º Paraná	1,931,956	9.6	71.7	199,554	9,681	1,519
6º Santa Catarina	951,180	4.7	76.4	95,285	9,982	1,643
7º Bahia	772,967	3.8	80.2	561,026	1,378	464
8º Rio de Janeiro	540,769	2.7	82.9	44,268	12,216	1,208
9º Mato Grosso Sul	530,664	2.6	85.5	350,548	1,514	974
10º Espírito Santo	373,206	1.9	87.4	45,597	8,185	1,141
11º Mato Grosso	352,170	1.8	89.2	881,001	400	1,060
12º Ceará	318,635	1.6	90.8	148,016	2,153	819
13º Pará	309,150	1.5	92.3	248,042	248	449
14º Rondônia	288,964	1.4	93.7	243,044	1,189	979
15º Alagoas	212,646	1.1	94.8	131	7,838	1,450
16º Pernambuco	209,216	1.0	95.8	98,281	2,129	993
17º Paraíba	173,155	0.9	96.7	56,372	3,072	616
18º Maranhão	149,775	0.7	97.4	328,663	456	481
19º Rio Grande Norte	123,664	0.6	98.0	53,015	2,333	794
20º Tocantins	112,766	0.6	98.6	286,706	393	463
21º Piauí	63,861	0.3	98.9	250,934	254	403
22º Sergipe	59,975	0.3	99.2	21,994	2,727	896
23º Amazonas	55,723	0.3	99.5	1,564,445	36	541
24º Distrito Federal	31,417	0.2	99.7	5,200	6,042	1,006
25º Acre	30,281	0.2	99.9	152,589	198	583
26º Roraima	9,881	0.1	100	230,104	43	498
27º Amapá	2,758	0.0	100	140,276	20	539
T O T A L	20.087.171			8.504.184		

Source: Embrapa-Gado de Leite, 2002b

(1) Productivity per area = milk production/ state area in km2.
(2) Productivity per state, including dual purpose herds: milk, beef and both.
(3) Productivity per animal = milk prod. * 1.000 / productive cows.

From the beginning of the 1990’s, following the national economic crisis and associated with the new Mercosul agreement, the dairy sector changed markedly (Ostrowski & Deblitz, 2001; EMBRAPA, 2002a). The new marketing systems promote esterilized milk, also called in Brazil as long-life milk (UHT- ultra high temperature) Long-life milk has shown a very significant growth over the last 5-6 years, replacing the most common milk in market, the type C milk (the lowest quality milk in terms of processing).

After 1990, the government discontinued interventions; simultaneously, globalisation of the economy continued and awareness of consumers increased, resulting in many changes at production system level. Dairy farms were forced to intensify production, using more advanced technology to stay in business. Increasing farm productivity and improving product quality to become more competitive could only succeed when costs were reduced and production efficiency increased. For the dairy farmer this meant an increased demand for milk quality, regularity and large-scale production. Consequently, investments in milk cooling and managerial skills at farm level have become crucial, but for some small-holders realising these improvements is economically impossible. During the crisis in 1990, many farmers were forced to leave the dairy sector, and many small dairy industries went bankrupt. Without an industry for milk commercialisation, farmers found themselves without milk collection facilities and were forced to sell their milk in informal markets. Dairy industries that survived the crisis were mostly large multinationals with fixed routes for their milk-collecting trucks. In many cases it was not economically viable to change these routes to include milk collection from small-holders living in remote areas. Small-holders have been trying to join co-operatives or purchase collective bulk tanks, to replace the cans and become more attractive to the dairy industry.

In the period 1990-2000, 1.8 million farms (37% of the total number of farms) produced some milk, and probably 600,000 farmers left the dairy sector after the crisis in 1990. However, an outlook on the sector indicates that milk production increases, growing productivity levels and growing internal demand are expected to continue over the next years (EMBRAPA, 2001).

4.4. The Brazilian dairy sector

Brazil has the largest crossbred dairy herd in the world, always innovating in view of the big challenge of milk production in the tropics. Total milk production in Brazil is the fifth in the world, with an annual production of more than 20 billions litres in 1998 (Table 1). The climate of Brazil offers the potential to produce milk year-round. Optimal soil and tropical pasture management could improve pasture productivity, and with supplementation, milk productivity could increase from 1000 to 15000 kg/ha/year (EMBRAPA, 2003).

Average productivity of dairy farms in Brazil is low, compared to other South American countries, such as Argentina (Gomes, 1999). Many factors contribute to this situation, including low specialisation level of farms, utilisation of dual-purpose breeds and crossbreeds, and the national milk price control policy, that until 1990 regulated prices at national level and stimulated milk imports to meet the national demand (Santos & Vilela, 2000).

There is an industrial concentration of dairy processing, which is held by a small number of national and multinational firms (EMBRAPA, 2002c). It has been estimated that from the total milk produced in Brazil more than half is sold to the twelve largest dairy companies; the remainder is sold in informal markets directly to the consumer without industrial processing (Santos & Vilela, 2000).

According to studies on the Brazilian dairy sector (EMBRAPA, 2001), current structural changes will continue and the sustainability of the milk production systems in Brazil will strongly depend on the economic efficiency of the dairy farms. However, these are partial conclusions based on a limited scope of sustainability, which should be considered as *multi-dimensional*, including social, economic and environmental issues (EES issues). Sustainable development not only depends on economic success, but ecological and social aspects should also play an important role.

For example, at production system level, increasing milk production per cow to very high levels can negatively affect the sustainable development of the production system, by affecting the cow's health or reproductive efficiency. At society level, considering the social function of a production system, such as its contribution to maintaining rural employment, positively affects sustainable development.

Moreover, high quality management of resources at the farm may make a positive contribution to the quality of the natural resources. Under good management, livestock production can improve natural resource quality by rehabilitating degraded areas, by enhancing soil quality, and/or increasing plant and animal biodiversity. Generally, good management will be searching for win-win scenarios (economically and environmentally attractive). Therefore, not only economic objectives should be considered, but social and environmental objectives should also be taken into account.

The Southeast region of Brazil contributes the largest share to total production (Table 2), but its contribution has decreased in the last few years from 48 to 45%, and traditional beef cattle regions in central Brazil have moved towards dairy cattle (Figure 2). From 1990 to 1997, the Center-west region has increased its contribution from 12 to 15%, probably stimulated by facilities for credit, low prices of grains and land availability. The main trends in the dairy production sector now show a reduction in the number of small dairy farms, replacement of labour by capital, use of more specialized herds, enlarged scale of production and intensification, and the use of cooling systems through bulk tanks.

Because in Brazil dairy farming is a traditional activity, it is found in all the five large regions of Brazil (Figure 2), with the South and central regions as the most productive. Milk production plays an important role in the national economy and in the culture of rural communities. Milk production represents about 10% of the Internal Gross Product of the Brazilian agricultural sector. Dairy imports account for about 10% of the domestic consumption of all dairy products.

Since the discovery of Brazil, beef and dairy cattle have been introduced in Brazil by European (mostly Portuguese) colonizers. During the last six decades, Holstein performance has been properly recorded, since they were introduced in the Brazilian dairy herd to improve productivity.

Table 2. **Distribution of Holsteins in Brazil according to region.**

DISTRIBUTION OF HOLSTEINS IN BRAZIL ACCORDING TO REGION, estimative over the last 10 years		
REGION	**HOLTEINS PUREBRED NUMBER OF ANIMALS**	**HOLSTEINS PUREBRED BY CROSSING AND CROSSBREDS NUMBER OF ANIMALS**
NORTH	42	83
NORTHEAST	7.469	5.461
SOUTHEAST	147.986	213.109
SOUTH	70.532	253. 061
CENTER WEST	8.007	74.674
BRAZIL	227.316	546.388
BRAZIL	TOTAL: 773.704	

Source: Holstein Breeders Association of Brazil (SCL, 2002)

In practice, the balance between positive and negative effects of using the Holstein breed can not be judged properly if the processes at system level and the production costs of the farming activity are not known by management, which can result in wrong decisions. To support decision making, all indicators should be related to activities in the production systems and evaluated with respect to their contribution to sustainable development. The question then focuses on how far the choices that are made within a certain production system are contributing to its sustainable development. In this study we will focus on the contribution of Holstein cows to the sustainability of dairy systems in Brazil.

Figure 2. **Milk production distribution in Brazil in 1998.**
(Selected area represents 80.2% of total production)

Source: EMBRAPA-Gado de leite, 2000.

4.5 The Holstein dairy systems

The Holstein dairy system can show high production performance under adequate management (Ribas et al., 1983a; Zambianchi, 1996). It is very important to know whether a choice should be made for a demanding breed and whether that contributes to dairy system SD or whether it is only compensating for all investments or other negative effects. In fact, very little is known about the impact of use of Holsteins on SD in dairy farming systems in Brazil. In the last two decades many positive and negative effects have been reported. Most of the dairy farms needed adaptations in terms of housing, bedding, feeding strategy and management, after the decision to use the Holstein pure breed to realise production increases.

More than 75% of the total milk production in Brazil originates from the South and Central regions (Table 1), where most dairy farms of pure Holstein breed are located. Until January 2000, in total 1,964,498 animals were registered at the Holstein Breeders Association of Brazil, with about 85% of the Holstein farms located in the states of Paraná, Minas Gerais, São Paulo and Goiás (SCL, 2002), representing more than 95% of the total number of Holsteins in Brazil (Table 2).

Within the regions, a large variation is found in Holstein dairy systems: organic and conventional dairy husbandry; production scale ranging from small to large; external inputs ranging from low to high; from intensive rotational grazing to conventional confined systems.

Climatic and cultural variation among those regions explains part of the large variation in dairy systems. The South has cold winters, with high temperatures in summer and with rainfall spread throughout the year; the Central regions are characterised by dry winters with mild temperatures, but the summers are hot and rainy (EMBRAPA, 2003). Due to their abundant water availability and mild climate, the South and Central regions have high potentials for dairy farming systems. However, areas such as the Extensive Mixed Farming System of the Central region of Brazil, are characterised by fragile soils with nutrient limitations, restricting their agronomic potential and influencing the strategic approaches to potential diversification of farm activities, to avoid even more pasture and soil degradation.

Evidently the dairy farming system sector is in transition: dairy farms are moving from traditional dairy areas in the Southeast to Central areas in Brazil, while at the same time the composition of the Brazilian dairy herd is changing. Contrary to the development in the early 1990’s, when the Holstein herd was increasing substantially, the actual number of Holstein cows registered during the last 5 years has been decreasing considerably. Simultaneously, Crossbred Girolandos (Gyr and Holstein) are increasing in all regions of Brazil. Since a few years, registration of Girolando as a special crossbred has started.

Holstein cows in Brazil are still the source of an important part of the national milk production, as pure breed or as crossbreed. Farmers and breeders continuously put efforts in improving their production performance (Ribas et al., 1983b; Queiroz et al., 1991; Ribas et al., 1993). Since their introduction in Brazil, there has been continuous import of animals and semen, and more recently of embryos. In the last decade, imported Holstein semen, mostly from North America, constituted 65% of the total semen used in the Brazilian herd (Costa et al., 1999). This import policy has introduced the breeding strategies of the exporting countries into the Brazilian herd, with all its positive and negative effects. Through genetic selection productivity per cow has increased (Table 3), but health and reproduction problems also become more evident. Problems associated with production intensification will be discussed in Chapter 4 and Chapter 5.

The economic losses caused by involuntary culling for health and reproduction problems of high yielding Holstein cows are already a great concern to farmers and breeders. Reproductive problems are the most expensive exit reason (Seegers et al., 1998, Olori et al., 2002) and replacement of highly productive cows is undesirable. Therefore, various aspects at animal level should be better understood to stimulate development towards greater sustainability.

Reproduction of Holstein cows in Brazil, even under good management practices is becoming problematic as has also been reported in other countries, such as The Netherlands, Australia, New Zealand and Canada (Meuwissen et al., 1995; Seegers et al., 1998; Vollema, 1998; Veerkamp, 2000; Pryce et al., 2001). Holstein cows need more services per conception than other dairy breeds, such as Jerseys (Oldenbroek, 1988). The anticipated age at first service has been anticipated by genetic selection (13 to 16 months), with first calving expected at 22 to 25 months of age. The gestation length is on average 280 days, varying between 261 and 293 days. Calving interval is between 15 and 17 months on average (ABCBRH, 2003).

However, in 2000 there was a reduction of 11.6% in Holstein semen imports (Madalena, 2003), while the use of national Holstein semen remained constant. The “genotype-environment” interaction plays an important role in farming system decisions regarding breed choice. Although Holsteins show high production performance in Brazil, farmers need to reduce animal maintenance costs. Breeders are thus selecting more robust animals, more adapted to the Brazilian environment. This trend results in changes in breeding strategies and in the future of the Brazilian dairy herd.

A reduction in the number of imported animals and in imported semen has become evident in the last five years. The reducing number of farms with registered pure Holstein animals is also witness of this new trend. In 2002, the Milk Recording Service (SCL) had 87,769 cows registered and 53,406 lactations recorded from 680 Holstein farmers (Table 4), in contrast to 96,649 animals with 66,014 lactations recorded from 790 Holstein farmers in 2000.

Table 3. Average milk production in 2002 of Holstein dairy cows in Brazil

<table>
<tr><td colspan="2">Lactation adjusted to 305 days with 2 milkings per day</td><td>7,280 kg</td></tr>
<tr><td colspan="2">Lactation adjusted to 305 days with 2 milkings per day, only adult cows</td><td>8,130 kg</td></tr>
<tr><td rowspan="2">*2 milkings per day</td><td>For 305 days</td><td>6,693 kg</td></tr>
<tr><td>from 306 to 365 days</td><td>8,574 kg</td></tr>
<tr><td rowspan="2">*3 milkings per day</td><td>For 305 days</td><td>7,975 kg</td></tr>
<tr><td>from 306 to 365 days</td><td>9,993 kg</td></tr>
</table>

Source: Holstein Breeders Association of Brazil (SCL, 2002)

Table 4. Holsteins registered at SCL (Milk Recording Services) in Brazil.

	1999	2000	2001	2002
Number of animals registered at SCL	100,802	96,649	97,226	87,769
Number of lactations	66,714	66,014	67,578	53,406
Farmers registered	888	790	744	680
Average herd size (number of animals)	75	84	90	79

Source: Holstein Breeders Association of Brazil (SCL, 2002)

5. The fragile Holstein cow

Holstein cows, having a high potential for milk production, today are fragile animals, showing a high risk of involuntary culling for reproduction and health problems. Cows are removed from the herd involuntarily before reaching their maximum production potential. However, culling is not a biological phenomenon as such, but results from a human decision.

Studies on Holsteins and the genetic antagonism between production and reproduction traits has shown that genetic selection for production traits only has resulted in a reduction in fertility and fitness of the Holstein cow (Hoekstra et al., 1994; Meuwissen et al., 1995). The emphasis on genetic selection for milk production only, as has been the prevalent trend in the Western world for decades, exposed Holstein cows to high involuntary culling rates, above 30% of the productive herd. Especially high yielding cows are at risk for culling for health and reproductive disorders (Vollema, 1998). Genetic selection based on only a few production traits however, can lead to undesirable correlated biological changes (Steverink et al., 1992), such as behaviour, health and reproduction problems. These biological problems finally result in culling of these animals.

Culling reasons as identified by farmers are subjective characteristics, but despite this fact, analysing this information is very useful in the search for sustainability indicators and for adapting herd management and herd-health schemes. If high yielding cows are more likely to be culled for health and reproduction problems, direct identification might make it possible to pay special attention to these animals to positively influence longevity and avoid involuntary culling. However, it is not clear by how much longevity can be increased by better management and by prevention or control of diseases. As high yielding cows have been intensively genetically selected for production traits, genetic antagonism between production and reproduction plays an important role in fertility and fitness.

There is a tendency for high yielding cows to reach their maximum milk production potential very early in life, even before maturity. This may lead to the wrong idea that maturity has been anticipated, while probably high metabolic demand resulted in biological problems that caused an early decline in production before maturity.

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Chapter 3

CHAPTER 3

EFFECT OF ECONOMIC CRISIS ON SUSTAINABILITY ASPECTS OF HOLSTEIN DAIRY SYSTEMS IN BRAZIL

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ABSTRACT

This analysis presents the development of the Holstein dairy system in Brazil, evaluating system sustainability during crisis time, based on changes on system's aspects as productivity, stability and resilience, and equity. Sustainability indicators are used to describe changes of system aspects during crisis.

Holstein cows registered at the National Dairy Cattle Archive from 1980 to 1992 were analysed, including the crisis period around 1990. The large period covered by the analysis can show terms of comparison. The Holstein dairy farming system showed high stability and resilience in terms of milk production, although it is evident its high sensitivity to disturbances.

(Key words: Sustainability, dairy system, Holstein, milk production, Brazil)

INTRODUCTION

Average productivity of dairy farms in Brazil is low, compared to other South American countries, such as Argentina (Gomes, 1999). Many factors contribute to this situation, including low specialisation level of the farms, utilisation of dual-purpose breeds and crossbreeds, and the national milk price control policy, that regulated prices at national level and stimulated milk import to meet the national demand (Santos & Vilela, 2000).

The Holstein dairy farming system can show high production performances under adequate management (Ribas et al., 1983a; Zambianchi, 1996). Holstein cows in Brazil are responsible for an important part of the national milk production, as pure breed or as crossbreed. Farmers and breeders continuously put efforts in improving its production performance (Ribas et al., 1983b; Queiroz et al., 1991; Ribas et al., 1993). Since its introduction in Brazil, there has been continuous import of animals and semen, and more recently of embryos. In the last decade, import of Holstein semen, mostly from North America, has increased to 65% of the total semen used in the Brazilian herd (Costa, et al., 1999). This import policy has introduced the breeding strategies of the exporting countries into the Brazilian herd.

Since 1986, the Brazilian government policy has focused on increasing milk production and programs for research on more intensive dairy systems have been started. The National Dairy Cattle Archive had increased the amount of animals registered, unfortunately in that same period, Brazil was going into a dramatic economic crisis. The crisis reached its deep point in 1990, after several plans from the government to stop inflation. The effect of crisis and this new policy on the sustainability of the Brazilian Holstein dairy system, however, is not known. What is the future development of the Holsteins in Brazil? To support this development, the National Dairy Cattle Archive (Empresa Basileira de Pesquisa Agropecuaria - Centro Nacional de Pesquisa em Gado de Leite EMBRAPA – CNPGL) was established, among others to manage data registered by the milk recording services of the Brazilian Holstein Breeders Association. This data set can be analysed to provide possible answers to this question.

The objective of the present study is to analyse the effect of economic crisis on sustainability of the Holstein dairy system in Brazil, based on system properties as productivity, stability/resilience and equity, using the Holstein data set of the National Dairy Cattle Archive.

MATERIAL AND METHODS

The Holstein farms

Holstein farms in Brazil differ from the "average" dairy farm in specialisation level, and are considered comparatively modern farms. At Holstein farms, high levels of inputs are used, such as concentrates, specialised equipment, automatic milking machines, and veterinary care. Some farms even use computerised feeding systems, and information and decision support systems with customised software. Therefore, the Holstein dairy system in Brazil is expected to be more susceptible to economic changes and market fluctuations through the years than less intensive dairy systems (Gomes, 1999).

The Holstein breed

Although the Holstein breed has been introduced in Brazil decades ago, the Holstein dairy system is still characterised by import of semen and animals to improve the herd genetically (Costa et al., 1999). In most exporting countries, the Holstein breed has been intensively selected for high and early production. Studies in Brazil have indicated lack of understanding about this breed under the Brazilian climate conditions and management practices (Nobre et al., 1985; Vasconcelos et al., 1989; Polastre et al., 1990).

Definitions used

In the present study, the following definitions are used:

Sustainability: Also referred to as sustainable development, is the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Becker, 1997). Sustainability of a system links continuity to context-dependent economic, ecological and societal (EES) issues. It is not considered an endpoint, but an ongoing dynamic development (Cornelissen et al., 2001; Ludwig et al., 1997). Aspects of sustainability include:

Productivity: The quantity of product or output from an agroecosystem per unit of some specified input (GIRA, 2001; Gerber, 1990; Marten, 1988).

Stability: a tendency of the variables or components of a system to remain within defined and recognisable limits, despite the impact of disturbances. Moreover, it is the ability of a system to persist and to remain qualitatively unchanged in response either to a disturbance or to fluctuations of the system caused by a disturbance (Heylighen, 2000b; Ludwig et al., 1997; Marten, 1988).

Resilience: the measure of a system's ability to remain within a domain of stability in response to fluctuations of the system by a disturbance, which means the ability of the system to return to that stable domain having once left or to absorb changes and still persist (Heylighen, 2000a). So, resilience depends on the kind and effect of the disturbance: the faster the system recovers, the higher its resilience.

Equity (or Equitability): The system's capability to distribute all benefits, costs, and the amount of production fairly among its stakeholders (GIRA, 2001; Marten, 1988).

Data

The data analysed consist of complete lactation records of Brazilian pure Holstein dairy stock, registered at the National Dairy Cattle Archive (Empresa Basileira de Pesquisa Agropecuaria - Centro Nacional de Pesquisa em Gado de Leite EMBRAPA – CNPGL) from 1980 to 1992, period which includes the national economic crisis in 1990. From 1991 to 1992, it is expected that the system would be recovered (Freitas et al., 2000). Although only a small percentage of the Holstein cows are monitored at the milk recording system, the national data set contains 154,053 lactation records of cows milked once, twice or three times a day. In the most representative dairy system from South and Southeast Brazil, cows are milked twice daily. The 118,802 records representing this system were selected from the total data set and farms are located in South and Southeast regions of Brazil: Minas Gerais, São Paulo, Paraná, Santa Catarina, and Rio Grande do Sul. The selected data set contains cow's individual information about date of birth, date of calving, age at calving, calving interval, season, lactation number, lactation length, milk and fat production per year and per lactation, milking frequency per day, location of the farm, and herd code.

Variables

Number of records per lactation number per year:

The total of 118 802 records contains a variable number of records per participating farm. Not all animals of a farm are included in the milk recording system. The total number of records was divided into groups, according to year of production and lactation number. Lactation classes were 1, 2, 3, 4, 5, 6, and a final class (7-10).

Lactation milk and fat production:

Individual cows of this population show a large variation in lactation length. To make lactation milk and fat productions comparable, individual production levels were adjusted to a lactation period of 305 days (Ribas et al., 1983a), using the equation proposed by Poutous and Mocquot (Poutous and Mocquot, 1975).

$$Y_{305} = 405/(100+d)*Y_d$$

Where: Y305 is the estimated lactation production at 305 days; d is the observed lactation length and Yd is the observed lactation production at day d.

Average lifetime milk production

By classifying the records into groups according to year of birth and year of first lactation, the records can be grouped by lactation number and average milk production per lactation number per year can be calculated. A group of animals having their first lactation in the same year can be followed in subsequent years. These groups are indicated as *year groups*. Average milk production was calculated for each year group as the median value for 305 days. When average milk production levels per lactation per year for these year groups are graphically presented, a curve result connecting the points for each lactation number. This analysis is called lifetime milk production analysis. A 'normal' lifetime milk production curve would have an increasing phase in the beginning, where production levels increase with increasing lactation number, reaching a maximum at a specific lactation number, after which milk production levels continuously decrease for the subsequent lactations. For this data set, maximum production is around the 5th lactation. This procedure allows comparison among different year groups and comparison of yields over lactations within each group, neglecting the age effect.

Milk availability

Total milk availability is defined as total median milk produced by Holsteins multiplied by the total number of records. When divided by the total number of inhabitants in the region under study, it is called milk availability per capita.

Total national milk availability per capita is calculated as total milk production divided by the total population of Brazil (IBGE, 2001; EMBRAPA-CNPGL, 2000).

The Holstein milk availability analysis is presented in a figure as a time trend for the period 1980 to 1992 and compared with the national milk production per capita.

System aspects and indicators

The approach to sustainability as an ability of farming systems to continue into the future is characterised by time trends (Hansen & Jones, 1996). The time trends approach expresses sustainability in terms of the direction and degree of measurable changes in system properties (or system aspects), as stability and resilience, through time (Hansen, 1996).

The behaviour of the Holstein system is the result of a complex chain of factors. In the sustainability analysis, it is necessary therefore, to identify and characterise multiple qualitative and quantitative indicators of sustainability that represent the multidimensionality of system aspects and the relationships among those aspects.

Many aspects of an agroecosystem can contribute to its sustainability, but certainly stability and resilience play an important role, because of their close relationship. Productivity is also related to sustainability. High productivity may be associated with higher or lower stability. For example, if production is based on high-yielding Holstein cows, that are more susceptible than other breeds to fluctuating economic and management stresses, oscillations in system productivity may occur.

However, a system with low stability can show high resilience, if it shows a high capacity to recover within a short time, which would make it more sustainable in the long term. By relating patterns of system aspects to sustainability indicators, it may be possible to identify mechanisms underlying associations between system aspects and sustainability (Marten, 1988).

The selection for aspects and sustainability indicators was strongly determined by available information in the data. Productivity will be related to milk and fat production per year of production and per lactation number. Stability and resilience will be related to several indicators: a) system structure in number and proportion of animals per lactation number and year of production; b) median milk and fat production; and c) milk production per age group. Equity will be related to milk availability per capita.

Statistical methods

Using the SAS program (SAS, 1985), a data distribution analysis was performed for milk yield and fat production. As the data showed a skewed distribution, the median or mid-point, was considered a better measure than the arithmetic average to represent the results. The difference between the quartiles Q3 and Q1 (75% and 25%, respectively) represents the variation or range.

Derived measures are used in the milk availability per capita analysis (IBGE, 2001; EMBRAPA-CNPGL, 2000).

RESULTS AND DISCUSSION

Productivity of the system

Average national annual productivity (EMBRAPA-CNPGL, 2000) increased from 676 kg/cow in 1980, to around 826 kg/cow in 1992. Annual productivity of the Holsteins in this data set however, showed some oscillation, from 6140 kg/cow in 1980 to 5926 kg/cow in 1992, but remains far above the national average. Therefore, Holstein farm systems, with pure-breds as well as crossbreeds, are expanding both in number of farms and in number of animals per farm (Santos & Vilela, 2000).

Between 1980 and 1992, total annual milk production in Brazil increased (EMBRAPA-CNPGL, 2000) from more than 11 billion litres to more than 15 billion. However, not much of this improvement was due to increasing productivity, in fact, more than 80% of this increase was due to increased numbers of animals (Gomes, 1996).

In the last two decades, the number of recorded cows in the Holstein herd has increased in size in Brazil. The number of records per lactation group increases with time for all lactation groups (Figure 1), especially after 1986 when the milk recording system was improved (Pereira, 1986). The Brazilian government modified the milk recording system in response to various requests of producers and researchers, to include new and modern parameters in the milk recording system. More cows of the same farm could be monitored in the milk recording system, making it a more representative sample. As a consequence, more animals were registered, both through more animals per farm and a larger number of participating farms.

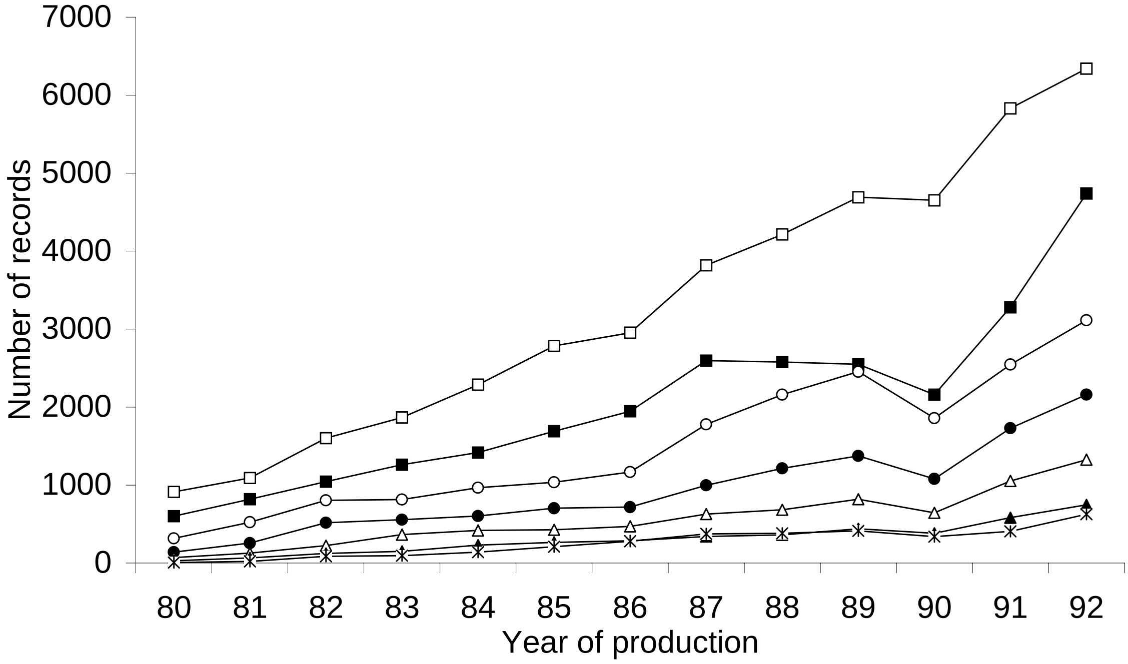
This change has affected the data set of the National Archive, illustrating that in Brazil, the Holstein dairy system is expanding (Figure 1), and will contribute even more to total national milk production in the coming years. However, between 1982 and 1992, despite the almost constant increase in number of records in lactation groups 1 to 10, the proportional distribution of records among lactation groups generally remained unchanged (Figure 2), showing system structure stability in terms of herd composition. From 1980 to 1982 around 90% of the population registered were young cows, in the 1st to 3rd lactation, after 1983, 90% of the cows registered were in the 1st to 4th lactation.

A disturbance occurred in 1990, as a consequence of a national economic crisis, affecting system stability, with a general reduction in total number of animals (Figure 1), and a reduction in the proportion of animals from the 2nd, 3rd and 4th lactation groups (Figure 2). In 1991, the recording system rapidly recovered and shows a higher number of records in 1992, illustrating system resilience.

Stability and resilience

The Holstein dairy system in Brazil is very diverse with high variability. The wide range of the values in the data is due to breed variability, seasonality, the different regions and the different management practices involved, as well as the large number of herds and farms included.

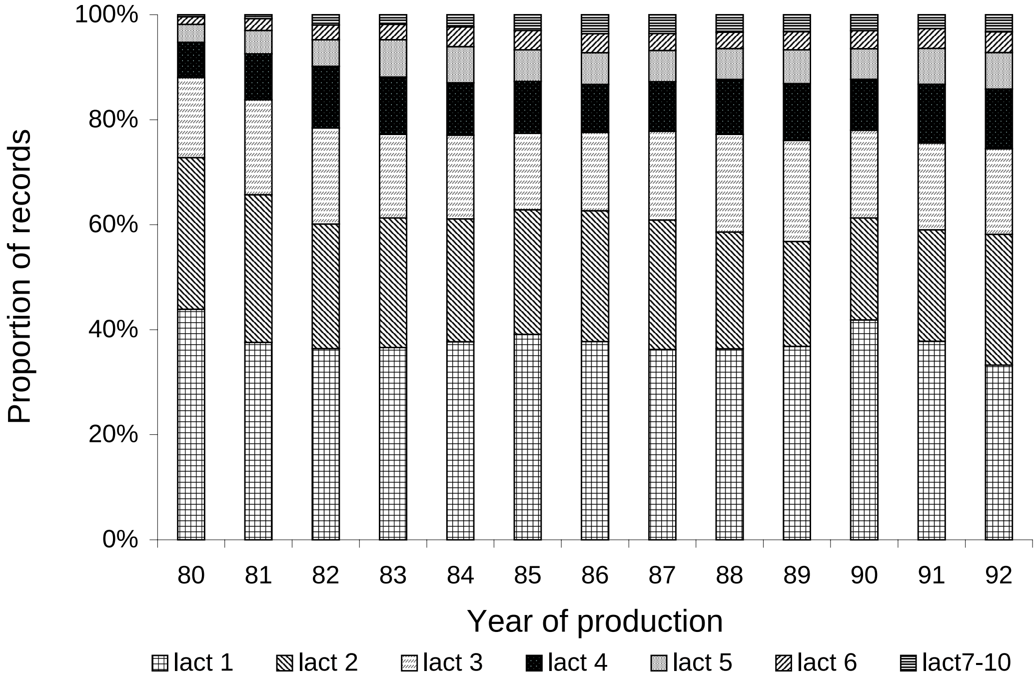
Figure 1. Number of records per lactation by year (□ Lactation 1; ■ Lactation 2; ○ Lactation 3; ● Lactation 4; Δ Lactation 5; ▲ Lactation 6; and * Lactation 7 to 10).



Although fluctuations occurred from 1980 to 1987, in general, the medians of milk and fat production may be considered constant over time (Figure 3), indicating system stability. However, the range (Q3 - Q1) tends to constantly increase (Figure 3). The median milk and fat production starts to decrease from 1987, reaching their lowest point in 1990, with a dramatic economic impact on the system (Figure 3 - inset). Taking a close look at the average milk production per cow in the period between 1987 and 1991, it is clear that the differences between year groups are reduced, as well as the differences between lactation number within group.

Year groups do not show expected normal lifetime milk production curves over lactations, those groups show disturbed curves with average minimum production in 1990, independently of lactation number. After 1991, the recovery capacity of the system is evident, showing its resilience in terms of production and increasing values for milk and fat yield.

Figure 2. Proportion of lactation records by year.



The consequences of the national economic crisis show up in this dairy system after 1987: the median milk and fat production starts to decrease, but the range (Q3 - Q1) increases. For economic reasons, farmers selected cows in the 2nd, 3rd and 4th lactations to be culled or not to include them in the milk recording system (Figure 1). Consequently, the proportion of high producing animals and low producing animals increased (Figure 2), which is expressed in an increase in range of productions in the data set (Figure 3).

Average lifetime milk production analysis provides information for the next sustainability indicator. Lifetime lactation curves, connecting median annual production levels per lactation, were constructed for year groups, consisting of cows of the same year of birth and year of first lactation (Figure 3 - inset, and Figure 4). The shape of a "normal" curve would show increasing median production values with increasing lactation number, until maximum production at the 3rd, 4th or 5th lactation and steeply decreasing after the 6th lactation. Normal curves in this analysis are not affected by the national crisis of 1990, i.e.year groups 1980, 1981, 1991 and 1992, are used as reference for comparison with disturbed curves, i.e. those of the year groups from 1982 to 1989, and for quantification of production losses (Figure 4).

In Figure 4, the reference year group is group 1981, consisting of cows of the same age, having their first lactation in 1981. The disturbed curves are from the three most affected year groups: 1985, 1986 and1987, with lactation of maximum production occurring during the crisis period, resulting in yields far below (about 15 to 20%) those of group 1981 (Figure 4).

In 1990, the range in medians for the different year groups attains its minimum, i.e. 5000 to 5500 kg/year (Figure 3 - inset), irrespective of age and lactation number, presumably as a result of reduced inputs (concentrates, medicines, etc.). Animals have been sold or exchanged for products, explaining the reduction in the number of animals in the milk recording system (Figure 1). The dramatic reduction in number of animals and inputs was part of the strategy to survive the crisis, as was a search for alternative feeds for the animals and alternative production possibilities in the farm.

After 1986, the difference in median yield between successive lactations, i.e. the difference between neighbouring points in the lifetime lactation curve, drastically decreases (Figure 3 - inset). In general, all groups show a smaller difference in median yield between the years 1989 and 1990, than in other periods. The normal difference among year groups, relative to the median milk yield, has also gradually decreased from 1987 to a minimum in 1990. In the two years following the crisis, where the resilience aspect of the system is evident, the system recovers and the difference among the medians of the different year groups increases (Figure 3 - inset), returning to the original (normal) situation.

The national contribution of milk production per capita decreased 3,2%, between 1980 and 1983 and only after 1985 shows a considerable stable increase of 15,2% in its contribution per capita. At national level, total milk production per capita is rather low. This production is certainly not enough to meet the national demand. To reduce this deficit, the Brazilian government is still stimulating milk import, with negative impacts on local dairy farmers and local milk production.

Figure 3. Median and range of 305d milk and fat production (□ Median Milk (Kg/cow); ■ Median fat (g/cow); ○ Range Milk (Q3 - Q1, Kg/cow); and ● Range fat (Q3 - Q1, g/cow).

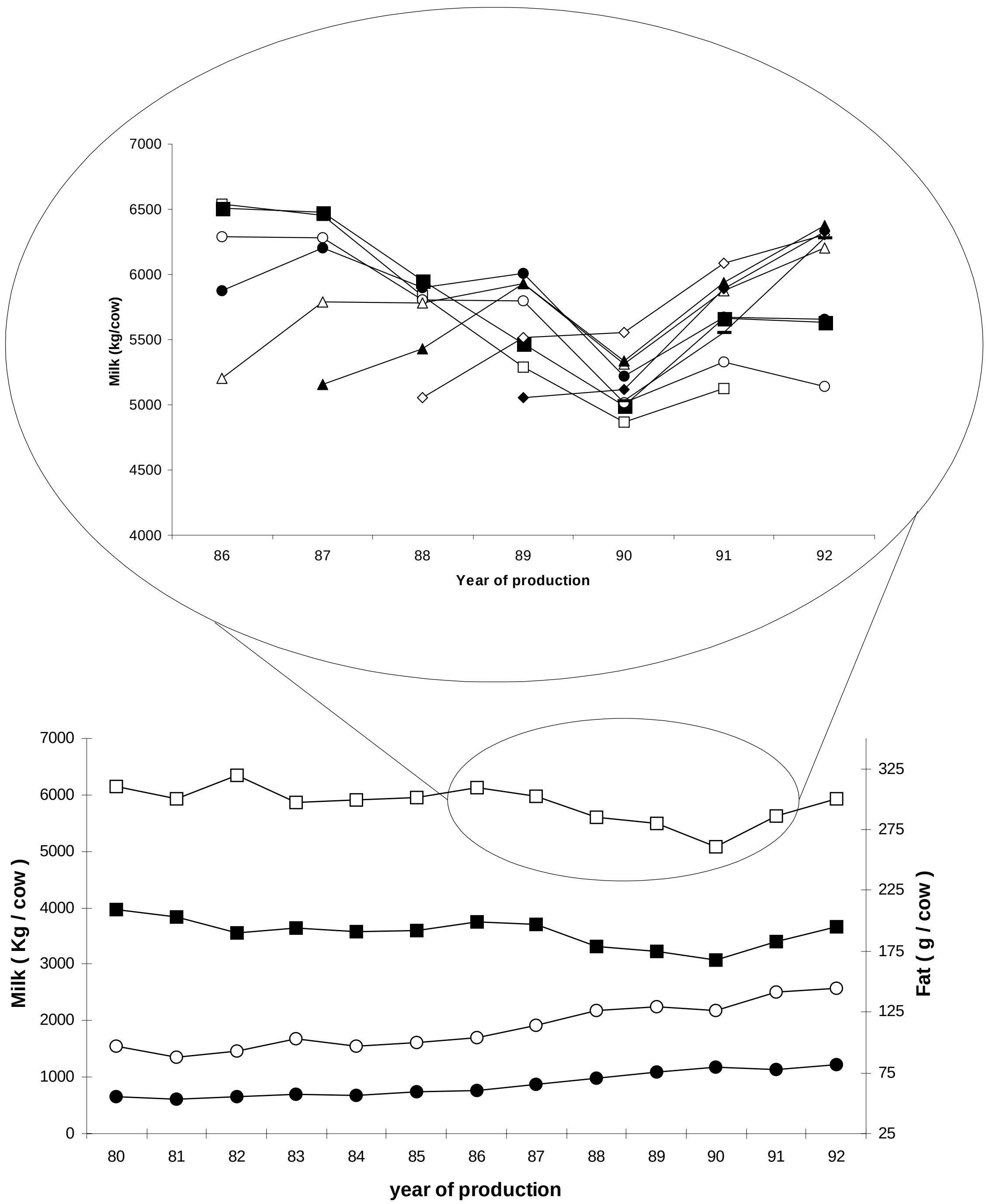


Figure 4. Proportional yield for three year groups (1985, 1986, and 1987) relative to year group 1981. (▬ year group 1981; ● year group 1985; □ year group 1986; ▲ year group 1987).

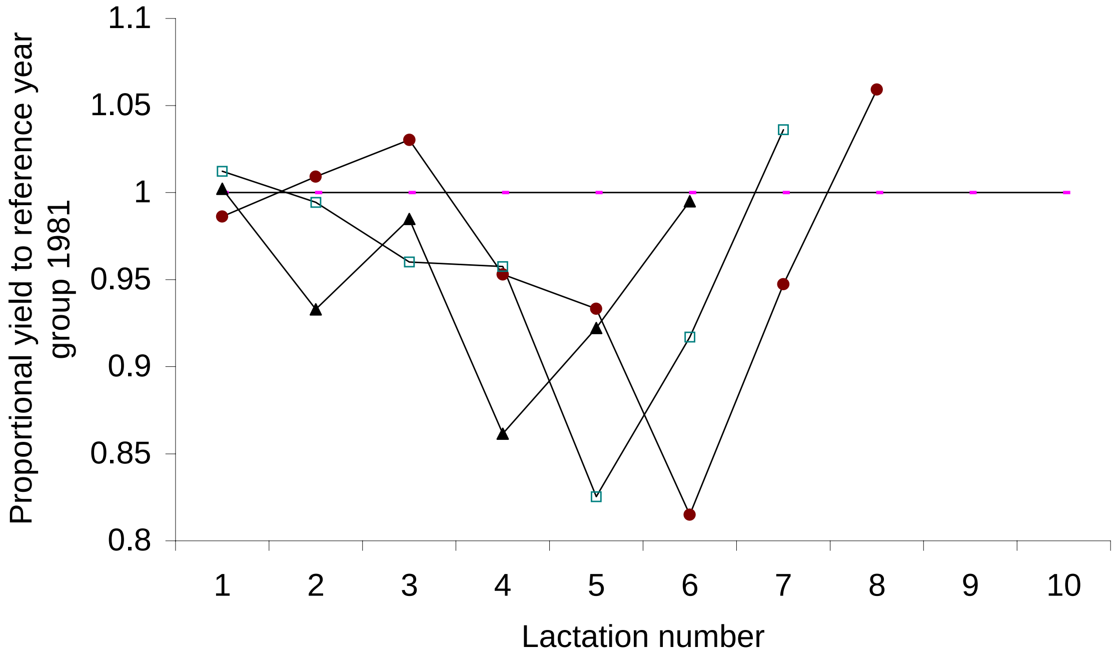
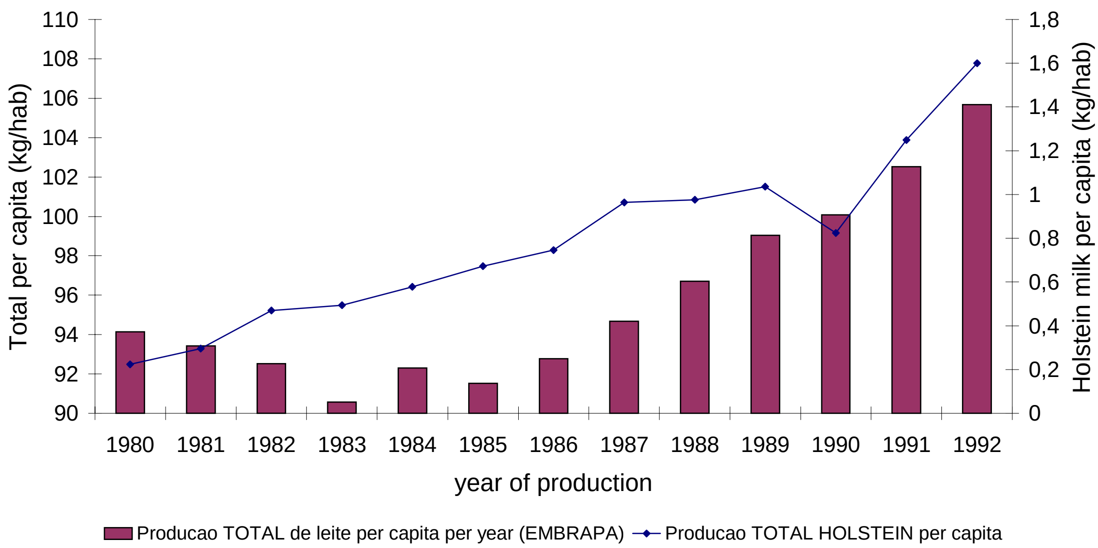


Figure 5. Milk production per capita (bars: Total annual milk production per capita - Source EMBRAPA - CNPGL, 2000; doted line: total Holstein milk production per capita).



Future research

In a sustainable animal production system, animals must exhibit a good balance in health, reproduction and production performance. Persistency of production therefore, comprises aspects within and over reproduction cycles (Grossman et al., 1998). Most animal production processes are cyclic, associated with reproductive cycles, and persistency is a possible indicator of the (health) state of an animal. Therefore, it is suggested that in future research the Holstein dairy farming system in Brazil should be analysed with respect to other sustainability indicators, as persistency of production, longevity, health and reproduction. In Brazil, persistency in Holstein cattle is already becoming an important issue (Queiroz et al., 1991).

The emphasis in selection on milk production traits, as prevailing in the Western world, may result in a reduction in fertility (Hoekstra et al., 1994; Meuwissen et al., 1995). For Brazilian conditions, lack of understanding prevails about the relation between milk production and reproduction efficiency for the Holstein breed (Nobre et al., 1985; Vasconcelos et al., 1989; Polastre et al., 1990). Milk production of European breeds in tropical and sub-tropical regions can be problematic, if environmental conditions are not ideal (Nobre et al., 1985; Ribas et al., 1983a). If these problems result in animals that are susceptible to stress, so that a large proportion has to be culled prematurely, due to reproductive or health problems (Meuwissen et al., 1995), such an animal production system is certainly not sustainable. The need for a consistent set of long-term biologically, ecologically, and sociologically sound breeding goals is being emphasised, because animal breeding governed only by short-term market forces may lead to unwanted side effects (Olesen et al., 2000). Understanding the production systems as part of a wider set of ecological, social-economic and institutional conditions (Van der Zijpp, 2000), is the only way to solve the dilemma of increasing production in a more sustainable way, to meet the demand for milk and other animal products for the next decades.

CONCLUSIONS

A system behaviour analysis to quantify the effect of crisis on sustainability of the Holstein dairy system in Brazil, based on system properties as productivity, stability/resilience and equity, as proposed in the current study, shows the dynamics of aspects of its sustainability over time. The development of system sustainability, defined as the ability of continuing into the future, is characterised by time trends. Compared to other dairy systems in Brazil, the Holstein system achieves a high level of annual milk productivity, above 5500 kg/cow and a fat productivity above 175 g/cow. However, no improvement in milk productivity is observed during the study period. Milk production remained stable in general, and the median of milk and fat production was rather constant over the years, except in 1990 when the economic crisis reaches its deepest point, but the range increased continuously. In the long term, it is expected that production will be maintained.

An increasing number of records and animals are observed from 1980 to 1992, especially after 1986, although the age composition per year group remained constant after 1983. The crisis in 1990 caused a decrease in number of animals and records, especially of young milking cows in the 2^{nd}, 3^{rd} and 4^{th} lactation. After the crisis, the system shows high resilience, characterised by a rapid increase in number of animals and records. In the long term, it is expected that the number of animals will increase and the system will show stable growth.

In general, the Holstein dairy farming system is characterised by high stability and resilience in terms of milk production. However, when year groups are more carefully analysed, the high sensitivity of the Holstein system to disturbances is evident. The lifetime production curves are disturbed from 1987 to 1990, suggesting considerable economic losses during that period of crisis. All year groups tend to a minimum milk production level, reducing differences among year groups. The system is thus less stable with respect to economic effects, but after the crisis, it shows rapid recovery in terms of production, as illustrated in 1990 to 1991 when the differences among year groups are again evident. This system's high resilience is due to its variability in farming systems and its diversity in animals.

In Brazil national milk production should increase, to meet the demand and decrease milk imports, that make Brazil so dependent on the international market and are disadvantageous for local milk production. In relation to total milk production, the Holstein dairy system the equity aspect scores high, it makes a relative large contribution to milk availability per capita and shows a high rate of increase in this characteristic for the study period.

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Chapter 4

CHAPTER 4

CULLING IN BRAZILIAN HOLSTEIN DAIRY HERDS

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ABSTRACT

The objectives are identification of culling factors and their relation to milk production of first lactation. Data of culling reasons during 1990 to 2000 were analyzed focusing on factors and problems that influence longevity of Holstein dairy cows in Brazilian herds. The data consisted of 19,698 lactation records of 8,532 Holstein cows from 27 herds, in which 5,251 cows were culled and given a culling reason, representing 61.5%. Herds were mainly located in Sao Paulo State (77.24%). The records show information about reproduction, health, age, and production per lactation and culling reasons. Because culling is subjective, mainly based on farmer's perception, more than 120 voluntary and involuntary culling reasons were found and classified into 9 culling factors for this analysis and related to milk production per lactation. To summarize the results of this study level of incidence (A) is very high for the culling factor other (44 %), high for reproduction (26%), and moderate for disease, health and low production (about 7%). Point of inflection (t_c) is early for accident, other and reproduction (about 1.7), medium for health, low production and sold (about 2.0) and late for disease, hoof and mastitis (about 2.4). There are indications that cows with a high first lactation production are more sensitive to hoof and health problems. No relation is found for culling factor reproduction and milk production.

Key Words: *Culling, Milk production, Longevity, Brazil, Holstein cows, Dairy cattle.*

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INTRODUCTION

Holstein farming systems have been adopted in many countries and import of semen is a common practice to exchange genetic material and improve production traits of local herds. The genetic antagonism between production and reproduction traits is becoming evident in higher culling rates, especially high yielding cows being at risk for involuntary culling for health and reproductive disorders (Vollema, 1998). As import of semen and animals is common practice among farmers and breeders in Brazil, it may be anticipated that the Brazilian herd will go through the same genetic changes, including the associated side effects that occurred in the exporting countries. In the last decade, milk production has increased, but that has been accompanied by increased problems in health and reproduction. These developments are of concern to Brazilian farmers and breeders. Replacement of high producing cows is undesirable and reproductive problems are the most expensive exit reason (Seegers et al., 1998). Therefore, better understanding of aspects at animal level might contribute to reduced economic losses caused by involuntary culling.

The relation between culling factors and the level of milk production plays an important role in culling strategies. Culling reasons indicated by farmers are subjective, but analysing this information can generate useful information for herd management. If high yielding cows are more likely to be culled for health and reproduction problems, early identification of this relation might prevent problems, reduce involuntary culling and increase longevity. Milk production records are essential in this process, as those allow identification of high-producing cows that are more sensitive to involuntary culling.

Therefore, objectives of this study are to identify culling factors and to analyse the relation of culling factors to the level of milk production. As an indicator of milk production level the 305 days milk production of the first lactation is used.

MATERIAL AND METHODS

Data of a ten-year study on culling reasons and milk production per lactation of Brazilian Holstein dairy herds have been used. They form the basis for development of models describing the relation of each culling factor during the animal's productive life to milk production of the first lactation and the lactation of culling.

Voluntary or involuntary culling

The productive life of a dairy cow, normally expressed in its longevity, ends at the moment of culling, when the cow leaves the herd. Culling is called voluntary when planned by the farmer, in many cases eliminating animals with undesirable characteristics or selling cows for economic reasons. Culling for low production is an example of voluntary culling, where the farmer selects the cows with the lowest production, regardless of their health condition (Dürr et al., 1997a; 1997b). When a cow, however, has to leave the herd for an unexpected reason, accident, disease or reproductive failure, culling is called involuntary.

Research is done to support farmers in culling decision-making, because culling and thus the longevity of the cow are under control of farmer's decisions and thus under management (Vollema, 1998). Management and breeding policies nowadays are not only directed toward increasing milk yield but also to reduce the number of involuntary cullings (Rogers et al., 1988, Olori et al., 2002). However, many factors can influence a farmer's decision to cull an animal, which gives culling data a subjective character. In general, the latest event is reported as the culling reason, but in reality it is common that cows leave the herd for a combination of reasons.

To predict culling is an important part of planning an animal's permanence in the herd and is crucial for herd management. The accuracy of prediction depends on understanding the factors involved in an animal's permanence in the herd and the identification of possible reasons for culling.

The biological aspects of dairy production make involuntary culling an unavoidable phenomenon, but longevity is of major economic importance in dairy cattle, thus involuntary culling is undesirable. Reducing culling for involuntary reasons reduces replacement of high producing cows, and increases the opportunity for voluntary culling (Dürr et al., 1997b), which improves herd performance.

Holstein dairy system in Brazil

Holsteins in Brazil are commonly used in crossbreeding programs, but pure-bred Holsteins are found in 17 out of the 26 states of Brazil. Holstein farms are mostly located in the South and Southeast region where the climate is more favourable for this European breed, recently, however, Holstein systems have expanded to the Central region of Brazil (ABCBRH, 2003).

At farming system level, analysis of the sustainability aspects of the Holstein dairy system in Brazil revealed its national importance in terms of milk production (Waltrick and Koops, 2002). At a low national annual productivity of dairy farms of around 1000 kg milk/cow at 305 day lactation, Holsteins can produce more than 6000 kg under Brazilian climate and management conditions. In the year 2000, there were 790 Holstein farms, with on average 84 animals per farm (SCL, 2002). At the end of 2000, more than 66 000 lactations had been recorded by the Milk Recording Services (SCL), which represents 68% of the total number of Holstein cows registered. Average milk production at 305 days increased 31% over the period 1990 - 2000 (from 6,135 kg to 8,047) (SCL, 2002).

Holstein dairy systems are generally intensive high input systems, and therefore strongly dependent on external resources and susceptible to market price fluctuations. In Brazil, Holstein dairy systems are characterised by high stability and resilience, although the systems are sensitive to disturbances (Waltrick and Koops, 2002).

Data

Data were collected retrospectively from 1990 to 2000 from Holstein cows in dairy herds in Brazil, and were used to analyse reproductive, health and production traits. The data set was from Clinica do Leite (ESALQ-USP) and consisted, initially, of 19,698 lactation records of 8,532 Holstein cows from 27 herds. Herds were mainly located in Sao Paulo State (74%), comprising 84.4% of the animals, while the remainder originated from the states Alagoas, Minas Gerais and Paraná. During the last 10 years 5,251 cows were culled, representing 61.5% of the total. For each culled cow the reason for culling was recorded, resulting in more than 120 different culling reasons. To reduce the number of culling reasons, they were schematically grouped into nine culling factors (Table 1). This grouping allows use of the complete sample, including rare reasons.

Table 1. Culling factors and respective culling reasons

Culling factor	Culling reasons
Accident	Unexpected accidents, poison, snake bite, trauma, hemorrhage
Disease	Infectious diseases, diarrhea, infections, hepatitis, pneumonia, ulcer, salmonella, tuberculosis, etc.
Hoof	Hoof and locomotion problems, rotten hoof.
Health	Not contagious problems: atrophy, toxic shock, cyst and tumors, intestine or abomasum displacement, fever, heart attack, sudden death, lordosis, calcium reaction, sadness, etc.
Low prod	Voluntary culling based on low production
Mastitis	mastitis reason
Reproduction	Abortion, anaestrus, caesarian, mummified fetus, twins, placenta retention, uterine rupture, parturition problems, etc.
Sold	Sold for production purposes to another producer
Other	No register, other reasons than above mentioned, no diagnosis, unknown

Only culled animals are included in this analysis, and therefore calculated probabilities must be interpreted as the probability of culling over the animal's lifetime. Thus in this case the predicted probability is the probability for culling given culling. Therefore, the probability for a particular living animal in a herd to be culled because of a particular culling factor is the predicted probability times the probability to be culled in a particular lactation.

Data were analyzed with a statistical program (SAS, 1985) to identify all culling reasons and to calculate milk production per lactation number, after which codes for culling reasons were transformed into codes for culling factors (Table1). The calculated probability for each culling factor throughout the animal's productive life is modelled with a non-linear regression model. A logistic function (Brown and Rothery, 1993) was selected to describe the cumulative probability (*y*) of culling for each of the culling factors in relation to lactation number:

$$y = \frac{A}{(1+e^{\frac{-(t-t_c)}{k}})} \qquad [1]$$

Where:

t is lactation number (1 …7); y is the cumulative probability (%) of culling over a cow's lifetime according to one of the culling factors (Table1) at lactation t, calculated as the sum of probabilities over lactation number 1 to t; A is the total probability (%) of culling for a particular culling factor; t_c is the point of inflection and k is a measure for duration of change in culling probability. Note that the sum of A over all culling factors is equal to 100%.

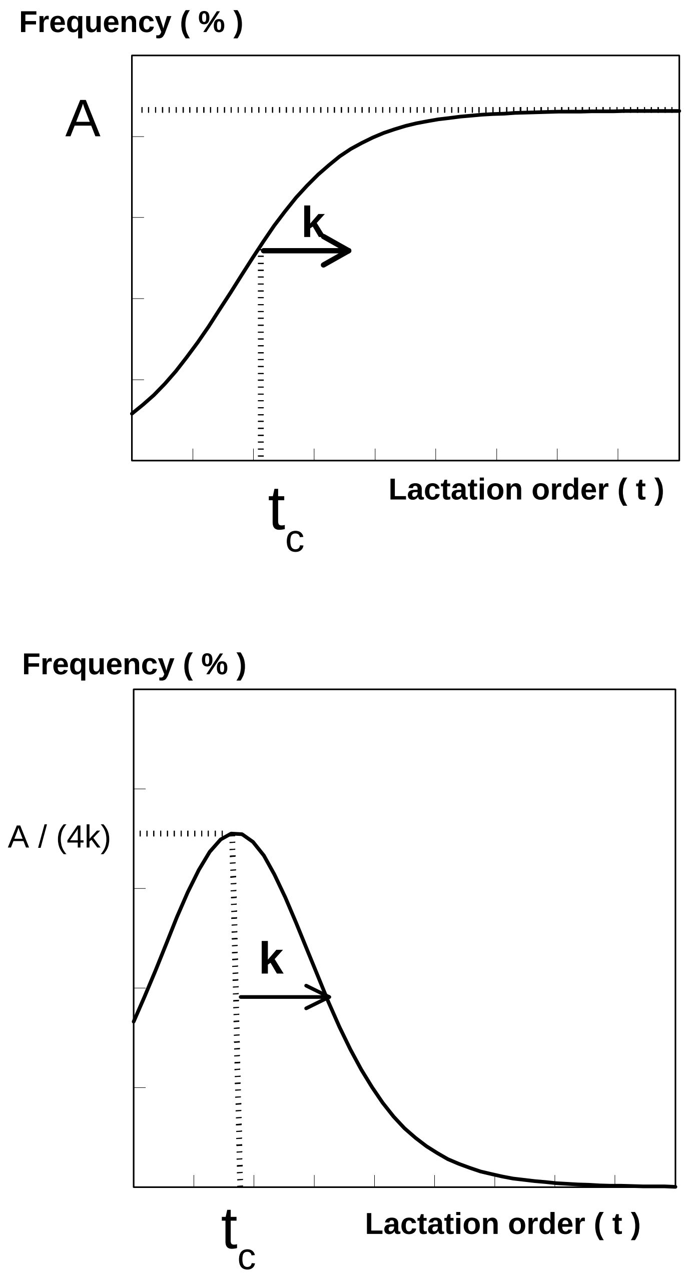
The change in culling probability over lactations is expressed by the first derivative of equation [1]:

$$\frac{dy}{dt} = \frac{\frac{A}{k}}{(1+e^{\frac{-(t-t_c)}{k}})(1+e^{\frac{(t-t_c)}{k}})} \qquad [2]$$

In equation [2], parameter and variable names are the same as in equation [1]. For lactation number (t) equal to the point of inflection (t_c), dy/dt is at its maximum, and equal to A/(4k).

To characterize the change in culling probability for each of the culling factors, A, t_c and k are used as new variables in the analysis. A nonlinear regression program (Sherrod, 1998) is used to estimate these parameters. . Equations [1] and [2] are graphically presented in Figure 1, where parameters A, t_c and k are indicated.

Figure 1. Schematic representation of frequency of culling as a function of lactation number



RESULTS AND DISCUSSION

Genetic improvement of Holsteins for dairy purposes has focused mainly on production traits. However, higher milk production may negatively affect health and reproduction and thus lead to premature culling (Beaudeau et al., 1994). Studies on the genetic antagonism between production and reproduction traits show that genetic selection on production only, may result in a reduction in fertility and fitness (Hoekstra et al., 1994; Meuwissen et al., 1995). Involuntary culling rates are high already for this breed (Dürr et al., 1997b), and especially high yielding cows are at risk for early culling due to health and reproductive disorders (Vollema, 1998). Sub-optimal nutrition management represents a key risk factor that may lead to increased incidence of metabolic diseases, causing low or even negative energy balances in the periparturient and early postpartum periods (Roche et al., 2000). Moreover, adult cows were once heifers that were exposed very early in life to insemination and pregnancy. Evidence from selection experiments shows a significant antagonism between early maturity and longevity (Essl, 1998).

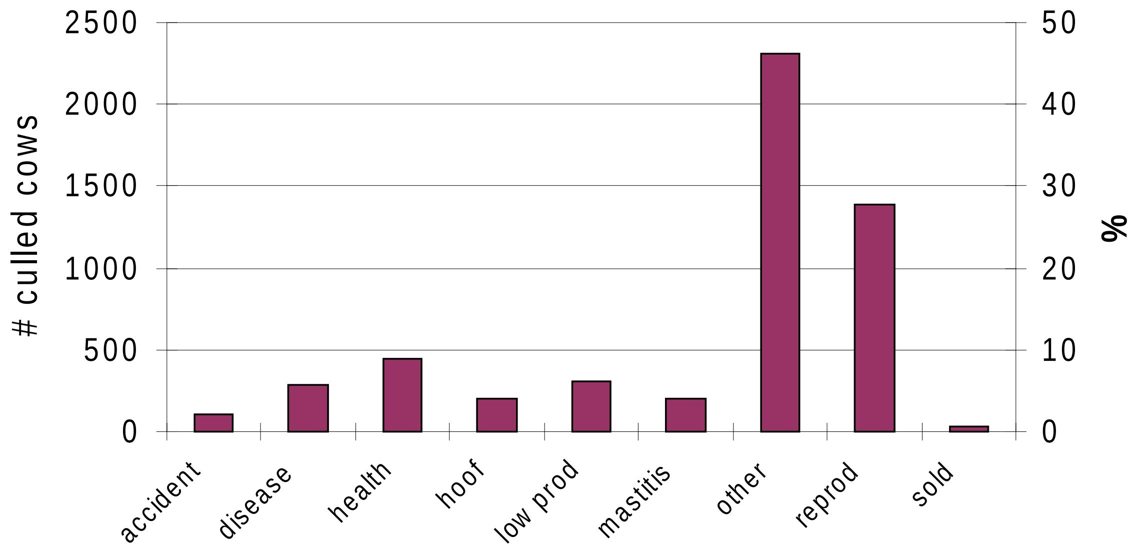
Length of the productive life of a dairy cow is considered a trait of major economic value, depending largely on its economic merit and life span, increasing the importance of functional traits, such as fitness and longevity. However, the average life span of cows participating in milk recording systems in the United Kingdom is just over three lactations (Kennedy, 2000). A short life span and consequent high replacement rates can represent considerable waste of resources in dairy systems that are continually under pressure to cut costs. A long productive life reduces the replacement costs per lactation and enables a cow to realise her maximum capacity of performance when attaining full maturity. Descriptive statistics on productive herd life in dairy cattle populations are therefore valuable tools for evaluating culling strategies and herd performance (Dürr et al., 1997a). Culling rates and reasons have been studied (Dentine et al., 1987; Seegers et al., 1998), and related to economic impact.

Culling incidence

The incidences of the 9 culling factors are presented (Figure 2), revealing the high incidence of culling due to other (44%) and reproduction (26%) reasons.

The probability of culling is strongly related to age and lactation number (Dürr et al., 1997a): the probability progressively declined with parity number (Figure 3), in agreement with the results of Seegers et al. (1998) and Dürr et al. (1997b). Most cows (56%) were culled already before the 3rd lactation and 89% were culled before the 5th.

Figure 2. Number of culled cows for the various culling factors



Equations [1] and [2] represent models to calculate the probability of culling for each culling factor throughout the animal's productive life. Results of the parameter estimations are given in Table 2. Calculated cumulative culling probabilities and their first derivatives as a function of lactation order for the five culling factors with highest incidences (other, reproduction, health, low production and disease) are given in Figure 4 and Figure 5, respectively.

Culling occurs mostly before the third lactation for all factors studied, but the moment of highest probability occurs around the second lactation (estimated t_c in Table 2). The data indicates management problems, probably regarding nutrition, confort or timing. Cumulative probabilities of culling rapidly increase during the first four lactations, as expressed in the value of k, the duration of change in probability. This duration does not show much variation with an average of 0.95. A higher value of k means a longer duration of change in probability.

Figure 3. Number of culled cows per lactation number

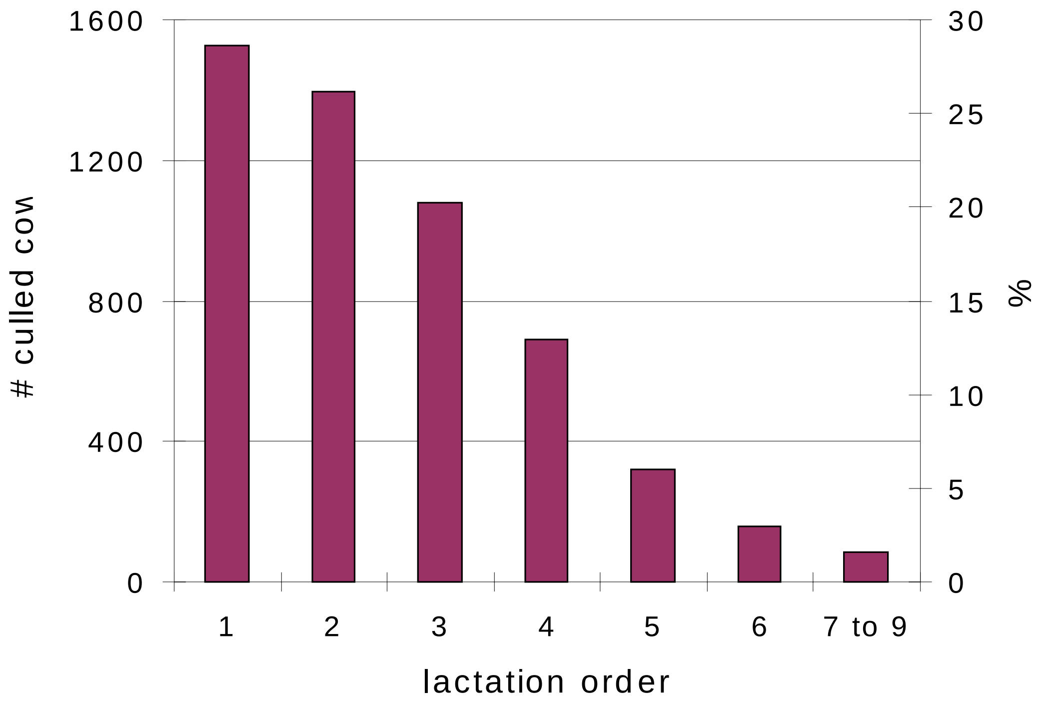


Figure 4. Cumulative culling risk as a function of lactation number for the five most important culling factors

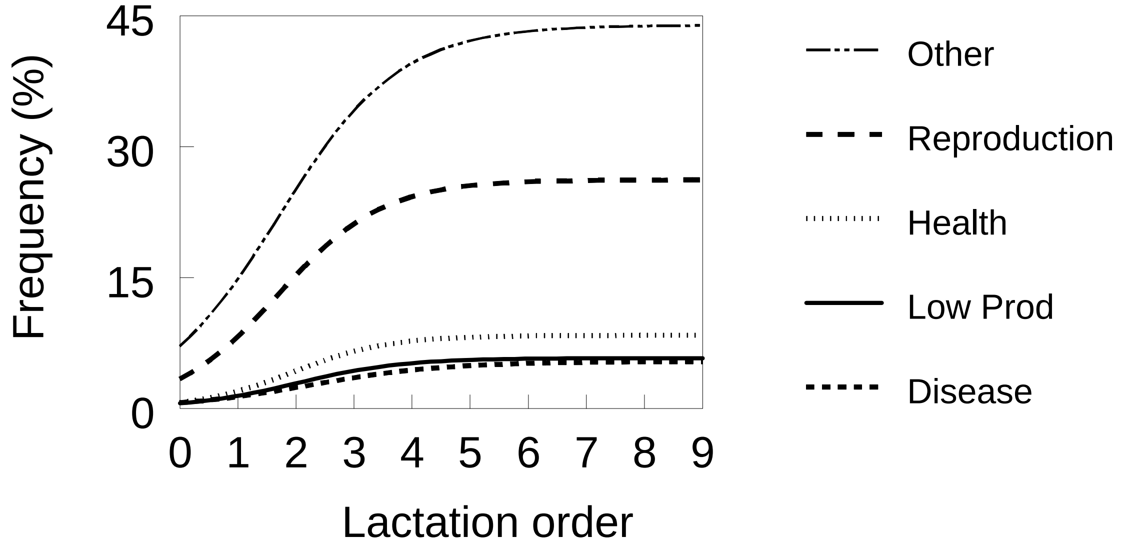
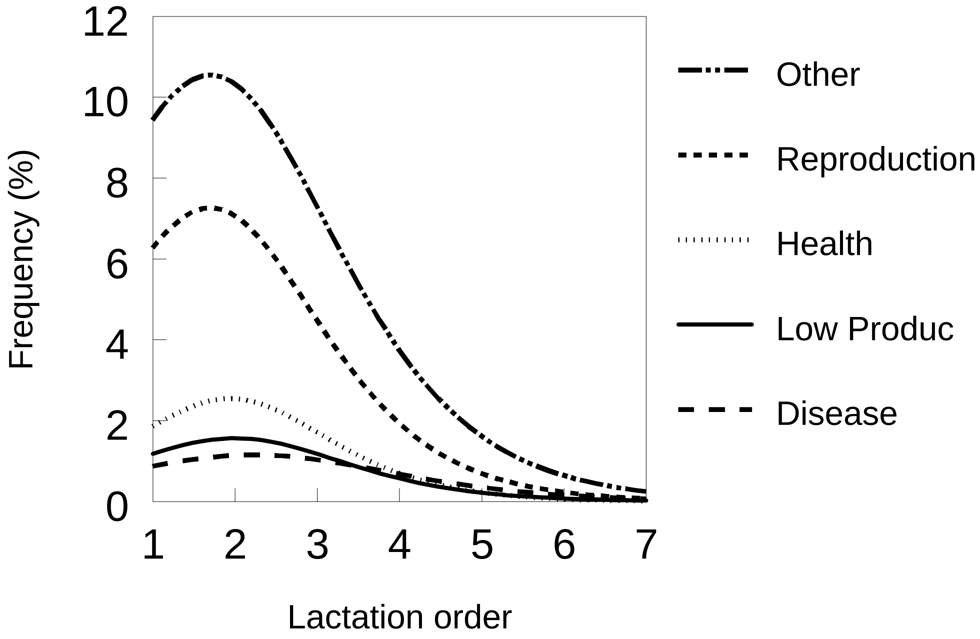


Figure 5. Predicted culling risk as a function of lactation number for the five most important culling factors



Level of incidence (A) is very high for other (44%), high for reproduction (26%), moderate for disease, health and low production (about 8% and 6% respectively), low for hoof and mastitis (about 4%) and very low for accident and sold (about 2% and 0.5% respectively). Point of inflection (t_c) is early for accident, other and reproduction (about 1.7), medium for health, low production and sold (about 2.0) and late for disease, hoof and mastitis (about 2.4).

Table 2. Estimates for parameter A, t_c, k and their respective standard errors (se) of Equation [2]

Culling factor	Estimates					
	A	se_A	t_c	se_{tc}	k	se_k
Accident	1.95	0.011	1.73	0.034	0.93	0.370
Disease	5.39	0.029	2.24	0.030	1.16	0.032
Health	8.38	0.300	1.94	0.019	0.82	0.019
Hoof	3.87	0.019	2.59	0.025	1.01	0.024
Low Production	5.77	0.053	2.00	0.050	0.92	0.051
Mastitis	3.77	0.021	2.48	0.029	0.91	0.046
Other	43.92	0.165	1.70	0.022	1.04	0.026
Reproduction	26.20	0.148	1.70	0.032	0.90	0.035
Sold	0.54	0.010	1.85	0.099	0.93	0.106

In Table 3, the goodness of fit is given for each logistic regression model (Equation [2]). The proportion of variance explained (R^2) is high (on average about 99.5%). The standard error of estimate low for all factors, ranging from 0.023 for accident to 0.317 for other. The Durbin-Watson test (DW) for autocorrelation was around 2 as expected, ranging from 1.622 to 3.171. The combination of goodness of fit parameters (R^2, RSE, and DW) confirms the likelihood of the models with the data (StatSoft, 1984-2002).

Table 3. Goodness of fit measures (R^2, Residual standard error (RSE) and Durbin Watson statistic (DW)) for parameter estimation of Equation [2]

Culling factor	Goodness of fit		
	R^2	SER	DW
Accident	0.998	0.024	1.62
Disease	0.999	0.048	1.74
Hoof	0.999	0.033	2.83
Health	0.999	0.062	3.08
Low Production	0.997	0.104	2.09
Mastitis	0.999	0.040	3.17
Other	0.993	0.317	2.83
Reproduction	0.998	0.305	1.94
Sold	0.986	0.019	2.89

Culling in relation to production

Cows were grouped according to lactations in which they were culled (LC), from lactation 1 to lactation 7-9. To see any indication of a relation of culling factors with the genetic milk production potential the 305 day milk production of the first lactation is used as an indicator. For LC groups 2 to 5 the average 305 day milk production in the first_lactation is presented in Table 4. LC group 1 is not included because many cows were culled during this lactation and therefore the estimated 305 day lactation is not very useful. LC groups >5 are not considered because of the low numbers.

Table 4. Average first lactation 305 day milk productions according to culling factor and lactation number in which the animals were culled.

Culling factor	Culled in lactation 2			Culled in lactation 3			Culled in lactation 4			Culled in lactation 5		
	n	kg milk	sd	n	kg milk	sd	n	kg milk	sd	n	kg milk	sd
Accident	29	7592	1631	22	6886	1588	11	6780	1912	5	6801	1207
Disease	60	7299	1602	60	7040	1674	41	6573	1427	26	6399	1681
Health	124	6815	1954	110	7310	1917	72	7541	1730	18	7213	1338
Hoof	37	6740	1617	51	7421	1702	40	7241	1794	20	7501	1563
Low Prod.	87	5041	2192	73	6033	1974	33	6400	2030	28	6324	1926
Mastitis	47	6960	1809	47	6292	2338	43	7114	1885	19	7138	1866
Other	590	6946	2112	430	6725	2089	294	6544	1741	131	6284	1573
Reproduction	411	6998	1782	282	6632	1779	151	6764	1754	72	6367	1587
Sold	10	8449	2123	4	8432	823	5	8346	2501	1	8360	

In general average productions in Table 4 have very high standard deviations, i.e. 1600 kg and higher. In data from commercial farms, such large variation is not unusual.

The factor sold represents voluntary culling, selecting high producing cows to be sold for production purposes. As expected, this factor has in all LC groups the highest first lactation production (about 8400 kg). The factor low production, which is also a voluntary selection, but now for cows that do not reach minimum average herd milk production as planned by the farmer and have to leave the herd for economic reasons. As expected this factor showed the lowest average production in lactation 1 for all LC groups, about 6000 kg.

The involuntary culling factors accident (7592 kg) and disease (7299 kg) showed the highest first lactation productions for LC group 2, other factors were around 6900 kg. In groups LC3 to 5, the factors hoof (7421, 7241 and 7501 kg) and health (7310, 7541 and 7213 kg) showed the highest first lactation productions. Culling factors accident, disease, mastitis and other had average first productions between 6200 and 7000 kg in LC3 to 5.

There is no indication for a relation of the culling factor reproduction with high production in the first lactation. However, culling for reproduction reflect problems regarding conception and young cows without conceiving are culled directly in the first two lactations. This fact request more research to determine, within the lactation, when is the highest risk of culling.

CONCLUSION

To summarize the results of this study one can say that the level of incidence (A) is very high for culling factor other (44 %), high for reproduction (26%), and moderate for disease, health and low production (about 7%). Point of inflection (t_c) is early for accident, other and reproduction (about 1.7), medium for health, low production and sold (about 2.0) and late for disease, hoof and mastitis (about 2.4). There are indications that cows with a high first lactation production are more sensitive to hoof and health problems. No relation is found for culling factor reproduction and milk production.

Culling because of reproduction problems generally happens after the lactation is closed, during parturition, the period postpartum or during the next services, mostly because problems of conception. Cows that are not able to conceive are costly and need to be culled despite their milk production potential. Hence, lactation LC of the animals included in the category *reproduction* will be the last recorded lactation. In contrast, animals included in culling categories *accident*, *health* or *disease* can be culled in the course of the lactation, resulting in a low milk production for the lactation of culling.

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Chapter 5

CHAPTER 5

EFFECTS OF INCREASING PRODUCTION POTENTIAL ON LIFETIME MILK PRODUCTION AND REPRODUCTION OF HOLSTEIN DAIRY COWS IN BRAZIL[1, 2, 3]

B. Waltrick[4] and W.J. Koops

ABSTRACT

The aim of this study was to characterize the effects of increasing production potential on lifetime milk production and reproduction of Holstein dairy systems in Brazil. The focus is on (1) age at maximum milk production (t_{max}) and (2) number of services needed per conception (INS_{ave}) and their relation to level of production. As indicator for genetic level of production, first lactation milk yield is used. The present study investigated data of 54,719 Holstein purebred cows from herds in Minas Gerais, Brazil, collected over a 20-yr period (1981-2000), with seven or more lactations. The expected lifetime production curve over lactations (LPC) was analyzed individually (119 cows) in relation to production level at first lactation (Y_1). The mean for Y_1 was 5000 kg and the estimated maximum milk production (Y_{max}) was 8000 kg. Average estimated t_{max} was 80 months, i.e. about 6.7 years, between the fourth and fifth lactation (4.7). Biological problems resulting from extremely high production levels could explain the differences in shape between potential and observed LPC's. If the animal production sector is searching for more sustainable systems, the age at maximum production could be used as a sustainability indicator, considering its effect on longevity, which is an issue of concern for sustainability of Holsteins in Brazil.

Key Words: *Milk production, Reproduction, Age, Holstein cows, Dairy*.

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INTRODUCTION

The Holstein breed is still being genetically improved in many countries. In Brazil, farmers and breeders import semen, embryos and animals from various countries (Costa et al., 1999), thus introducing breeding strategies from the exporting countries into the Brazilian herd. Semen from local Holsteins is also being used in breeding programs; however, contradictory results have been reported with respect to genotype-environment interactions (Rorato et al., 2000). Genetic selection based only on a few production traits can lead to undesirable correlated biological changes (Steverink et al., 1992), such as behavior, health and reproduction problems. Currently, Holstein cows are fragile and have a high risk of involuntary culling for reproduction and health problems, thus being removed from the herd before reaching their maximum production potential (Waltrick & Koops, 2003 in prep.).

It is expected that genetic selection would increase overall milk production potential, i.e. for all lactations. Therefore, it would already be possible to identify a high yielding cow at the end of the first lactation (Jairath et al., 1995). The lactation of maximum milk production is expected at maturity, when the animal is fully developed (Spedding, 1975). However, there is a tendency for high yielding cows to start producing at a high level in their first lactation, but to show a decline already after one or two lactations.

The lactation of peak production of high yielding cows precedes their maturity. The hypothesis therefore is that observed production does not reach its potential, probably due to biological problems. Hence, peak production is not attained when the animal reaches maturity, but the decline in production has set in already before that moment.

This study focuses on effects of increasing genetic production potential on lifetime milk production and reproduction in Holstein dairy systems in Brazil. The main objective is to quantify (1) age at maximum milk production and (2) number of services needed per conception, in relation to genetic production potential. As indicator for this genetic potential, first lactation milk yield is used.

MATERIAL AND METHODS

Lifetime Production Curve (LPC)

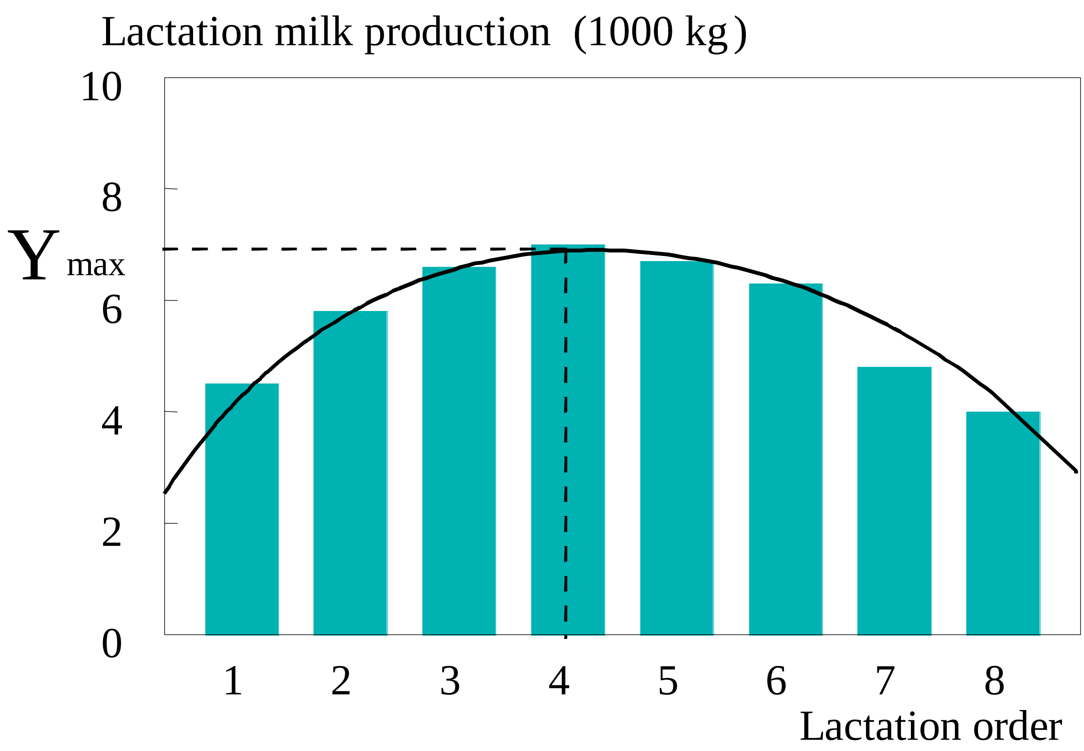
Lactation curves initially show an increasing phase, culminating in the production peak, followed by a long phase of declining production (Grossman & Koops, 2003). With respect to length and peak yield, lactation curves tend to be of similar shape (Spedding, 1975). The parity effect, or lactation order, also affects the shape of the curve, because as the animal grows older, lactation starts at an increasingly higher level (Wood, 1969). The same phenomenon is observed in successive lactation curves: after the first lactation peak production tends to increase to a maximum, followed by a gradual decline. The lactation with maximum milk production is expected at a constant stage of maturity and a given metabolic age (Taylor, 1985). Under optimal climatic and management conditions, the lactation of maximum peak production for Holsteins is generally between the 3rd (Waltrick, 1996) and 6th (Freitas et al., 2000), when the animal is fully developed.

The production curve over lactations is referred to as the Lifetime Production Curve (LPC), as defined by Boettcher (2000). Total milk production in the first lactation tends to be lower than in the following lactations. Under normal nutritional and management conditions, milk production increases rapidly after the first lactation, until maximum production is reached at maturity, after which it tends to decline as the animal ages. Figure 1 shows an example of an expected LPC, with maximum production in the fourth lactation. This curve can be described by a symmetric quadratic equation:

$$Y_t = Y_{max} - \left(\frac{t - t_{max}}{c} \right)^2 \qquad [1]$$

in which, Y_t is estimated lactation milk production at age t; Y_{max} estimated maximum milk production; t age expressed in lactation order or months; t_{max} age at maximum production in appropriate units and c is a shape parameter, characterizing the slope of the lifetime production curve (steepness). In Figure 1, Y_{max} is estimated at 6990; t_{max} at 4.4 and c at 0.068.

Figure 1. A schematic expected lifetime production curve (LPC), milk production in relation to lactation order



Animals, not fully developed and producing at a very high level in the first lactation, are mobilizing all their reserves to achieve that high production. When this leads to excessive metabolic stress, it can result in a too rapid rate of ‘cow turnover’: cows are ’burning out’ too early and replacement rate is high in such high yielding herds.

A negative genetic correlation exists between milk production level and most fertility traits (van Arendonk et al., 1989; Hoekstra et al., 1994; Grosshans et al., 1997; Kadarmideen et al., 2000), hence fertility problems in dairy cows may be expected to increase with increasing milk yield.

High yielding cows: longevity and burnout

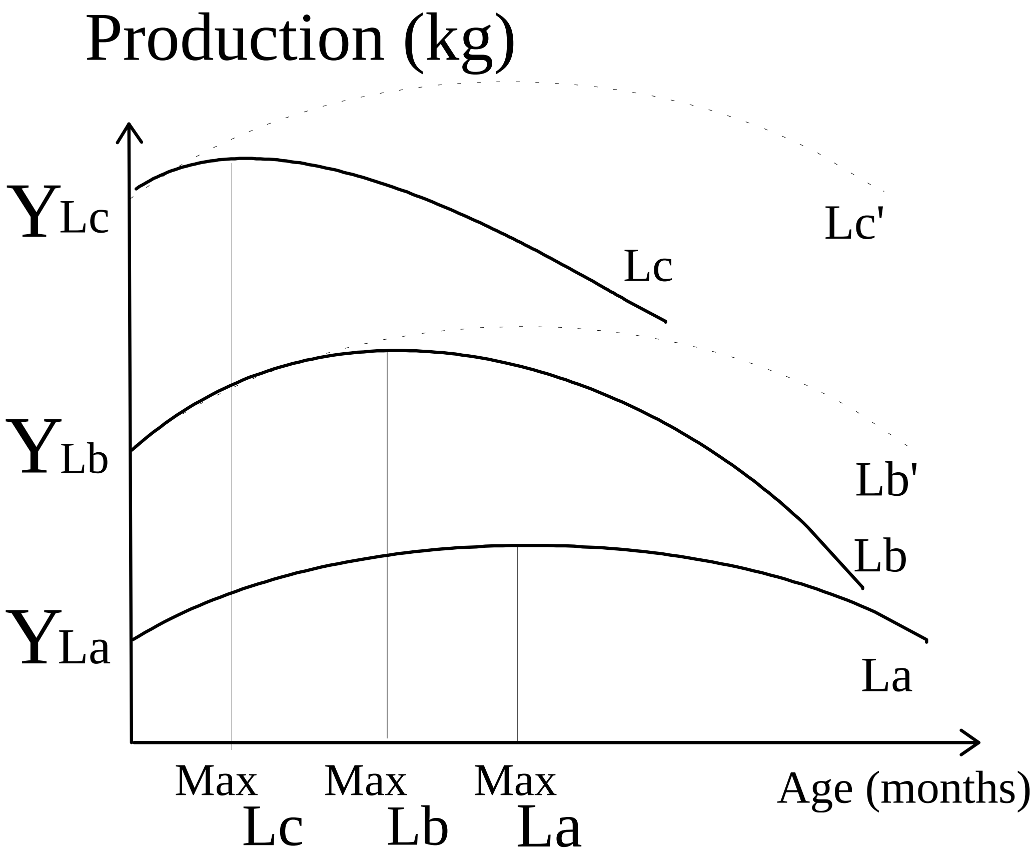
Although high yielding cows are more susceptible to burnout (Boettcher, 1998), careful management in higher producing herds, through preferential treatment of high yielding cows, by either delaying re-breeding or giving them more chance to conceive (Durães et al., 1999) may prevent the added stress, limiting longevity. As management often compensates in this way, it is difficult to unequivocally establish differences in longevity between animals in high and low producing herds. Although careful management can minimize the burnout effect, it can not completely be avoided. Higher production generally compensates for the investments in improved management (Durães et al., 2001). However, ethical and welfare concerns also play a role with regard to therapeutic or hormonal treatment of dairy cows to prevent or cure diseases and improve fertility. Improved herd management may temporarily prevent disease outbreaks and reduced fertility, but this increases cost, and therefore a combination of improved management and genetic selection for good health and fertility is a more (cost-) effective long-term solution (Kadarmideen et al., 2000). Optimal management of high yielding cows requires careful balancing of their genetic characteristics, metabolism and energy requirements. This may have serious implications for the production system, especially with regard to the choice of the energetic balance of their diet (Pryce et al., 1999; Pereira, 2003) and to prediction of food intake, accounting for the effect of lipid mobilization in energy requirement calculations (Nielsen et al., 2003).

However, if burnout cannot be avoided by improved management practices and does affect production and reproduction, then involuntary culling of cows at early ages may be necessary. Burnout may cause delays in the development of the productive and reproductive organs and can drastically reduce longevity and consequently, change the shape of the LPC, causing a decline in production in the first 4 lactations, at a time when the expected LPC would show an increase.

Burnout appears one of the most important factors underlying high rates of involuntary replacement during early lactations (Mason, 2003). Burnout can be the result of a combination of factors, such as genetic properties, management and physiological causes (Collard et al., 2000; Waltrick & Koops, in prep.). Unexpected problems in the first 3 lactations, such as sudden death, udder breakdown, feet and leg problems, infertility, diseases and injuries and/or periods of negative energy balance, will result in involuntary disposal of young cows. If these losses during the first 3 lactations could be reduced, annual net profit would increase substantially (Bauer et al., 1993; Mason, 2003).

In Figure 2, three examples (L_a, L_b and L_c) of expected LPC's are presented for three different levels of production. Example L_a is the situation similar to that in Figure 1, example L_b represents the curves most commonly found in the literature and L_c represents high yielding curves (Olori et al., 1999; ABCBRH, 2003; Grossman & Koops, 2003). The genetic level of production is indicated by the production in the first lactation (Y_{La}, Y_{Lb} and Y_{Lc}), the initial points of the LPC's on the Y axis.

Figure 2. The theory of expected lifetime production curve (LPC) increasing the level of expected maximum milk production in relation to age (solid line is observed LPC, dashed line is potential LPC).



Each expected LPC can show two possible patterns, represented by the dashed and the solid line, respectively. The dashed line represents the potential and the solid line the observed pattern, a difference that may be the result of a delay in development.

The expected age at maximum production is the same for the three example LPC's. In reality however, the observed curves show an earlier decline in production, the timing apparently depending on the level of production in the first lactation. In other words, the age at maximum production decreases when production level increases (from Y_{La} to Y_{Lc}) and the age at maximum production is lower in the observed than in the potential LPC. This phenomenon thus represents loss of production in the second part of the LPC (Bauer et al., 1993; Mason, 2003).

As a consequence of this phenomenon, the shape of the LPC will change from symmetric to asymmetric. That can be taken into account by adding a parameter b to Equation [1]:

$$Y = Y_{max} - \left(\frac{t - t_{max}}{c + b \times t} \right)^2 \qquad [2]$$

Equation [2] describes the LPC as a function of age for individual animals, with four characteristics: maximum yield (Y_{max}), age at maximum production (t_{max}), and parameters c and b. To avoid unrealistic results, age at maximum production (t_{max}) was restricted between 27 and 120 months. However, cows for which the estimated t_{max} assumes a value on the limit of the range do not have a normal LPC: if estimated t_{max} is less than 27 months, production after the first lactation continuously declined and if estimated t_{max} exceeds 120 months, production continuously increased. Both values thus indicate abnormal conditions.

Data

The data initially consisted of 111, 258 lactation records of Holstein purebred herds collected over 20 years (1981-2000) from 54, 719 cows of the Holstein Association of Minas Gerais, Brazil. Milk production was adjusted to 305 days according to the regulations of the Serviço de Controle Leiteiro (SCL : Milk Recording Service) (SCL, 1999). To characterize the LPC, data of animals with a real lifetime production record are needed; therefore cows having completed at least seven lactations were selected, to make sure that the lactation with maximum production is included. As cows with seven or more lactations could have some missing records, for the selected cows at least five records should be available, including the first lactation, because all parameter estimates are based on first lactation milk yield.

Reproductive performance is an important determinant of dairy production efficiency (Grosshans et al., 1997), for which, however, comparative studies of different production systems are scarce. As no direct measures of fertility were available, an indicator had to be identified showing a high correlation with calving interval and other direct measures (Olori et al., 2002). The conception-related trait, number of services per conception, which reflects the ease of conception following an insemination, has been reported as a suitable criterion for fertility in dairy cows (Grosshans et al., 1997; Kadarmideen et al., 1997). Due to lack of data on services per conception before 1990 and because of disturbed LPC's of cows with lactation records in the year 1990, all cows with lactation records before 1990 were excluded (Waltrick & Koops, 2002). The national economic crisis in Brazil in 1990 resulted in all milk production records of SCL being at the minimum level. The crisis also resulted in a reduction in the number of animals and records (Waltrick & Koops, 2002), especially of young milking cows in the 2^{nd}, 3^{rd} and 4^{th} lactation. The result of this data reduction was a residual data set of 119 cows.

Variables

Individual lactation records adjusted to 305 days (SCL, 1999), over the whole productive life of the cow were analyzed, to determine maximum milk production (Y_{max}) and the associated age (t_{max}). To investigate the relation of reproduction and increased production, the average number of inseminations per conception (INS_{ave}) was calculated and used as a measure for reproduction efficiency. The average was calculated as the sum of all inseminations per cow, divided by the number of lactations. First lactation milk yield (Y_1) is used as proxy for the genetic milk production potential of the cow.

Statistical Analysis

The SAS program (SAS, 1985) was used to estimate the parameters of Equation [2] and for statistical analyses.

RESULTS AND DISCUSSION

When estimating the parameters of Equation [2], t_{max} for six cows attained the lower bound of 27 months and for 18 cows the upper bound of 120 months. The latter, indicating a continuously increasing LPC, is probably the result of improved management at the farms in the course of time.

The standard deviations for the variables used in the analysis of the 119 cows were in general large (Table 1). This is not surprising, as all information originates from commercial dairy farms, with many types of noise. The coefficient of variance for Y_1, Y_{max} and t_{max}, for instance is 30% or more**.** Y_1 was directly measured, while Y_{max} and t_{max} were derived from Equation 2, but they show similar coefficients of variance. The means for Y_1 and Y_{max} are in the expected range, respectively about 5000 and 8000 kg (ABCBRH, 2003; SCL 2003). Average estimated t_{max} is 80 months, i.e. about 6.7 years, which is between the fourth and fifth lactations (4.7). Comparison with the literature is not possible, because t_{max} is an unusual measure in dairy production studies.

Studies of small herds in Brazil revealed maximum production to be around 69 to 75 months (Durães et al., 1999). Curves discussed in the literature refer to average production per age class, including all cows from different lactation order, or to average production per lactation class, including all cows in that year. Records from SCL (Figure 6), indicating 4 to 5 years as the age at maximum production in the year 2002 (age classes CJ and CS), give no information on lactation order, which means that cows could be at different lactation order at the same age. Also common used is the cumulative milk production curve as a lifetime production curve, which offers no visual distinction of production between lactations.

In this study, total milk production of each lactation is used to build a lifetime production curve, analyzing the same group of cows in the course of their productive lifetime, to determine the age at the lactation of maximum production. Lactation order three to six have been identified in the literature as the range for t_{max} (Waltrick, 1996; Freitas et al., 2000). Average estimated t_{max} was 80 months, i.e. about 6.7 years, between the fourth and fifth lactation (4.7).

Figure 3. Estimated maximum milk production (Y_{max}) in relation to milk yield in the first lactation (Y_1)
$Y_1 = 1593+0.422\ Y_{max}$
$R^2 = 0.355$

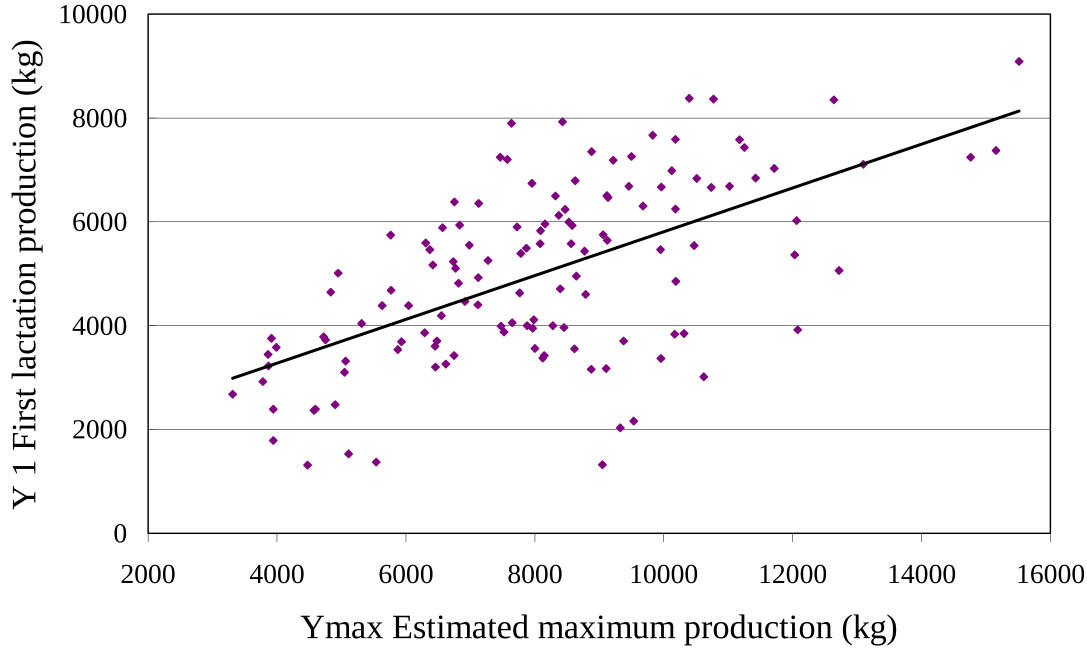


Figure 4. Estimated age at maximum production (t_{max}) in relation to milk yield in the first lactation (Y_1)
$Y_1 = 6133 - 14.3\ t_{max}$
$R^2 = 0.054$

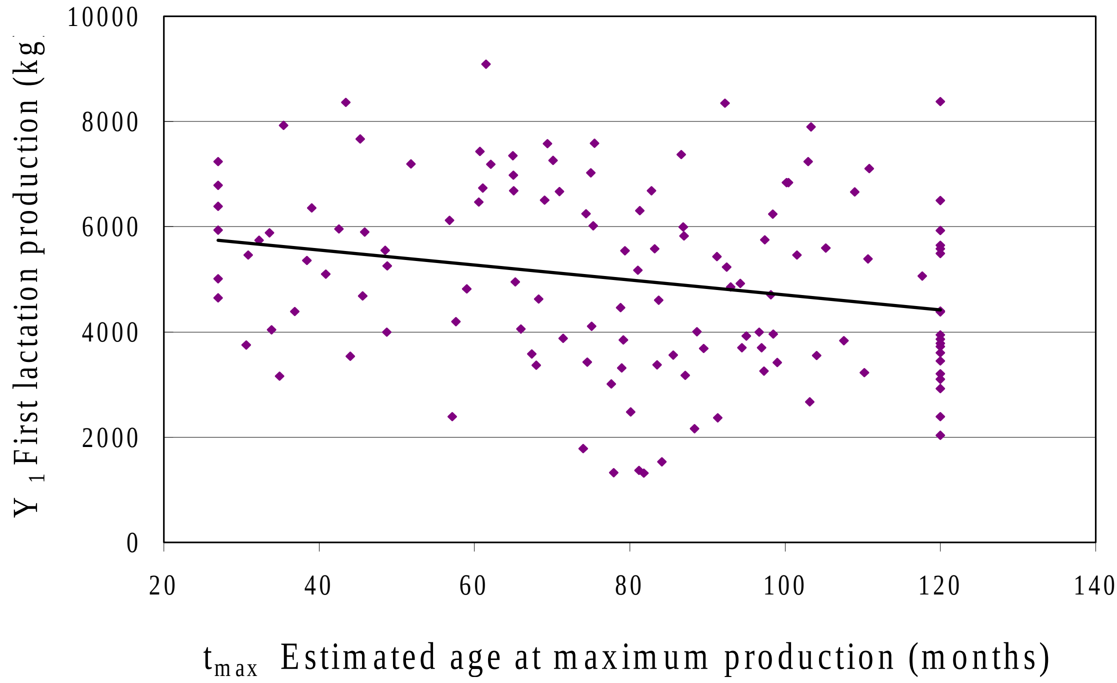


Figure 5. Average number of services per conception (INS_{ave}) in relation to milk yield in the first lactation (Y_1)

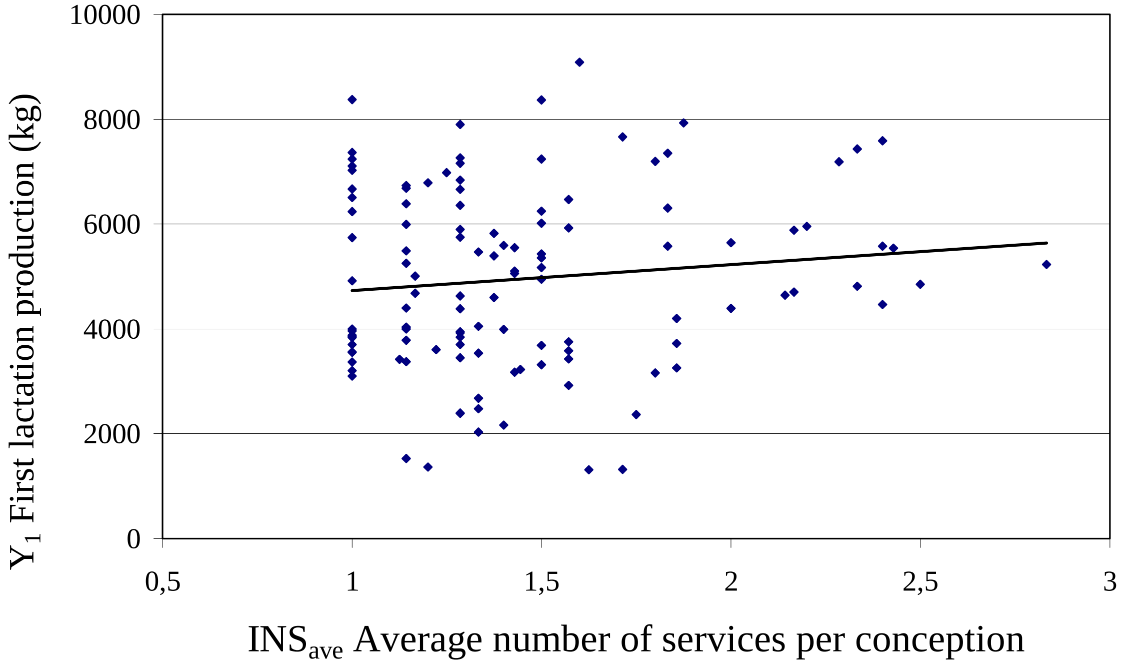
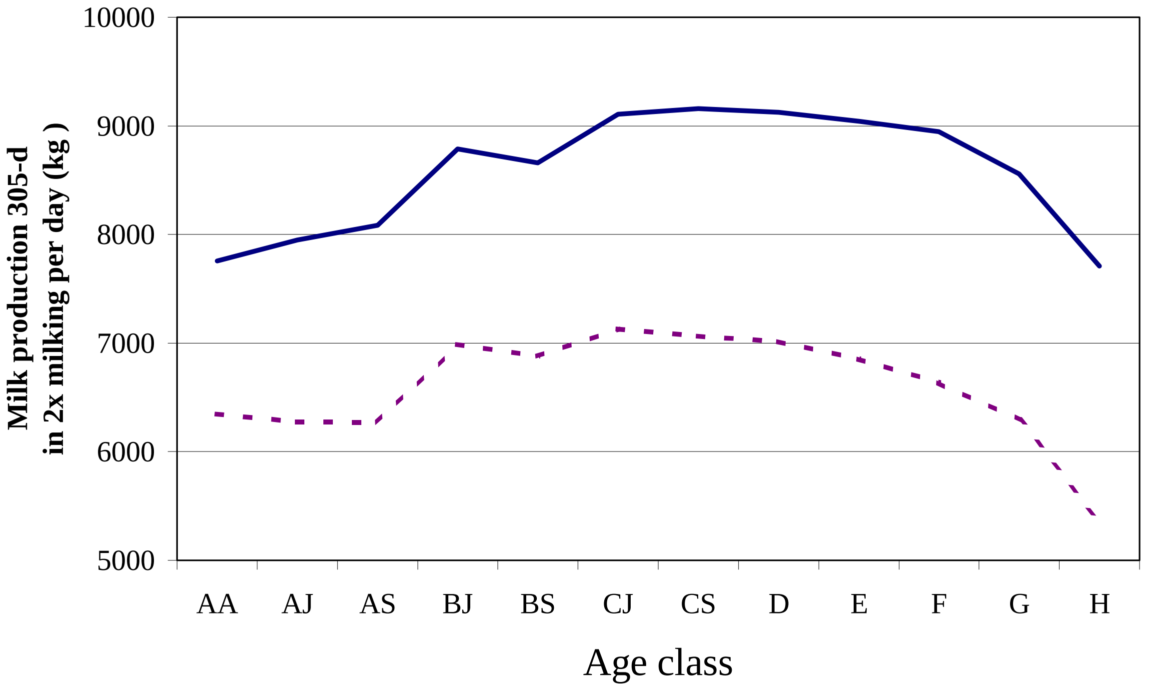


Figure 6. Average milk production (305-d of 2x milking) recorded by SCL (Milk Recording Service) in 2002 (the solid line is high yielding group, dashed line is low yielding group). The legend of age classes is given in Table 3.



Parameters c and b describe the shape of the LPC's. Estimated values for both parameters do not significantly deviate from zero ($P>0.05$). Moreover, the values of c and b are difficult to judge separately, because they are negatively correlated (Table 2; $P<0.01$), i.e. low values for c are compensated by higher values for b.

Average number of services per conception (INS_{ave}) is 1.45, which is low (Pereira et al., 1995b; Pryce et al., 2001; Montgomerie, 2002; Cavestany et al., 2003), probably due to fact that cows with low reproduction efficiency had been culled already long before their seventh lactation. Results of a study in the UK show that 64% of cows conceived at first insemination, which means that the average number of services for a conception was 1.56 (Kadarmideen et al., 2000).

The focus of the current study is the relation between t_{max} and production level, in this study represented by the first lactation production Y_1. Table 2 shows a highly significant correlation of both Y_{max} and t_{max} with Y_1, respectively 0.582 and -0.258. The correlation between Y_{max} and Y_1 is high, as expected (Jairath et al., 1995; Boettcher, 2000; Freitas et al., 2001). Genetically, first lactation milk yield is highly correlated with most measures of lifetime performance. Given this high positive genetic correlation, first lactation milk yield by itself can give an indication of lifetime performance. This characteristic is being considered already in selection programs of dairy cattle as a proxy for longevity.

The correlation of t_{max} and Y_1 is negative, thus supporting the hypothesis that increasing production is associated with an earlier age of maximum production (Figure 2).

The hypothesis that increasing production negatively affects reproduction efficiency is not fully corroborated by the data: the coefficient of the positive correlation (0.125) between INS_{ave} and Y_1 is not significant ($P>0.05$).

Table 1. Means and standard deviations of used variables (N=119).

Variable			
Name	Meaning	Mean	Standard deviation
Y_1	First lactation 305 d milk production (kg)	4928	1705
Y_{max}	Estimated maximum lactation production (kg)	7997	2431
t_{max}	Estimated age at maximum lactation production (months)	80	28
c	Estimated steepness parameter	-0.75	2.80
b	Estimated asymmetry parameter	0.005	0.088
INS_{ave}	Average number of inseminations/conception	1.45	0.41

High yielding cows have a higher initial milk production (Y_1) and are more likely to have a higher maximum lifetime milk production (Y_{max}), as shown in Figure 3. The relation can be described by the linear regression equation:

$Y_1 = 1593 + 0.422Y_{max}$.

The graph shows overestimation of Y_1 at lower levels of Y_{max}, suggesting that the relation might be curvilinear.

High yielding cows, with a high production level at first lactation (Y_1) reach maximum production (Y_{max}) at a younger age (t_{max}) (Figure 4). The regression line can be described by:

$Y_1 = 6133 - 14.3\ t_{max}$

Table 2. Correlation matrix of used variables (N=119). Bold coefficients are significant at
P< .001. (See Table 1 for explanation of variables)

Variable	Y_1	Y_{max}	t_{max}	c	b	INS_{ave}
Y_1	1					
Y_{max}	**0.582**	1				
t_{max}	**-0.258**	0.040	1			
c	0.037	0.027	-0.067	1		
b	-0.074	-0.053	0.068	**-0.645**	1	
INS_{ave}	0.125	-0.000	-0.143	0.132	0.045	1

However, the bounds set for t_{max} could affect the regression equation. To avoid this effect, we selected Y_1 as the dependent variable in the equation, because the estimation technique (Least Squares) is minimizing the deviations of the dependent variable.

Figure 4 shows lower values for t_{max} of cows yielding high in the first lactation and thus with a high metabolic demand at an early age. These cows may be paying a price in the form of production and/or reproduction problems at later stages, resulting in involuntary culling. Most involuntary culling occurs before the 4th lactation, but the risk is highest around the 2nd (Waltrick & Koops, in prep.).

Table 3. Legend of age classification of the SCL (Milk Recording Service)

AGE CLASS	years
AA	until 2
AJ	2 to 2.5
AS	2.5 to 3
BJ	3 A 3.5
BS	3.5 to 4
CJ	4 to 4.5
CS	4.5 to 5
D	5 to 6
E	6 to 7
F	7 to 8
G	8 to 10
H	over 10

Source: SCL (2003)

The correlation between Y_1 and average number of inseminations per conception (Figure 5) is not significant (Table 2), but the graph shows that for INS_{ave} > 2, no low values of Y_1 have been recorded. That may be the result of the culling strategy of the farmer. Cows with a low production and low reproduction efficiency have been culled already before the 7th lactation. It remains doubtful thus, whether in this data set a functional relationship exists between increasing production and an increasing number of inseminations per conception. This is one of the consequences of the large variability in 'real world'-data.

Holstein heifers are inseminated already at a very young age, after 13 to 15 months, which results consequently in calving for the first time at ages of 24 to 27 months. Various body components are still developing during this period and attain maximum growth rates at different ages (Koops, 1989); growth is maximal during puberty, and pregnancy during this period of life, followed by a high-yielding lactation, can affect the animal's growth.

For dairy cows, production and biological events are closely related, and milk production normally starts after calving. When the normal life cycle for a mammal is considered as a series of developmental events, comprising conception, birth, growth, sexual maturity, breeding for the first time, senescence and death, disruption in one of these events in the animal's life implies changes in the others (Taylor, 1985). Although the various parts of the body grow simultaneously and in an orderly way, the body does not grow as a unit, because various tissues grow at different rates from birth to maturity (Campbell & Lasley, 1969).

Selection experiments for early maturity suggest a significant antagonism with longevity (Essl, 1998). These results do agree with the theory of age in metabolic days (Taylor, 1985), that postulates that larger animals reach maturity later than small animals in proportion to their adult body weight. High yielding cows which are large ruminants are being selected for early maturity and high production. However, in contrary to the theory, they show an early peak in maximum milk production, before maturity. It could suggest that the age at maturity is anticipated, while probably the decrease in production has been anticipated caused by biological problems. The decrease in production starts before the potential peak of maximum milk production at maturity (Figure 2). It might be possible that animals that are not fully developed yet and already showing a high production level, being more susceptible to burnout. These cows probably mobilize all their reserves in the beginning of their productive life to attain such high production levels already at their first lactation, thus very early in their lifetime.

A possible explanation could be that instead of going through all the metabolic events in life and develop their own body, these high-producing animals are in negative energy balance before attaining full physical development, which can lead to ketosis or fatty liver disorders (De Vries & Veerkamp, 2000). Physical problems later in life can be the result of a high demand on the animal at a young age, resulting in high indices of involuntary culling among high yielding cows. Correlations between metabolic stress and energy imbalance have been reported in relation to production level (Boettcher, 1998; Veerkamp, 2000): Energy intake of high yielding Holstein cows is less than half their energy requirements for production in the first few weeks of lactation (Pryce et al., 2001).

Genetic selection for production only, has led to a decline in fertility. As the genetic potential for production increases, so does the gap between energy input and output during early lactation (Veerkamp, 1998). Breeding programs focusing on production traits lead to cows that are more likely to mobilize body reserves, which may negatively affect fertility (Pryce et al., 2001), as a strongly negative energy balance results in a delay in postpartum start of luteal activity (De Vries & Veerkamp, 2000). In a traditional 365-day calving interval system, the ideal timing for re-breeding is around 80 days postpartum, which coincides with peak milk production and the nadir in the energy balance (Pryce et al., 2000).

Increased digestive and locomotive problems have also been shown to be associated with longer and more extreme periods of negative energy balance (Collard et al., 2000; Veerkamp, 2000). A study carried out with a Brazilian herd on the effect of physiological and environmental factors on total milk production revealed the high incidence of parturition disorders (Pereira at al., 1995a). Although the production potential of high genetic merit Holstein cows on grass-based systems is high, their lower reproductive performance raises doubts about the suitability of high yielding cows for those systems (Buckley et al., 2000). As physical and reproductive problems affect longevity and have a strong economic impact on the dairy activity, longevity analysis has become part of the procedure for identifying the most profitable strategy for dairy herd replacement (van Arendonk, 1985; Bauer et al., 1993; Hadley, 2003). Replacing cows at the end of their sixth lactation resulted in the highest annuity value

(Bauer et al., 1993), but the differences were minor from the third to the tenth lactation.

Reported average number of lactations completed by cows in the USA was 2.5, and only 30% of the cows remained in the herd after the fourth lactation (Mason, 2003). In a further analysis, production level was considered one of the many factors that can affect burnout and longevity; it revealed that every 1000 kg increase in milk yield in the first 305-day production period reduced lifetime days in milk by about 65 days. Correlation studies in Brazil indicated that each 237 kg increase in production, resulted in 9.4 days increase in the calving interval (Silva et al., 1998).

Pursuing breeding goals determined only by short-term market forces, leads to undesirable side effects on the sustainability of the Holstein dairy production system. Sustainable animal production aims at long-term and equitable goal attainment for food production, resource efficiency, economic viability, productivity, environmental soundness, biodiversity, social acceptability and ethical aspects. Thus, breeding programs that aim at contributing to sustainability, must include both, market and non-market, economic traits (Olesen et al., 2000).

IMPLICATIONS

High yielding cows have higher milk production in their first lactation and are more likely to have a higher production performance during their lifetime, achieving a higher maximum milk production at younger ages. Hence, these high yielding cows have a higher metabolic demand during the heifer developmental phase and are, therefore, more susceptible to burnout. An early decline in production occurring before maturity could be an indication of, not only economic losses, but also an acceleration of senescence of these animals. Biological problems can force production to an early decline and finally reduce cow's longevity. Therefore, an early decline in production increases the differences in shape between potential and observed LPC's.

Monitoring the differences in shape of potential and observed LPC's could be considered when evaluating early burnout risk for high yielding cows. The age at maximum production could be used as a sustainability indicator considering its effect on longevity, which is an issue of concern for the sustainable development of Holstein dairy systems.

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Chapter 6

CHAPTER 6

A FRAMEWORK TO EVALUATE SUSTAINABLE DEVELOPMENT OF DAIRY SYSTEMS IN BRAZIL

ABSTRACT

A general framework of indicators for sustainable development evaluation applicable to different dairy farming systems in Brazil is proposed based on 5 steps to address sustainable agriculture and rural development, which considers the multidimensional character of sustainability. This analysis of sustainability includes the identification of sustainability indicators that take into account the technical-economic and the environmental-ecological trade-offs of production processes. Therefore emphasis is given here to the use of systems approach that offers a comprehensive perspective that accounts for the interrelationships between the technical, environmental, social, economic, and political aspects of sustainability. An integrated social, economic and environmental accounting framework is proposed based on an intensive grazing systems and its applicability to other production systems is discussed by evaluating impacts and changes in activities on the sustainability indicators presented.

INTRODUCTION

The scope of sustainability on development of dairy systems, also called sustainable development, has increased in the last decades as extensive traditional dual-purpose systems are increasingly being replaced by more specialized intensive systems, especially Holstein dairy systems. Developments in current Holstein dairy systems can be questioned in relation to their contribution to sustainable development (SD). Guaranteeing the sustainable development of farming activities is no longer only a farmer's responsibility, but more and more becomes a public concern, as farming activities increasingly affect the environment outside the boundaries of the farm (Cornelissen, 2003).

The importance of sustainable development of agricultural production systems creates the need to find appropriate methods to measure and evaluate sustainability (Rugby & Caceres, 2001). The concept of sustainable development used here is that defined in the World Commission on Environment and Development report (Brundtland, 1987):

"*…a sustainable development meets the needs of the present, without compromising the needs of future generations…*"

Characterization of sustainability includes both quantification and diagnosis of constraints (Hansen & Jones, 1996; Holling, 1995), applying the potential benefits of the sustainability concept to provide feedback about future impacts of current decisions, and focusing research and intervention by identifying constraints.

The actual problems of the Brazilian dairy production systems reported by the Brazilian Research Institute for Agriculture (EMBRAPA) are: (i) sustainability of the production system; (ii) profitability of the dairy activity; (iii) equity, for the wide range of farmers and within the dairy sector; (iv) food security and milk quality (EMBRAPA-Gado de Leite, 2002).

Quantification of sustainability means evaluation, or assessment, of issues related to SD, which is complex, as sustainability remains an elusive concept, specially when dealing with large number of small-holders (De Jong, 1996). The relative degree of sustainability is determined by a range of parameters (MAF, 1997; 1999). To identify the parameters involved and their developments, simple measurements can be very informative, to indicate whether activities are contributing to SD, in the sense of appraising developments as changes “away from” or “toward” sustainability.

To evaluate and monitor changes on-farm requires a range of indicators of different types, commonly referred to as sustainability indicators (SI; Cornelissen, 2003). Information from measurements of SI at farm level may be used for decision–making at society level and at farm level with respect to social, economic and environmental (EES) issues.

Assessment of sustainable development is complex, as farmer's decision-making processes with respect to strategic and operational management add complexity to biological and economic processes. In Brazil, a large variation in farming styles and a wide range of dairy production systems can be recognized, due to, among others, regional differences in cultural traditions and climatic conditions (Pereira et al., 1995). Dairy farms range from low-input systems with high-Zebu grade herds extensively grazing tropical pastures to high-capital confinement systems with Holstein purebred herds. Crossbreds are widely used, mostly based on conversion of pasture into milk. A wide variation in pasture quality and quantity, as well as in cow performance is being reported (Chapter 2). For farming systems evaluation, this variability must be taken into account as an important aspect of sustainability. Hence, tools should be developed for evaluation and monitoring of sustainable development of these different dairy farming systems. These tools should provide information for farmers regarding decision making on existing systems, presenting the major strong EES points of each system and its constraints.

In this study a general framework has been developed for sustainable development evaluation applicable to dairy farming systems in Brazil. An integrated social, economic and environmental accounting framework has been selected, on the basis of an intensive grazing system and then its applicability is discussed for other dairy systems, in order to evaluate the generality of the framework.

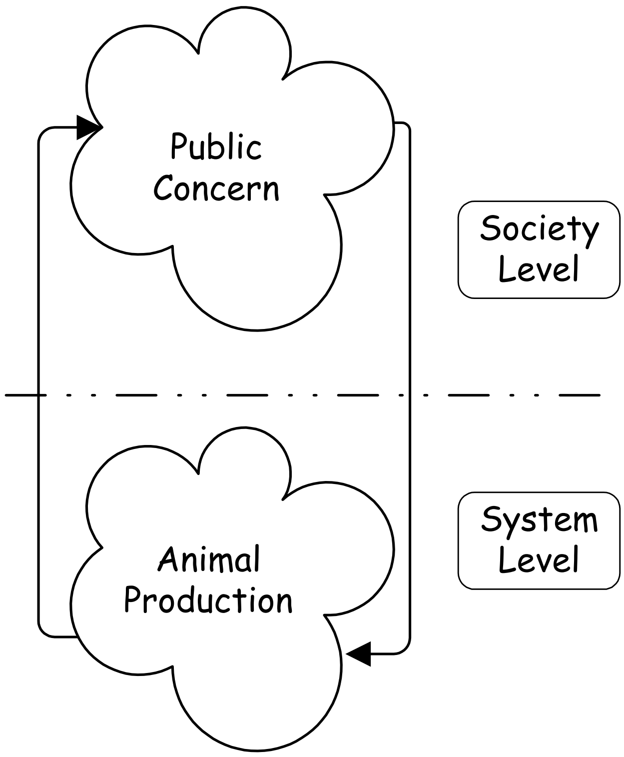
MATERIAL & METHODS

The term sustainability has been defined in many different ways, which indicates that it is a vague or fuzzy term and differs in meaning according to different stakeholders (Hansen, 1996), stakeholders, defined here as those that influence the functioning of the production system or are dependent on its functioning. Stakeholders have different perceptions about sustainability, however indicative measures are needed to obtain objective information aimed at quantifying sustainability: thus a ‘soft’ issue linked to ‘hard’ characteristics, such as production, pollution, use of resources, etc.

Two levels of sustainability concern can be distinguished, public concern and production system concern (Figure 1). Communication between these two levels can become problematic if stakeholders at society level have a qualitative perception (soft systems), while at production system level, most perceptions are quantitative (hard systems) (Cornelissen, 2003). Issues of concern for sustainable development of dairy production systems refer to activities performed at production system level that influence concerns at society level. Society evaluates the impact of dairy activities, which may raise concern at society level; these issues are identified by the relevant stakeholders and may lead to proposals for change at production system level. These issues can become a farm concern dealing with the question on how to continue the production system based on the proposed more sustainable activities. When farmers then change activities at farm level, that might have an impact on sustainability and thus affect public concern, after which the cycle can start again (Figure 1).

Cornelissen (2003) presented an evaluative framework of sustainable development to transform identified issues of concern into tangible sustainability indicators using established criteria. At farm level, sustainability indicators are monitored and interpreted by farmers and other stakeholders, resulting in information to support society in reaching an overall conclusion with respect to the contribution of a current production system to society’s sustainable development (De Haan, 1998). With this framework it is possible to exemplify and recognize pressures from human and economic activities on the environment that lead to changes in the state of the environment and may provoke responses by society to change the pressures and maintain the state of the environment.

Figure 1. **The sustainability situation (Cornelissen, 2003)**



Use of a "systems approach" to evaluate the sustainability situation according to Figure 1, can be illustrated by considering the pressures on the environment from dairy activities originating from the management of nutrients on the farm. In an unsustainable production system more nutrients are removed from the soil than imported, so that soil fertility is gradually depleted and pastures degrade. In situations where more nutrients are applied than removed, as occurs around the dairy barns, there is a risk for pollution of groundwater. Thus, manure management is a key factor in nutrient management in dairy production systems. Traditionally, manure management has focused primarily on the production, collection, storage, and field application of manure. In a systems approach, this focus expands to include concerns about human and animal health, odour and fly control, nutrient import and handling, ration balancing and feeding management, optimisation of dietary nutrient utilization and palatability and nutrient digestibility.

Therefore, a systems approach requires a broad spectrum of scientific expertise as represented in multidisciplinary teams of agronomists, dairy scientists, economists, engineers, microbiologists, soil scientists, veterinarians and managers to deal successfully with the complex issues pertaining to dairy nutrient management (Grusenmeyer & Cramer, 1997). Thresholds for nutrient surpluses related to environmental sustainability are being implemented by regulations and laws, often based on background information from literature (MAF, 1999). The results of indicator measurements at farm level have to be compared to these environmental thresholds and need to be monitored over time.

Table 1. **A general framework for sustainability evaluation of dairy systems**

STEP	DESCRIPTION	ACTION
1	Description of a production system	Define context and characteristics of a dairy production system.
2	Identification of EES issues	Assessment of sustainability issues for dairy systems and classification into Economic, Ecological and Societal issues (EES)
3	Choice of indicators	Derivation of indicators from the EES issues, based on presented criteria.
4	Measure sustainability indicators	Measurements or observations of indicators.
5	Evaluation and monitoring	An integrated social, economic and environmental accounting approach to evaluate the sustainability indicators in relation to issues of step 2.

Per issue of concern, the framework proposes on-farm sustainability indicators (SI). The basis of the general framework is a 5-step procedure (Table 1), as described by Cornelissen (2003). This general framework should result in a list containing issues and indicators applicable to dairy systems in Brazil, extensive or intensive systems (Chapter 2) and will be developed by going through steps 1-3 of the procedure of Table 1, steps 4 and 5 are more specific in nature and require a local and individual approach, therefore they are just briefly discussed in this general framework.

To operationalise development of the framework, one Brazilian system (Management Intensive Grazing (MIG) system, Chapter 2) is used as starting point. This system is described as base system in the first step of the procedure in Table 1.

The value of information from a sustainability indicator derives from its capacity to reduce uncertainty about the state of the issue of concern and its contribution to any desired outcome (Pannel & Glenn, 2000). In the search for suitable indicators, five criteria have been selected based on literature and practical experience (Dore, 1997a; 1997b; Cornelissen, 2003).

A good indicator should meet the following criteria:

- ***Relevance***: the indicator should be associated with one, or several, issues of concern.
- ***Simplicity***: easy to use and interpret, information from the indicator should be easily and understandably presentable in an appealing way to the target audience.
- ***Quality***: comprising two aspects: *reliability* and *sensitivity*. The quality of an indicator depends on the reliability of its measurements and its sensitivity to changes in a system, thus responsive to changes and providing a representative picture. These changes can occur across time and space and the value of the indicator should express the 'state' of sustainability associated with each change and lead to the appropriate action. However, it is relevant to determine beforehand whether the indicator should be sensitive to small or large changes.
- ***Trend or target value***: it is necessary to assess the contribution of an individual indicator to sustainable development, therefore identification of a possible target value, reference or trend over time is needed.
- ***Accessible data:*** the desired information can be collected from accessible data, while there is still time to act; therefore the information should be available at reasonable prices and should be easy to update.

RESULTS

1- Description of a base production system

The base dairy system chosen is a Holstein dairy system based on intensive grazing. It is a system that has being recommended by EMBRAPA and Agricultural Universities in Brazil as a sustainable option for dairying with respect to resource use and economic indicators. It is a low input system, restricting costs for feeding concentrates by using pastures, however using a high production potential dairy breed.

This base dairy system is referred to as Management Intensive Grazing (MIG) in the southern and central regions of Brazil. There are some differences among regions related to the winter supplementation in MIG. Generally, it is characterised as a system where animals are kept continuously on pasture and more than 50% of dry matter intake (DMI) comes from grazing. Intensive grazing requires high quality pasture management.

In the southern region, the MIG system is being adopted by 43% of the dairy farms (Krug, 2001), 51% are semi-confined, 0.07% confined and 5.4% are extensive systems. In the central region, the MIG system is being promoted and many farmers are adopting, however precise data on total number of farms adopting the MIG system are not yet available. The concept of this MIG system in Mato Grosso do Sul is presented in a schematic map (Figure 2) where system boundaries and relations within the system are shown, including the various inputs and outputs (Boogaard, 2003).

Identifying all the processes within the system is very important when evaluating sustainability. The conceptual representation (Figure 2) illustrates the functioning of the system and its subsystems as a whole. Characteristics of the MIG system are summarized in Table 2.

The MIG system is a rotational grazing system in which animals at a high stocking density are rotated through several paddocks at short time intervals varying from a few hours to a few days (12 h to 3 days). By rotating the animals on the pastures, animal performance is maximised and the pasture has time to recuperate between grazing periods. The system uses tropical pastures in summer (September to February) and supplementation in winter (March to August).

The tropical forage species commonly used are elephant grass (*Pennisetum purpureum*), Mombaça (*Panicum maximum*), Andropogon (*Andropogon gayanus*), Brachiaria spp., Paspalum spp., and Setaria spp (Carnevalli, 2002; Fagundes et al., 2001). The forages Mombaça and elephant grass are widely used in Brazil, because of their high production capacity. In the southeastern and central regions, because of climate limitations only tropical grasses are available. Tropical grass production and management has been exhaustively reported in the literature (Fonseca et al., 1998; Deschamps et al., 2000; Vilela et al., 2002; Heringer et al., 2002).

In the southern region of Brazil, MIG is possible during summer and winter. In the winter MIG is based on ryegrass (*Lolium multiflorum* and *Lolium perenne*), lucerne (*Medicago sativa*) and black oat (*Avena strigosa*), supplementation is based on silage, hay and concentrates.

Winter in the central regions of Brazil is followed by a dry season, and pasture production is insufficient to practice the MIG system. Therefore in the central regions sugarcane is the winter supplementation and concentrates.

Soil quality, carrying capacity of pasture and grazing pressure or livestock density are determinants for the intensity of rotation per paddock in pasture management. At pasture establishment, it is recommended to correct soil pH annually and fertilize it (N-P-K) (Assis, 1995).

The season, the amount of rainfall and temperatures influence the pasture production during the year. Daily herbage intake varies according to the season and year, being relatively high in summer, intermediate in autumn and spring and relatively low in winter, average herbage allowance is around 11.3 ± 0.45 kg of DM/cow (Aroeira et al., 1999).

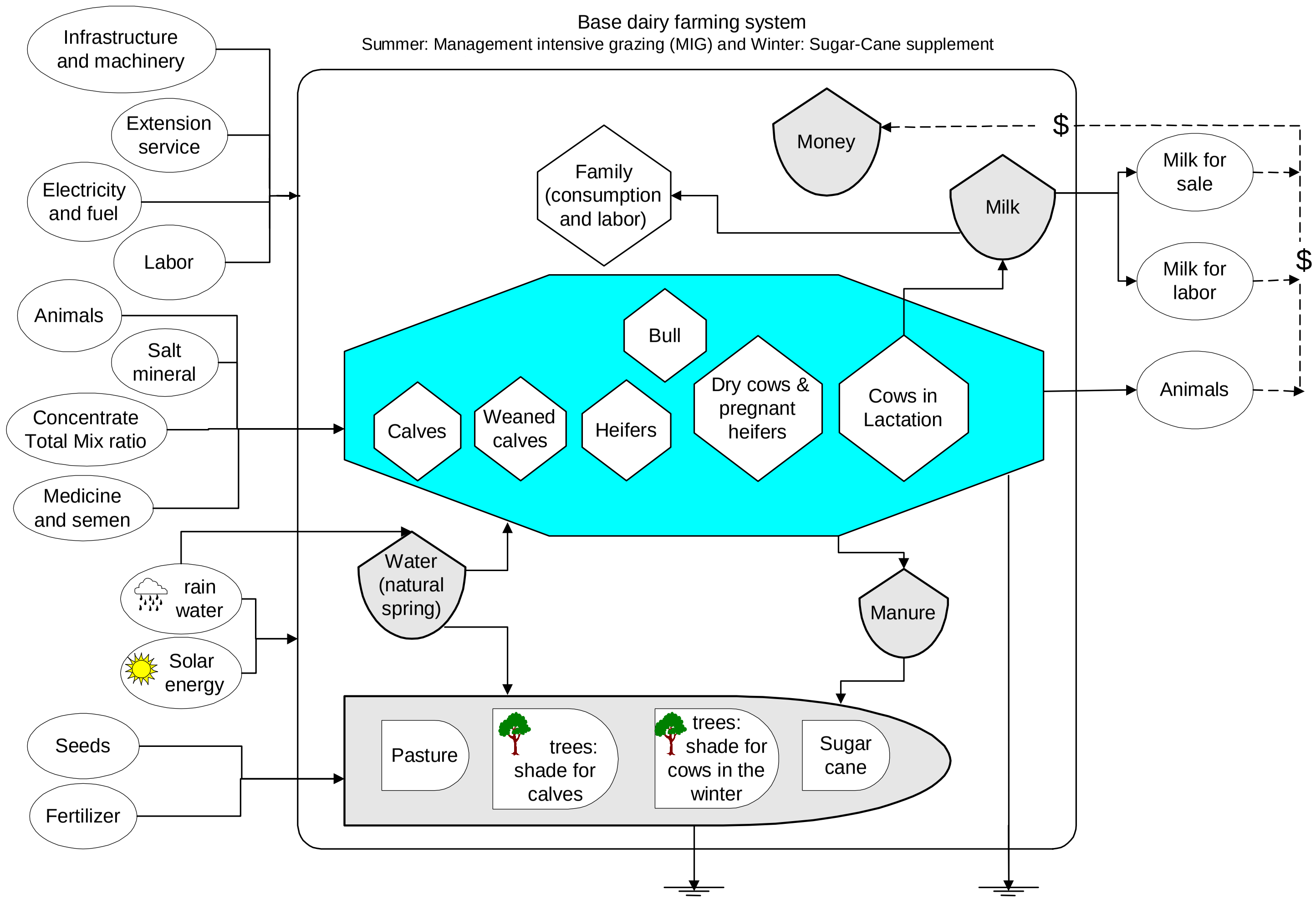
The proper use and management of supplements can make the difference between profit and loss for small farmers (Ørskov, 1999) as well as the choice of breed, Holstein or crossbred. Farmers have been choosing for Holstein because of its milk production potential, however this breed only reach its high production potential when concentrates are consumed in high amounts. Grazing cows feeding only on pasture generally loose weight and have a decreased milk production. Farmers are trying to find a more efficient balance between the milk produced per kilogram of concentrate, because concentrate is a costly item in the dairy activity. A limit is set to concentrates in the diet: 10 kg DM per cow per day to minimise the risk of metabolic problems in the rumen (Camargo, 2002). Many farmers are adopting sugarcane as supplementation, although milk production potential with sugarcane supplementation is less than with corn silage and hay. The price and risk of sugarcane production is 2/3 of that of silage (FEALQ, 2000, Martin et al., 1999), which makes sugarcane more suitable for smallholders and for the different dairy farming styles. However, intensive high production systems with Holstein herds require adaptation of the cows and management to use sugarcane as supplement.

Table 2. Characteristics of the base dairy system

CHARACTERISTIC	SYSTEM DESCRIPTION (Boogaard, 2003)	SYSTEM DESCRIPTION (Krug, 2001)
Concept	Low input (low costs), based on rotational pasture by intensive grazing in summer and sugarcane supplementation in winter	Low input (low costs), based on rotational pasture by intensive grazing in summer and winter, with grass and silage supplementation in winter
Dairy breed	Holstein 100%	Holstein 55%, Jersey 16%, Crossbred 28%
Location	Central region of Brazil, Mato Grosso do Sul state	Southern Region of Brazil, Rio Grande do Sul state
Area used for dairy activity	Total 18 ha, with 10 ha pasture	Total 11 ha, with 10 ha pasture
Paddock number and size	16 paddocks of 0.625 ha each	10 paddocks of 1 ha each
Soil fertility	Soil acid; soil pH must be corrected and fertilized (N-P-K)	Soil acid; soil pH must be corrected and fertilized (N-P-K)
Stocking density	4 to 8 AU/ha AU: animal unit	1.26 AU/ha AU: animal unit
Milking frequency, Use of milking machine (%)	Twice a day, 100% use of milking machine	Twice a day, 51% use of milking machine 49% hand milking
Number of animals per farm	54 AU, 32 cows in lactation	11 AU, 8 cows in lactation
Artificial insemination rate (%), Services per conception	Artificial insemination 100%, 1.45 services	78% artificial insemination 22% bull, 1.51 services
Calf management	Colostrum is given during the first 72 hours after birth; weaning at 60 kg live weight, milk supply is substituted by forage and concentrates	Colostrum is given during the first 72 hours after birth; weaning at 60 kg live weight, milk supply is substituted by forage and concentrates
Calving interval	around 13 months	Around 14 months

CHARACTERISTIC	SYSTEM DESCRIPTION (Boogaard, 2003)	SYSTEM DESCRIPTION (Krug, 2001)
Heifer management, Age at first service and age at first calving (months)	Grouped according to body weight; inseminated at 16 to 18 months of age; calving at 25 to 27 months	Grouped according to body weight; inseminated at 17 to 18 months of age; Calving at 28 months
Average daily milk production	15 kg/cow, 450 kg/farm	10 kg/cow, 77 kg/farm
Average live weight of cows	500 kg	450 kg
Grazing and resting days of pasture	Grazing 2 days, resting 30 days	Grazing 3 days, resting 30 days
Summer supplementation	Concentrates at 2 kg/cow/d (20 % crude protein); if pasture carrying capacity allows, supplementation can be reduced	Concentrates at 2 kg/cow/d (20 % crude protein) and silage, if possible hay
Winter supplementation	Concentrates at 7 kg/cow/d and sugarcane very finely chopped at 6 kg/cow/d, plus urea (1% by weight of the diet). Mombaça grass for grazing when available	Concentrates at 2 kg/cow/d (20 % crude protein) and silage, if possible hay
Drink water and mineral salt	Unrestricted at the dairy barn and in paddocks	Unrestricted at the dairy barn and in paddocks
Mastitis control/prevention	Pre dip and post dip after each milking	Pre dip and post dip after each milking
Farmers taking courses (%) Getting technical assistance	* only farmers from the association were studied, all get technical assistance	41% 56%
Recording of economic flows (%)	65%	21%
Participation in associations (%)	100%	68%
Daily milk production per animal (total number) Annual milk production (kg/ha/year)	8 kg 3,041	7 kg 2,555

Figure 2. The base dairy system in Mato Grosso do Sul, Brazil.



Livestock density, paddocks and pasture capacity:

Depending on the resting period adopted per paddock, livestock density varies from 4 to 8 cows/ha in Mombaça pasture, considering 40 cows, with an average live weight of 500 kg, producing on average 15 kg milk/d, in a dairy farm with 10 ha of pasture. Average herd milk production is 450 kg/d. Normally, pasture fertilization starts after September, and according to adopted pasture management, the paddocks are planned and divided. Paddocks are designed and divided in accordance with the characteristics of the farm, but the size is generally between 0.5 and 1 ha. The number of paddocks depends on the grazing and resting periods adopted. If a pattern of 2 grazing days and 30 days resting is selected, 16 paddocks will be needed in this example of the base system (EMBRAPA-Gado de Leite, 2003b). The area of each paddock depends on the total pasture area available on the farm (Boogaard, 2003).

Daily management in summer and winter

During summer, lactating cows start with rotational grazing, grazing during the day and supplemented at night. If pasture carrying capacity allows, the supplementation can be reduced, if not, an alternative is to reduce stocking density, however this is not common practice because of infrastructure (fixed fences).

Generally, supplementation comprises concentrates (with 20 % crude protein) at 2 kg/cow/d. To increase the energetic and protein value of concentrates, cottonseed and urea are used to adjust the diet (Assis, 1982).

In winter in the central region, following morning milking, cows are brought to pasture or to shaded areas under trees, where they receive concentrates and sugarcane plus urea (1% by weight of the diet) as roughage supplement. At the end of the afternoon, cows are milked again and then returned to the shaded areas, to spend the night, where they are fed again concentrates and sugarcane. Total supplementation is composed of 7 kg of concentrates, 6 kg of very finely chopped sugarcane and 60 g urea, and 2 kg of Mombaça grass. At the end of the winter and in the dry season, grass production is very low and the proportion sugarcane and concentrates increases, however, milk production decreases.

Breeding and calf care

Artificial insemination is generally used, however with the use of a bull for oestrus detection. It is common for Holsteins that all parturitions are assisted, often with help of a veterinarian. Calving interval is around 13 months.

After birth, calves are registered and housed individually (EMBRAPA-Gado de Leite, 2003b); colostrum is provided during the first 72 hours after birth, providing life-supporting immune and growth factors, promoting health and vitality of the newborn (Healthtrak, 2002). Calves from low productive cows are removed from the herd. Remaining calves are weaned at 60 kg live weight, generally around 60 d of age, milk supply is suspended and only forage and concentrates are given. After weaning, the calves join the heifers, grouped according to body weight. They are all inseminated at 16 to 18 months of age, calving at 25 to 27 months of age.

Milking

Generally, milking is twice a day, but at some intensive farms three times. In the morning before milking, cows come from paddocks, and in the waiting room of the dairy barn receive water unrestrictedly. Just before and after milking, cows are tested for mastitis. Concentrates are supplied during milking. After milking, cows are returned to the paddocks, where mineral salt and fresh water is presented. The second milking of the day follows the same schedule. Heifers and lactating cows in the first phase of lactation always start grazing a new paddock to guarantee that the best quality feed is available for cows with high production and high energy requirements.

2 - Identification of EES issues

To assess the contribution of activities in the dairy system to sustainable development a set of economic, ecological and social (EES) issues of concern is presented in Table 3. These issues were identified by several stakeholders and published in official reports from Brazil, Australia, New Zealand and the Baltic Sea Region (EMBRAPA-Gado de Leite, 2002; Krug, 2001; MAF, 1997; 1999; Baltic21, 1998; Dore, 1997b). Prevailing dairy production systems and societal imperatives lead to identification of issues that, combined, define the common ground for sustainable development (SD) as point of departure for local initiatives that aim at contributing to SD (Cornelissen, 2003).

Table 3. Areas of concern and issues derived from official reports

AREA	ISSUES
Production	Information and data recording on the production system
	Dairy market conditions
	Adapted technology for different regions and dairy systems
	Genetic potential for milk production of the herds
Natural resources	Fossil energy use and efficiency of energy use
	Erosion, nutrient management and soil fertility
	Pasture condition and pasture carrying capacity
	Biodiversity and genetic resources of dairy breeds
	Air and water management
	Enterprise diversity and risk spreading
Human and animal welfare	Public health and food security: quality of produced milk, contaminants and residues in milk
	Use of hormones, growth promoters and antibiotics
	Management skills of dairy farmers and managers
	Animal welfare and threats to animal health
Social	Population growth (rural/urban)
	Equity, in relation to scale of production, and access to technology, extension services and government subsidies.
	Social infra-structure in rural areas
	Preservation of nature and historical values
	Rural exodus and urbanization
	Rural education, training, information supply and management skills of dairy farmers and managers
Economic	Economic profitability of dairy farming
	Competitiveness of the dairy sector
	Stimulus for dairy production, productivity and milk quality.
	Identification of production costs and profit
	Economic security: employment and market opportunities

Public concern can be characterized through multiple issues at society level that represent perceptions of the impact of current practices in dairy farming on society and the environment, for example issues with respect to animal behaviour, welfare of farmer and animals, physiology and health, environmental degradation, use and quality of resources. Public concern also may refer to social issues, such as combating poverty, and securing employment, food security and food safety (De Haan et al., 1997a).

In the same perspective, production system concern can also be characterized through multiple issues that are relevant for the continuity of the production system. Agricultural practices could be changed or adopted in response to public concern, which in turn may affect public concern. As an example, increasing average herd size for economic reasons (economic issue) results in an increase in manure production at dairies, and if manure management is sub-optimal, environmental pollution may result. This environmental issue may attract public concern and reinforce the need for regulatory agencies to prevent pollution, which could result in changes at farm level in activities related to manure management (cf. Henkens & van Keulen, 2001).

As this study focuses on on-farm issues to develop a tool for production system sustainability evaluation and monitoring, the relevant issues were selected from Table 3, and presented in Table 4, where each issue is assigned a code for further use. Criteria used for selection were: (1) the farmer should be able to act upon indicators relating to the issue, (2) issues must be related to the dairy system described in Step 1, and (3) issues should also be relevant to other dairy systems.

3- Choice of indicators

Derivation of a set of indicators from the EES issues for evaluation of sustainability has to be based on the selected criteria. Because of the large variability in conditions in Brazil, the level of acceptability for particular indicators (thresholds) may vary according to regions, hence local assessment of sustainability indicators is recommended to adapt the framework to specific local conditions. In the absence of clearly defined thresholds for the performance indicators, data collection and analysis will be linked to goals and issues. If observed values are not within the desired range or exceed thresholds, action can be taken.

Identification of suitable indicators and their data sources is an indispensable component of monitoring sustainable development in agricultural systems. Selected indicators may differ for different stakeholders. Farmers at system level and policy makers at society level are facing different problems and therefore they may opt for different indicators to evaluate sustainability. Therefore, the need arises to reach a compromise with respect to indicators that are considered worth monitoring at both, farm and society level.

Table 4. Areas of concern and issues for on-farm sustainability evaluation

AREA	ISSUES	CODE
Production	Information and data recording on the production system	Info
	Dairy market conditions	Market
	Adapted technology for the different regions and different dairy systems	Adapt
	Genetic potential for milk production of the herds	Genetic
Natural resources	Fossil energy use and efficiency of energy use	Energy
	Erosion, nutrient management and soil fertility	Erosion
	Pasture condition and pasture carrying capacity	Pasture
	Air and water management	Air/water
	Enterprise diversity and risk spreading	Diversity
Human and animal welfare	Public health and food security: quality of produced milk, contaminants and residues in milk.	Quality
	Use of hormones, and antibiotics	Medicine
	Management skills of the dairy farmers and managers	Management
	Animal welfare and threats to animal health	Animal
	Rural education, training and information supply	Education
Economic	Economic profitability of dairy farming	Profitability
	Identification of production costs and profit	Costs

In practise, matching the indicators with the different criteria is difficult, because it is not possible to quantify. It is however, a good exercise to discuss each indicator in the light of each of the criteria. In the next step (which is not part of this study) it may turn out that some of the indicators do not meet one or more of the criteria.

For each on-farm issue one or more indicators have been derived (Table 5), based on the concept of the MIG system, described in Step 1. This implies that indicators are certainly relevant (first criterion) for this system. Values for some indicators can be read from Table 2, for instance stocking rate is 4 to 8 cows/ha. In general however, the farmer should perform many measurements and calculations to produce the values of all indicators from Table 5.

Most of the indicators are simple, thus meeting the second criterion (simplicity). As for the third criterion (quality), it is difficult to predict the behaviour of the indicators in time and space. Their quality should be assessed when they are used. The most serious problem is the fourth criterion (trend or threshold), required to judge the value of the indicator. For instance, is a stocking rate of 6 cows/ha too high in the light of the concerns on erosion and pollution? An answer to this question requires more research in co-operation with experts and stakeholders. In some cases thresholds are available from literature. As for the final criterion (accessibility), examining the list of indicators (Table 5) shows the first two are: Information available and Data recording. If these two attain zero-values, a real problem will be faced. In any case, a protocol needs to be developed to indicate how the values for indicators in Table 5 should be obtained.

4 - Measure sustainability indicators

During this step on-farm indicators will be observed or measured. Sometimes an indicator may be very difficult to quantify, some indicators will be missing therefore it is important that more than one indicator per issue is available.

Important system characteristics were measured by Krug (2001) in the southern region of Brazil (Rio Grande do Sul state) and by Boogaard (2003) in the Central region, those results will be presented as example for implementation of the framework (Table 6). Other dairy systems will be discussed further with respect to the general applicability of the framework and the selection of indicators.

Table 5. Issue code (see Table 4), proposed indicator and unit of measurement

CODE	INDICATOR	UNIT OF MEASUREMENT
Info	- Information available,	- No(0), basic(1), complete(2)
	- Data recording	- None(0), hand-written(1), digital(2)
Market	- Regional milk price	- $/litre
	- Monopoly of dairy market	- Number of possible delivery points
	- Market	- Formal(3), informal(1), both(2)
Adapt	- Use of local feed	- % feed from local resources
	- feed efficiency	- Milk produced per kg concentrates
Genetic	- Type of dairy breed	- General average milk prod. of breed
Energy	- Use of tractor, truck, cars	- No(0), rented(1), owned(2)
	- Efficiency	- Fossil energy use/kg milk
Erosion	- Stocking rate	- animal units/ha
	- Soil cover	- m^2/ha
	- Use of fertiliser	- kg nitrogen/ha
Pasture	- Productivity	- kg dry matter/ha harvested
Air/water	- Stocking rate	- animal units/ha,
	- Manure storage facility	- yes/no
Diversity	- Activities at the farm	- Number of economic farm activities
	- Recycling of nutrients	- % use of nutrients from local resources
	- Recycling of waste	- % waste recycled within the farm
Quality	- pH of milk	- pH
	- Somatic Cell Counting of milk (SCC)	- SCC
Medicine	- Use of BST hormone	- quantity per cow
	- Veterinary costs	- $/cow
Management	- Education level	- primary(1), secondary(2), higher(3)
	- Participation in courses	– frequency per year
Animal	- Disease incidence	- veterinary costs (R$/cow)
	- Shade comfort	– shade area m^2/ha
Education	- Education level	- primary(1), secondary(2), higher(3)
	- Participation in courses	- frequency per year
Profitability	- Net farm income	- $/year,
	- Profitability: income per farm or per kg milk	- $/year/farm or $/year/kg milk
Costs	- Economic administration: costs per kg milk	- $/year/kg milk

5 - Evaluation and monitoring

Evaluation of indicators follows an integrated social, economic and environmental approach, and is based on the effect of activities within the dairy system on sustainability. As sustainability is a dynamic notion, sustainability indicators should be monitored over time.

The acceptability levels or thresholds for each indicator may be derived from literature (EMBRAPA-Gado de Leite, 2003b and 2003c), but they may require adaptation to specific local conditions, such as average milk price, average milk production per farm, average farm size. In the South, farms are smaller in size and own smaller numbers of animals than farms in Central region. The milk price is higher in the South than in the Central region.

Evaluation and monitoring must follow a participatory approach to directly and actively involve farmers and other stakeholders in the sustainability analysis. This study will not focus on the process of evaluation and monitoring of indicators itself, but focus on possible sustainability indicators for the different dairy production systems in Brazil.

DISCUSSION

Sustainable development for dairy farming systems has been extensively discussed (cf. Spedding, 1995; Dore, 1997a; 1997b, EMBRAPA-Gado de Leite, 2002), even though doubts have sometimes been expressed on the usefulness of the concept (Spedding, 1993; 1995). In very ‘general terms’ objectives pursued in such sustainable systems can be summarized as:

(i) enhancing farm productivity in the long-term;
(ii) minimizing or avoiding adverse impacts on the natural resources;
(iii) maximizing net social benefits (monetary and non-monetary terms);
developing farming systems that are flexible to manage in view of risks.

Table 6. Issue code (see Table 4) and indicator values in Mato Grosso do Sul and Rio Grande do Sul.

CODE	Mato Grosso do Sul (Boogaard, 2003)	Rio Grande do Sul (Krug, 2001)
Info	-basic(1)	- basic(1)
	- hand-written(1), digital(2)	- hand-written(1), digital(2)
Market	-$ 0.49/litre	- $ 0.50/litre
	-	- 23 cooperatives
	- Formal(3), both(2)	- Formal(3), informal(1), both(2)
Adapt	- import of concentrates and mineral salt	- import of concentrates and mineral salt
	- feed efficiency	- milk produced per kg concentrates
Genetic	- Holstein (15 kg/d)	- Holstein 15 kg/d, Jersey 13 kg/d, crossbred 8 kg/d
Energy	- No(0), rented(1), owned(2)	- No(0), rented(1), owned(2)
Erosion	- 4 to 8 AU/ha	- 1.26 AU/ha
Pasture		- 9,880 kg dry matter/ha harvested/year
Air/water	- 4 to 8 AU/ha	-1.26 AU/ha
	- No manure storage	- No manure storage
Diversity		
Quality		
Medicine	- No hormone use	- No hormone use
Management	- primary(1), secondary(2)	- primary(1), secondary(2)
	- twice a year	– varyiable
Animal		
Education	- primary(1), secondary(2)	- primary(1), secondary(2)
	- twice a year	- variable
Profitability		- 21% of gross margin
		- 12% of gross margin
Costs		- 79% of gross margin

In order to judge the sustainability of specific dairy farming systems and their contribution to sustainable rural development, these general objectives have to be translated into explicit characteristics that can be quantified explicitly. Moreover, effects of possible changes in activities within the farming system on these characteristics should also be explicitized. For that purpose, a more operational definition of sustainability is necessary. Among the many definitions of sustainability in the literature (Rugby & Carceres, 2001), we have selected one based on the concept of the ability of a purposeful system to continue into the future. Dealing with the future, sustainability of a dairy production system can not directly be observed; hence its development with respect to sustainability should be monitored and evaluated.

For that purpose, a framework was developed to evaluate dairy farming systems in Brazil, within the wider sustainability view, that has schematically been classified in economic, environmental and social (EES) issues. These issues evidently are not independent, so that sometimes rather arbitrary choices have to be made

For the purpose of sustainability evaluation, a set of indicators has been identified that allows quantification of the degree of sustainability of a particular system. On the basis of the indicators, effects of modifications in the system (adaptations in activities) can be judged with respect to their contribution to sustainable development, by explicitly describing their impact on the indicators. The issues have been derived from reports by different stakeholders in various countries (Spedding, 1995; Reed & Bert, 1995; Dore, 1997a; 1997b; MAF, 1999; EMBRAPA-Gado de Leite, 2002).

Emphasis in the current study is on indicators at production system level, but because of the ‘two faces’ characterizing sustainability (Cornelissen, 2003), they can also serve to support policy makers at regional or national level, in decision-making on sustainability issues.

The framework has been developed on the basis of a detailed description of the MIG (Management Intensive Grazing) system, a dairy production system widely practiced in South and Central Brazil. The system is being recommended by EMBRAPA, the national agricultural research organization and Agricultural Universities in Brazil as a sustainable option for dairying with respect to resource use and economic indicators. To judge the generality of the framework, it should be applied to other systems within the wide range of dairy production systems in Brazil.

Economic issues

At dairy production system level, economic viability is a major sustainability characteristic. This characteristic is evaluated on the basis of economic indicators that should reflect (at least) the economic performance of the dairy activity and, if applicable, also that of other economic activities within the production system (farm). In the framework developed in this study, two indicators have been identified for evaluation of the economic performance of the system, net farm income, the balance between revenues and costs and profitability, the long-term economic viability of the system.

An additional indicator identified within this issue is fossil energy use and efficiency of energy use, that next to economic, also has environmental connotations, as it is directly related to CO2-production, which has consequences for climate change, and as such may also have social aspects. Moreover, enterprise diversity and risk spreading is included as an economic indicator, while management skills of the dairy farmers are of direct influence on the performance of the system.

At society level, an important characteristic affecting economic performance is presented by the dairy market conditions that affect the possibilities for sale of the dairy products as well as the price setting.

Environmental issues

Environmental issues play a major role in sustainability evaluation at both the production system level and the society level. They deal primarily with the quality of the natural resources. At production system level, that refers in first instance to soil quality that is directly affected by system management. At societal level, the qualities of land, water and air are at stake that also are influenced by the activities at production system level, and are then referred to as externalities.

Environmental issues appear to be major areas of interaction between the two levels, and have therefore received relatively much attention in sustainability evaluation.

Within the framework, restricted to the production system level, these considerations have been expressed in the indicators erosion, nutrient management and soil fertility, pasture condition and pasture carrying capacity. It is evident that a compound ‘indicator’, such as ‘erosion, nutrient management and soil fertility’encompasses in fact a major part of the natural resource quality characteristics of the dairy system. For effective monitoring and evaluation this indicator will have to be sub-divided in (many) more tangible characteristics. In preparing for the design of a prototype dairy farm in the Netherlands aiming at realising very strict environmental targets (hence environmental issues were the main focal point) several dozen individual indicators were identified (Aarts et al., 1992) to get a good insight in current performance and possibilities for improvements. During implementation of this framework it may also be necessary to further elaborate this indicator.

Social issues

Social acceptability is another characteristic of sustainable dairy farming systems. Social issues also play a role at both the production system level and society level. Again, in practice, social issues are hot debating points in the interaction between production system level and society level. Particularly animal welfare has dominated the discussion on sustainability between the animal production sector and society. Although especially intensive animal production systems have come under attack on the basis of this issue, dairy farming systems have not escaped attention.

Within the framework developed in this study, social issues have been translated in the indicators public health and food safety (quality of milk produced, contaminants and residues in milk), animal welfare and animal health (use of hormones and antibiotics). Culling risk and age at maximum production could be potential indicators for animal health and welfare, as potential measures of impacts on livestock of intensification of dairy systems. Education of the farmer may make it possible to improve the results of the farm, at the same time it often improves health and well-being (Baltic21, 1998).

There is a clear need for development of more evaluation and monitoring tools which effectively document the current status of dairy systems and grazing lands, and allow ex-ante judgment of effects of projected changes in resources use patterns. Most proposed indicators in the literature are strongly technical in focus, while economic and social issues are increasingly important, especially in the interaction between different levels. It has been recognized that for different groups of users (on-farm, off-farm) the types of indicators considered most useful (or even considered indispensable) are likely to differ, but insufficient attention has been paid to the nature of these differences. This appears to reflect a lack of emphasis on actual decision making (Pannel & Glenn, 2000).

A limitation on the use of sustainability indicators is that they are often difficult to quantify, especially those dealing with social issues (Cornelissen, 2003). Nevertheless, indicators and associated thresholds are indispensable to make sustainability operational both at farm management and policy design level.

Sustainable production systems make the best use of nature's goods and local services, so technologies and practices must be locally adapted. The most sustainable production system is likely to emerge from new configurations of social capital, comprising relations of trust embodied in new social organizations, and new horizontal and vertical partnerships between institutions, and human capital comprising leadership, ingenuity, management skills, and capacity to innovate (De Haan et al., 1997b).

Dairy production systems are very labor demanding. Some intensive systems are developing towards mechanization and automation, reducing the number of workers in the farm, but requiring more specialization and training. Social issues related to labor intensity depend on the production system, but in general labor intensity can be expressed in milking days per year, vacation days, labor necessary per dairy system, per cow or per litre milk, labor per hectare, and whether milking is by hand or machine.

Framework applicability to other dairy systems

A holistic, integrated economic-environmental accounting framework developed in the current study can be applied to evaluate sustainability of different dairy farming systems in Brazil.

Studies have been performed, comparing indicators for different dairy systems (Krug, 2001; Pacini, 2003), from extensive to intensive systems in some cases combining indicators, however evaluation has to consider local differences. The indicators proposed in this study are general and applicable for all the systems, as described by Krug (2001) and can be considered as a starting point for further development.

Economically, intensive confined systems with total mix ration feeding (TMR) showed higher daily net income than pasture systems supplemented with concentrates (PC), but also incurred the highest costs, which means high inputs with high outputs. However, on a per unit basis (per 100 kg of milk), the PC system gave the highest economic returns (Tozer et al., 2003; Boogard, 2003). These rankings must be interpreted with caution, however because the yield-per-cow differs across systems. In most cases net income is a better measure of profitability than the per unit returns.

When changing feed prices and milk revenue showed TMR to be more profitable in the wake of most changes, except for the combination of high feed prices and low milk prices, which makes the PC system more profitable. In this comparison health, medical care and behavior was not taken into account (Fredeen et al., 2002). In Canada, contrary to findings in dairy farms in Brazil (Abdalla et al., 1999), cows in MIG produce higher yields than those in confined, but have lower body weights.

Genetic variation among breeds and cows of the same breed in relation to feed intake and feed utilization exists and there are evident differences among breeds and crossbreeds. In this case, genotype–environment interaction plays an important role in the choice of the right breed (or crossbreed) for the farming system proposed.

Manure handling is considered an important item when systems are economically compared, because manure costs increase as the level of intensity increases from pasture systems (MIG) to free-stall feeding (confined), however for the Brazilian production systems manure is seeing as an opportunity for crop production. Costs of moving manure for field application must be accounted for both systems, confined and grazing, and will likely be less economically attractive, but environmentally necessary. The government is creating incentives for manure storage buildings and many dairy farmers are involved in this new developing program. Furthermore, managing manure nutrients through multi-crop forage production can be explored (Newton et al., 2003). Sustainable manure management must not focus only on the production, collection, storage, and field application, but in a total systems approach, this focus must expand to include concerns about human and animal health, odour and fly control, nutrient import and handling, ration balancing and feeding management, optimization of dietary nutrient utilization and palatability and nutrient digestibility. Within a “System View” on sustainability, further risks must be considered, such as storage and leaking from manure lagoons to groundwater and farm economics of nutrient management. Therefore, sustainable manure and nutrient management must optimize nutrient flows and utilization at every point within the total dairy system (van Keulen et al., 2000).

The sub-tropical and tropical climate determines the fodder, grass and pasture availability through the year, which limits the activities of dairy production systems. Genetic variation among dairy breeds and variation in available grasses might be keys to sustainability (EMBRAPA-Gado de Leite. 2003a and 2003b).

CONCLUSIONS

A general framework based on 5 steps is proposed to address sustainable agriculture and rural development, which considers the multidimensional character of sustainability. This analysis of sustainability includes the identification of sustainability indicators that take into account the technical-economic and the environmental-ecological trade-offs of production processes. Therefore, emphasis is given here to the use of a systems approach that offers a comprehensive perspective that accounts for the interrelationships between the technical, environmental, social, economic, and political aspects of sustainability.

The effects of livestock development on social and environmental issues can only be assessed in the long term, which requires assessment of the consequences of current developments in livestock farming systems. To make such assessments operational farmer participation in intensive monitoring of technical, social and economic indicators is required.

A holistic, integrated economic-environmental accounting framework developed in the current study can be applied to evaluate sustainability of different dairy farming systems in Brazil. To increase confidence in its usefulness, it has to be applied in more different situations.

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Chapter 7

CHAPTER 7

GENERAL DISCUSSION

This study presents an overview of the sustainable development of dairy system in Brazil focusing on the contribution of Holstein cows. The indication of Holstein as the best dairy breed choice for dairy farming is evaluated, to understand constraints and opportunities of dairy production systems in Brazil. The studies presented in this thesis evaluate systems' sustainability at society and at farm level, illustrated by the contribution of Holstein to dairy production systems in Brazil.

This research is composed of three parts:

1- A system behaviour analysis (Chapter 2 and 3),

2- Sustainability at animal level: health, reproduction, and production (Chapter 4 and 5),

3- A general framework proposal for sustainability analysis (Chapter 6).

Focus is given to a systems approach to explain and explore the function of dairy systems and their contribution to sustainable development, especially regarding the dairy production potential on pasture.

Starting with a view of production systems in relation to their economic, social and ecological context, then studies in-depth specific system components at animal level. Focus is given on cow's health and reproductive performance and their mutual relations regarding biological problems and metabolic events in lifetime. Finally, based on the issues of concern, a methodology for monitoring sustainability is proposed within the context of the dairy systems.

Sustainable activities in dairy systems can contribute to increased food production, and improve rural people's welfare and livelihoods. Clearly much can be done with existing resources, and dairy systems can be economically, environmentally and socially sustainable. Systems with high sustainability are making the best use of nature's goods and services whilst not damaging these assets (Pretty et al., 2003).

By relating patterns of productivity to sustainability indicators, such as production aspects to ecological, environmental and social indicators, it may be possible to identify the mechanisms responsible for associations between system properties and its effects on sustainability (Marten, 1988). The strategies proposed in the literature to evaluate sustainability are many, but the choices of issues and indicators are likely to differ between production systems and stakeholders.

The contribution of Holstein cows to sustainability of dairy production systems

1- System behaviour analysis

The effect of crisis on sustainability of the Holstein dairy system in Brazil was quantified (Chapter 1), based on system properties as productivity, stability/resilience and equity, showing the dynamics of aspects of its sustainability over time. The development of system sustainability was here characterised by time trends. Compared to other dairy systems in Brazil, pure Holsteins achieve the highest annual productivity per cow. In 1990, when the economic crisis reaches its deepest point, all lifetime production curves (LPC) were indicating considerable economic losses, regardless the age class of the cow. Moreover, economical losses were resulted not only from decrease in milk production, but also from decrease in number of animals and records, especially of young milking cows. After the crisis, the system shows high resilience, and is rapidly able to increase number of animals and records and production per cow is increased. A stable growth could be expected from the trends in the beginning 90s. However, since a few years ago (SCL, 2003), the number of farms and breeders of Holsteins is decreasing rapidly although the national dairy herd is still increasing in number of animals and Holstein cows are increasing in average annual productivity. The Holstein system is becoming less stable and highly dependent on external inputs. The Holstein farmers from traditional Southeast dairy regions are changing to other cattle breeds and activities. In the future, it is expected that sustainable Holstein dairy farming will only be found in certain regions of Brazil, and under certain management and farming systems.

Population growth is the fueling demand for dairy products while at the same time limiting the traditional resources for livestock production and land availability. Increase urbanization and decrease in land availability is changing the geographical distribution of milk farms in Brazil, which are moving towards central regions.

Holstein dairy system in Brazil

Holstein is responsible for most of the national milk production, as pure breed or in crossbreed "Girolando". Farmers and breeders have been trying to improve production, mostly by genetic and management improvement (Queiroz et al., 1991; Ribas et al., 1993), and Holsteins in Brazil are showing high production performances under adequate management (Ribas et al., 1983a and 1983b; Zambianchi, 1996; SCL, 2003). However, milk production and reproduction of Holstein cows in the tropic ad semi-tropic regions can be problematic if the environmental conditions are not ideal (Pereira et al., 1995b). Genetic problems are already evident as result from selection only for production traits, having a negative effect on fitness and reproduction.

Despite the low national annual productivity of dairy farms, which at 305 days lactation is around 1000 Kg milk/cow in 1990, Holsteins can produce on average more than 6000 kg milk/cow under the Brazilian climate and management conditions. In the year 2002, average milk production of Holsteins in Brazil, recorded by Milk Recording Services (SCL) was 7,280 kg milk/cow, there were 680 Holstein farms having in average 79 animals per farm (SCL, 2003). At the end of 2002, more than 53,400 lactations have been recorded. However since 1999, the number of farms and breeders of Holsteins is decreasing rapidly, despite the fact that milk production at 305 days increased 31% during 1990 and 2000 (SCL, 2003). Holstein dairy production systems are very management demanding and generally need high inputs to sustain production, thus classified as intensive high input systems, which reflects its strong dependence on resources and market prices fluctuation in Brazil.

High input systems are most confined systems and are competing in the dairy sector with low input systems, most based on pasture. However most dairy production systems are not economically sustainable but are integrated with other agriculture activities justifying farm high investments. Nevertheless, in terms of productivity per cow, despite of decreasing number of farms and animals in the last few years, the Holstein dairy farms have a continuous increasing annual productivity. Simultaneously, Holstein dairy farms have increasing rates of involuntary culling, especially by young cows (Chapter 4).

Milk is not the only product of the Holstein dairy farm, heifers sale is also a good source of income, as well the integration crop livestock (Mixed Farming).

It is important to link historical development with current perspectives to understand the dynamic oscillation of the relative changes in the dairy system, to avoid one-sided and arbitrary evaluation of their sustainability perspective. In general, the Holstein dairy system has high stability and resilience in terms of milk production, but with high sensitivity to disturbances. Because of their high production capacity, Holstein cows at national level make a relative large contribution to milk availability per capita, which has being increasing during the last decade. The rate of increasing in milk production was higher than the population growth, reflecting that the dairy production are meeting the national demands and in short future no milk importation will be necessary, probably, Brazil will be able to export.

For many years the milk importation policy made Brazil very dependent of the international milk market and disfavour the local milk producer, which could not compete with low prices of imported subsidised milk and finally, the farmer could not invest on its own activity in order to improve efficiency of production. Until 1990 the milk price was regulated by the government at national level. The national milk production was not enough to supply the demand and importation of milk powder was stimulated by the government competing with local producers (Santos and Villela, 2000).However, in last few years, milk importation is reduced and there is still perspective for farmers to increase farm productivity and increase efficiency by better use of resources, what can contribute to their competitiveness in the milk national market.

In fact, the annual productivity of the average dairy farms in Brazil is low, compared to other South American countries, as Argentina for example (EMBRAPA-Gado de Leite, 2000), but Holstein farms productivity is higher than the national average, especially farms in South region have the best performance of Brazil, the efficiency in production is due to climate and better quality feeding strategies based on winter grasses (EMBRAPA-Gado de Leite, 2003).

Some other factors contribute to average low productivity of national dairy farms, including low specialisation level in terms of dairy activity; utilisation of dual-purpose breeds and crossbreeds; and the milk price control policy (until 1990).

During the last decade, the dairy systems are developing towards intensification adapting to changes in the dairy sector. Farmers with higher information level are using Holstein breed in many regions of Brazil, from intensive confined systems to management of intensive grazing systems (MIG).

Sustainability of a system thus, associates with changes and continuity to context-dependent economic, ecological and societal (EES) issues. Sustainability is not considered and endpoint, but an ongoing dynamic development (Ludwig et al., 1997; Cornelissen et al., 2001). Evaluation of system structure with emphasis on the long-term trends, such as milk yield and reproduction rates, can show the background of system continuity against the short-term fluctuations and traumatic disturbances (Chapter 3).

The success factors involve not only production aspects of the cows but also farmer’s skills and information needs (Chapter 6). This mutual relation is very important. One of the major problems for animal status monitoring and farm-level information is to determine farmer’s information needs and capacity of data recording. Information supply should be of a more individual nature helping dairy farmers to improve managerial skills and to support decision making.

In Brazil, a large range of different dairy farm systems and styles are found, in order to evaluate the different systems’ sustainability a general framework was proposed in this study to be considered as a starting point, which permit the inclusion of more indicators based on EES and local adaptations of indicators thresholds.

Issues vary widely among farmers and over time, but critical success factors with respect to economic performance are found to be the most important with timely information supply (monthly or quarterly reports). Most agricultural sustainability improvements seen in the 1990s arose despite existing national and institutional policies, rather than because of them. But without appropriate policy support (Pretty et al., 2003) and information services, the improvements are likely to remain at best localized in extent, and at worst simply wither away.

Recently, traditional beef cattle regions have moved towards dairy cattle, and dairy farmers in traditional dairy regions are leaving the dairy activity focusing on more specialised crop production, for example corn silage production and sugar cane.. From 1990 to 1997, the Southeast region, the largest producer decreased its participation from 48 to 45% of the national milk production, while the Center-west region, a great beef and grain producer increased its participation from 12 to 15%. Facilities for credit, low price of grains and land availability may have been the main reasons for the Center-west high dairy performance (EMBRAPA-Gado de Leite, 2001).

Dairy sector in Brazil

A new macroeconomic policy in Brazil from the beginning of the 1990's together with the Mercosul agreement changed markedly the dynamics of the dairy sector (EMBRAPA-Gado de Leite, 2001). From the consumer side, the results have been improvements in milk quality, price and variety of dairy products. In the industry, a new set of manufactured products; different distribution channels; and marketing systems have been created, with emphasis on the long-life milk (UHT), which has faced a very significant growth over the last 5-6 years by replacing especially the type C milk.

From the dairy farmer side, increased demand for milk quality, regularity and large-scale production. Consequently, investments specialised dairy breed, in milk cooling and managerial skills at the farm level have become crucial. As well, small farmers have been joining themselves in cooperatives of collective bulk tanks, replacing the cans. Dairy farmers that were not able to follow this new tendency have been facing marginality, and selling their milk in informal markets.

Dairy industry monopoly can be considered a threat for the sustainability, in terms of equity, because their politic favour and stimulate only large scale farms with stable production during and over years. Lack of infra-structure and the willingness of dairy industries reduce the incentives to develop small-scale land-based dairy farming in remote areas. Social inequality, different levels of income, allow for different motivations to join or leave the dairy sector, as well as to adopt technologies to avoid environmental degradation, leading to different valuation of environmental resources and willingness to conservation. Poorly defined regulations and poorly developed instruments to value and allocate costs and benefits of environmental goods difficult the design of feedback mechanisms for environmental degradation (De Haan et al, 1997).

The dairy sector is developing towards encouraging intensive dairy production systems. However, 90% of the dairy farms are small-scale production systems, which are characterised in a variety of mixed farms. By intensification of production in mixed farms, important productivity gains can be achieved by enhancing nutrient and energy flows between the system's components, as the MIG system discussed in Chapter 6, but it is not expected large increases in scale of production.

There is already tradition and potential for improving mixed farming in the dairy regions of Brazil. Grazing systems can also intensify production by intensive rotational management of pasture (MIG). However, in intensive production systems, the manure waste can have a negative environmental impact if management is not adequate. But if infrastructure and marketing are available, can be powerful instruments on transport of allocation of residues and to make farming profitable, possible alternatives for off-farm income may generate enough capital for investments in soil and water conservation.

Under favourable agro-ecological and market conditions, further intensification of production can occur by the absorbing capacity of surrounding lands. Specialized Holstein farms with confined systems will have to respect the resource endowments of a region, and the nutrient balances can be maintained by the environment's ability to absorb waste, stimulating the potential for mixed farming. There are policies promoting transformation of mixed farming into specialized dairy enterprises in rural areas to increase scale and efficiency of production. To improve milk quality requires infrastructure an institutional development. In SD view, the idea to intensify must avoid high concentration of animals and production systems, thus system's diversity. This is the challenge to produce with high efficiency without concentrating animal production in a given area and recycling most wastes within the farm region. Wherever possible these win-win scenarios (economically and environmentally attractive) should be promoted (De Haan et al, 1997). Mixed farming, by internalization of environmental costs, promotes efficient input use, reduces wastes and saves non-renewable resources, therefore improves the sustainability of production.

Three inter-linked regional initiatives were proposed by FAO (FAO, 2003) for agricultural development which agrees EMBRAPA (EMBRAPA-Gado de Leite, 2002), based on: sustainable resource management; improved resource access, and increased small farm competitiveness.

A wide variety of technologies exists to improve the sustainability of livestock production. However, the quest for sustainability should not be limited to technological interventions, such as controlling the stocking rate to prevent land degradation, or improving feed quality to reduce methane emission and global warming, because it is not livestock, but it is the human actions and activities which shape livestock effect on the environment (De Haan et al, 1997).

2 - Sustainability at animal level: health, reproduction, and production

Sustainable production systems need animals with a good balance of health, reproduction and production performance. For decades the Holstein breed has been intensively selected for higher production, which has resulted in metabolic changes (Van der Lende, 1995). The consequences of these changes in the animal's metabolism are becoming evident but not completely understood, the increase in reproduction and health problems are certainly indication of unbalanced development.

Genetic selection of Holsteins

Genetic selection for early and high milk production only, with no attention on traits like health, longevity or persistency of production, is likely to have a negative impact on longevity. Most of these traits are genetically correlated, and an unhealthy cow will have a higher risk to be culled and not able to persist at a high level of production (Vollema, 1998). Genetic selection for production traits only, tends to decrease fitness, in particular declining the reproductive performance (Meuwissen *et al.*, 1995), because much of the genetic gain in production is due to the increase in frequency of detrimental alleles for reproduction. It means that selection for production will preferentially select heterozygous genotypes, which will increase the frequency of the negative allele for reproduction. This decline of reproductive performance can be prevented by selection on reproductive fitness (Frankham *et al.*, 1988; Gibson & Engstrom, 1995).

Increased intensification and industrialization of livestock production requires increasingly uniform genotypes and has caused the extinction of some, and the genetic erosion of other, local livestock breeds. There are currently about 600 breeds at risk of extinction, about 20% of the total global livestock breeds (De Haan et al., 1997). In addition, it is projected that by the year 2015 the U.S. Holstein population will only have an effective population size of 66 animals (De Haan et al., 1997). Loss of biodiversity is never accounted in development favoring exotic breeds, which could attempt to distort the semen importation market.

It is important for future breeding programs and the systems decision making at sustainability perspective that the Holstein, as a dairy breed choice, can improve the Brazilian national productivity, but in many other countries it is already evident some negative effects of intense genetic selection for production traits. The consequences of intensive genetic selection for high and early milk production are reflected in metabolic changes, health and reproduction problems, and cow's longevity can not necessarily increase only by management improvement, such as by prevention and control of diseases (Beaudeau et al., 1993).

Although there appears to be great potential to improve economic efficiency by selecting cows for feed intake and live weight or by possible indicator traits (Veerkamp, 1998), there is still uncertainty about traits related to health, reproduction, and energy balance of the Holstein breed.

Persistency and longevity

In intensive Holstein dairy systems, a high percentage of cows are very sensitive to stress and must be involuntary culled before reaching maximum production. Increasing the incidence of reproductive and health problems certainly is not contributing to SD. Persistency and longevity within and over reproduction cycles are good indicators of the (health) state of an animal. Persistency is defined as the ability of an animal to maintain a high level of production (Grossman *et al*, 1999). In Brazil, persistency in Holstein cattle is being mentioned (Queiroz, *et al*, 1991; Pereira, *et al*, 1995a) showing the effect of cow's age and calving season on production and on persistency (Polastre et al, 1987). However, most production processes of a cow, such as calving and milk production, are cyclic as a result of reproductive cycles. Thus evaluation of performances over the whole productive life of a cow, as suggested by LPC (Chapter 5), can be a good indicator of persistency over cycles.

Age and maximum production

High yielding cows have higher milk production in their first lactation and are more likely to have a higher production performance during their lifetime, achieving a higher maximum milk production at younger ages. Hence, these high yielding cows have a higher metabolic demand during the heifer developmental phase and are more susceptible to burnout. Analysing cow's LPC (Chapter 5), an early decline in production occurring before maturity could be an indication of economic losses by burnout and accelerated senescence of these animals. Biological problems of a young cow can force production to an early decline, and finally result in culling and reduce cow's longevity.

Therefore, monitoring the shape of potential and observed LPC's could be considered when evaluating early burnout risk for high yielding cows. The age at maximum production could be used as a sustainability indicator considering its effect on longevity, which is an issue of concern for the sustainable development of Holstein dairy systems.

Within the lactation, the maximum production is expected within the first two months of lactation, afterwards production declines (Nobre, *et al*, 1985). Over lactations (LPC), maximum production is expected when the animal is fully mature, as proposed by the genetic size-scaling theory (Taylor, 1985), maturity is a metabolic event in animal's life, expected to occur at the same age in metabolic days proportional to animal's adult body weight. The maximum production is expected at maturity, when the animal is fully mature in body size. Therefore, within the same breed, not much variation is expected of age at maturity.

Studies on age in relation to reproductive indicators, such as age at first calving (Neiva, *et al*, 1992b; Teodoro, *et al*, 1993b) and calving interval (Teodoro, et al, 1993a) are available data for possible use as sustainability indicators. Many authors refer to age at maximum production in Brazilian dairy herds (Reis & Silva, 1987; Milagres, *et al*, 1988; Neiva, *et al*, 1992a), but no evaluation of the relation of age and production is being mentioned, suggesting that more research is needed on Holstein cattle in Brazil (Ribas *et al*, 1993; Queiroz *et al*, 1991), data availability for characterisation of this breed in all the different farming systems and different regions of Brazil is required.

Culling

In the last decade, despite the desired increased milk production, also increased health and reproduction problems (Chapter 4). Health disorders of dairy cows have a great impact on farm profit, increasing direct and indirect costs, and further culling decision is often based on economic considerations. This fact is already worrying Brazilian farmers and breeders. The replacement of high producing cows is undesirable and reproductive problems are the most costly exit reason (Seegers et al., 1998). Investments on equipment to control climate conditions in order to adapt the environment to the breed choice seem a costly solution to avoid culling. The use of ventilators and douches to refresh Holstein cows within dairy barns are extremely costly and make high use of electric energy, which is not contributing to SD. There are, therefore, aspects at animal level and farmer style that if better understood, could help on avoid culling, by finding the best choice of breed (or crossbreed) to farm environment, and prevent un-necessary investments. Thus genetic-environment interaction plays an important role by culling, if better understood one could prevent and reduce economic losses caused by involuntary culling.

Regarding health management, it is reasonable to assume that farmer's involuntary culling decision-making process is based on entire disease history of the cow (Beaudeau et al., 1994), but only the last reason is often reported as cause of culling.

The relation between culling factors and milk production can be used as an indicator for sustainability analysis. Culling reasons as declared by farmers are subjective data, but if monitored and analysed, this information could be a useful indicator for SD, because culling reasons can reveal many of the constraints related to the production system, at both animal and at management level.

Voluntary or involuntary culling

The productive life of a dairy cow, normally is measured by its longevity, ends at the moment of culling, when this cow leaves the herd. Voluntary culling is planned by the farmer, to eliminate unprofitable animals or with undesirable characteristics.

By culling for voluntary reasons, the farmer is improving the herd performance by selecting the best producing cows (Dürr et al., 1997). However, biological aspects of dairy production make undesirable involuntary culling common. If involuntary culling rates are too high for high yielding cows, there is no flexibility in the herd planning to voluntary replacement.

Culling occurs mostly before the 4th lactation, but the highest risk of culling is around the 2nd lactation. The high culling rates are due to reproduction and health problems, which are involuntary and may result from a negative effect of increased milk production. Management and breeding policies are facing the dilemma to increase milk yield and decrease causes of involuntary culling (Rogers et al., 1988).

If culling data could be monitored and used as an indicator for SD, it would permit more research to support Brazilian farmers on culling strategies and decision making to improve cow's longevity. The cause for culling can be a biological problem, but culling is not a biological phenomenon, but results from a human decision (Beaudeau et al., 1993; Vollema, 1998). However, many are the factors that can influence and lead the farmer to take the culling decision, and may not reflect the whole farmers' culling decision process and attitude (Beaudeau et al., 1994). It is common to find culling decision based on combined culling reasons, but only the last reasons is reported. The associations between health disorders and specific reasons for culling are poorly documented, probably because the associations are complex and mostly farmer's reported culling reason provide information only about the most immediate shortcoming of that cow (Beaudeau, 1993). Understanding the factors involved in animal's permanence in the herd and identification of the farmer culling decision and possible reasons for culling are crucial factors for herd management.

3 - A general framework proposal for sustainability analysis

Although sustainability issues are of general interest, the benefits of improved decision making are indirect. For the long term sustainability issues, understanding leads to improve decision making. The general framework proposed many indicators (Chapter 6), but farmers will make their own choices based on their perceptions about whether indicators are worth monitoring, further, thresholds must be locally adapted according to region of Brazil.

Therefore, a systems approach requires a broad spectrum of scientific expertise as represented in multidisciplinary teams of agronomists, dairy scientists, economists, engineers, microbiologists, soil scientists, veterinarians and managers to deal successfully with the complex issues pertaining to dairy nutrient management (Grusenmeyer & Cramer, 1997).

Table 1. A general framework for sustainability evaluation of dairy systems

STEP	DESCRIPTION	ACTION
1	Description of a production system	Define context and characteristics of a dairy production system.
2	Identification of EES issues	Assessment of sustainability issues for dairy systems and classification into Economic, Ecological and Societal issues (EES)
3	Choice of indicators	Derivation of indicators from the EES issues, based on presented criteria.
4	Measure sustainability indicators	Measurements or observations of indicators.
5	Evaluation and monitoring	An integrated social, economic and environmental accounting approach to evaluate the sustainability indicators in relation to issues of step 2.

Per issue of concern, the framework proposes on-farm sustainability indicators (SI). The basis of the general framework is a 5-step procedure (Table 1), as described by Cornelissen (2003). This general framework resulted in a list containing issues and indicators applicable to extensive or intensive dairy systems in Brazil (Table 1).

Management Intensive Grazing (MIG) system, is used as starting point. This system is described as base system in the first step of the procedure in Table 1. The results of indicator measurements at farm level have to be compared to thresholds and need to be monitored over time.

Focus is given to on-farm issues to develop a tool for production system sustainability evaluation and monitoring, the relevant issues were selected and presented. Criteria used for selection were: (1) the farmer should be able to act upon indicators relating to the issue, (2) issues must be related to the dairy system described in Step 1, and (3) issues should also be relevant to other dairy systems.

The identification of the main institutions to regulate and control the negative environmental effects and promote the positive ones is the final key component of the framework for sustainable livestock production (De Haan et al., 1997). Both existing livelihood levels and the potential for future improvement depend upon the quality and availability of natural resources. The resource base of a farming system is best conceptualised as the average resource endowment of typical dairy farm, measured according to their productive potential when using existing technologies (FAO, 2003).

Sustainability concerns:

- sufficient economic performance to support the farmer and the activity
- exhaustion of resources (soil, energy, biodiversity)
- pollution of soil, water and air
- development of rural areas
- sufficient and good quality milk
- health and welfare of farmer and animals
- managerial skills of the farmer

In order to judge the sustainability of specific dairy farming systems and their contribution to sustainable rural development, these general objectives have to be translated into explicit characteristics that can be quantified explicitly. Moreover, effects of possible changes in activities within the farming system on these characteristics should also be explicitized.

On the basis of the indicators, effects of modifications in the system (adaptations in activities) can be judged with respect to their contribution to sustainable development, by explicitly describing their impact on the indicators. The issues have been derived from reports by different stakeholders in various countries (cf. Spedding, 1995; Reed & Bert, 1995; Dore, 1997a; 1997b; MAF, 1999; EMBRAPA-Gado de Leite, 2002).

Studies have been comparing indicators for different dairy systems (Krug, 2001, Pacini, 2003), from extensive to intensive systems in some cases combining indicators, however evaluation has to consider local differences. The indicators proposed in this study are general and applicable for all the systems, as described by Krug (2001) and can be considered as a start point for further development.

The sub-tropical and tropical climate determines the fodder, grass and pasture availability through the year. Genetic variation among dairy breeds and variation on available grasses might be the key to sustainability (EMBRAPA-Gado de Leite. 2003a and 2003b).

Integration of livestock and crop

The integration of livestock and crop activities may be the main opportunity for intensification (De Haan et al., 1997). Mixed farming provides opportunity to diversify, allow the use of waste products (crop by-products, manure) as inputs to the other (as feed or fertilizer). Combining crops and livestock promotes greater biodiversity and also has the potential to maintain ecosystems functioning and health, increasing system capability to absorb shocks to the natural resource base (Holling, 1995).

The use of rotations between various crops and forage legumes replenishes soil nutrients and reduces soil erosion. The manure replenishes soil fertility and helps to maintain or create a better climate for soil micro-flora and fauna. This is also possible by using crop residues. The key issue is the nutrient balance, most farming systems have a negative nutrient balance when exporting products, thus manure use can be a key element for the crop-livestock integration.

Sugarcane as supplement

An economic alternative for crop and cereal feeding that have high price and annual risk, is the use of sugarcane-based feeding systems. Sugarcane is one of the highest yielders of biomass per unit time and area. It can be used in nutrition of dairy cows. As a perennial crop, sugarcane production has low external input. In contrary to the past history of sugarcane in large plantations in Brazil, nowadays more and more small-holders intensive systems are using sugarcane as alternative when summer grasses and forages does not grow.

Pasture

A strong public awareness of the value of grazing areas has emerged. Rangelands in all zones are increasingly seen as a global resource, not only for livestock, production, but also for eco-tourism, carbon sequestration and biodiversity conservation (De Haan et al., 1997).

The introduction of pasture species into ranched areas can permit land recovery and subsequent higher stocking densities on a rotational basis, while stocking of dual-purpose cattle in smaller holdings which previously have been largely crop-based can also bring benefits (FAO, 2003).

Grass is one of the large resources of Brazil and its use should be maximised by the farm, it is ideal feed for ruminants, and by far the cheapest feed available. High dry matter grass silage costs around three times the price of grazed grass (FEALQ. 2000). In addition, some regions in South Brazil have high quality winter grass that can support milk production better than the best silage, thus saving on concentrate costs which are about 4 to 5 times the price of grazed grass (Krug, 2001). By grazing it is possible to save the additional fixed costs associated with silage and housing, including additional slurry costs, bedding, labour, machinery, electric and veterinary costs. By maximise the use of grazed grass it is possible to maximise profit, while maintaining dairy hygiene, animal welfare and environmental protection.

Environmental impact of dairy manure

Manure is an excellent source of nutrients for pastures, crops and forages. Intensive grazing concentrate the livestock density to small areas and allows the animals to pasture over the whole area of each paddock and spreading manure this way in the whole grazing area. However, if excess amounts of manure are dropped in one point, or is applied beyond the use capacity of the crops and holding capacity of the soil, or if manure is improperly applied, losses by surface runoff and leaching can contribute to eutrophication of surface water bodies or contamination of groundwater (Dore, 1997). Problems with dairy cattle manure also can occur from lagoon leakage, overflow, spills, etc. The major environmental concern with land application of manure is the potential contamination of surface waters and groundwaters with excess of N and P, odor and fly problems.

CONCLUSIONS

A strategy to address sustainable agriculture and rural development must consider the multidimensional character of sustainability (EES). Measuring methods to evaluate sustainability propose indicators taking into account the technical-economic and the environmental-ecological trade-offs of production processes. Therefore emphasis is given to the use of systems approach that offers a comprehensive perspective that accounts for the interrelationships between the technical, environmental, social, and economic aspects of sustainability.

In Brazil a large variation of dairy production systems is found, basically they are *Extensive or Intensive systems.* The extensive systems are only possible when large areas of natural and/or cultivated pastures are available. Within the *Intensive Systems*, three different systems can be distinguished: *Confined, Semi-confined and Intensive grazing system*. All production systems have potential for develop towards sustainability, which concerns:

- sufficient economic performance to support the farmer and the activity
- efficient use of resources (soil, energy, biodiversity) and reduce costly inputs
- prevent pollution of soil, water and air
- development of rural areas and make productive use of the knowledge and skills of farmers, so improving their managerial skills
- sufficient and good quality dairy products
- health and welfare of farmer and animals

Therefore the general framework considers the following issues:

1- *Production*
2- *Natural resources*
3- *Human and animal welfare*
4- *Economic*

A more sustainable agriculture makes the best use of nature's goods (environmental and genetic resources) and services, so technologies and practices must be locally adapted, mostly likely to emerge from new configurations of management skills and capacity to innovate, making the best use of local potential, regarding dairy breed and farmer style with minimum of external inputs.

Therefore the contribution of Holstein to sustainability can be positive only under good managerial skills and good soil and climate conditions. Holsteins have increased milk production potential, but to achieve it, it is necessary good management and high use of inputs (feeding, veterinary care) and resources (energy), which can have a negative impact on sustainability.

Concepts traits as persistency of lactation and age at maximum production can reveal some misunderstood negative developments occurred to this breed. Understanding the consequences of metabolic changes can lead to a new dimension to the contribution of Holstein to sustainability as the most productive but very demanding dairy breed.

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SUMMARY

The concern and scope of sustainability on development of dairy systems increased in the last decades. In Brazil extensive traditional duo-purpose systems make place for more specialised intensive systems. The development of dairy systems is being towards intensification of resources used by production systems, raising the concern about sufficient capacity of adapting to current and future demands and the impact regarding environmental, social and economic aspects. The changes in activities of the current dairy farming systems can be questioned in relation to its contribution to sustainable development. It is becoming not only a farmer issue to guarantee the sustainable development of his farming activity, but more and more it is becoming a public concern when farming activities are reaching out the boundaries of the farm.

Holstein dairy cows are mostly found in farms in South and Central regions of Brazil. They have high genetic milk production potential and are used by different farming systems, from confined to grazing systems. However, Holsteins are fragile animals and very management demanding, which implicit request farm adaptations.

This research investigates possible contributions of Holsteins in the development of sustainable dairy systems in Brazil. The scope of the analysis range from society level to production system level, with a description of system's behaviour and its important characteristics, focusing on the characteristics of Holstein cows at animal level, their production potential, health and reproductive performance within the dairy systems.

The dairy farming systems in Brazil can be classified as *Intensive* and *Extensive* systems. Within the *Intensive Systems*, three different systems can be distinguished: Confined, Semi-confined and intensive grazing system. The use of crossbreeding between Zebu and Holstein cattle is very popular due to dual purpose - milk and beef- and better adaptation to tropical condition. The breed preference is heavily associated to the levels of farm management, capital investment and expected productivity of labour and capital. By analysing different dairy production systems, it is possible to identify important sustainability indicators (SI) that are related to the contribution of Holstein to sustainability. This research is composed of three parts, system behaviour analysis in Chapter 1, 2 and 3 (part i), animal health, reproduction

and production in Chapter 4 and 5 (part ii) and a framework proposal for sustainability analysis in Chapter 6 (part iii).

Part one (i)

In chapter 1, the Brazilian dairy systems are studied giving a description of the sustainability assessment and the problems identified for Brazilian dairy systems. Chapter 2 brings a detailed description of dairy production systems in Brazil and the dairy sector in relation to sustainable development, with emphasis on Holstein production systems. Dairy farms range from low-input systems with high-Zebu grade herds grazing extensively tropical pastures to high-capital confinement systems with Holstein purebred herds. Large differences among production systems can be distinguished. The challenge for characterisation of sustainability is to use a framework that includes all the different Brazilian dairy farming systems, because all this variation is important for system resilience.

In chapter 3 the system development is analysed over two decades with special attention to effects of national economical crisis in 1990. Complete lactation records of pure Holstein herds of South and Southeast Brazil registered at the National Dairy Cattle Archive were analysed aiming to understand and support SD. The development of the Holstein dairy system in Brazil is presented and evaluated crisis effect on system sustainability, based on system properties as productivity, equity, and stability/resilience.

Part two (ii)

System analysis focusing at animal level, evaluates intensive selected high yielding Holstein cows that show undesirable health and reproduction problems. Chapter 4 explores culling factors in relation to milk production of the first lactation, focusing on factors and problems that influence longevity of Holstein dairy cows in Brazilian herds. Because culling is a subjective decision, mainly based on farmer’s perceptions, culling reasons were identified and classified into culling factors. Models have been developed to predict culling risk variation in time, that can be applied in support of herd management and culling decision planning. Data of 27 herds of intensive dairy farms in São Paulo are analysed for incidence of health and reproduction problems.

In chapter 5, the theory on lifetime milk production and the maximum production is introduced. Maximum milk production is expected at maturity; however, most high yielding cows show peak production before maturity. Increased potential milk production as a result of genetic selection and the increased correlated negative (side) effects, such as biological changes, behaviour, health and reproduction problems are discussed.

Individual milk production data of Holstein herds in Minas Gerais, from cows with at least seven lactations, is analysed in relation to age at maximum production, number of inseminations needed per conception and production level of first lactation. A model is proposed to describe milk production curve over time.

Part three (iii)

In chapter 6, a framework for sustainable development evaluation for Brazilian dairy farming systems is presented. This general framework is a tool to evaluate sustainable development and to provide basic information to support decision-making. An integrated social, economic and environmental accounting framework proposed can be applied to different production systems (scenarios) to evaluate impacts of activities on sustainability indicators. The evaluation combine the multidimensional aspects of sustainability (economic, ecological and social), and is presented as issues from where a list of sustainability indicators (SI) is proposed to evaluate and monitor sustainability.

This general framework for sustainable development evaluation is applicable to different dairy systems and is based on 5 steps. This analysis includes the identification of sustainability indicators that takes into account the technical-economic and the environmental-ecological trade-offs of production processes. Therefore emphasis is given to the use of systems approach that offers a comprehensive perspective that accounts for the interrelationships between the technical, environmental, social, economic, and political aspects of sustainability.

The framework is demonstrate by using a base system, which is an intensive grazing system. Further applicability as a general framework, is discussed to other production systems by evaluating impacts and changes in activities on SI presented. The contribution of Holstein cows to the sustainability of dairy systems is quantified by using on-farm sustainability indicators and discussed.

Sustainability multidimensional evaluation

A system behaviour analysis based on system properties as productivity, stability/resilience and equity, showed the dynamics of aspects over time quantifying the effect of crisis on sustainability (Chapter 3). The development of system sustainability is defined as the ability of continuing into the future and is characterised by time trends. Holstein system achieves a high level of annual milk productivity, in 1992 reaches 5500 kg/cow and in 2002 reaches 7280 kg/cow (Chapter 2 and 3). Median milk production reaches its deepest point in 1990 and the data range increased, showing the large variation in the data set. From 1980 to 1992 an increasing number of records and animals are observed, however the age composition per year group remained constant. The crisis in 1990 caused a decrease in production for all age classes, reduce the number of animals and records, especially of young milking cows in the 2nd, 3rd and 4th lactation. After the crisis, the system shows high resilience. It was expected stable growth after 1992. However, this trend changed during the last few years, the breeder association milking recording system (SCL) reveals a constant decrease in number of Holstein farms, in number of herds and animals recorded, but productivity per cow is increasing.

In general, the Holstein farming system is characterised by high stability and resilience in terms of milk production, however, it shows high sensitivity to disturbances. Dairy farms, in order to keep stable productivity, have a high rate of cow replacement. Holstein cows of today are fragile animals and have a high risk of involuntary culling for reproduction and health problems (Chapter 4). Involuntary culling is not only a result of biological problems, it is not even a biological phenomenon itself, but it results from human decision. Despite cows´ high potential for milk production, high yielding cows are culled before reaching their maximum production potential because of involuntary reasons. High incidence culling factors were in this order: *other, reproduction, health, low production,* and *disease*. Culling occurs mostly before 4th lactation, but highest risk is around 2nd. Average estimated age at maximum production, t_{max}, is 80 months, i.e. about 6.7 years, which is between the fourth and fifth lactations. Average number of services per conception is 1.45. Furthermore, fertility problems in dairy cows may be expected to increase with increasing milk yield.

High yielding cows have higher milk production in their first lactation and are more likely to have a higher production performance during their lifetime (Chapter 5), achieving a higher maximum milk production at younger ages. Hence, high yielding cows have a higher metabolic demand they are more susceptible to burnout. The early decline in production, occuring before maturity, could indicate acceleration of senescence and reduction in cow’s longevity, which result in economic losses. Certainly this is not contributing to system sustainability.

A general framework based on 5 steps is proposed to address sustainable agriculture and rural development, which considers the multidimensional character of sustainability (Table 1). Measuring methods and evaluation of SI must account for the technical-economic and the environmental-ecological trade-offs of production processes (Table 2). Therefore, emphasis is given here to the use of a systems approach that offers a comprehensive perspective that accounts for the interrelationships between the technical, environmental, social, economic, and political aspects of sustainability. A holistic, integrated economic-environmental accounting framework developed in the current study can be applied to evaluate sustainability of different dairy farming systems in Brazil.

Intensification of Holstein systems, when not well managed can have a negative effect on sustainability. Generally Holsteins farms makes more use of resources than other dairy farming systems. Therefore, only when resources are available and well managed Holstein farming systems can be sustainable.

Table 1. A general framework for sustainability evaluation of dairy systems

STEP	DESCRIPTION	ACTION
1	Description of a production system	Define context and characteristics of a dairy production system.
2	Identification of EES issues	Assessment of sustainability issues for dairy systems and classification into Economic, Ecological and Societal issues (EES)
3	Choice of indicators	Derivation of indicators from the EES issues, based on presented criteria.
4	Measure sustainability indicators	Measurements or observations of indicators.
5	Evaluation and monitoring	An integrated social, economic and environmental accounting approach to evaluate the sustainability indicators in relation to issues of step 2.

Table 2. Areas of concern and issues for on-farm sustainability evaluation

AREA	ISSUES	CODE
Production	Information and data recording on the production system	Info
	Dairy market conditions	Market
	Adapted technology for the different regions and different dairy systems	Adapt
	Genetic potential for milk production of the herds	Genetic
Natural resources	Fossil energy use and efficiency of energy use	Energy
	Erosion, nutrient management and soil fertility	Erosion
	Pasture condition and pasture carrying capacity	Pasture
	Air and water management	Air/water
	Enterprise diversity and risk spreading	Diversity
Human and animal welfare	Public health and food security: quality of produced milk, contaminants and residues in milk.	Quality
	Use of hormones, and antibiotics	Medicine
	Management skills of the dairy farmers and managers	Management
	Animal welfare and threats to animal health	Animal
	Rural education, training and information supply	Education
Economic	Economic profitability of dairy farming	Profitability
	Identification of production costs and profit	Costs

RESUMO

Vacas leiteiras de raça Holandesa são vacas de alto potencial genético para produção de leite e são encontradas em diferentes sistemas intensivos de produção, desde o sistema confinado, semi-confinado, ao sistema intensivo à pasto das regiões Sul e Central do Brasil. Todavia, vacas de raça Holandesa são animais frágeis e muito exigentes em manejo, o que exige certas adaptações ao nível de unidade produtora.O desenvolvimento da atividade leiteira segue rumo a intensificação no uso dos recursos disponíveis, o que gera uma certa preocupação sobre a capacidade da atividade leiteira de adaptar-se às demandas atuais e futuras no impacto ambiental, social e econômico.

Esta pesquisa investigou as possíveis contribuições da raça Holandesa para o desenvolvimento sustentável da atividade leiteira no Brasil. É uma análise que abrange desde do nível de sociedade até ao nível de sistema de produção, iniciando com uma descrição do comportamento do sistema e suas principais características, seguindo com um enfoque ao animal, e as principais características da raça Holandesa, seu potencial produtivo, saúde e performance reprodutiva dentro dos sistemas de produção encontrados no Brasil.

Os sistemas de produção de leite no Brasil podem ser classificados como sistema *Intensivo* ou *Extensivo*. Dentre o sistema *Intensivo*, podemos distinguir três diferentes sistemas: Confinado, Semi-Confinado e intensivo à Pasto. O uso de gado mestiço é muito comum em fazendas de leite. Geralmente as vacas mestiças são o resultado de uma cruza entre gado Zebu com gado de origem Européia, principalmente Holstein. O gado mestiço é bem aceito devido a sua dupla aptidão, leite e carne, e ou por sua melhor adaptação às condições tropicais. A escolha da raça para a atividade leiteira está altamente relacionada ao nível de manejo da unidade produtora, do capital investido e das expectativas de produtividade em relação ao trabalho e ao capital exigido.

Ao analisar os diferentes sistemas de produção, é possível identificar os importantes indicadores de sustentabilidade (SI) que nesta pesquisa foram relacionados à contribuição da raça Holandesa para a sustentabilidade dos sistemas de produção de leite. Esta pesquisa é composta de três partes: a análise do comportamento do sistema leiteiro nos capítulos 1, 2 e 3 (i); a saúde animal e

performance reprodutiva nos capítulos 4 e 5 (ii); e encerra propondo uma metodologia de análise de sustentabilidade no capítulo 6 (iii).

Primeira parte (i)

O capítulo 1, os sistemas de produção de leite no Brasil são introduzidos e estudados, seguidos de uma descrição sobre a metodologia a ser usada para avaliação de sustentabilidade e sobre os problemas identificados relacionados à atividade leiteira no Brasil. No capítulo 2 há' uma descrição detalhada sobre os sistemas de produção de leite no Brasil e sobre o setor leiteiro em relação ao desenvolvimento sustentável, dando ênfase aos sistemas de produção de leite com uso da raça Holandesa.

Há uma grande variação entre os sistemas de produção de leite no Brasil. Os sistemas podem ser sistemas de baixo custo, com animais de alto grau de sangue Zebu no rebanho em pastoreio intensivo, cujo pasto geralmente é de gramíneas tropicais indo até sistemas do tipo confinado de alto investimento de capital e com uso de animais de raça pura. As diferenças são grandes entre estes sistemas, o desafio para caracterização da sustentabilidade está em incluir e abranger todos os diferentes sistemas de produção de leite, pois esta variação é importante e determina sua elasticidade.

No capítulo 3 o desenvolvimento sustentável é analisado baseado em dados de duas décadas, dedicando uma atenção especial aos efeitos da crise econômica de 1990. Registros completos de lactações de vacas de raça Holandesa do Arquivo Nacional de Gado de Leite, rebanhos registrados na região Sul e Central foram analisados com objetivo dar um maior entendimento e apoio ao desenvolvimento sustentável. O efeito da crise econômica sobre a sustentabilidade do sistema de produção com gado Holandês foi quantificado, baseando-se em produtividade, eqüidade, estabilidade e elasticidade. Indicadores de sustentabilidade são usados para quantificar as mudanças ocorridas durante a crise.

Segunda parte (ii)

Nesta parte a análise dos sistemas de produção enfoca o nível do animal, avaliando vacas selecionadas geneticamente para alto potencial produtivo em sistemas intensivos. Vacas da raça Holandesa demonstram sintomas indesejáveis de problemas de saúde e reprodução. O capítulo 4 exploram-se fatores de descarte, em relação ao nível de produção de leite na primeira lactação, identificando as causas (fatores) e problemas que influenciam a longevidade das vacas leiteiras desta raça em rebanhos brasileiros. Pois a decisão de descarte de uma vaca, apesar de ser um dado subjetivo, é baseado na percepção do produtor. Estas decisões foram identificadas e classificadas em fatores de descarte. Modelos matemáticos foram desenvolvidos para prever a variação no risco de descarte, com o objetivo de dar apoio ao gerenciamento e planejamento de descartes de animais do rebanho. Dados de 27 rebanhos de sistemas intensivos de produção, em fazendas de leite na região do Estado de São Paulo, foram analisados quanto à incidência de problemas de reprodução e saúde.

No capítulo 5 é introduzida a teoria sobre a relação entre idade e a produção total de leite da vida produtiva da vaca. O pico de produção é esperado no momento de maturidade do animal, porém, vacas de alto potencial de produção demonstram o pico antes da maturidade. Considerado como resultado da seleção genética, o aumento no potencial de produção de leite da raça Holstein é discutido com relação aos possíveis efeitos negativos gerados por esta seleção, como mudanças biológicas, mudanças no comportamento, problemas de saúde e de reprodução, e a alta exigência metabólica decorrente da alta produção numa idade jovem.

Dados de produções individuais em rebanhos Holstein no Estado de Minas Gerais, selecionando vacas com no mínimo sete lactações, foram analisados em relação à idade no momento da máxima produção, com número de serviços por concepção, e o nível de produção da primeira lactação. É proposto um modelo para descrever a curva de produção de leite ao longo da vida produtiva do animal.

Terceira Parte (iii)

No capítulo 6, um plano para avaliação do desenvolvimento dos sistemas de produção de leite é apresentado. Este plano é uma ferramenta de avaliação da sustentabilidade dos sistemas de produção e serve para gerar informações de apoio ao produtor e a sociedade sobre as questões de sustentabilidade no momento de tomada de decisões. Este é um plano geral para avaliação de sustentabilidade que considera 3 dimensões EES simultaneamente, sendo aplicável aos diferentes sistemas de produção no Brasil. Este plano pode ser dividido em 5 fases (Tabela 1).

O plano integra as diferentes dimensões da sustentabilidade, econômica, ecológica e social (EES), e propõe ser aplicado aos diferentes sistemas de produção (cenários) para avaliar o impacto de atividades exercidas na fazenda de leite sobre os indicadores de sustentabilidade. Esta avaliação combina os três aspectos EES da sustentabilidade e apresenta questões que gerou a lista dos indicadores (IS) para avaliar e monitorar a sustentabilidade dos sistemas de produção (Tabela 2).

A aplicabilidade deste plano é exemplificado através de um exemplo de sistema de produção, sendo o sistema escolhido o sistema de produção intensivo à pasto. A extrapolação do plano para outros sistemas de produção é discutido através de exemplos das principais atividades desenvolvidas em cada sistema de produção. Mudanças em atividades causam impacto nos IS apresentados, o que permite quantificar objetivamente a variação de tais indicadores IS, contribuindo ou nào para o desenvolvimento sustentável. O foco é dado a contribuição da raça Holandesa (Holstein) para a sustentabilidade do sistema de produção de leite baseado em indicadores medidos na fazenda de leite.

Avaliação multi-dimensional da sustentabilidade

Esta análise de sustentabilidade inclui a identificação de indicadores para a quantificação das relações diretas e inversas entre processos produtivos e o impact sobre o ambiente. Ênfase é dado ao uso de uma visão sistêmica, a qual oferece uma perspectiva de compreensão para as relações entre os aspectos da sustentabilidade, sendo eles técnico, ecológico, social, econômico, ou político. Esta estratégia considera a multidimensionalidade da sustentabilidade (EES). Os métodos para medir e avaliar indicadores de sustentabilildade devem ser sensíveis às possíveis relações inversas entre indicadores.

A avaliação do comportamento do sistema foi baseada na análise das características e das propriedades do sistema, como produtividade, estabilidade/resiliência, e eqüidade (também mencionada como eqüitabilidade). Demonstram a dinâmica destas características ao longo do tempo e o efeito da crise econômica sobre a sustentabilidade dos sistemas (Capítulo 3).

O desenvolvimento do sistema de produção para ser sustentável deve antes de tudo ter a habilidade de continuar ao longo do tempo, podendo ser caracterizado por curvas de tendências (*time trends*). Os sistemas de produção de leite com a raça Holandesa podem alcançar altos níveis de produtividade, com uma média anual acima de 5500 kg/vaca em 1992 até 7280 kg/vaca em 2002 (Capítulo 2 e 3). A produção de leite média sofreu uma redução durante a crise econômica de 1990, quando a amplitude dos dados aumentou consideravelmente, demonstrando a grande variação existente nos dados do arquivo zootécnico nacional. De 1980 a 1992 houve um aumento no número de registros do arquivo (registros de lactações), assim como também um aumento no número de animais registrados, porém permaneceu constante a estrutura de idade na população dos rebanhos analisados. A crise de 1990 causou um decréscimo na produção de todas as classes em estudo.

Houve uma redução no número de animais e nos registros de lactações, especialmente de novilhas e vacas de 2ª , 3ª e 4ª lactação. Depois da crise de 1990, o sistema se recupera mostrando alta resiliência, mostrando um crescimento estável depois de 1992. Porém, esta tendência mudou desde 1999, segundo dados do sistema de controle leiteiro (SCL) da associação brasileira dos criadores de raça Holandesa que revelam uma redução constante no número de fazendas, número de rebanhos e animais registrados, porém a produtividade (kg/vaca/ano) tem aumentado.

Em geral, fazendas de leite com raça Holandesa são caracterizadas por alta estabilidade e alta resiliência em termos de produção de leite, porém mostram alta sensibilidade a distúrbios. Estas fazendas de leite, para manter uma produção estável, devem ter uma alta taxa de reposição do rebanho. Isto é resultado da fragilidade das vacas Holandesas, que têm um alto risco de descarte involuntário, devido a causas inesperadas, por motivo de problemas reprodutivos e problemas de saúde (Capítulo 4). O descarte involuntário não é somente resultado de problemas biológicos, nem é considerado como um fenômeno biológico, pois o descarte é resultado de uma decisão do produtor. Vacas de alto potencial para produção de leite são descartadas involuntariamente antes mesmo de atingir seu potencial máximo de produção. Os fatores de descarte de maior incidência nos rebanhos analisados são: *outros, reprodução, saúde, baixa produção e doença*s. O descarte ocorre geralmente antes da 4ª lactação, mas o momento de maior risco de descarte acontece na 2ª lactação. A média estimada da idade no momento da máxima produção, t_{max} é 80 meses, isto é, aproximadamente com 6,7 anos de idade, o que corresponde em média entre a 4ª ou 5ª lactação.A média do número de serviços por concepção é 1,45.

Problemas de fertilidade em vacas Holandesas podem aumentar a medida que aumenta o potencial produtivo destes animais de alta produção. Estas vacas apresentam já na primeira lactação uma alta produção de leite e tendem a apresentar uma maior produção por lactação durante a vida produtiva (capítulo 5), e alcançam em idade jovem a máxima produção. Por isso, vacas Holandesas de alta produção tem uma maior exigência metabólica e são mais suscetíveis ao estresse (*burnout*), que pode levar a um declínio na produção antes deste animal alcançar a maturidade. Este declínio precoce em produção pode ser um indício de uma senescência acelerada e antecipada, que levaria a uma redução na longevidade de animais de alta produção e consequentemente resulta em perdas econômicas. Certamente é um fator que não está contribuindo para a sustentabilidade do sistema produtivo.

O desenvolvimento sustentável nas últimas décadas tem ampliado seu âmbito de percepção nos sistemas de produção no Brasil. Fazendas de sistema extensivo e explorativo, com uso de raça mestiça de duplo objetivo (carne e leite), vêm dando espaço para fazendas mais especializadas, de sistemas intensivo de produção com uso de rebanhos mais especializados.

Mudanças de atividades nos sistemas de produção de leite com raça Holandesa, indo rumo a intensificação, podem ser questionadas quanto à contribuição ao desenvolvimento sustentável (Capítulo 6). A sustentabilidade do sistema de produção está se tornando não só uma responsabilidade do produtor, como está alcançando fronteiras fora da fazenda de leite e se tornando uma questão de interesse público, principalmente no que se erfere às questões ambientais.

A intensificação dos sistemas de produção de leite em fazendas de raça Holandesa, quando não bem manejada, pode resultar num efeito negativo sobre a sustentabilidade do sistema, pois fazem alto uso de recursos naturais, do potencial produtivo do animal, de insumos, energia elétrica e energia não-renovável (fóssil). Por este motivo, a raça Holandesa é somente recomendada quando recursos estão disponíveis na fazenda e esta tenha um ótimo manejo, para que as atividades desenvolvidas possam contribuir para a sustentabilidade.

Table 1. Plano geral para análise de sustentabilidade de sistemas de produção de leite

FASE	DESCRIÇÃO	AÇÃO
1	Descrição do sistema de produção	Definir o contexto e caracterizar o sistema de produção de leite.
2	Identificação das questões EES	Determinar as questões relativas à sustentabilidade do sistemas de produção e classificação das questões em Econômica, Ecológica e Social (EES)
3	Seleção de indicadores de sustentabilildade (IS)	Derivar os indicadores da tabela das questões EES, de acordo com o critério de seleção apresentado.
4	Quantificação dos indicadores de sustentabilidade (IS)	Medidas, observações e coletas de dados dos indicadores de sustentabilidade da FASE 3.
5	Avaliação e monitoramento dos indicadores (IS)	Avaliação integrada das dimensões econômica, ecológica e social, através dos indicadores (IS) em relação às questões listadas na FASE 2.

Table 2. Áreas de interesse e questões ao nível de fazenda de leite relacionados a sustentabilidade

ÀREA	QUESTÕES DE SUSTENTABILIDADE	CÓDIGO
Produção	Informação e registros sobre o sistema de produção	Info
	Condições de mercado no setor de leite	Mercado
	Tecnologia direcionada e adaptada para as diferentes regiões edafo-climáticas e os diferentes sistemas produtivos	Adaptar
	Potencial genético dos rebanhos para produção de leite	Genética
Recurso Natural	Uso de energia não renovável (fóssil) e eficiência no uso	Energia
	Erosão, manejo de nutrientes e fertilidade do solo	Erosão
	Condição e capacidade de lotação da pastagem	Pasto
	Manejo do ar (emissão de gases) e da água	Ar/água
	Diluição do risco através da diversificação de atividades na fazenda de leite	Diversidade
Saúde e Bem estar	Saúde pública e segurança alimentar: qualidade do leite produzido, e resíduos contaminante no leite	Qualidade
	Use de hormônios e antibióticos	Medicamento
	Capacidade de manejo e higiene dos animais	Manejo
	Bem estar e riscos a saúde do animal	Animal
	Educação rural, treinamento e capacitação do produtor e fornecimento de informação	Educação
Economia	Rentabilidade e lucratividade da atividade leiteira	Rentável
	Identificação dos custos de produção e margens de lucro	Custos

SAMENVATTING

De bezorgdheid omtrent en het belang van duurzaamheid bij de ontwikkeling van melkveehouderijsystemen zijn de laatste decennia toegenomen. In Brazilië maken traditionele extensieve dubbeldoel systemen plaats voor meer gespecialiseerde intensieve systemen. Door de ontwikkeling van melkveehouderijsystemen in de richting van intensievere systemen met een hoger gebruik van hulpbronnen neemt de bezorgdheid toe of er voldoende adaptief vermogen is om aan de huidige en toekomstige vraag te voldoen, met betrekking tot milieukundige, sociale en economische aspecten. De veranderingen in het functioneren van huidige melkveehouderijsystemen zijn twijfelachtig wat betreft haar bijdrage aan duurzame ontwikkeling. Het is niet langer alleen een kwestie voor de veehouder om de duurzame ontwikkeling binnen zijn agrarische werkzaamheden te garanderen, maar meer en meer wordt het een publiek belang aangezien de werkzaamheden de grenzen van het agrarisch bedrijf overschrijden.

Holstein koeien worden voornamelijk gevonden bij agrarische bedrijven in de zuidelijke en centrale regio’s van Brazilië. Ze beschikken over een hoog genetisch potentieel voor melkproductie, en worden gehouden in verschillende veehouderijsystemen, variërend van beperkte weidegang tot volledige graassystemen.

Holsteins zijn echter kwetsbare dieren en vragen veel aandacht van het management, wat impliciet bedrijfsaanpassingen vraagt. In dit onderzoek wordt de mogelijke bijdrage van Holsteins aan duurzame melkveehouderijsystemen in Brazilië onderzocht. De reikwijdte van de analyse gaat van maatschappelijk tot productiesysteem niveau, met een beschrijving van het systeemgedrag en belangrijke kenmerken, met betrekking tot de eigenschappen van Holstein koeien op dierniveau, hun productiepotentieel, gezondheids- en reproductieprestaties binnen melkveehouderijsystemen.

De melkveehouderijsystemen in Brazilië kunnen worden geclassicificeerd als *Intensieve* en *Extensieve* systemen. Binnen de *Intensieve Systemen* kan een driedeling worden onderscheiden: beperkte, half-beperkte en intensieve graassystemen. Het gebruik van kruisingen van Zebu en Holstein vee is erg populair door haar dubbele doel (melk en vlees) en haar betere aanpassingsvermogen aan het tropische klimaat. De voorkeur voor ras is sterk geassocieerd met het beschikbare niveau van management, investeringen en verwachte productiviteit van arbeid en kapitaal. Door verschillende melkveehouderijsystemen te analyseren is het mogelijk om belangrijke duurzaamheidsindicatoren te identificeren die de bijdrage van Holsteins aan duurzaamheid illustreren. Dit onderzoek bestaat uit drie delen, een analyse van systeemgedrag in de Hoofdstukken 1, 2 en 3 (deel i), diergezondheid, reproductie en productie in Hoofdstuk 4 en 5 (deel ii) en een voorstel voor een model voor duurzaamheidsanalyse in Hoofdstuk 6 (deel iii).

Eerste deel (i)

In Hoofdstuk 1 worden de Braziliaanse melkveehouderijsystemen bestudeerd en de problemen geïdentificeerd met behulp van een beschrijving van de duurzaamheidsevaluatie. Hoofdstuk 2 geeft een gedetailleerde beschrijving van melkveehouderijsystemen in Brazilië met betrekking tot duurzame ontwikkeling en nadruk op productiesystemen waarin van Holsteins gebruik wordt gemaakt. Melkveebedrijven variëren van lage-input systemen waarin een hoog gehalte Zebu-vee wordt gehouden op extensief tropisch grasland tot hoge-intensieve systemen met beperkt weiden waarin gebruik wordt gemaakt van pure Holsteins. Er bestaan grote verschillen tussen productiesystemen. De uitdaging voor het karakteriseren van duurzaamheid is het gebruiken van een model dat alle verschillende melkveehouderijsystemen in Brazilië omvat, omdat al deze variatie belangrijk is voor de veerkracht van een systeem.

In Hoofdstuk 3 wordt de systeemontwikkeling geanalyseerd over de laatste twee decennia, met speciale aandacht voor de gevolgen van de nationale economische crisis van 1990. Complete lactatie gegevens van pure Holstein veestapels in zuid- en zuidoost Brazilië van het Nationale Melkvee Archief werden geanalyseerd met als doel het begrijpen en ondersteunen van duurzame ontwikkeling.

De ontwikkeling van Holstein melkveehouderijsystemen in Brazilië wordt gepresenteerd en geëvalueerd aan de hand van crisis effecten op de duurzaamheid van een systeem, gebaseerd op systeemeigenschappen zoals productiviteit, rechtvaardigheid en stabiliteit/veerkracht.

Tweede deel (ii)

Systeemanalyse op dierniveau evalueert intensief geselecteerde hoogproductieve Holstein koeien die ongewenste gezondheids- en reproductieproblemen laten zien. In Hoofdstuk 4 wordt dieper ingegaan op redenen voor afvoer met betrekking tot melkproductie bij eerste lactatie, met aandacht voor factoren en problemen die de levenslengte van Holstein melkkoeien in Braziliaanse veestapels beïnvloeden. Omdat afvoer een subjectieve beslissing is die hoofdzakelijk gebaseerd wordt op de perceptie van de veehouder, werden de redenen van afvoer geïdentificeerd en geclassificeerd tot afvoerfactoren. Modellen werden ontwikkeld om de variatie in afvoerrisico over de tijd te kunnen voorspellen, welke kunnen worden gebruikt bij de ondersteuning van management van de veestapel en het plannen van de afvoer. Data van 27 veestapels van intensieve melkveebedrijven in São Paulo werden geanalyseerd voor de incidentie van gezondheids- en voortplantingsproblemen.

In Hoofdstuk 5 wordt de theorie over de totale melkproductie gedurende het leven en de maximale productie geïntroduceerd. Maximale melkproductie wordt verwacht bij volwassenheid, maar de meest hoogproductieve dieren pieken in de productie voor volwassenheid. De toegenomen melkproductie als resultaat van genetische selectie en toegenomen negatief gecorreleerde (neven-)effecten, zoals biologische veranderingen, gedrags-, gezondheids- en voortplantingsproblemen worden bediscussieerd.

Individuele melkproductie data van Holstein veestapels in Minas Gerais, van koeien met tenminste zeven lactaties, worden geanalyseerd in relatie tot leeftijd bij maximale productie, het aantal inseminaties dat nodig is per bevruchting en het productieniveau van de eerste lactatie. Een model wordt voorgesteld om de melkproductiecurve in de tijd te beschrijven.

Derde deel (iii)

In Hoofdstuk 6 wordt een model gepresenteerd voor de beoordeling van Braziliaanse melkveehouderijsystemen wat betreft duurzame ontwikkeling. Dit algemene model is een middel om duurzame ontwikkeling te beoordelen en dient om basisinformatie te verschaffen welke kan worden gebruikt bij het nemen van beslissingen. Een geïntegreerd sociaal, economisch en milieukundig model zoals voorgesteld, kan worden toegepast bij verschillende productiesystemen (scenario's) om de impact van activiteiten op duurzaamheidsindicatoren te evalueren. De evaluatie combineert multi-dimensionale aspecten van duurzaamheid (economisch, ecologisch en sociaal-maatschappelijk) en wordt gepresenteerd als onderwerpen van waaruit een lijst van duurzaamheidsindicatoren wordt voorgesteld om duurzaamheid te evalueren en te monitoren.

Dit algemene model voor de evaluatie van duurzame ontwikkeling is toepasbaar op diverse melkveehouderijsystemen en is gebaseerd op vijf stappen. Deze analyse omvat de identificatie van duurzaamheidsindicatoren die rekening houden met technisch-economische en milieukundig-ecologische uitwisselingen van productie processen. Daarom wordt nadruk gelegd op het gebruik van systeem benadering, die een veelomvattend perspectief biedt waarin relaties tussen technische, milieukundige, sociaal-maatschappelijke, economische en politieke aspecten van duurzaamheid worden meegenomen. Het model wordt gedemonstreerd aan de hand van een basissysteem, dat een intensief graassysteem is. Verdere toepasbaarheid als een algemeen model wordt bediscussieerd aan de hand van andere productiesystemen door het evalueren van effecten en veranderingen van activiteiten op de gepresenteerde duurzaamheidsindicatoren. De bijdrage van Holstein koeien aan de duurzaamheid van melkveehouderijsystemen wordt gekwantificeerd door gebruik te maken van duurzaamheidsindicatoren die op het agrarisch bedrijf aanwezig zijn en vervolgens bediscussieerd.

Multi-dimensionale evaluatie van duurzaamheid

Een analyse van het gedrag van een systeem gebaseerd op systeemeigenschappen als productiviteit, stabiliteit/veerkracht en gelijkheid, toonde de dynamiek van de aspecten over de tijd met behulp van de gekwantificeerde effecten van een crisis op de duurzaamheid (Hoofdstuk 3). De ontwikkeling van systeemduurzaamheid wordt gedefinieerd als het kenmerk om door te kunnen gaan in de toekomst en wordt gekarakteriseerd door trends in de tijd. Een systeem gebaseerd op Holsteins kan een hoge jaarlijkse melkproductie bereiken, zoals 5500 kg/koe in 1992 en 7280 kg/ koe in 2002 (Hoofdstuk 2 en 3). De gemiddelde melkproductie bereikte haar dieptepunt in 1990 en nadat de reikwijdte van de data was vergroot, werd grote variatie in de data set zichtbaar. Van 1980 tot 1992 nam het aantal registraties en dieren toe, hoewel de leeftijdsverdeling over de jaargroepen constant bleef. De crisis in 1990 veroorzaakte een terugval in productie voor alle leeftijdsgroepen, en een reductie van het aantal dieren en registraties, in het bijzonder van jonge melkkoeien in de 2^{e}, 3^{e} en 4^{e} lactatie. Na de crisis vertoonde het systeem een grote veerkracht. Verwacht werd dat na 1992 een stabiele groei zou optreden. Echter, deze trend werd de laatste paar jaar doorbroken, aangezien het melkregistratiesysteem van de fokkerijorganisatie (SCL) een constante daling in het aantal Holstein bedrijven laat zien, zowel wat betreft aantal dieren als het aantal veestapels, maar de melkproductie per koe is gestegen.

In het algemeen worden Holstein bedrijfssystemen gekenmerkt door een hoge stabiliteit en veerkracht wat betreft melkproductie, maar tevens een hoge gevoeligheid voor verstoringen. Om de productiviteit stabiel te houden, hebben melkveebedrijven een hoog ratio van vervanging van koeien. De huidige Holstein koeien zijn kwetsbare dieren en hebben een hoog risico voor onvrijwillige afvoer vanwege vruchtbaarheids- en gezondheidsproblemen (Hoofdstuk 4). Onvrijwillige afvoer is niet alleen het resultaat van biologische problemen, het is zelfs niet een biologisch fenomeen, aangezien het resultaat is van een menselijke beslissing. Ondanks het hoge potentieel voor melkproductie, worden hoog-productieve koeien afgevoerd voordat zij hun maximale productiepotentieel bereiken als gevolg van onvrijwillige redenen. Afvoerredenen met hoge incidentie waren in volgorde van hoog naar laag: *andere, vruchtbaarheid, gezondheid, lage productie* en *ziekte*. Afvoer vindt het meeste plaats voor de vierde lactatie, maar het hoogste risico ligt rond de tweede. De gemiddelde geschatte leeftijd voor maximale productie, t_{max}, is 80 maanden, dus ongeveer 6.7 jaar, wat ongeveer tussen de vierde en vijfde lactatie ligt. Het gemiddelde aantal inseminaties per bevruchting is 1.45. Verder mag worden verwacht dat vruchtbaarheidsproblemen in koeien vaker optreden als de melkgift stijgt.

Hoogproductieve koeien hebben een hogere melkproductie in hun eerste lactatie en van hen mag worden verwacht dat zij een hogere productie prestatie hebben gedurende hun leven (Hoofdstuk 5), wat ze in staat stelt tot een hogere maximale melkproductie op jonge leeftijd. Vandaar dat hoogproductieve koeien een hogere metabolische vraag hebben en gevoeliger zijn voor een burn-out. De vroege daling in productie, die plaats vindt vóór volwassenheid, zou een versnelling van het verouderingsproces en een reductie in de levenslengte van de koe kunnen aangeven, wat kan resulteren in economische verliezen. Natuurlijk draagt dit niet bij aan de duurzaamheid van het systeem.

Een algemeen model gebaseerd op 5 stappen voor duurzame landbouw en plattelandsontwikkeling is opgezet om het multi-dimensionale karakter van duurzaamheid weer te geven (Tabel 1). Meetmethodes and evaluatie van duurzaamheidsindicatoren moeten rekening houden met de technisch-economische en de milieukundig-ecologische uitwisseling met het productieproces (Tabel 2). De nadruk ligt daarom bij het gebruik van een systeembenadering die een veelomvattend perspectief biedt en daarbij rekening houdt met relaties tussen technische, milieukundige, sociale, economische en politieke aspecten van duurzaamheid. Een holistisch, geïntegreerd economisch-milieukundig model, dat in dit onderzoek is ontwikkeld, kan gebruikt worden om de duurzaamheid van verschillende melkveehouderijsystemen in Brazilië te evalueren.

De intensivering van de Holstein systemen kunnen een negatief effect hebben op duurzaamheid, wanneer ze niet goed gemanaged worden. In het algemeen maken Holstein melkveehouderijsystemen meer gebruik van grondstoffen dan andere melkveehouderijsystemen. Daarom kunnen Holstein veehouderijsystemen alleen duurzaam zijn wanneer de grondstoffen aanwezig zijn en er een goed management is.

Tabel 1. Een algemeen model voor de evaluatie van duurzaamheid voor melkveehouderijsystemen.

STAP	BESCHRIJVING	ACTIE
1	Beschrijving van het productiesysteem	Definiëren van context en kenmerken van een melkveehouderijsysteem
2	Identificatie van EES-aspecten	Beoordeling van duurzaamheids-aspecten voor melkveehouderijsystemen en de classificatie in Economische, Ecologische en Sociologische (EES) onderwerpen
3	Keuze van indicatoren	Afleiding van indicatoren van de EES-aspecten, gebaseerd op aanwezige criteria
4	Meten van duurzaamheids-indicatoren	Meten of observeren van indicatoren
5	Evaluatie en controle	Een geïntegreerde benadering die rekening houdt met sociale, economische en milieu aspecten om duurzaamheidsindicatoren te evalueren in relatie tot stap 2

Tabel 2. Aandachtsgebieden en onderwerpen voor duurzaamheidsevaluatie op een bedrijf

AANDACHTSGEBIED	ONDERWERP	CODE
Productie	Informatie en data verzameling van het productiesysteem	Info
	Omstandigheden van de zuivel markt	Markt
	Aangepaste techniek voor de verschillende regio's en verschillende melkveehouderijsystemen	Adapt
	Genetische potentie voor melkproductie van de veestapels	Genet
Natuurlijke hulpbronnen	Gebruik van fossiele energie en efficiëntie van energiegebruik	Energie
	Erosie, nutriëntenmanagement en bodemvruchtbaarheid	Erosie
	Conditie van de weide en draagkracht van de weiden	Weiden
	Lucht en water management	Lucht/water
	Bedrijfsdiversiteit en risicospreiding	Diversiteit

Welzijn van mens en dier	Volksgezondheid en voedselveiligheid: kwaliteit van de geproduceerde melk, verontreinigingen en residuen in de melk	Kwaliteit
	Gebruik van hormonen en antibiotica	Medicijn
	Managementvaardigheden van de veehouders en managers	Management
	Dierenwelzijn en bedreigingen voor diergezondheid	Dier
	Plattelandsonderwijs, training en informatievoorziening	Educatie
Economie	Economisch rentabiliteit van het houden van melkvee	Rentabiliteit
	Identificatie van productiekosten en opbrengsten	Kosten

ABOUT THE AUTHOR

Beatriz de Araujo Waltrick was born on February 16th , 1968 in the city of Lages, state of Santa Catarina, South Brazil. Beatriz did her primary studies and attended a scientific secondary education at Application College of the Federal University of Santa Catarina (UFSC) in Florianópolis. After secondary school, she started in 1985 her studies in Agronomy at UFSC. In 1990 she participated in an international exchange of universitary students doing a traineeship at the National Foundation for Research in Zoological Gardens in Amsterdam (The Netherlands). She returned to Brazil and obtained a Higher Diplome in Agronomy (1991). After graduation, she married and moved to the Netherlands. At Wageningen University, she continue her research career and in January 1996, she obtained the MSc-Degree in Animal Sciences at Wageningen University. The MSc Thesis was on age comparison at maximum production for different species of domesticated animals. She did then a especialisation on Information Technology at the Informatica School of Amsterdam (SICA), where she obtained her diploma on software programming and system design (1998). At the end of 1998 she was awarded a schoolarship by Wageningen University and WOTRO (The Netherlands) to start a PhD research project on sustainability analysis of dairy production systems in Brazil.

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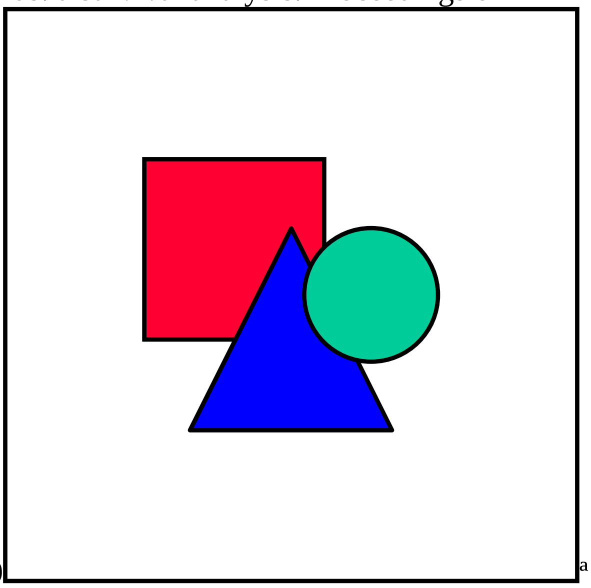

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