through the Internet. Public service is presented in not electronic form. It is relevant, when Internet presents electronic forms and user can fill out it and to receive an analogue of writed document with signature;

- **4 – collaboration level.** Electronic system of a service through Internet acting through the day, public Internet page, administering by service provider or by responsible administrative layer makes possibility for user fully participate in a process through Internet. User makes request through the Internet and receives electronic public service. User certifies its identity in information system by using secure electronic signature or by certified qualified certificate, and when it can receive public service.

Lithuanian Republic Parliament on 25 May, 2006 enacts a law of Lithuanian Republic information society service, which acts from the 1 July, 2006. The main aim of this law – to describe and to fix the law regulation basics of society rapports, related with information society service. Enacted law makes favourable conditions for developing of service and electronic business based on modern technologies. The service of information society includes various economical activity, which is performed in connection with electronic communication network, especially product selling through the Internet. For this category depends the service without payments, for example, information presenting through the Internet service, means for information search, and service, which includes information translation by communication network, allotment of access for communication or the publishing of information of service receiver through the Internet. Hereby, the aim of a plan of electronic government concept realization means – to transfer gradually to electronic space important for people and business subjects service – public purchasing, dispensation of certificaties of birth, dearth, marriage and divorce, and other certificate and licences, declaration of living place, organizing the competitions for state job, and various public service, related with education, health care and others.

Users in Lithuania are most widely using the public service of a first level. The most popular activity through the Internet in the 1st quarter of 2007 year was the information search in infopages and databases (47.3%), electronic relation usage (40.8%), reading newspapers and magazines through Internet or its downloading (31.7%), playing the games, downloading of a games or music records (26.9%) etc. The assortment of Internet service between young people groups is slowly expanding – the new services appears, such as participating in video conferencies, searching information about products and service, downloading of computers software etc.

In the Internet portals of government institutions presented information can be accessed by a large part of users. In a 1st half year of 2007 there was send about 20% requests of 15 – 74 years old people to public administrative institutions through the Internet (in 2006 year – 14%). Their visit aims are various – to get common information about institution, about its activity areas (68%), to search information about public service of institution and its order (37%), to search interseted law and administrative information (36%) etc. At present time the most popular are public service of a second and third level – electronically filled forms and other information for electrnic service receiving (28%), downloading of the forms for receiving the service of institution (25%) etc. Internet users cannot use the service of the fourth maturity level, because its only a little part of such service transfered to Internet (in separate state institutions only about 1%).

The difficulties of transfering of public service, especially to the higher maturity level and not enough interest of the users depends on a lack of information and advertisement about public electronic service, on the shortage of public service compatiblity between separate institutions of public sector, on a lack of the common plan for creating public service and possibility to use qualified electronic signature, and the questions of a law basis for transfering of service to electronic space etc.

The best developed are such public service as people and legal persons payment declaration, the payments of social insurance, the presentation of customs declarations and statistical data, employment service, public libraries service etc. The electronic service of incomes payment in a 1st half of 2007 year there was used by 44% of a visitors of public administrative institutions, the service of job search – 27%, the service of studying – 19%, service of law information search – 18% and the transport service – 18%. Through the last four years rapidly increses usage Internet banking service between 16 – 74 years old people (3 times), information related with health care (3.8 times), using information from state institutions webpages (about 2 times) (Figure 2).

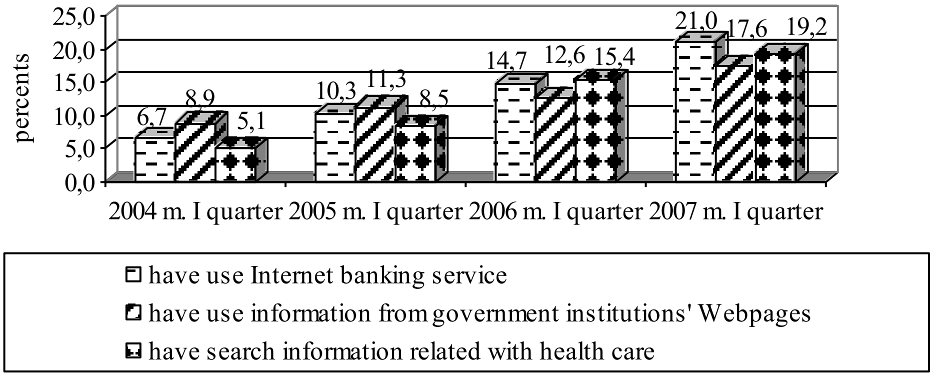

Figure. 2. Rendering of electronic public service through the Internet

Information technologies are related with development of electronic commercial activity, i.e. electronic shops and product purchasing through the Internet. However, users have not enough information about electronic shops in Lithuania, though more often information about in traditional shops purchased products is searched. There was established by research, that a little more than 3% of examined people have purchase in Lithuanian Internet shops, and permanently it have did a little more than 1%, however, from the permanent Internet visitors through the last six months of 2007 year 32% have made the purchase through the Internet once.

The development of telecommunication infrastructure and public service, without stimulating people need to use it, did not give requested results. So begins the company „I have begin" at the LR Government committee of Information society development. Its stimulates people, which are not use information technologies, to use computers and Internet, and those people, which are used information technologies – to inform about the possibilities of information society. About two third parts Lithuanian people are not enough informed about the benefits of information technologies, so they are confident, that they don‘t need it. The knowledge of rural areas people is lack of Internet usage for various payments, declarations of living place or purchasing the products. Internet is not used to access public administrative institution even by people with high knowledge. The main criteria for investments for computerizing of household with a lower incomes should be the benefits of computers and Internet, and payment privelegies for hardware purchasing should made their decission easier. Many things should be determined by rural area family consciousness, i.e. intention to connect to the information society. The amount of rural communities with possibilities of computers‘ usage have quickly increase, so the possibilities for decreasing of digital disjuncture in rural areas in a several years by using local initiatives and the resources of Europian Union are increasing.

Conclusions

1. It is observable quick increase of households with Internet access points at home. However, remains marked differencies in information technologies usage between city and rural areas households and differencies according to the age groups. The computers‘ costs and people incomes difference, the level of telecommunication infrastructure, not enough motivation of information technologies usage necessity and understanding of rendering benefit has influence on people decission.

2. In rural areas Internet access point is established at every fourth household, so Internet most often is used in schools, libraries or at public Internet access points. Rural areas people connecting to information society should be improved in this year. In all Lithuania should be established 1000 Internet centres, and every rural area people should find the Internet access point in a distance of 8 km. Besides, Internet point should be established in rural regional centres. From those points high-speed Internet should be rendered for people and various institutions. Further processing of company „I have begin" should be continued, and its stimulates of computers‘ and Internet usage.

3. People most widely are used the public service of informative character. The most popular activity through the Internet remains information searching in infopages and in databases, usage of electronic communication, reading of newspapares and magazines through the Internet and its downloading, playing the games, downloading of the games or music records.

4. The request of people and business to use information technologies is closely related with the level of transfering of public service to electronic space. At present time between visitors of institutions‘ webpages most popular are the public service of the second and the third level (rendering forms with electronic filling etc). The best developed electronic public service is related with people and legal persons‘ payment declaration, social insurance payments, customs declarations and statistical data presenting, employment service, public libraries service etc.

5. The main criteria for investments for household computerizing in city and rural areas for people with a low incomes should be the rendered benefit of computer and Internet, and payment privelegies for hardware purchasing should made their decission easier. Many facts should be determined by rural family consciousness, i.e. intention to become a full right member of information society.

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ICT IN AGRICULTURE, FOOD TECHNOLOGY AND FORESTRY

METABOLIC ACTIVITY ASSESSMENT SPECIALISED MICROCLIMATE CHAMBER WITH CONTROL SYSTEM

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Abstract

Metabolic activity is important parameter assessing intensity and dynamics of biological processes. Measurement of metabolic activity can serve as an indicator of normal process as well as an alarm signal if processes go unexpected or wrong way. Metabolic rate can be used as early diagnosis before unwanted process becomes visible and clear.

Authors of this article have developed a room-size microclimate chamber (house) with possibilities to determine metabolic activity of a bioprocess measuring its impact on microclimate parameters. The construction of the chamber and its control have to allow accurate assessment of environmental impact on the system as well as control impact of microclimate control to be able to calculate the metabolic activity.

Im = Ie – Ic, where Im - impact of metabolism, Ie - impact of environment and Ic impact of microclimate control system. This equation is based on balance equation of a steady state of the microclimate where control system compensates impacts of metabolism and environment to keep the microclimate stable.

Microclimate chamber is built as a sandwich panel construction and can be installed indoors or outdoors. Control parameter is temperature with possibility to develop additionally the system for humidity and gas composition control. The control system is developed using programmable logic controller (PLC) that can execute complicated control algorithms allowing registering all activities of the control system. The program of PLC is created using 'cyclogram – algorithm – state machine' approach and ladder logic notation. Algorithm of temperature control, state diagram and summary of transition guards of the state diagram are demonstrated.

Setup of metabolic rate measurement in case of wintering honey bees is demonstrated.

Keywords: *microclimate, metabolism, control algorithm.*

Introduction

A process where metabolism of living organisms is involved is understood as a bioprocess in this article. Metabolism (gr. metabole – exchange) is a set of chemical reactions that occur in living organisms in order to maintain life. These processes allow organisms to grow and reproduce, maintain their structures, and respond to their environments. Metabolic activity is important parameter assessing intensity and dynamics of biological processes (Klipp et.al.2006). Measurements of metabolic activity can serve as indicator of normal process as well as alarm signal if processes go unexpected or wrong way. The metabolic rate can be used as early diagnosis before unwanted process becomes visible and clear.

Unfortunately in many cases it is hard to measure metabolism directly without interrupting normal development of biological process (Stalidzans et.al. 2000; Klipp et.al.2006). Interruption of normal circumstances can change metabolic rate of the process and measurements indicate wrong values.

Experimental work on the biological process often requires stationary microclimate with controlled parameters of experimental environment. The microclimate control system has to compensate the deviations that are caused by environment where the experimental room is located as well as the metabolic activity of the observed bioprocess.

Authors of this article suggest developing a specific experimental environment: a room-size microclimate chamber (house) with possibilities to measure metabolic activity of a bioprocess by determining its impact on microclimate parameters. The construction of chamber and its control have to allow accurate assessment of environmental impact on the system as well as control impact of microclimate control to be able to calculate the metabolic activity. Cases where the target microclimate parameters values are constant are discussed in this article.

Materials and Methods

In a microclimate chamber with controlled microclimate metabolic rate can be determined using balance approach: constant microclimate parameters can be reached if microclimate control system impact (Ic) compensates impact of metabolism (Im) in the chamber and impact of environment (Ie) where chamber is located (Figure 1):

$$Ic = Im + Ie \qquad (1)$$

Balance equation can be transformed to calculate the impact of metabolic process:

$$Im = Ie - Ic \qquad (2)$$

Balance equations of impact can be calculated for each microclimate parameter that is changed by metabolic activity:

$$Im_k = Ie_k - Ic_k,\ \ k = 1..n, \qquad (3)$$

where k – microclimate parameter changed by metabolic activity.

Thus metabolic activity measurement can be performed choosing the most convenient or accessible microclimate parameter. Measurements of several microclimate parameters give better confidence about result.

Described approach demands exact calculation of the 1) impact of control system on the microclimate (Ic) and 2) environmental impact (Ie) on the chamber.

Control system has to be executed with possibility to forecast and register any microclimate change related activity (electric heat, humidity, gas injection and so on). That demands more complicated control algorithm and equipment than in case of microclimate control without necessary calculating of the impact.

The microclimate chamber can be assembled indoors as well as outdoors. Assessment of impact of the environment can be a very complicated task if the microclimate chamber is outdoors and exposed to wind, rain, and (or) sun. In such cases impact on parameters like temperature and humidity has to be calculated assessing impact on the microclimate in the chamber. Impact curves can be found during experiments without metabolic processes in the chamber. Then Im = 0 and control system impact is equal to the environment impact acting in opposite directions (Ie = -Ic).

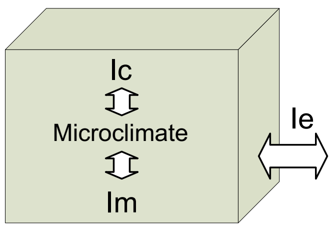

Figure 1. Interactions of metabolic, control and environmental impacts.

The control system is developed using programmable logic controller (PLC) that can execute complicated control algorithms allowing registering all control system activities. The program of PLC is created using ‘cyclogram – algorithm – state machine’ approach and ladder logic notation (Berger, 2000).

Results and Discussions

Execution of the microclimate chamber

The microclimate chamber is executed as a building with effective floor surface 25 m^2 (6,25m x 4,00m) and height in along the longest side of the building 2,4 m and height at the ridge 3,00 m. The building has a metal frame and white sandwich panel walls with thickness 80 mm (U=0,428W/m²K), ceiling with thickness 100 mm (U=0,347W/m²K) and floor with thickness 100 mm (U=0,347W/m²K). On one side of the wintering building there is a metal door 1,00m x 2,00m without additional insulation.

The building is equipped as follows (Figure 2):

1) The control of the microclimate of the room has been performed using Siemens S7-200 PLC.
2) The inside temperature (T_i) and outside temperature (T_o) data is collected using 1-Wire temperature 8 sensor's network (E_i1-8 and E_o1-8 respectively). DS1820's (or DS1920's with different physical connection) sensors made by Dallas Semiconductor (http://www.maxim-ic.com/products/ibutton/products/ibuttons.cfm#sensor) are used. The temperature sensor's network is connected to controller S7-200 via TEMP08 1-Wire to RS232 interface and RS232/RS485 physical interface converter.
3) Constantly working air recirculation fan (F_{rec}1) with capacity 1800 m^3 h^{-1} (at 30 Pa) and electric capacity 130 W homogenising the air and its temperature inside building.
4) Cooling ventilator system (F_a1) consists of suction fan with frequency converter controlled capacity (max. capacity 2000 m^3 h^{-1}) and electric capacity of 75W.
5) Fresh air fan (F_{ox}1) with air exchange capacity 100 m^3 h^{-1} and electric capacity 13 W is working constantly to ensure fresh air.
6) Electrical duct heater (EK1) with maximal capacity 3000 W is controlled using pulse width modulated (PWM) signal.
7) Electrical cooler (EK2) with cooling capacity 500 W is controlled using pulse width modulated (PWM) signal.
8) The building is equipped with a light traps to ensure darkness in the building in case of necessity.
9) Air pressure switches (SW_{rec}1 and SW_{ox}1) measure air pressure difference before and after the fans F_{rec}1 and F_{ox}1 indicate if fans are operating.

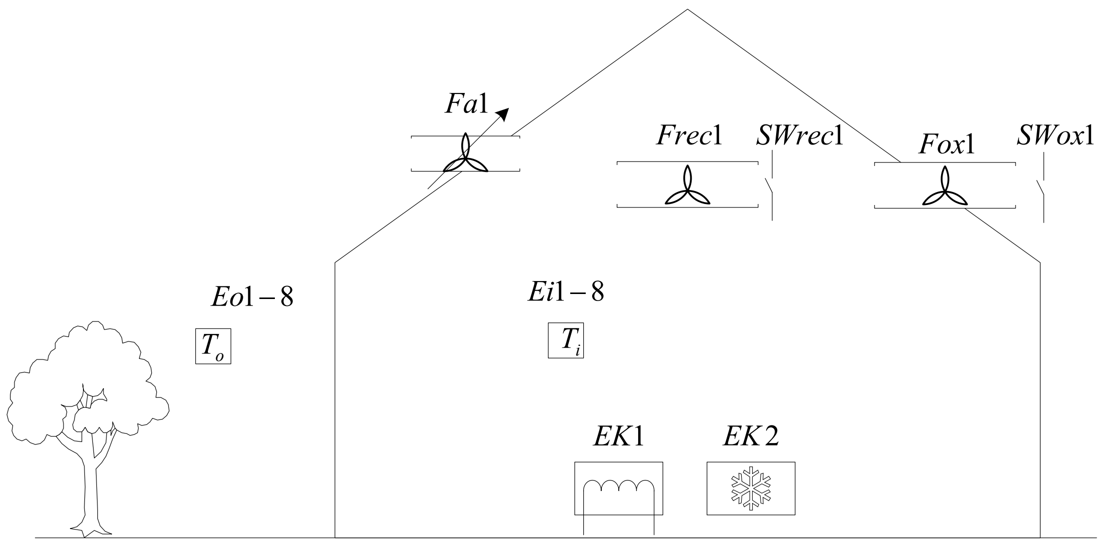

Figure 2. Main components of the system

Control algorithm and control system

A control criterion of the microclimate chamber is the chamber target temperature (T_t). Various curves of T_t dynamics can be executed. Usually constant temperature is required. Humidity and gas exchange is maintained close to the environmental values due to constantly working $F_{ox}1$. Control of humidity and gas content on a defined level can be added to the control system if necessary. Electrical heater EK1 is used for heating. Cooling can be executed by cooling ventilator F_a1 with adjustable speed if outside temperature T_o is lower than target temperature T_t. The cooler EK2 is used if $T_o > T_t$. The control system works to reach the nearest possible temperature to the target one if the capacity of control means is not sufficient. Summary of system variables in case of T_t=const=+6ºC±2 is demonstrated in Table 1. The algorithm of temperature control program is demonstrated in Figure 3. State diagram (Figure 4) and summary of transition guards of the state diagram (table 2) demonstrate execution of the control algorithm.

Table 1.

Summary of system variables and constants for T_t=const=+6ºC±2.

Symbol	Name	Symbol (program)	Data type	Values
$F_{ox}1$	Oxygen fan	Y_Fox1	Bool	1-On,0-Off
$F_{rec}1$	Recirculation fan	Y_Frec1	Bool	1-On,0-Off
F_a1	Adjustable fan	R_Fa1_speed	Byte	Min/ Max
$SW_{ox}1$	Air pressure transducer of $F_{ox}1$	X_Fox1	Bool	1-IsOn,0-IsOff
$SW_{rec}1$	Air pressure transducer of $F_{rec}1$	X_Frec1	Bool	1-IsOn,0-IsOff
EK1	Heater	R_EK1, Y_EK1	Int, Bool	Min/Max (PWM)
EK2	Cooler	R_EK2, Y_EK2	Int, Bool	Min/Max (PWM)
E_o1-8	Outside temperature sensor	R_Eo1..8	Real	-85..125^{0}C
E_i1-8	Inside temperature sensor	R_Ei1..8	Real	-85..125^{0}C
SensOK	Sensor reading flag	X_SensOK	Bool	1 – reading OK, 0 – reading failure
T_t	Target inside temperature (const)	R_Tt	Real	Const = 6^{0}C
T_o	Current outside temperature	R_To	Real	-85..125^{0}C
T_i	Current inside temperature	R_Ti	Real	-85..125^{0}C
T_{o_hConst}	High T_o (const)	R_To_high	Real	Const = T_t = 6^{0}C (e)
T_{o_lConst}	Low T_o (const)	R_To_low	Real	Const = $T_{high} - P_s$/CHT = -4^{0}C
T_{o_high}	$T_o > T_{o\_high}$	X_To_high	Bool	1 – true, 0 – false
T_{o_low}	$T_o < T_{o\_low}$	X_ To_low	Bool	1 – true, 0 – false
T_{i_hConst}	High T_i (const)	R_Ti_high	Real	Const = 8^{0}C
T_{i_lConst}	Low T_i (const)	R_Ti_low	Real	Const = 4^{0}C
T_{i_high}	$T_i > T_{i\_high}$	X_Ti_high	Bool	1 – true, 0 – false
T_{i_low}	$T_i < T_{i\_low}$	X_ Ti_low	Bool	1 – true, 0 – false
t_T	T_i alarm timer	X_tT	Timer	10min
t_{Tpool}	Temperature pooling interval	X_tPool	Timer	10s
START	System START signal	X_ START	Bool	1-START
STOP	System STOP signal	X_STOP	Bool	1-STOP
Operate	Flag to memory START and STOP (operating state ON/OFF)	X_Operate		1-On,0-Off
VD_{on}	Normal operation output signal	Y_VDon	Bool	1-On,0-Off
VD_{ox}	$F_{ox}1$ failure output signal	Y_VDox	Bool	1-On,0-Off
VD_{rec}	$F_{rec}1$ failure output signal	Y_VDrec	Bool	1-On,0-Off
VD_{thi}	$T_i > T_t$ output signal	Y_VDthi	Bool	1-On,0-Off
VD_{tlo}	$T_i < T_t$ output signal	Y_VDtlo	Bool	1-On,0-Off
VD_{sf}	Sensor reading failure output signal	Y_VDsf	Bool	1-On,0-Off

Assessment of control system impact and impact of the environment

Possibility to record all the parameters of microclimate and environment as well as activities of the control system allows calculating of Ie and Ic using mathematical models of physical processes taking place.

In the case of complicated microclimate chamber interaction with environment a separate experiment without metabolic processes can be used to develop a mathematical model of environmental impact. During experiment with metabolism environmental impact can be calculated from the model.

Calculations become challenging if control system uses environment to maintain constant microclimate. Then environment acts as a separate impact factor and as a control instrument at the same time. That is the case if outside air is used to cool the microclimate chamber. Air temperature then has to be calculated as cooling media (within control system) and as environmental impact when outside air is cooling the chamber through the walls.

Another possibility is to isolate the chamber fully from environment ensuring constant environment around the chamber, but this approach usually is more expensive.

Accuracy problems occur if impact of metabolism is much smaller than the one of control system and environment.

Experiment setup for assessment of bee colony metabolic rate at constant temperature

Setup of application in the case of microclimate system for assessment of honeybee metabolic activity will be demonstrated. The temperature fluctuations affected by honeybee's warming power emitted and compensated by the microclimate control system is the parameter used in order to estimate the metabolic activity of honeybees. The microclimate chamber (25 m^2 floor surface) described above can contain up to 100 bee colonies that have passive period during winter (they do not fly) and therefore can be kept in closed dark room. Indoor wintering of bee colonies is quite popular wintering method especially in countries with colder climate (Furgala and McCutchenon 1992). Usually the temperature control in typical wintering buildings is controlled without possibility to assess the energy balance and impact of environment that would be necessary to determine the metabolic rate of bee colony.

Besides academic interest about energy consumption of bee colonies during winter there is also practical aspect: metabolic rate of bee colonies is important parameter indicating the current stage of bee colonies. In the winter during passive mode the warm power of 100 colonies is within 160-340 W, during limited brood rearing it is 410-650 W and when brood rearing is started intensively warm power would be 750-1020 W (Krauze et.al. 2003). It is important to be sure that intensive brood rearing does not take place in the microclimate chamber. After detecting rapid increase (2-3 fold) of metabolic activity the chamber temperature has to be lowered to

inhibit brood rearing or bees have to be placed outdoors if that is the right period in spring for intensive brood rearing. Using in previous chapter described system temperature control takes place accordingly the Figure 5.

The ability to measure power spent by the control system in order to keep the T_t and to take into account environmental impact allows assessing metabolic rate of wintered bee colonies. Scientific investigations of bee colony metabolic activity require high accuracy of the control system while in case of practical beekeeping it is easy to register rapid increase of metabolic activity within some days (Stalidzans et.al. 2000; Krauze et.al. 2003) concluding, that intensive brood rearing has started.

Generally it would be more advantageous to assess metabolic activity using microclimate parameters that are influenced by environment in easy assessable way. For instance measuring of concentrations of metabolic gases in case of honeybee metabolism (carbon dioxide and oxygen) knowing air exchange rate with environment can eliminate impact of outside air as concentration of both gases in the air is constant with a very high accuracy and without fluctuations.

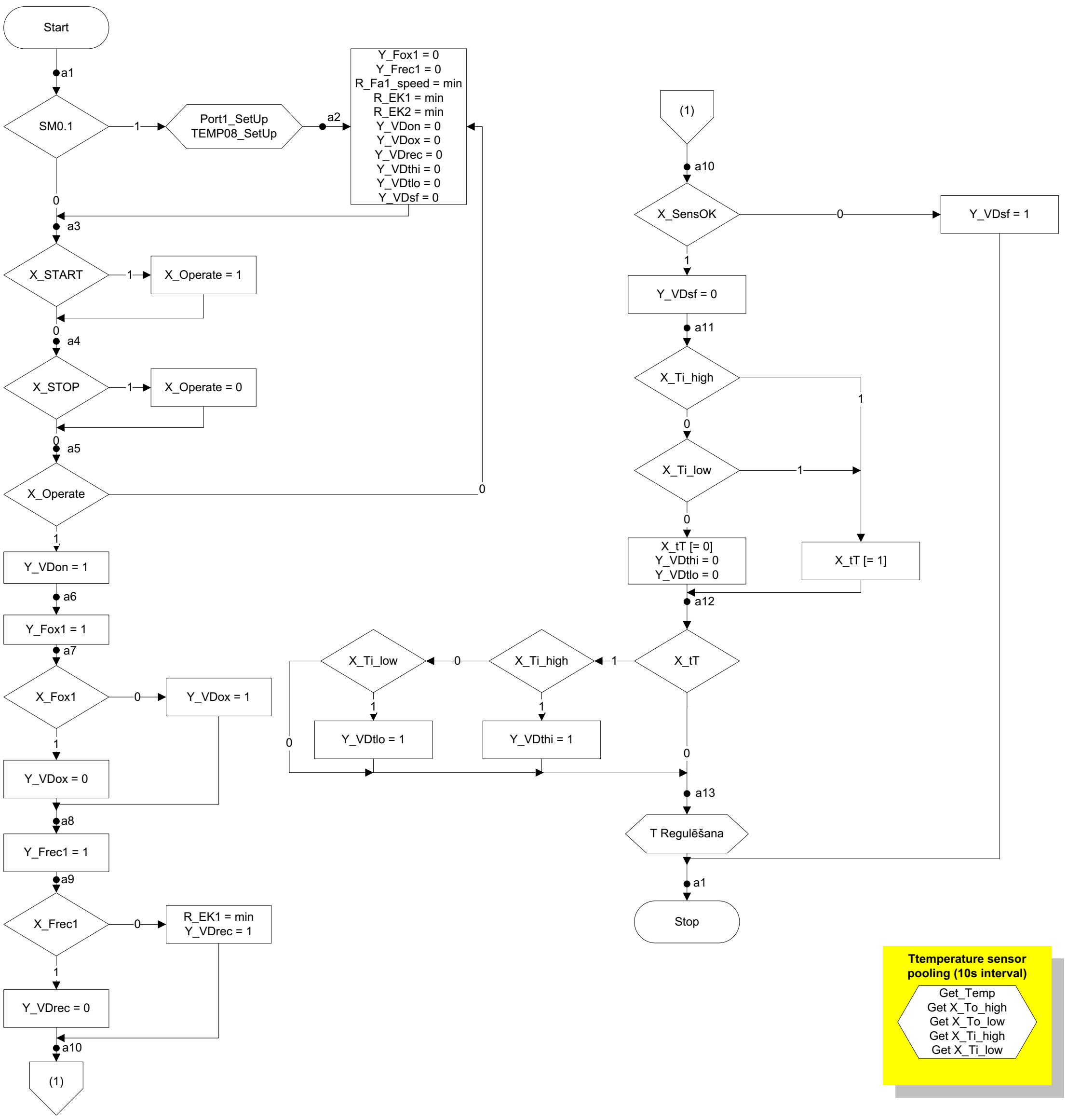

Figure 3. Algorithm of the temperature control program

Conclusions

A room-size (25 m^2 floor surface) controlled microclimate chamber with possibilities to measure metabolic activity of a bioprocess measuring its impact on microclimate parameters has been developed. The construction of chamber and its control allows accurate assessment of environmental impact on the system as well as control impact of microclimate control to be able to calculate the metabolic activity using equation $Im_k = Ie_k - Ic_k$, $k = 1..n$, where Im_k – impact of metabolic process on microclimate parameter, Ie_k – influence of environment on the

Microclimate parameter k, Ic_k – impact of control system on the microclimate parameter k, k – microclimate parameter changed by metabolic activity.

Microclimate chamber is built as a sandwich panel construction and can be installed indoors or outdoors. Control system is based on Siemens S7-200 PLC. Control parameter is temperature with possibility to develop additionally the system for humidity and gas control. Chamber is equipped with two constantly working fans: 1) recirculation fan for homogenizing the microclimate within the chamber and 2) air exchange fan to ensure fresh air in the chamber. Thus humidity and gas exchange is maintained to have the values close to the environmental values due to constantly working. Electrical heater is used for heating. Cooling can be executed by cooling ventilator with adjustable speed if outside temperature is lower than target temperature in the chamber. The cooler is used if outside temperature is lower than target temperature. Chamber and environment temperatures are measured with 8 temperature sensors each.

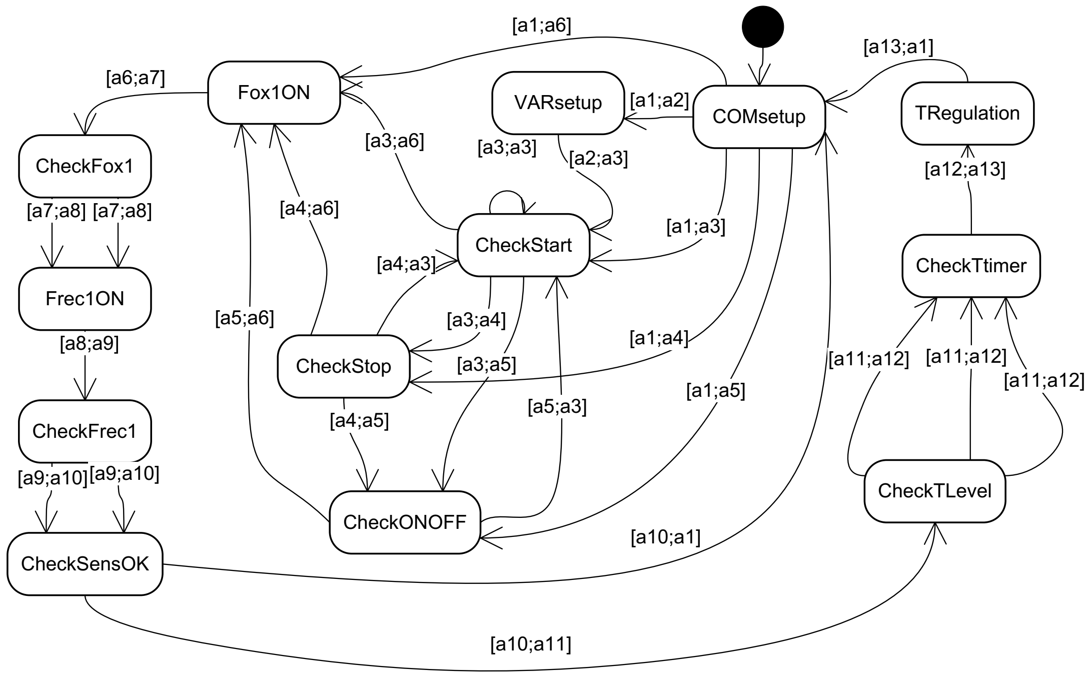

Figure 4. State diagram of the program

Table 2.

Summary of transition guards of the state diagram

Symbol	Name	Transition guards	Symbol	Name	Transition guards
a1	COMS etup	a1;SM0.1;[Port1TEMP08_Setup];a2 a1;$\overline{\text{SM0.1}}$;X_START;[X_Operate];a4 a1;$\overline{\text{SM0.1}}$;$\overline{\text{X\_START}}$;X_STOP;[$\overline{\text{X\_Operate}}$];a5 a1;$\overline{\text{SM0.1}}$;$\overline{\text{X\_START}}$;$\overline{\text{X\_STOP}}$;X_Operate;[Y_VDon];a6 a1;$\overline{\text{SM0.1}}$;$\overline{\text{X\_START}}$;$\overline{\text{X\_STOP}}$;$\overline{\text{X\_Operate}}$;[VARSetup];a3	a8	Frec1O N	a8;[Y_Frec1];a9
a2	VARS etup	a2;[VARSetup];a3	a9	Check Frec1	a9;X_Frec1;[$\overline{\text{Y\_VDrec}}$];a10 a9;$\overline{\text{X\_Frec1}}$;[Y_VDrec;$\overline{\text{Y\_EK1}}$];a10
a3	Check Start	a3;X_START;[X_Operate];a4 a3;$\overline{\text{X\_START}}$;X_STOP;[$\overline{\text{X\_Operate}}$];a5 a3;$\overline{\text{X\_START}}$;$\overline{\text{X\_STOP}}$;X_Operate;[Y_VDon];a6 a3;$\overline{\text{X\_START}}$;$\overline{\text{X\_STOP}}$;$\overline{\text{X\_Operate}}$;[VARSetup];a3	a10	Check SensO K	a10;X_SensOK;[$\overline{\text{Y\_VDsf}}$];a11 a10;$\overline{\text{X\_SensOK}}$;[Y_VDsf];a1
a4	Check Stop	a4;X_STOP;[$\overline{\text{X\_Operate}}$];a5 a4;$\overline{\text{X\_STOP}}$;X_Operate;[Y_VDon];a6 a4;$\overline{\text{X\_STOP}}$;$\overline{\text{X\_Operate}}$;[VARSetup];a3	a11	Check TLevel	a11;X_Ti_high;[X_tT];a12 a11;$\overline{\text{X\_Ti\_high}}$;X_Ti_low;[X_tT];a12 a11;$\overline{\text{X\_Ti\_high}}$;$\overline{\text{X\_Ti\_low}}$; [$\overline{\text{X\_tT}}$;$\overline{\text{Y\_VDthi}}$;$\overline{\text{Y\_VDtlo}}$];a12
a5	Check ONOF F	a5;X_Operate;[Y_VDon];a6 a5;$\overline{\text{X\_Operate}}$;[VARSetup];a3	a12	Check Ttimer	a12;X_tT;X_Ti_high;[Y_VDthi];a13 a12;X_tT;$\overline{\text{X\_Ti\_high}}$;X_Ti_low; [Y_VDtlo];a13 a12;X_tT;$\overline{\text{X\_Ti\_high}}$;$\overline{\text{X\_Ti\_low}}$;a13 a12;$\overline{\text{X\_tT}}$;a13
a6	Fox1O N	a6;[Y_Fox1];a7	a13	TRegul ation	a13;[TRegulation];a1
a7	Check Fox1	a7;X_Fox;1[$\overline{\text{Y\_VDox;}}$]a8 a7;$\overline{\text{X\_Fox1}}$;[Y_VDox];a8	-	-	-

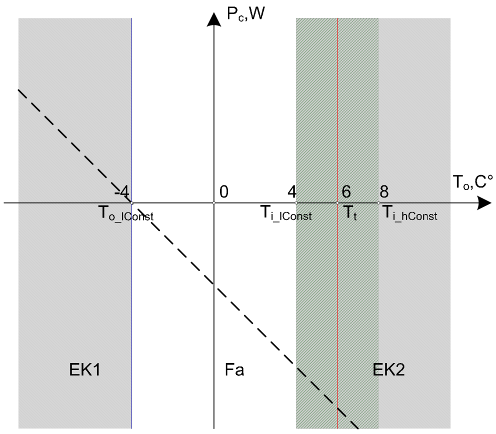

Figure 5. Impact of temperature control system to keep the target T_t=+6°C±2 (marked with a shadow) is demonstrated by a thick interrupted line. Positive values of power (Pc) mean heating of the building and negative values indicate that the building has been cooled. Zones of activity of mechanisms depending on outside temperature T_o are marked. When the outside temperature T_o is below equilibrium point (warm of bees keep the T_t) the electrical heater (EK1) is operating. Between T_{o_lConst} until T_t the cooling fans (F_a) are operating cooling the building with outside air. When the outside temperature exceeds T_t cooling fans become ineffective and the cooler (EK2) should be operated.

The control system is developed using programmable logic controller (PLC) that can execute complicated control algorithms allowing registering all control system activities. The program of PLC is created using ‘cyclogram – algorithm – state machine’ approach and ladder logic notation.

Described approach can be used in case of bee wintering indoors to determine status of brood rearing in the colonies.

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