The Output of the Research Institute of Agricultural Machinery since 1990

S. Ivanovs, D. Viesturs, A. Vilde, I. Ziemelis
Research Institute of Agricultural Machinery

Abstract. The research work at the Research Institute of Agricultural Machinery is connected with investigations into soil mechanics, the choice of energy-saving and rational technologies for the production of agricultural crops, seeking out possibilities for the mechanisation of non-conventional agricultural crops, and research of rational utilisation of alternative sources of energy. Studies have been conducted to raise the soil tillage quality, and to reduce energy requirement and costs. Motivation is given for the design parameters of the soil tillage mechanisms, more efficient soil tillage methods and technical means. Mathematical methods have been developed for the investigation of the technological processes of soil tillage and the choice of rational technologies for growing agricultural crops. Investigations have started lately in the application of the GPS technologies in precision agriculture and assessment of the ecological aspects of soil tillage mechanisation. The work has started in the recent years at the development of technologies and means of mechanisation for growing non-conventional crops: cranberries, highbush blueberries, sea buckthorns, etc., and for processing their products. A machine system has been developed for growing large cranberries; experimental models of the machines have been made and tested. As a perspective direction can be noted a theoretical research into rational use of the sources of renewable energy, the development of machine designs and their practical application. Experimental collector equipment has been developed, which follows the movement of the sun, for the use of the energy of solar radiation. Solutions are sought to use the plant biomass for the production of energy. Equipment has been made for heating piglets in the piggeries where the air carried out of the piggery by the ventilation systems is used as a source of heat. Ecologically harmless technologies are offered for biological agriculture. The work is going on at the issues of mechanised growing and harvesting of technical crops: flax and sugar beet. Various flax harvesting technologies have been worked out and economically motivated depending on the specificity of the flax growing farms and their financial resources.
Key words: agriculture, mechanisation, technology, renewable energy, machinery.

Introduction

The Research Institute of Agricultural Machinery was founded in 1960 in Ulbroka as the Scientific Research Institute of Agricultural Mechanisation and Electrification. During its existence the Institute has changed its name several times. Since 1998, the Institute has been integrated into the Latvia University of Agriculture (LLU) as an independent legal entity; and since 29 September 2004, it has been operating in its present legal status – an agency of LLU.

At the initial stage its operation was connected with regional machine building, i.e., the development of machines and tools for small peasant farms and household plots. At the assignment of the Ministry of Agriculture, technical documentation was made up there, as well as pilot samples, and the specimens of machinery purchased in the European countries were tested. After receiving positive conclusion from the Baltic Machine Testing Station, the machines were sent for manufacturing. In approximately a four or five year period, the former Institute of Mechanisation designed about 40 machines and sent them for manufacturing.

The output of this period is reflected in popular science articles, brochures, catalogues, designs of the buildings, technical documentation of the machines, and working drawings. The previous system of scientific publications had failed but a new one was not created yet. The collections of articles, synopses of lectures and other materials had to be published on one's own effort and initiative. In 1991-1992, the system of financing changed from the financing of the entire institution to the financing of individual grants; determination of equitability, or nostrification, took place. The law "On Scientific Activity", adopted at the end of 1992, stabilised the situation, fixed the status of research institutions and researchers, the order of financing, etc.

The stage of local machine building came to an end in 1993-1994. With the development of a new form of large-scale agricultural production, a new direction of the future research-technological investigations appeared. During this time the number of the staff decreased approximately from 90 to 35. However, the scope of the themes to be studied was very wide. In the year 1995, the Institute was engaged in the implementation of 10 projects, or grants, financed by the Latvian Council of Science (LCS). When the LCS financing for the years 1996-1997 started, stricter criteria were introduced, such as participation at international conferences, scientific publications, patents, etc., and thus the researchers of the Institute gradually acquired the skills that are necessary for the participation at the conferences abroad, and long-term cooperation developed with the research institutes in Lithuania, Poland, and Belarus. Participation took place practically in every country of Central Europe. The most important directions of the activity of the Institute gradually evolved, and the number of themes decreased. After the year 2000, using the subsidies assigned by the Ministry of Agriculture, several modern items of the research equipment were acquired, mainly for the studies of rational use in precision agriculture and in the field of energy. Since 2005, the Institute has been receiving base-financing, and since 2006 – also financing for the execution of the LLU research projects, which provides an opportunity to expand investigations in the principal directions as well as to start arrangement of the infrastructure. The following sections of the paper contain an exposition and a future vision of the research directions.

Results and Discussion

Soil tillage mechanics, energy-saving soil tillage technologies and machines

Soil tillage mechanics is a subdivision of science about the functional relationships of agricultural technological processes and machines. Their cognition provides a possibility of solving the mechanisation issues of agricultural production in a more motivated, economical and faster way. That is why the studies in soil tillage mechanics have been unofficially conducted already since the time when the Institute started its operation, but officially as a theme of research – since 1997.

The theoretical and experimental investigations into the energy requirement of soil tillage processes, as well as the technical solutions and recommendations for energy reduction have been included into several dozens of publications with a common subject matter in Latvian, Russian, and, since 1997, also in the English language. Approaches have been formulated and motivated concerning the course of the soil tillage technological processes and energy requirement. In contrast to the previous views, a hypothesis was advanced and proved that the draft resistance of the operating parts of the machines and the respective soil tillage energy requirement depend on the impact of dual forces upon them: the forces which are determined by the mechanical properties of soil (the mechanical strength (hardness) of soil which causes resistance to the penetration of the operating parts into soil, as well as resistance to its deformation), and the forces which depend on the physical properties of soil (the forces of weight and inertia caused by the transferred mass of soil, as well as resistance to friction and adhesion). Guided by this conclusion, relationships of the strength of materials and theoretical mechanics are applied for analytical determination of the forces acting upon the operating parts of the machines and their elements (Vilde, 1999a).

Mathematical methods have been worked out for the investigation of the soil tillage technological processes allowing the determination of the soil transfer and the force of its impact on the operating parts of the machines, finding their rational design and optimal parameters of the technical equipment in order to ensure high-quality soil tillage with a minimum consumption of energy (Rucins, Vilde, 2006) The obtained analytical relationships are used for determination of the optimal parameters of the operating parts of the machines and the draft resistance in connection with the technological properties of soil (Vilde, 2003). These methods and the obtained relationships allow motivation for the solution of an energy-saving technology and design of the operating parts, the development of highly efficient, economic machines and aggregates for the basic soil tillage and its pre-sow preparation, as well as finding ways of their efficient application.

Approximately half of the draft resistance of the soil tillage machines (ploughs) arises due to the resistance of soil sliding along the surfaces of the operating parts. In order to study this phenomenon more extensively and intensively, a computerised tribometric stand was developed in 2003 and was used by the students of master and doctoral studies for working out the promotion papers, as well as for other investigations connected with the tillage and the physical-mechanical properties of soil.

Motivated, more efficient energy-saving technologies and machines have been worked out on the basis of the research materials for the basic and pre-sow tillage of soil. In all, 16 kinds of machines are developed for more efficient soil tillage under zonal conditions.

The main directions are substantiated for joining technological operations of soil tillage and the design solutions of combined stubble breakers; ploughing and cultivation aggregates are worked out. The combined machines allow optimisation of the technological processes for the basic and pre-sow tillage of soil, reduction of the completion times of operations, fuel, labour and costs by 14-30%. The developed and recommended solutions are applied in the machine designs (drag-looseners, cultivators) at the enterprises of Latvia.

A new improved method has been worked out for the optimisation of the functional parameters of soil tillage aggregates (Vilde, 1999b). The optimum parameters: the speed and the working width of the machine to gain maximum efficiency of the soil tillage aggregates with minimum energy (fuel) consumption, the relations of the draft power of the tractor and the specific resistance (power) of the machines being as the functions of speed. In order to achieve high specific efficiency of the soil tillage aggregates with a minimum consumption of energy, machines should be used with a low coefficient of the dynamic resistance. By means of this method optimal parameters of harrowing, ploughing and cultivation are determined. They are applied to substantiate the working width of the designed machines and aggregates, as well as to choose and complete sets of machines for the high-speed and powerful tractors. Normative documentation of the energy requirement of technological processes and fuel consumption have been worked out and the specific consumption of fuel calculated for growing the field crops by the intensive, conventional, simplified and minimised technologies, as well as the amount of fuel which is necessary for Latvia (Vilde, 1995).

On the whole, by using the revealed solutions in the conventional soil tillage technology it is possible to save 24-36% of energy (46-110 kWh ha^{-1} and the corresponding 12-27 kg ha^{-1} of diesel fuel), to raise labour efficiency by 16-32%, and decrease the costs by 14-26%. By optimising the operation of the sugar beet harvester it is possible to lower its energy intensity by 20-30%, and save 5-8 kg ha^{-1} of diesel fuel.

The future research will be devoted to the reduction of the energy requirement of technological processes as well.

Precision agriculture, GPS technologies

In the recent years, in cooperation with the Institute of Soil and Plant Sciences, investigations are evolving in "Precision Agriculture". Owing to the possibilities of the new machines and equipment, the GPS technologies, with the help of the global positioning system, allow to find, analyse and react in a corresponding manner to the qualitative properties of the cultivated plots of land and implement an agricultural farming system (soil tillage, fertilisation, selection of sorts, etc.) that is most suitable for them.

In order to coordinate the investigations in the development, introduction and determination of the efficiency of the technologies applied in precision agriculture, as well as to acquaint with them students, agricultural specialists and farmers, the Research Centre for Precision Agriculture is being formed on the basis of the Research and Study farm "Vecauce" of LLU. The curriculum "Global positioning technologies in agriculture" has been worked out for training of the students of LLU Technical Faculty, etc. For its better acquisition, a manual has been written and published with the help of the EU co-financing under the title "Global positioning technologies in agriculture" (Vilde et al., 2008). This direction is considered as perspective, and the work should be continued.

Investigations into mechanised sugar beet growing and harvesting

A new stage started in the solution of problems of mechanised sugar beet growing in 1990, when, due to the sugar deficit in the country, possibilities were sought how to avoid it and satisfy the needs of the population and food industry by means of self-made beet sugar. The production of beet sugar had fallen to 16 thousand tons a year, which ensured only about 20% of the need for sugar in Latvia (Vilde et al., 1996). Principal attention was paid to the reduction of labour consumption in thinning–weeding of sugar beets and the use of machinery that is more suitable for the conditions of the peasant farms, as well as to mechanised growing of the most suitable sorts of beets. In cooperation with "Uzvara–Lauks" Ltd it was found out that, using quality seeds with a high germination power and appropriate precision seeders, it was possible to sow the seeds at extreme distances (16-18 cm) and thus manage without thinning of the beets and, applying efficient herbicides, also without weeding and inter-row cultivation of the plantations. As the most suitable for the peasant farms were recognised one-man harvesters which did not gather the leaves. These harvesters were coupled to a 2-3 row tractor for the farms with smaller sugar beet areas, and 6 row mobile harvesters for large farms.

With the use of the methods of the probability theory and mathematical statistics, distribution relationships between the plants and their density were theoretically determined in the sugar beet plantations, as well as their impact on the expected yield, which was confirmed in experimental investigations. It was found out that the distribution inhomogeneity of the plants was functionally dependent on the germination power of the seeds on the field: the higher was their germination power, the higher was their homogeneity of distribution, and vice versa (Vilde, Cesnieks, 2005). The structure of the sugar beet production costs was analysed and recommendations were worked out for their reduction paying particular attention to more efficient usage of the more expensive machines (Vilde, 2002).

In 1995, a conception was worked out and successfully implemented for the development of the sugar beet production in order to fully ensure Latvia with home-made sugar of up to 100 thousand tons a year (Vilde et al., 1996). In 1998, altogether 68 thousand tons of beet sugar was harvested, which was the highest achievement in comparison with the other pre-war and post-war production volumes. The technology and the level of mechanisation of sugar beet production were approaching the standards achieved in the countries of Western Europe, yet the production costs, due to a lower remuneration of the workers, were lower. Investigations should be continued because sugar beet growing and sugar production in Latvia can be restored.

Investigation of the technological variants of flax harvesting in Latvia

The topicality of research in this direction was stipulated by the fact that harvesting is the most labour-consuming stage in the flax growing technology (approximately 70% of all the labour consumption), which, in many ways, determines the prime cost and quality of the finished product and total consumption of energy. Due to the sharp rise in prices of energy in the 1990s, flax harvesting by combine harvesters became less efficient, and suggestions were needed how to improve it. In the recent years, the interest has increased in the application of a two-phase harvesting technology used in several countries of Western Europe by which flax is pulled, at first, and spread in ribbons together with the seedy pods for drying and ripening of the seeds under natural conditions. After that, 6-10 days later, the flax is lifted, the seeds are threshed out, but the flax straw is spread on the ground. Compared to the combine harvesting, this method presupposes approximately 2.6 times less consumption of energy for final drying of the seedy part of the yield, etc. The basic factor that restricts the introduction of this technology in Latvia is that it requires considerably more expensive machines and the risk is high that the seeds may be damaged in rainy weather. Studies were conducted to determine the limits of the efficiency of these two technologies under the conditions of Latvia. Figure 1 shows the prime cost of the flax stalks when the flax is harvested by means of combine harvesters and with a two-phase method on different backgrounds of yields.

The difference in the prime costs of the flax stalks using a combine harvester and a two-phase method of harvesting, decreases with the increase in the yields. Summary calculations show that introduction of self-propelled machines for the two-phase flax harvesting technology can be justified for the time being only on condition that the yields are more than 5 metric tons from a hectare and the annual output of one machine is more than 120 ha. According to the prognoses in a ten-year perspective, both flax harvesting methods will be applied in approximately equal proportions.

In the 1990s, the Institute was intensively engaged in the development of machines and implements for harvesting of flax which would ensure lower consumption of labour and losses of its quality. The most popular machines among the ones which are used for processing the flax stalks are the fluffers of the flax ribbons with which almost all the flax seeders in Latvia were equipped (many of them are still operating today). Investigations were conducted into the efficiency of various flax processing methods during its maturing.

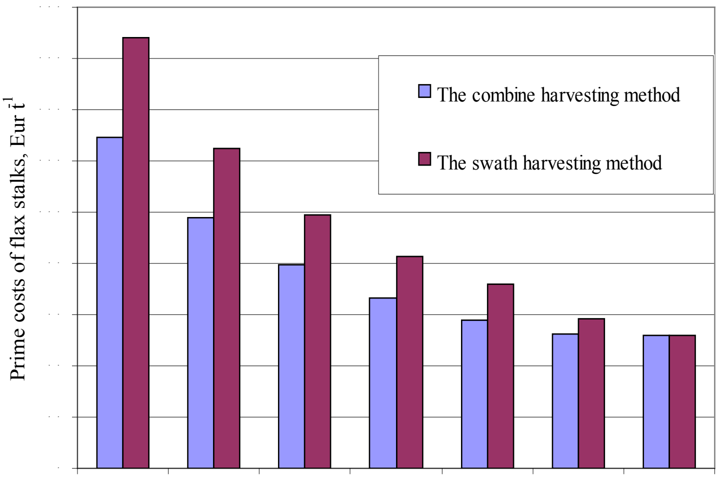

Fig. 1. The prime cost of the flax stalks according to the combine and the swath harvesting methods of flax.

The impact of fluffing on the quality of the product depends, to a great extent, on the crop capacity, i.e., the thickness of the layer of flax in the ribbon. In the experiments with flax the crop capacity of which was 2.8 t ha^{-1} and the maturing period was 19 days, application of single fluffing ensured an increase in the sort number not more than by 12% in contrast to the previously used maturing of flax without any special treatment; however, when the yield of the flax stalks exceeded 4.2 t ha^{-1}, even two-fold fluffing with a 10-day interval did not ensure uniform maturing (particularly in the bottom layer), and extra 5-8 days of maturing were necessary to complete the biological process in all the layers. When the ribbon of flax is turned over by 180º, it is separated from the ground and laid again on the surface of the field. In experiments with the flax, the crop capacity of which was 4.2 and 6.0 t ha^{-1}, application of two-fold overturning with a 9-day interval, in contrast to flax maturing without special treatments, ensured an increase in the sort number by 18.1 and 28.5%, respectively. It was established that, in case the yield of the flax stalks is higher than 3.0-3.5 t ha^{-1}, overturning of the flax ribbons must be included at any rate into the technology. The machines for the overturning process are considerably more complicated by their design and less efficient than the fluffers which slow down their overall introduction into the flax growing industry in Latvia. A series of practical recommendations have been worked out, and a book under the title "Flax growing and pre-processing technologies and machines" was published in 2007 (Ivanovs, Lazovska, 2007). Further investigations are aimed at the study of optimal technologies for growing similar technical crops – oil flax and hemp.

Investigations and development of a system of machines for growing of berries

During the last 10-15 years, interest has increased in the cultivation of berry crops. However, the unsettled situation with the technological and technical provision of agricultural farms of different sizes has hampered its implementation. On the basis of the investigations, a system of machines has been worked out for laying out plantations of cultivated cranberries, their cultivation and gathering. Investigations have been conducted, preliminary designs developed and specimens of machines made for sand and peat application based on a distributor of organic fertilisers, two types of a manual applicator for the weed control with a contact method, machines for the preparation (collection) and planting of sprouts, and implements for the water-level adjustment on the cranberry plantations (Ivanovs et al., 2007). On the whole, the total requirement for capital investments which are necessary to start the production of cultivated cranberries on a 10 ha area is approximately 180 thousand euro, including approximately 30 thousand euro in order to purchase the necessary machines and implements. In the pre-storage stage, the most essential part of expenditure (32%) goes to the care after the plants and harvesting. Considering the great interest and scientific topicality of the issue, it is planned to continue the work in this direction.

As a result of the investigations into the harvesting processes of sea buckthorn berries, a technology has been improved and an equipment designed for the separation of berries from the stalks and their cleaning, machines have been worked out for the care after strawberry plantations, etc. (Лачгалвис, Эпро, 2005).

Investigations into the efficiency of the self-propelled field cultivation machinery

The direction of these studies logically developed in the middle/the second half of the 1990s. During this period there were more than 100 thousand land properties, the supply of various machines constantly increased, and from 1996 the government started subsidising technical improvement of the branch including the purchase of machines. However, often there were no criteria for their choice and estimation of the expected results of their application on the farms of various sizes and intensities. A computerised technological calculation method was worked out in the years 1997-1998. By varying the data, which characterise the technology (the performed operations, the machines used, the applied fertilisation and plant protection means, their prices, expected yields, and so on), this method allows to calculate the prognosticated costs per unit of product (Kopiks et al., 1998). In such a way, before starting the technological innovation it is possible to analyse various variants and choose the final one in the estimation of the expected economic results. Using this method it is possible to compare the costs of various aggregates (soil tillage, harvesting, etc.) depending on the cultivated area, and therefore to choose the optimal one for the farms of different sizes. By further improvement of this method, nomograms of profitability were drawn up for the production of the most important kinds of products (Kopiks, Viesturs, 2002).

The issues of energy provision of the farms were studied, namely, the capacity of the tractor related to the cultivated area within the context of development trends of the farms (Asejeva et al., 2003). It was found out that with the growth in the areas on the farms, the use of machines improves and the required energy supply in kW ha^{-1} decreases. On the farms with areas under crop over 200 ha, the energy supply is 1.2-1.6 kW ha^{-1}. According to the estimates by some authors, the specific energy supply, which would be necessary for an average farm in Latvia to do the work in optimum terms and quality, is approximately 2.50 kW ha^{-1}. These studies characterise also the trends of the development of the fleet of tractors. The comparative data about the changes in the tractor fleet on the farms of different sizes for the period of 2000-2007 are shown in Figure 2. As it is evident, the number of tractors is decreasing on the

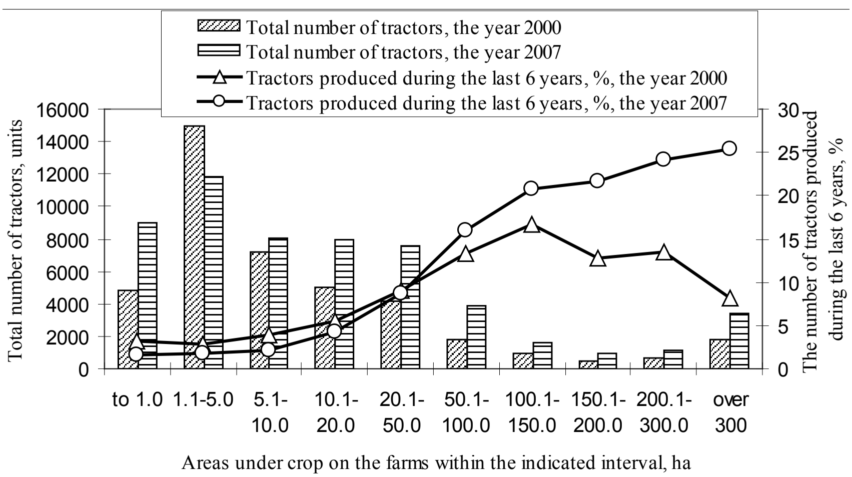

Fig. 2. The total number and percentage of tractors produced during the last 6 years on the farms with different areas under crop (the years 2000 and 2007).

small farms (except the farms with areas less than 1 ha and specialised in providing services) but increasing on the large farms with areas over 100 ha. It is typical that the number of tractors, which undergo technical checkups, is diminishing every year – in 2008 it made only 36%. This indicates aging of the tractor fleet, as well as advances an issue about the expediency of technical checkups. A conclusion can be drawn that, due to the concentration of production, the purchase of more powerful tractors will grow and the average specific energy supply in kW ha^{-1} of the farms will diminish. At the expense of the liquidated worn-out tractors, the total number of tractors will decrease, and after 5-8 years there might be 32-36 thousand operable tractors in the country (Asejeva et al., 2008).

A mathematical model has been worked out for the minimisation of the variable costs of the mechanised field operations using the MS Excel programme and handling it as an optimisation task of non-linear programming (Kopiks, Viesturs, 2008). By using this model it is possible to adjust to the area under crop of any individual agricultural farm a definite agrotechnical term for the execution of the work, the required working width of the aggregate, and the capacity of the tractor at the allowed loading, thereby ensuring minimal fuel consumption and minimal costs of the performed work. The developed model supplements the simulation methodology of the process management with a variant that can be used in agricultural production.

By developing the evaluation methods for technologies in 2009 and the subsequent years, it is necessary to start technological modernisation and assessment of the economic usefulness of the farms which are interested in the on-line mode ensuring calculations for concrete conditions of farming.

Investigations of the ecological aspects in the mechanisation of crop farming

One of the important tasks set for most of the many-sided investigations carried out by the Institute was the improvement of the ecological indices. In the perspective it is planned to aim this direction also at the improvement of the technical supply of the evolving biological crop farming (Vilde, 1995, 1999b).

Investigations have been conducted also into the aspects of ecological safety, mainly the issues of the working precision, uniformity, and longevity of the operating parts of field sprayers and distributors of mineral fertilisers. Several articles and a brochure (Vilde, 2002) have been prepared, as well as a summary (Pinnis, 2003) containing a motivation for the necessity to carry out periodic testing of the quality of field sprayers.

A research was conducted on the technology of ecological haylage preparation in rolls sealed in an elastic film, developed in the early 1990s. Recommendations were made on the improvement of this technology and application of the general-purpose machines existing on the farms for this purpose. These recommendations helped expand essentially the extent of the use of this progressive technology in Latvia. Together with the scientists from the Warsaw Agrarian University investigations were conducted seeking possibilities to reduce the prime cost of the haylage rolls sealed in an elastic film as well as to minimise the adverse impact on ecology. It is intended to continue the international cooperation started in this direction with an aim to solve together the scientific problems which are topical for those countries. A book was published under the title "Technologies and machines for the preparation of grass forage" that was intended for practitioners and students. Investigations were made in comparative economic efficiency of various technological variants of forage preparation, an algorithm was made for the calculation of economic indices on the computer, as well as studies on the improvement of the technology and technical means for the cultivation of the early sorts of maize to be processed into high-quality silage, etc.

There are studies in drying and storage of grain harvested by a combine in ventilated bins using the heat of the sun or a firewood furnace as the most acceptable solution for small and medium-sized peasant farms (Cesnieks et al., 2002). Implementing the market-oriented research project in cooperation with the Institute of Solid State Physics of the University of Latvia, computerised equipment has been created for constant control (monitoring) of the drying process. This enabled production of the highest quality food grain receiving twice as high remuneration for them than for the unconditioned grain from the combine harvester.

Research in the ecological safety of technologies and machines, which are adapted for biological farming, will be continued.

Rational use of the renewable energy

The aim of the research – to decrease the consumption of fossil energy resources in the stationary processes of agricultural production by using in a more rational way the power of electric heaters, regaining the heat flowing away through the ventilation systems, and acquiring the sources of alternative energy, including the heat of solar radiation, the heat of the outdoor air and biofuel.

Heat retrieval in the ventilation processes

High losses of heat arise in the ventilation process, which has a negative impact on the heat balance in cattle-sheds in the heating season. This is confirmed by the calculations of the heat balance in piggeries at various heat resistances and for all the main age groups of pigs (Ilsters et al., 2006). In the analysis of the heat balance of the piggery, the temperature T_d, at which it is necessary to start heating of the fresh air, can be determined in graphic way or calculated according to the following expression:

$$T_d = T_c - 2T_c \cdot (Q_{com} - Q_{sp}) \cdot (Q_{com} - Q_{sp} + Q_d)^{-1}, \tag{1}$$

where T_c – the air temperature in the piggery, ºC;

Q_{com} – the total power of the sources of heat, W;

Q_d – the losses of heat at a negative outdoor air temperature, the numerical value of which is equal to the air temperature in the piggery, ºC.

In order to decrease the need for energy resources for heating the air in the heating period, one of the solutions is heating the fresh cold air by means of a heat exchanger using the polluted air flowing from the piggery as a source of heat.

Analysis and laboratory experiments of various materials in order to clear up their suitability for making heat exchangers, showed that at the 60-80% moisture of air the intensity of the heat transfer through the wall made from hollow structure polyvinylchloride boards (PVC) sufficient heat transfer was possible. A technical design of such a heat exchanger was drawn up (Patent LV 13559 B). An experimental specimen of the heat exchanger and a factory-made heat exchanger WVT-120K (Germany) with surface areas 100 and 50 m^2, respectively, were tested under production conditions in a piggery with 500 fattening pigs. Figure 3 shows temperature variations of the flows of air and the capacity of the heat exchanger when the outdoor air temperature falls during the night

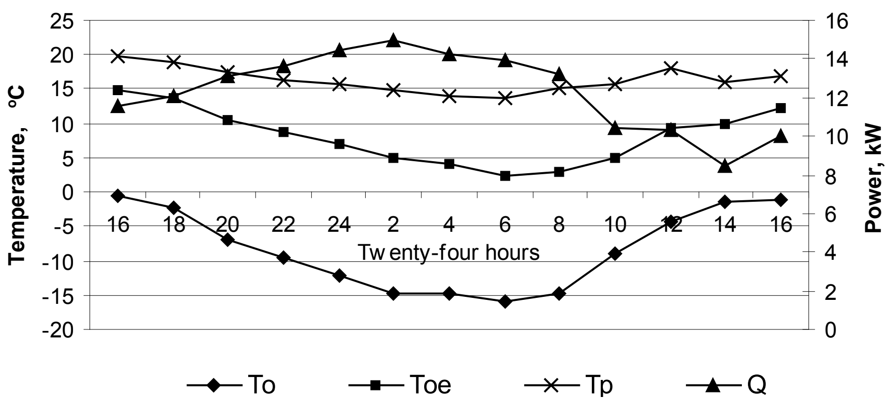

Fig. 3. The temperature variations of the air flows and the efficiency of the heat exchanger when the temperature of the outdoor air falls during the night hours: To – the outside air temperature, ºC; Toe – the inflow air ending temperature, ºC; Tp – the temperature in the pigsty, ºC; Q – the power of the recovered heat energy, kW.

hours. Depending on the outdoor air temperature, it would be purposeful to use 45-75% of the retrieved heat (Илстерс и др., 2007).

In the warm winters of the recent years when the mean temperature of 3 months was positive there was no heat deficit in the piggeries. Under such weather conditions, the heat retrieved by means of a heat exchanger with a temperature of 15 °C cannot be used in a direct way. At the same time, the energy resources are consumed to produce heat with a higher temperature.

In order to use the heat retrieved by heat exchangers more efficiently, a project is worked out about directing the heat warmed up in the heat exchanger to the evaporator of the outdoor air heat pump thus achieving a higher transformation coefficient of the heat pump (coefficient of performance – COP), which is essential when the heat pump is operated in the winter period (Patent LV 13726 B). An outdoor air heat pump Octopus IS 81 (Sweden) has been purchased and installed in a piggery with 96 farrowing pens to test the efficiency of the project under the conditions of production. Its rated power of heat is 17 kW at the driving power of the compressor 5 kW. The purchase of the heat pump and its operation, which started under production conditions in the piggery, is a foundation for further investigations into the acquisition of the sources of alternative energy for the needs of agricultural production.

The use of the energy of solar radiation

The common (classical) flat plate collectors of solar energy are built in such a way that the sun heats only one side of the collector absorber which faces the sun. The other side is covered with the heat insulation. In the period of several years, collectors have been created that follow the direction of the sun (Patents LV13371; 13516; 13549; 13696; 13711; 13712; 13713), including such in which, using mirrors, both sides of the flat plate collector absorber are radiated.

To specify the data about what part of the solar energy is used by the stationary collector and the collector which follows the direction of the sun, a mobile recording device MD-4 was worked out and made for the measurement of meteorological parameters. It contains two piranometer thermal batteries, one of which is placed in a stationary position but the other follows the sun so that the surface receiving its rays of heat is always directed perpendicularly to direction of the falling rays of the sun. Using this device for three years (2005-2007), from the 1st of March till the 1st of November, the air temperature, relative moisture and the power of the solar radiation were recorded at every 12 minute intervals (Fig. 4). The three-year average indices are the following:

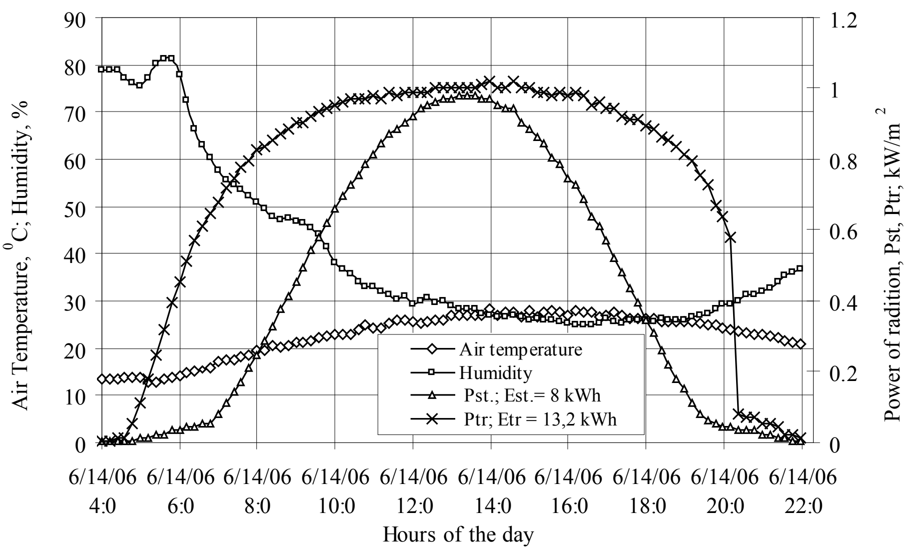

Fig. 4. The air temperature, humidity, and the power of solar radiation.

the average daily temperature – 13.7 ºC; the amount of the solar radiation energy daily received by the stationary to the south oriented surface – 1096 kWh m^{-2}; and the amount of the solar radiation energy daily received by the surface following the sun – 1538 kWh m^{-2}.

The results show that during the data recording season, the surface, which followed the sun, has received on average 1.4, but in the middle of summer – 1.65 times more thermal energy than the stationary southward oriented surface.

In contrast to the stationary collectors, the collectors which follow the sun have several advantages (Ziemelis, Kancevica, 2005). In the middle of summer, at about 6 o'clock in the morning, the rotary collector has already received 50% of the maximum radiation power. During the day, the collector, which follows the sun, uses the energy of solar radiation completely. Considering these positive features, as perspective can be regarded the work at the improvement of the design of the collector, which follows the sun, with an aim to create a compact individual water heater using solar radiation as a source of energy.

The use of biomass

The use of energetic wood is perspective. The main crops are osiers, willows, aspen trees, poplars, and reeds. The wood biomass is formed in a cycle of 2-4 years. The average growth of the biomass dry matter is about 10 t ha^{-1} a year. Also the dry matter of grasses can reach even 10 t ha^{-1} a year. According to the results of research conducted at the Institute and the calculations, from 1 t of the green mass it is possible to obtain approximately 200 kg of granules, 15-20 m^3 of biogas, and 0.6-0.7 m^3 of liquid organic fertilisers. Consequently, from 1 ha of the grassland area it is possible to obtain 40.3 MWh of energy carriers – granules and biogas (36 MWh and 4.3 MWh, respectively). Prospects are estimated for the use of solar radiation in the drying process of granules. An industrially built hothouse with a two-fold film cover should be regarded as economically most profitable. Such a hothouse can accommodate equipment for the production of granules (Зиемелис и др., 2008).

Direction of the further work

The research work is in progress at the combined supply of heat using the sources of renewable energy: biomass, the energy of the sun and the wind, heat pumps, heat exchangers, heat accumulation, and so on.

Conclusions

The strategic development plan of the Research Institute of Agricultural Machinery sets the directions for its further activity: studies in the technologies and equipment of competitive renewable energy resources replacing the fossil fuel; improvement of field crop growing technologies that are efficient in production, ecologically safe and safe resources for biological and conventional agriculture with the use of GPS technologies; participation in strengthening the intellectual potential of the nation by evolving engineering sciences and taking part in the implementation of national and international projects. As a result of the realisation of the strategic plan, the Institute is to be transformed into an internationally acknowledged research centre in the directions mentioned above.

References

1. Asejeva, A., Kopiks, N., Viesturs, D. (2003) The development trends of cereal growing technologies in Latvia. *Proceedings of the International Scientific Conference "Economic Science for Rural Development".* Jelgava, 170-174.
2. Asejeva, A., Kopiks, N., Viesturs, D. (2008) Application of economic-mathematical simulation for the choice of the technical support of technologies of agricultural crops. *Proceedings of the International Scientific Conference "Economic Science for Rural Development"*, No. 16, 15-19.
3. Cesnieks, S., Cesnieks, A., Vilde, A. (2002) Grain drying and storage on farms. *International Scientific Conference "Safe and Economical Agricultural Technologies". Proceedings of the conference held in Priekuļi, Latvia, 25-26 July 2002.* Priekuļi, 118-120.

4. Ilsters, A., Jesko, Z., Ziemelis, E. (2006) Efficiency of the use of heat exchanger in the pigsty. *7th International Scientific Conference: Engineering for Rural Development.* Jelgava, 45-50.
5. Ilsters, A., Ziemelis, I. (2005) Development of heat exchangers for use in pigsty. *The 4th research and development conference of central and eastern European institutes of agricultural engineering (CEE Ag Eng).* Proceedings. Moscow, VIESH, 128-133.
6. Ivanovs, S., Lazovska, V. (2007) *Linu novākšanas un pirmapstrādes sagatavošanas tehnoloģijas un mašīnas.* LLU LTZI, Ulbroka, 117 lpp.
7. Ivanovs, S., Viesturs, D., Bergs, J. (2007) Economic aspects of growing cultivated cranberries. *Journal of research and applications in agricultural engineering,* Vol. 52 (3). Poznan, PIMR, 67-69.
8. Kopiks, N., Viesturs, D. (2002) Оценка рентабельности производственных технологий для сельскохозяйственных культур. *International Scientific Conference "Safe and Economical Agricultural Technologies".* Proceedings. Priekuļi, 58-61.
9. Kopiks, N., Viesturs, D. (2008) The choice of optimum ploughing and sowing aggregate for different amounts of work. *Proceedings of the 7th International Scientific conference "Engineering for Rural Development".* Jelgava, 118-123.
10. Kopiks, N., Viesturs, D., Balode, R. (1998) Laukkopības kultūru ražošanas tehnoloģiju analīzes metode. *LLU raksti,* Nr. 16 (293), B – tehniskās zinātnes, 129-135.
11. Pinnis, U. (2003) *Minerālmēslu izkliedētāji*. Ulbroka, 24 lpp.
12. Rucins, A., Vilde, A. (2006) Impact of the plough body parameters on the soil tillage efficiency*. Proceedings of 5th International Scientific Conference "Engineering for Rural Development", Latvia University of Agriculture, Faculty of Engineering.* Jelgava, 42-47.
13. Vilde, A. (1995) Kraftstofbedarf für Pflanzenproduktion. *Lauksaimniecības mehanizācija,* 1, Rīga, 283-287.
14. Vilde, A. (1999a) Dynamics of the soil tillage machine operating parts and their elements. *Proceedings of Latvia University of Agriculture,* Vol. 1 (295), 36-44.
15. Vilde, A. (1999b) Energetic and economic estimation of soil tillage systems. *Folia Universitatis Agriculturae Stetinensis 195,* Agricultura 74. Szcecin, 213-222.
16. Vilde, A. (2002) Development of technologies and machinery for production of sugar beet in Latvia. *International Scientific Conference "Safe and Economical Agricultural Technologies". Proceedings of the conference held in Priekuļi, Latvia, 25-26 July 2002.* Priekuļi, 62-66.
17. Vilde, A. (2003) Impact of soil moisture and composition on its properties and energy consumption of tillage. *International Scientific Conference "Motor Vehicle, Logistics, Alternative Fuels." Proceedings, April 24, 2003.* Jelgava, Latvia, 137-141.
18. Vilde, A., Cesnieks, A. (2005) Modelling plant spacing and yields of crops by sowing seeds at exact intervals. *Simulation in Wider Europe. 19th European Conference on modelling and Simulation ECMS, June 1-4, 2005.* Riga, 420-423.
19. Vilde, A., Laže, J., Briedis, P., Strautnieks, A., Tūls, V. (1996) Cukurbiešu ražošanas un pārstrādes attīstības iespējas Latvijā. *Lauksaimniecības nozaru attīstības iespējas.* Publikācijas, 8. krājums. Latvijas Valsts Agrārās ekonomikas institūts, Rīga, 40-50.
20. Vilde, A., Ruciņš, Ā., Viesturs, D. (2008) *Globālās pozicionēšanas tehnoloģijas lauksaimniecībā.* Jelgava, 47 lpp.
21. Ziemelis, I., Kancevica, L. (2005) Rational water heating by solar energy. *Proceedings of the second international scientific conference "Rural Development 2005".* VAGOS, Volume 2, Book 2. Akademija, Kaunas region, Lithuania, 51-53.
22. Зиемелис, Э. Ф., Упитис, А. А., Кристапсонс, М. Ж. (2008) Возобновляемые ресурсы в системе энергоснабжения сельского региона. *Труды 6-ой международной научно-технической конференции "Энергообеспечение и энергосбережение в сельском хозяйстве",* Часть 4. Москва, 57-62.
23. Илстерс, А.Т., Кристапсонс, М.Ж., Шкеле, А.Э. (2007) Экономия энергоресурсов с применением утилизаторов тепла. *5-я международная научно-практическая конференция "Экология и сельскохозяйственная техника", Санкт-Петербург, 15-16 мая*, 219-225.
24. Лачгалвис, Э., Эпро, В. (2005) Изыскание новых методов очистки ягод от примесей. *4th International Scientific Conference "Agricultural Engineering Problems".* Proceedings. Jelgava, 243-246.