SUSTAINABILITY ASPECTS IN ESTONIAN CATTLE BREEDING

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Abstract. The main goal of investigation was connected with genetic improvement of farm livestock within sustainable dairy farming where further mathematical modelling may improve farm efficiency. Dairy farming system was simulated on the basis of the genetic and economical input parameters and structure of dairy population provided by the participating stock companies, Animal Breeders' Association of Estonia and Animal Recording Centre. Models were aimed at underpinning sustainable dairy genetic improvement programmes. Introduction of longevity as a breeding goal trait into Estonian Holstein breeding programme improved the efficiency of dairy system within sustainable dairy farming on 16.9%. Described methodology by including longevity into breeding goal of cattle enables the breeders to achieve greater genetic progress and profitability.
Keywords: sustainable dairy production, longevity, economic weights.

ESTIJOS GALVIJŲ VEISIMO ASPEKTAI IŠLAIKANT EKOLOGINĘ PUSIAUSVYRĄ

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Santrauka. Pagrindinis tyrimo tikslas buvo susijęs su genetiniu žemės ūkio gyvulių gerinimu plėtojant ekologinį pieninių galvijų ūkininkavimą, kai tolimesni matematiniai modeliavimai gali pagerinti fermos produktyvumą. Pieninių galvijų ūkininkavimo sistema buvo imituojama įtraukiant genetinius ir ekonominius parametrus. Galvijų populiacijos struktūra buvo numatyta remiantis bendradarbiaujančiomis akcinėmis bendrovėmis, Estijos gyvulių veisėjų asociacija ir gyvulių registracijos centru. Modeliai buvo nukreipti į pienininkystės genetinio gerinimo programas. Ilgaamžiškumo, kaip veisimo požymio įvedimas į Estijos holšteinų veisimo programą, 16,9 proc. pagerina pienininkystės sistemos efektyvumą. Aprašyta metodika, kurioje įtrauktas galvijų ilgaamžiškumo požymis, veisėjams suteikia galimybę pasiekti genetinį progresą ir pelningumą.
Raktažodžiai: ekologinę pusiausvyrą išlaikanti pieninė produkcija, ilgaamžiškumas, ekonominiai svoriai.

Introduction. Sustainability in animal breeding and reproduction is defined as the extent to which animal breeding and reproduction contribute to maintenance and good care of animal genetic resources for the future generations (Merks, 2003). Favourable genetic predisposition for health and fertility is a key to welfare and longevity of farm animals in different production systems. Sustainability can be improved by means of reproduction and selection of farm animals. Definition of sustainability has to be worked out by the breeders into applicable breeding goals and scenarios. In economically oriented breeding programmes, the aim is to increase the aggregate genotype which is a function of additive genetic values of traits of interest weighted with economic values (Wolfová, Nitter, 2004). Breeding goals must be based on consumer and society demand and therefore contribute to sustainable farm animal production. A breeding goal is a set of characteristics of the cow to be improved by selection. Health and fitness traits have increased in value relative to milk production, leading to their inclusion in breeding goals. Although this will reduce the potential improvement in production it is economically important to select for these "functional traits". The breeding goal reflects those parts of the overall objective that are possible to change genetically. Integration of traits into breeding programmes requires among others knowledge of economic values of these traits. The economic value of a trait expresses to what extent economic efficiency of production is improved at the moment of expression of one unit of genetic superiority for that trait (Groen, 1989).

The length of life of dairy cow has substantial impact on the economic performance. In selection indices it is the most important trait after production all over the world (Canavesi *et al.*, 2003). International genetic evaluation of longevity has been shown to be feasible (Van der Linde & De Jong, 2002; Jakobsen, 2003; Van der Linde & De Jong, 2003; Jakobsen et al, 2004). The largest effect is probably that a longer average life decreases the cost of replacement per year. Also, a longer average life will lead to a higher production of cows in later high-producing lactations (Strandberg and Sölkner, 1996). An increased length of productive life from about three to four lactations increased milk yield per lactation or profit per year by 11-13% (Renkema and Stelwagen, 1979; Essl, 1998). Longevity is an overall indicator of the suitability of cow relative to a given environment (Powell and Van Raden, 2003). According to Rendel and Robertson (1950), a longer productive life in dairy cattle increases profit at farm level by reducing the annual cost of replacements per cow in the herd, by increasing the average herd yield through an increase in the proportion of cows in the higher producing age groups, by reducing the replacements which have to be reared, and therefore allowing an increase in size of the milking herd for given acreage and by an increase in the culling possible. The average milk, fat and protein production per dairy cow per year has increased due to the more intensive use of high productive breeds. The increase in milk production is also a result of the European milk policy as due to the implementation of milk quota system in the European Union the number of cows has reduced.

For a long time productivity has been the main selection criterion. The term "functional traits" is used to summarise those characteristics that increase the efficiency not by higher output of dairy products but by reduced costs of input. Major groups of traits belonging to this category are health (incl. longevity), fertility, calving ease, efficiency of feed utilisation, and milkability (Groen *et al.*, 1997). Since 1995 in Estonia the milk performance has risen about 2400 kg (39%), but the fertility parameters and functional traits have deteriorated (Results of Animal Recording in Estonia, 2005). The population size has decreased by 22%. To avoid the negative tendencies, breeding organisations have changed their breeding goal, paying less attention to production and increasing emphasis on functional traits.

Issues of sustainability are included under umbrella ideas of maintaining and making wise use of resources as well as preserving natural values (Fig.1). According to Gamborg and Sandǿe (2003), it is indeed difficult *not* to be in favour of a development which: (i) allows industry to prosper, (ii) gives a sustained yield of high quality products, (iii) protects the natural environment, (iv) caters for the needs of future generations, (v) makes provisions for the needs of poor people, and (vi) takes care of animal welfare, etc. However, the problem now becomes one of balancing several potentially conflicting ideals. Bromley put it in the wording as: sustainability is at once a fine idea and hopeless concept. It is good because it reminds us of the fate of future persons, it is hopeless because it begs for operational content (Bromley, 1998). There are two solutions for the practical use of sustainability - to surrender the concept of sustainability to decision makers and politicians and to create greater awareness about distributive justice and the value of nature.

	Key concept	Key aspect
Time	Sustainability / Sustained yield	*Procurement* of goods *Wise use* of resources
↓	Sustainability / Sustainable development	*Preservation* of species and ecosystems *Distribution* between generations, between rich and poor *Consideration* of biodiversity, animal welfare, working environment, food safety, farmer profitability

Fig 1. **Diagram of selected aspects of sustainability, as the concept has developed over the past 350 years (Gamborg and Sandǿe, 2003)**

The paper gives a brief history of genetic evaluation of dairy cattle in Estonia and aims to provide an introduction to dairy system in the context of the application of sustainability in dairy cattle breeding and reproduction as a new concept in Estonia. The objective of current investigation was to develop and evaluate sustainable dairy system model on the basis of the input parameters provided by the Estonian dairy farmers, participating stock companies, Animal Breeders' Association of Estonia and Animal Recording Centre. The paper presents a set of breeding goal traits and with the aim to achieve greater genetic progress in sustainable cattle breeding. Economic value of traits has been estimated with PC Program for estimating economic weights in cattle (Wolfová and Wolf, 1996). Selection response has been estimated by SIP program (Wagenaar *et al.*, 1995). Estonian large-scale system of dissemination of information is described to ensure for farmers a quick access to state, research, and market information by using website and Internet and in this way also to have some contribution to sustainable development of animal husbandry.

A history of selective dairy breeding in Estonia

In Estonia, organised breeding can be traced back to 1899, when the first performance tests of dairy cattle were conducted following the example of the Scandinavian countries. In 1909 a cattle testing department was established and this is considered as the beginning of performance testing.

In 1940, animal recording covered 71,692 cows out of 439,800 ones in Estonia. Animal recording was conducted by 388 milk recording societies, which serviced 10,256 herds in total. During World War II, animal recording suffered a heavy blow in Estonia, but fortunately, it did not stop entirely.

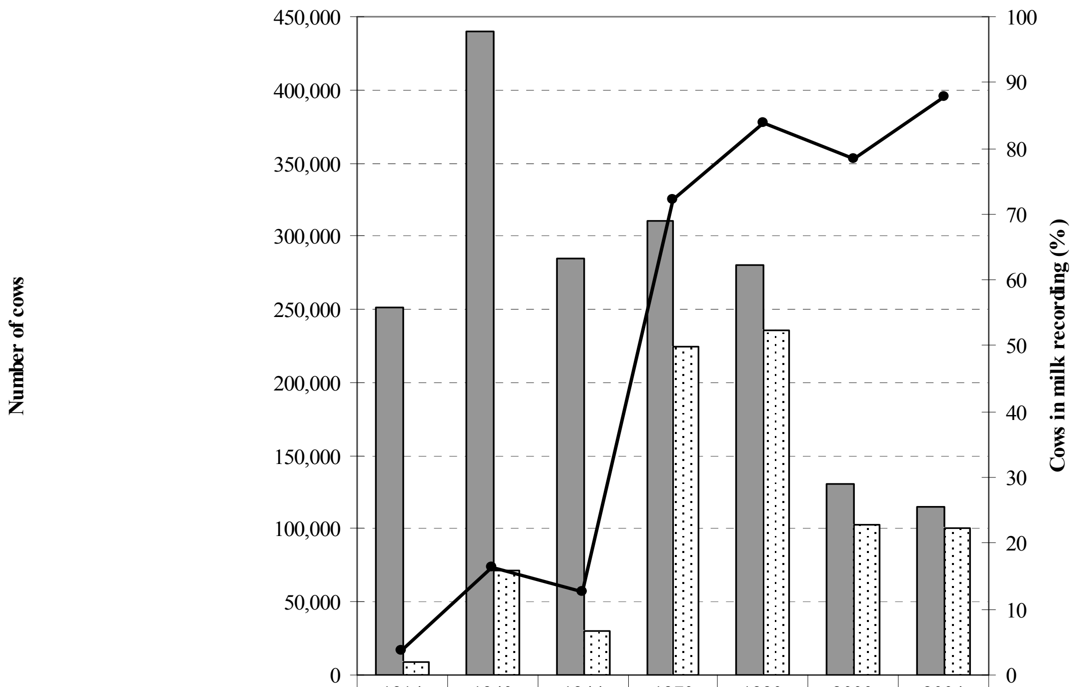
In 1944, the number of cows was 284,500 and recorded cows 29,784, respectively. Collective farms continued animal breeding and animal recording.

By 1960, the number of cows had risen to 295,800 of which 140,507 were included in animal recording.

At present, the Animal Recording Centre (ARC) provides animal recording services in Estonia. It is a state agency in the area of administration of the Ministry of Agriculture. The animal recording services are rendered to owners of dairy cattle, beef animals, porcine animals and goats, also to dairy industries. The Centre also sells ear-tags for farm animals.

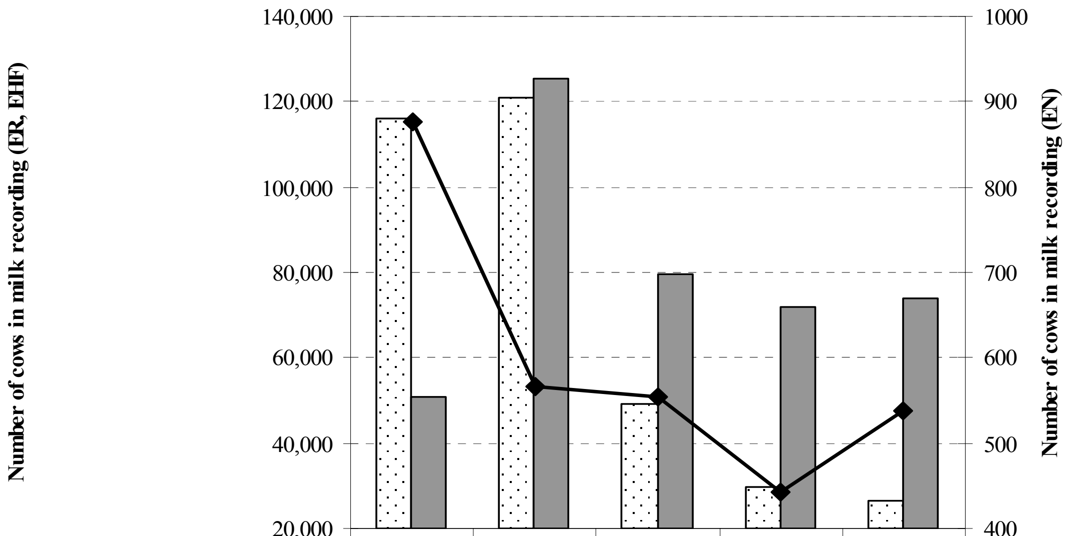
Development of animal recording and milk production of different dairy breeds in Estonia are presented in Figures 2, 3 and 4 (Results of Animal Recording in Estonia, 2005). As of 1 January 2005, 2,467 herds with a total of 100,991 cows were included in milk recording.

The number of cows in milk recording amounted to 87.9% of the total number of cows. The milk yield in herds in milk recording has constantly increased over the recent years. In 2004 the average milk yield per cow was 6,055 kg, i.e. 362 kg more than in 2003.



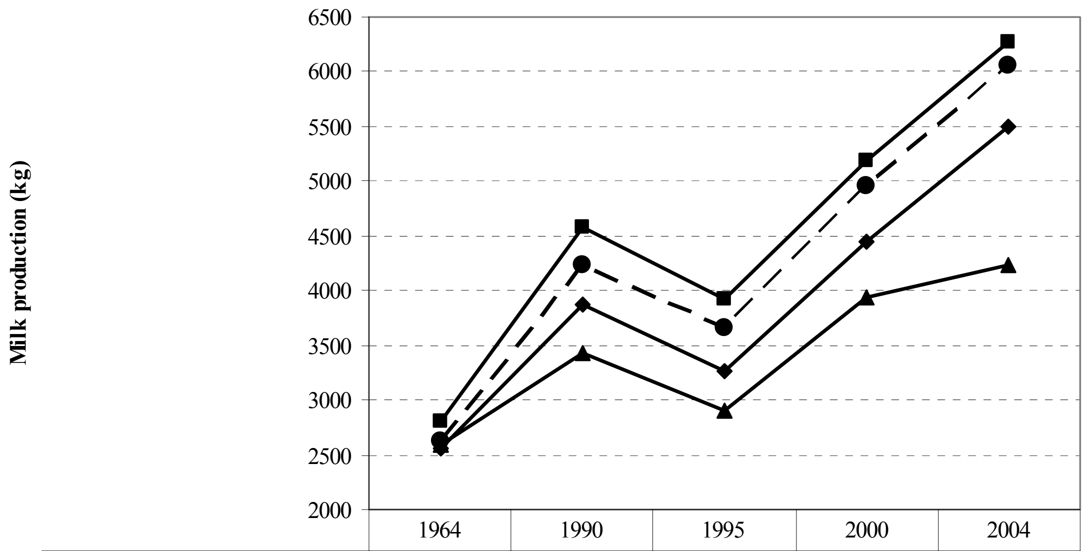
	1914	1940	1944	1970	1990	2000	2004
Cows total	251,000	439,800	284,500	310,500	280,700	131,000	114,900
Cows in milk recording	9,000	71,692	29,784	224,496	235,627	102,524	100,991
% of cows in milk recording	3.6	16.3	12.7	72.3	83.9	78.3	87.9

Fig 2. **Number of cows in milk recording**



	1965	1990	1995	2000	2004
Estonian Red (ER)	116,184	121,125	49,282	29,875	26,571
Estonian Holstein (EHF)	50,750	125,235	79,767	71,799	73,781
Estonian Native (EN)	877	566	555	443	538

Fig 3. **Number of cows in milk recording by breeds**



	1964	1990	1995	2000	2004
Estonian Red (ER)	2,551	3,869	3,272	4,441	5,498
Estonian Holstein (EHF)	2,799	4,586	3,915	5,182	6,269
Estonian Native (EN)	2,588	3,430	2,897	3,936	4,239
Breeds average	2,630	4,232	3,666	4,960	6,055

Fig 4. **Annual milk yield per cow by breeds**

Milestones of Animal Recording Centre are the following (Pentjärv and Uba, 2004).

1964 – Electronic data processing of animal recording in the mainframes of educational and research centres.

1971– Establishment of the Laboratory of Milk Analyses at the Estonian Institute of Animal Breeding and Veterinary Science and the beginning of protein content determination.

1979 – The beginning of somatic cell count determination.

1991 – The concentration of animal recording database and data processing.

1993 – Foundation of the Animal Recording Centre of the Republic of Estonia.

1994 – Introduction of Milk Analysers System 4000. Creation of the Field Service Department engaged in developing services, organising training, counselling and testing, and selling of ear-tags.

1995 – The Animal Recording Centre becomes a member of International Committee for Animal Recording (ICAR) and International Bull Evaluation Service (INTERBULL).

1998 – The transition of performance data processing from the mainframe to PC-type servers; a relational database (ORACLE) becomes the working environment.

1999 – The Laboratory of Milk Analyses becomes an accredited testing laboratory. A connection with the Animal Recording Centre is established for animal breeding organisations and animal owners via the Internet.

2000 – In addition to animal recording, administration of direct benefits of the state.

2002 – The Estonian Accreditation Centre issues a certificate of milk samples analysing conformity with standard EVS-EN ISO/IEC 17025.

In Estonia animal recording is regulated by acts and regulations, which are based on the regulations set by the International Committee for Animal Recording (ICAR). Performance is recorded according to the regulations, where an animal keeper or a person authorised by the farmer is liable for keeping initial accounts and forwarding data to the Animal Recording Centre. Calculation of yields is based on the results of test milking. Upon calculation of lactations of cows the interpolation method is used.

Genetic evaluation of dairy cattle

Routine genetic evaluation of dairy cattle began in the early 1980s by assessment of sires on the basis of the milk production data of their female offspring by way of comparison between offspring and their contemporaries (Pentjärv and Uba, 2004).

1992 – Introduction of the BLUP sire model for evaluation of production traits.

1996 – Introduction of the BLUP animal model.

1997 – Genetic evaluation of conformation traits.

1998 – Genetic evaluation of udder health traits.

1998 – Participation in Interbull's international evaluation of bulls with the production data of the Estonian Holstein breed.

1999 – Introduction of the BLUP test day animal model.

2001 – Participation in Interbull's international evaluation of bulls with the udder health data of the Estonian Holstein breed.

Derivation of economic values of milk production traits and longevity

For the derivation of the economic values, a bioeconomical model of a closed herd which included the whole integrated production system of dairy breed was used (Wolfová and Pžibyl, 2001). The total discounted profit for the herd was calculated as the difference between all revenues and costs that occurred during the whole life of animals born in the herd in one year and that was discounted to the birth year of these animals.

Core elements of the program are modules describing the age distribution of the herd based on different possible fates of cows, the production level in each lactation and cost rations on a daily basis. Detailed definitions of all evaluated traits and complete description of the method and the individual models used for the calculation of economic weights can be found in Wolfová and Wolf (1996). A computer program developed by Wolfová and Wolf (1996) was used for the calculations of economic values for the various traits. It was assumed that the number of breeding heifers was constant when increasing the length of production life in cows.

The total discounted profit for the herd was calculated as the difference between all revenues and costs that occurred during the whole life of animals born in the herd within one year and that which was discounted to the birth year of these animals:

$$Z_T^0 = Z^0 S_{StFU}$$

$$Z^0 = \sum_{k \in \Omega} N_k (R_k q_{R_k} - C_k q_{C_k})$$

with

Ω={*BCa*, *CCa*, *FBu*, *BHei*, *CHei*, *CCo*1, *CCo*2+}

where

Z_T^0 - total discounted profit in the population of the given breed (closed herd)

S_{StFU} - number of standard female units (StFU = one cow place occupied during the entire year)

Z^0 - discounted profit per StFU

N_k - average number of animals in category *k* per StFU

R_k, C_k - average revenues and costs, respectively, per animal of category *k*

q_{R_k}, q_{C_k} - discounted coefficient for revenues and costs, respectively, in category *k*

The discounting coefficients for the revenues were calculated by the following equation:

$$q_{R_k} = (1+u)^{-\Delta t_{R_k}}$$

where

Δt_{R_k} - average time interval between the birth of animals of category *k* and the time of collecting revenues

u - discounting rate (expressed as a fraction).

The discounting coefficients for the costs were calculated in the same way and with the same discounting rate.

The not discounted profit (i.e., the average profit per year in the entire balanced system) was calculated by setting *u*=0 so that all *q*'s took the value 1.

The discounted economic weight of a given trait *i* was defined as the partial derivative of the total profit function for the closed herd with respect to the given trait, whereby all traits were assumed to take their mean values:

$$a_i = \left\{ \partial Z_T^0 / \partial x_i \big|_{\mathbf{x}=\boldsymbol{\mu}} \right\} / S_{StFU}$$

where

x_i - value of the trait *i* under consideration

x - vector of the values of all traits (dimension of x = number of traits)

μ - vector of the means of all traits.

Revenues of the farm came from milk production, and beef production from bull calves and culled cows. Costs were divided into costs variable per cow, costs fixed per cow and costs fixed per farm. Variable costs included costs of feed, diseases, dystocia, milking, insemination, replacement and costs of producing bull calves. Fixed costs included costs of labour, milking, parlour, electricity, housing and milk recording.

The situation based on production and economic data of the joint stock companies was defined for the Estonian Holstein population as presented in Table 1. The statistical data were taken from the Results of Animal Recording in Estonia (2002).

Table 1. **Applied economical and biological parameters to derive economic values**

Price of milk carrier (EEK/kg)	1.75	Length of pregnancy (days)	278
Price for 1% protein content in milk (EEK)	0.3	Calving interval (days)	410
Price for 1% fat content in milk (EEK)	0.1	Number of inseminations for pregnancy in cows	2.0
Price of one insemination (EEK)	300	Interval between calving and 1st breeding in cows (days)	83.3
305-day milk production in 1st lactation (kg)	5539	Age of heifers at 1st breeding (days)	624
Milk protein content (%)	3.24	Discounting rate (% per year)	10
Milk fat content (%)	4.09		
Average number of lactations	4		
Maximum number of lactations	10		

Some of the applied 127 input parameters to derive economic values are presented in Table 1. Revenues of the farm came from milk production, and beef production from bull calves and culled cows. Costs were divided into costs variable per cow, costs fixed per cow and costs fixed per farm. Variable costs included costs of feed, diseases, dystocia, milking, insemination, replacement and costs of producing bull calves. Fixed costs included costs of labour, milking parlour, electricity, housing and milk recording.

Genetic superiority in different selection scenarios

Estimated genetic and phenotypic parameters for 305-day milk production traits in first lactation of Estonian Holstein cattle are presented in Table 2.

Two selection scenarios have been considered. The first includes in breeding goal milk carrier (water with lactosis) production, fat and protein production and the second selection scenario involves besides named milk components' production also longevity. The results are presented in Table 3. As production traits and longevity belong to the different categories of measurement (kg-s versus days), the differences of those two scenarios are expressed in profitability. Including longevity into the breeding goal increases the genetic progress per lactation per cow by 1470 EEK (94 EUR). Profitability per lactation amounts to 8691.5 EEK if the longevity is not included into the breeding goal and 10161.5 EEK in case it is. By including longevity in the sustainable breeding goal the profitability per lactation increased by 16.9%.

Table 2. **Estimated genetic and phenotypic parameters for 305-day production traits in first lactation of Estonian Holstein Cattle (heritability - h^2 on the diagonal; phenotypic correlation - r_p above and genetic correlation - r_g under the diagonal)**

Trait	Unit	Production	Standard deviations		h^2, r_p, r_g			
			Genetic	Phenotypic	Carrier	Fat	Protein	Longevity
Carrier	kg	5513	365	587	0.287	0.790	0.924	0.19[1]
Fat	kg	249	12.6	23.3	0.826	0.349	0.864	0.15[1]
Protein	kg	197	10.6	19.4	0.890	0.858	0.293	0.20[1]
Longevity	days	-	180	329	0.13[1]	0.13[1]	0.13[1]	0.03[2]

[1]Powell and Van Raden, 2003
[2]Olori *et al.*, 2003

Table 3. **Profitability and economic weights[1] of milk components and longevity**

Trait	Unit	305-day production	Economic weight, EEK	Profitability per lactation, EEK
Carrier	kg	5513	0.9	4961.7
Fat	kg	249	-4.8	-1195.2
Protein	kg	197	25	4925
Longevity	lactation	-	210	1470

[1]Economic weights are expressed in EEK per unit of given trait and per standard female unit (1 EUR=15.6 EEK)

Information dissemination system

Farmers and advisors need a large-scale system of dissemination of information that would ensure quick access to state, research, and market information. To reach this aim, web site of agricultural advisors was launched, a development plan was prepared for agricultural sciences, attention was paid to the development of agricultural vocational schools into in-service training centres, development of the services of public Internet access points; the Estonian Farmers' Federation started to publish the information paper Good Advice. Advisors and their support centres have been assisted by procurement of the equipment they need for providing their services.

At the end of 2001, the Ministry of Agriculture of Estonia launched a project to improve the efficiency of dissemination of agricultural and rural information and advisory activities. An Internet portal for rural undertakings and an information dissemination system with the coordinating national centre and county centres were launched in the course of the project. The information system helps farmers and rural undertakings to find and understand information, and gives the Ministry of Agriculture regular feedback on the information needs of rural undertakings.

In 2002, the coordinating function was performed by the Rural Development Foundation (RDF), which guided the county units. RDF supports farmers and other entrepreneurs in rural area to find necessary financial resources to develop entrepreneurship. The Ministry of Agriculture selected county farm associations as the county units as a result of a competition. The county information units held training days, and helped those interested in finding information.

Estonian Chamber of Agriculture and Commerce (ECAC) acts as the national coordinating centre from 2003, and the county units continue to act under the guidance of the information dissemination centre set up at the ECAC. The local farm associations are still the information units in most counties. The aim of the county units is to make the necessary information available to rural undertakings and to keep the Ministry of Agriculture in touch with the information needs of rural undertakings. Besides daily informing activities, the information units organise training days for rural undertakings. Since 2003, the ECAC information dissemination centre also administers and updates the Internet portal for rural undertakings. Since 1999 the breeding organisations and producers have been given an opportunity to make use of animal recording database and services available in Internet. This option is now being used by all breeding organizations, the State Breeding Inspection and research institutes. Generally there is a great interest as they have daily access to the most up-to-date on their herd data 24 hours a day. More than 50% of owners of dairy cattle under milk recording are using internet service of Animal Recording Centre of Estonia. 46% of Estonian inhabitants is using internet and more than 50% of them has internet access also at home.

Conclusions

Selection is an effective way of improving dairy cows for a wide range of economically important traits. Statistical techniques and artificial insemination allow the breeders to improve their breeding work effectively. These modern tools will enable even greater selection for consumer driven traits. In future, the emphasis will continually be on traits that enable the cow to produce high yields of milk economically, but there will be greater emphasis on traits affecting cow health and welfare. This is what we call sustainable dairy production system. Generation of indexes for sustainable dairy cattle breeding is the main task for successful economically profitable dairy system. A breeding goal is a set of characteristics of the cow to be improved by selection. These are the characteristics that a breeding company wants to improve or individual farmers would like to improve in their breeding programme. The fewer the number of traits in the goal, the greater the rate of improvement for these traits. But by including more traits, the overall economic improvement achieved may be greater, as long as the additional characteristics are of economic importance. Health and fitness traits have increased in value relative to milk production, leading to their inclusion in breeding goals. By including longevity in the sustainable breeding goal of Estonian Holstein, the profitability per lactation increased by 16.9%. Sustainable dairy system needs understanding and dissemination of results, and in Estonia this is widely performed by using IT techniques.

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