EFFECT OF ANIMAL KEEPING TECHNOLOGIES ON THE PIGSTY INNER CLIMATE IN SUMMER

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Abstract. In the process of research, the temperature and the contents of moisture, oxygen, carbon dioxide and ammonium hydrate were measured diurnally above the pigs' pen and simultaneously outdoor air temperature and relative humidity were measured. To measure these parameters, the appropriate sensors, connected to ALMEMO Data Logger 8990-8 were used. The PC AMR Win Control software was used for the saved data processing. The results of given research are about inner climate parameters in four pigsties which use different pigs breeding technologies. The measurements were carried out at 1.5 m high above pig's pen diurnally and in summer.

Keywords: pigsty, pig-pen, deep litter, liquid manure, tendering work, scraper, chain conveyer, environmental air temperature, relative humidity, oxygen, ammonia, carbon dioxide, data logger, indoor climate.

Introduction

A pig farm represents a biotechnical system „man-machine-animal", which together with the indoor climate of buildings or premises constitutes a work environment for producing animal products. Indoor climate parameters of working environment have impact on the human capacity for work [1-3] and the productivity of animals [3-5]. Humidity and ammonia have more harmful effect on premises [6], whereas the indoor climate depends on various factors such as applicable tending technology, number of animals, systems for providing animals with forage and water, removal of manure, use of litter, and season or outdoor climate [3-8]. The indoor air temperature and relative humidity of a pigsty have been researched more thoroughly [3, 7, 8]. The working environment air gas composition, its variations on a daily basis and its dependence on applicable technologies and animal keeping methods have been studied to a lesser extent.

The aim of the present research was to find out the impact of different methods for animal keeping and tending works on indoor working environment during summertime. The daily developments of air velocity and contents of oxygen, carbon dioxide and ammonia were measured at the height of 1.5 m above the floor of pigsty in the central part. Study results provide further information concerning the indoor climate in pigsties and also allow selecting the method for keeping of animals with the least harmful tending environment.

Matherials and methods

Indoor climate was studied in pigsties for 1000 fattening pigs, 250 sows with piglets, 800 fattening pigs and 650 young pigs, which are hereinafter referred to as Pigsty A, B, C and D (Table 1). Pigsties were made of silicate bricks and reinforced concrete. In Pigsty A dry fodder was manually delivered from hand cart to Groba feed automat, with 30 fatlings in pens with scanty litter. In Pigsty B 250 sows with piglets were fed manually from hand cart to trough. Fattening pigs and young pigs were fed with dry fodder delivered by automatic conveyor from automatic feeders. Automatic conveyor Big Dutchman was used in Pigsty C and Roxcell device was used in Pigsty D. In Pigsty A and B sawdust was used for litter, it was removed to storage with a scraper and chain scraper. In Pigsty C fattening pigs were kept on straw litter (50 pigs per pen), the manure was removed with shovel-loader after replacing the fattening pigs in the pigsty. In Pigsty D liquid manure system was used, where manure was drained from pen with 20 young pigs into a channel below grated floor, leading to pump-room, where it was pumped to manure storage. Nipple drinkers were used as drinking device in all pigsties. Ventilation was regulated by automatic forced ventilation.

The methods of the study were based on the Health Protection Act of the Republic of Estonia [9] and Finnish standards [10], American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. (ASHARAE) [4] according to which the numerical values of indoor climate parameters of work environment can be defined for animals at the height of 1.0 m and for human workplace at the height of 1.5 m. In order to study the daily changes in indoor climate of pigsties depending on outdoor climate, methods for animal keeping, performing technological processes, activities of the tender and

animal behaviour, the indoor air temperature, relative humidity, air velocity and contents of oxygen, carbon dioxide and ammonia were measured on a daily basis at the interval of 60 seconds in the central part of pigsties at the height of 1.5 m above the floor of the pigsty in summer. Simultaneously outdoor air temperature and relative humidity were measured during 24 hours.

ALMEMO Data Logger 8990-8 equipment with relevant sensors was used for studying the indoor climate.

Table 1

Data on pigsties

Item	Pigsty A	Pigsty B	Pigsty C	Pigsty D
Number of tenders	1	2	1	1
Number on pigs	1000 fatlings (15-80 kg)	250 (sows with piglets)	800 fatlings (25-100 kg)	650 young pigs (15-50 kg)
Way on keeping	Pens with litter	Pens with litter	Deep-litter	Liquid manure system
Ventilation	Compulsion ventilation	Compulsion ventilation	Compulsion ventilation	Compulsion ventilation
Air flow control	Automatic	Automatic	Automatic	Automatic
Additional heating	Heating lamps for young pigs	Missing	Missing	Water-heated floor
Fodder delivery	Hand-cart Groba feed automat	Hand-cart trough	Automatic system Big Dutchman	Automatic system Roxcell
Manure disposal	Scraper УС-15	Chain scraper ТСН-160	With tractor	Liquid manure, with flow to the pumping-station
Drinking device	Nipple drinker	Nipple drinker	Nipple drinker	Nipple drinker
Litter used	Sawdust	Sawdust	Straw	Missing

Air temperature and relative humidity were measured with AMR-manufactured sensor FH646-1 with measurement area –20…+80 °C (measuring accuracy 0.01 °C) and 5–98 % (measuring accuracy 0.1 %), respectively. Oxygen sensor ZA9000-AK2K measurement area was 0-100 % and measuring accuracy is 0.01 %. Carbon dioxide content was measured with sensor FY A600-CO_2 with measurement area 0–2.5 % and measuring accuracy 0.01 %. Air velocity was measured by using thermo-anemometer FHA645TH2 with measurement area 0–2.0 $m \cdot s^{-1}$ and resolution 0.001 $m \cdot s^{-1}$. Ammonia content was measured with Gas Monitor Pac III equipment manufactured by Dräger Safety AG & Co, its measurement area was 0–250 ppm and measuring accuracy 1 ppm. HygroLog device by Rotronic with HygroClip S sensor were used for measuring outdoor temperature and relative humidity (measurement area –40…+85 °C and 0–100 %, accuracy ±0.3 °C and ±1.5 %, respectively). Measurement results were analysed by using computer programmes AMR WinControl, Pac III Software 3.nn, HW3 and statistically processed by using programme MS Excel [11].

Results and discussion

Indoor air temperature, relative humidity and ammonia concentration are the main indoor climate parameters of the pigsty [12, 13]. The recommendatory temperatures for pigs depending on their age and live weight are considered as follows: the lowest admissible temperature 5 °C, the highest 32-34 °C and optimum 16-21 °C [4, 6, 13, 14]. Relative humidity of the indoor air is recommended 60-75 %, not over 85 %, because then also the other microclimatic parameters deteriorate [5, 7, 14]. Surplus humidity causes drippings, mould and mildew on building border area and reduces heat resistance of the building and pigs as well. Insufficient air humidity less than 55 % can cause mucous membrane desiccation because of dust in the room [7, 15].

The study results revealed that by outdoor air temperature range from 8.8-21.8 °C, the indoor air mean temperature of all pigsties (17.0-24.5 °C) was practically within the limits (Table 2, Fig.1-4).

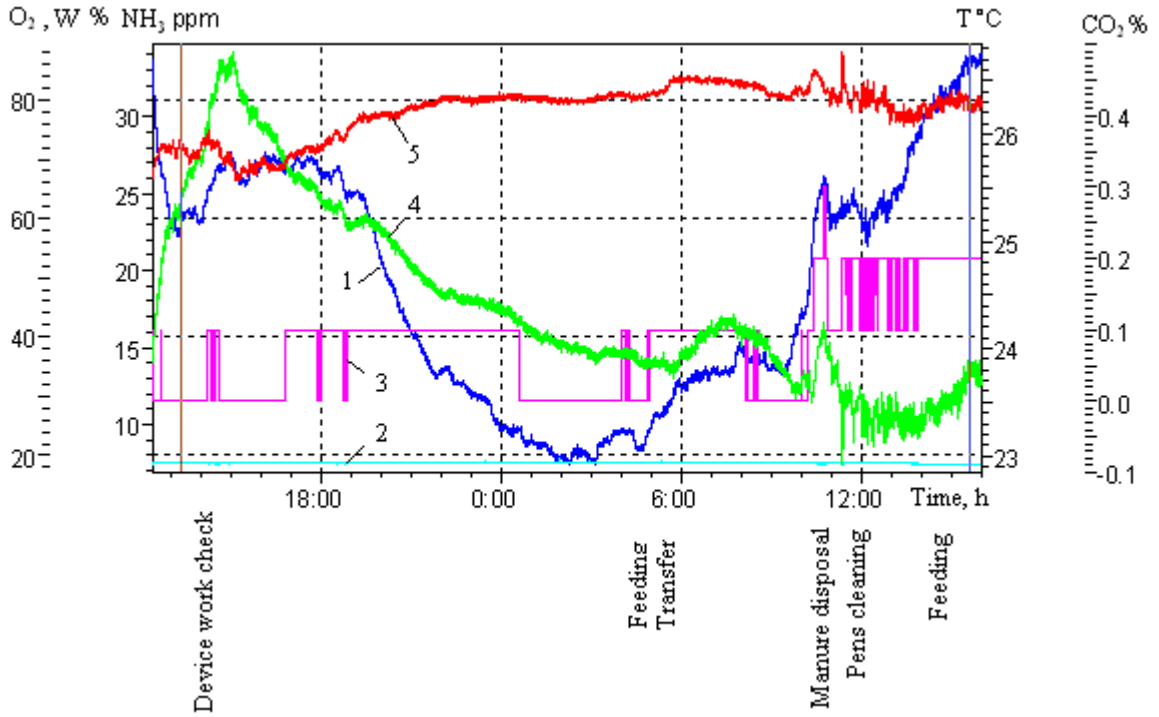

Fig. 1. **Pigsty A inner climate parametric difference diurnally:**
1 – temperature, 2 – oxygen, 3 – carbon dioxide, 4 – ammonia, 5 – relative humidity

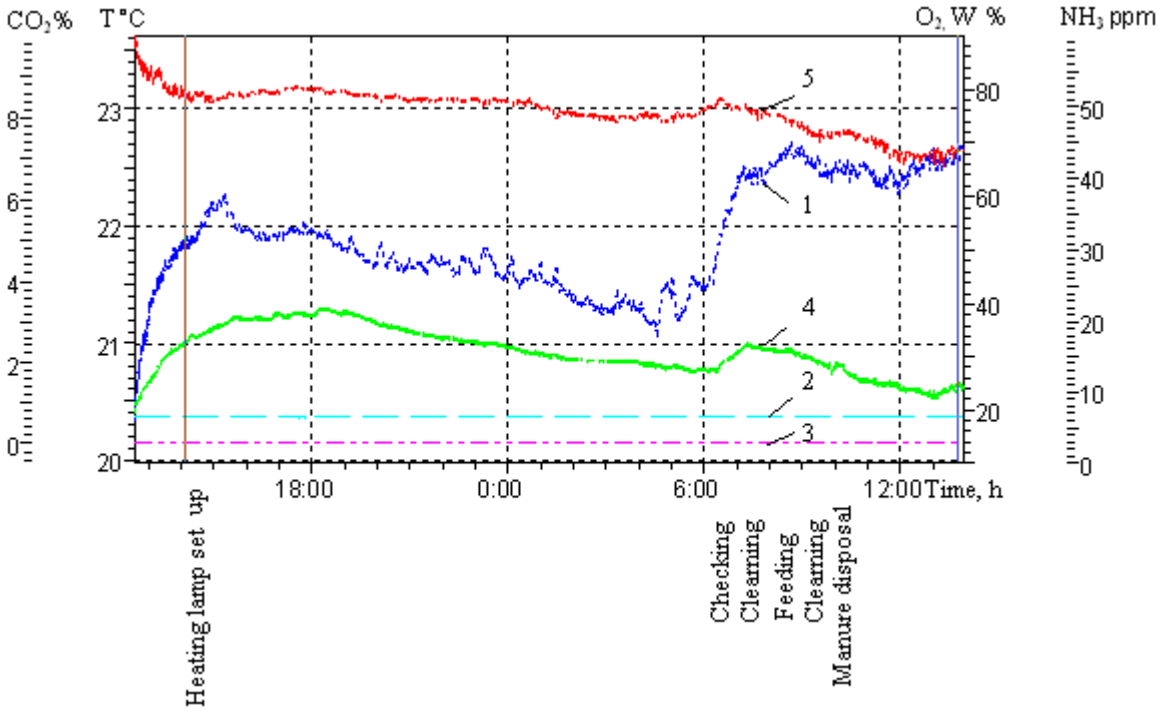

Fig. 2. **Inner climate diurnal parametric difference in pigsty B:**
1 – temperature, 2 – oxygen, 3 – carbon dioxide, 4 – ammonia, 5 – relative humidity

The measured mean relative humidity was 68.1-78.6 %, exceeding the limits in Pigsties A and D, while in Pigsty D it rose to the limit 90 %, affected by excessive humidity of outdoor air and pen clearing (washing) (Table 2, Fig. 4). The oxygen content showed lesser alterations, remaining within the limits 18.6-20.5 %.

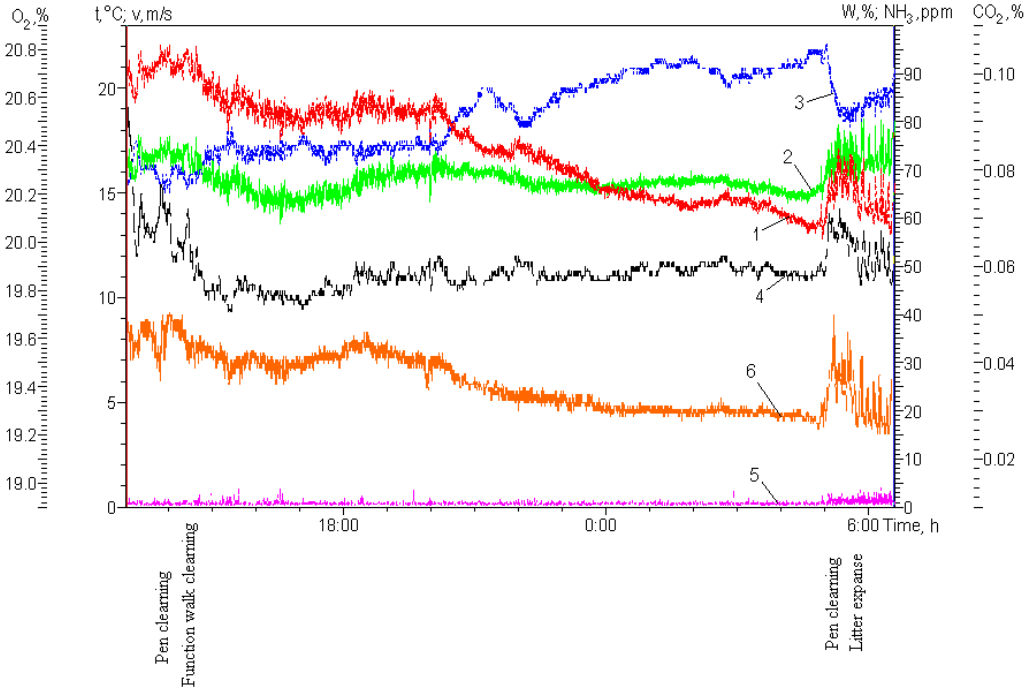

Fig. 3. **Daily change of numeric values of indoor climate parameters in Pigsty C:**
1 – temperature, 2 – relative humidity, 3 – oxygen, 4 – carbon dioxide, 5 – air velocity, 6 – ammonia

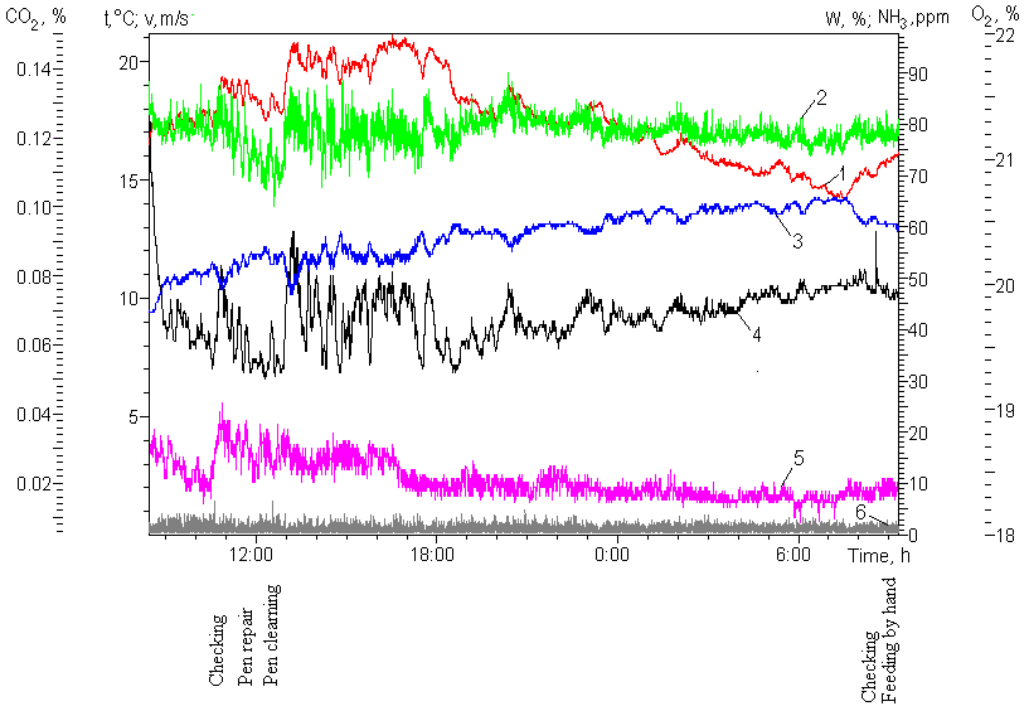

Fig. 4. **Daily change of numeric values of indoor climate parameters in Pigsty D:**
1 – temperature, 2 – relative humidity, 3 – oxygen, 4 – carbon dioxide, 5 – ammonia, 6 – air velocity

Carbon dioxide is originated in the course of metabolism and is emitted mainly by animal breathing, to a smaller extent by manure, dung-water and fodder waste, forming 0.15-0.25 % concentration in the indoor air [16].

The measurements in pigsties showed that the daily mean concentration of carbon dioxide in the indoor air was 0.06-0.08 % (Table 2), raising from 0.09 up to 30 % in the time of pen clearing, manure removal and feeding while the pigs were excited. The situation calls for ventilation improvement in the pigsties when performing the tendering works.

Table 2

Indoor climate parameter values in the Pigsties

Measured parameters	Min	Max	Average	Standard deviation	Standard error
			$\bar{x}$	σ	σ_x
Pigsty A					
Temperature, °C	22.92	26.72	24.51	1.11	0.011
Relative humidity W, %	66.4	88.0	78.31	4.446	0.045
Oxygen O_2, %	18.49	19.41	18.74	0.00	0.000
Carbon dioxide CO_2, %	0.02	0.30	0.08	0.001	0.000
Ammonia NH_3, ppm	7.0	34.0	18.00	6.089	0.061
Outdoor temperature, °C	14.1	25.9	21.75		
Outdoor relative humidity, %	47.5	99.9	67.2		
Pigsty B					
Temperature, °C	21.07	22.72	21.91	0.429	0.005
Relative humidity W, %	65.5	80.6	75.79	0.035	0.000
Oxygen O_2, %	18.53	18.75	18.64	0.000	0.000
Carbon dioxide CO_2, %	0.0	0.0	0.0	0.000	0.000
Ammonia NH_3, ppm	9.0	22.0	16.08	0.018	0.006
Outdoor temperature, °C	15.1	27.4	18.65		
Outdoor relative humidity, %	35.3	92.3	71.6		
Pigsty C					
Temperature, °C	12.80	22.10	17.04	2.344	0.030
Relative humidity W, %	58.9	80.5	68.11	3.025	0.038
Oxygen O_2, %	20.20	20.82	20.53	0.158	0.002
Carbon dioxide CO_2, %	0.05	0.09	0.06	0.005	0.000
Ammonia NH_3, ppm	6.0	43.0	20.92	8.008	0.101
Air speed v, m/s	0.086	0.981	0.17	0.079	0.001
Outdoor temperature, °C	12.2	24.5	18.15	4.313	0.124
Outdoor relative humidity, %	44.5	97.7	71.88	18.549	0.535
Pigsty D					
Temperature, °C	14.17	21.11	17.60	1.885	0.021
Relative humidity W, %	63.90	90.00	78.59	2.984	0.033
Oxygen O_2, %	19.92	20.70	20.38	0.170	0.002
Carbon dioxide CO_2, %	0.05	0.14	0.07	0.007	0.0001
Ammonia NH_3, ppm	4.0	27.0	8.76	4.491	0.050
Air speed v, m/s	0.085	1.552	0.25	0.136	0.002
Outdoor temperature, °C	1.2	21.2	8.75	4.423	0.114
Outdoor relative humidity, %	43.4	100.0	84.19	15.430	0.398

Ammonia is originated in the decomposition process with the presence of excrements and urine. Ammonia is extremely toxic for organisms, causing liver troubles and constant nervousness, irritating respiratory organs, inflicting chemical burns. Capacity of ammonia diffusing through cell walls increases ammonia riskiness for mammals [7]. The utmost permissible concentration of ammonia in the work zone air is 25 ppm (for 8-hour workday). For pigs the concentration limit is 20 ppm [6,17].

Indoor climate investigation showed that daily mean ammonia concentration in the air was 9-21 ppm (Table 2, Fig. 1-4). But ammonia concentration in the pigsties increased, reaching the peak 43 ppm during tending works in Pigsty C, where fatlings were kept on deep litter (Fig. 3, Table 2).

The average measured air velocity was 0.17-0.25 m/s, up to 1.5 m/s (Pigsty D).

Conclusion

1. During the research the air temperature, relative humidity and velocity; oxygen, carbon dioxide and ammonia content were measured round-the-clock above the pig pen. Simultaneously the outdoor air temperature and relative humidity were measured.
2. Data Logger with appropriate sensors and programmes AMR WinControl, Pac III Software 3.nn, HW3 were used for the research, the measurement data were statistically processed.
3. The mean values of air temperatures 17.0-24.5 % and relative humidity 68.1-78.6 % in the pigsties were found to be within the limits.
4. Carbon dioxide daily mean content in pigsties was 0.06-0.08 %, but in the time of pen clearing, manure removal and feeding, when the pigs were excited, the concentration in air increased from 0.09 to 0.3 %.
5. The ammonia daily mean concentration (9-21 ppm) did not exceed the limits. It increased only in the Pigsty A for fatlings up to 34 ppm during the service of feed automat Groba, which caused an intensive animation of pigs, and also in Pigsty C up to 43 ppm during the manure removal from the feeding area.
6. To improve the indoor air quality in pigsties during tending works the ventilation needs to be made more effective.

References

1. Liiske M., Hovi M., Lepa J., Palge V. Soojusprotsesside matemaatilised mudelid ja energiakulu. OÜ Tartumaa Trükikoda, Tartu, 1998. - 87 lk.
2. Sada O., Reppo B. Handling technologies impact on the pigsty air quality. Engineering for rural development. Proceedings 5th International Scientific Conference. Jelgava, Latvia, 2006. - pp. 114-119.
3. Liiske M. Sisekliima. Eesti Põllumajandusülikooli kirjastus, Tartu, 2002. - 188 lk.
4. ASHARE Handbook General engineering data, Environmental for Animals and Plants. HAVAC application, 1791 Tullie Circle, Atlanta GA 30329, USA. - 1987.
5. Tuunanen L. Karhunen J. Fan powered extraction and natural ventilation in animal houses. Vakolan tutkimisselostus 44, 1986. - 64 s.
6. CIGR. Report of working group on Climatization of animal houses. SFBIV, Aberdeen, 1984. - 72 pp.
7. Mothes E. Stallklima. VEB Deutscher Landwirtschaftsverlag, Berlin, 1973. - 190 S.
8. MWPS-33. Naturalventilating Systems for Livestock Housing. First Editions. Mid-West Plan Service. 1989.
9. https://www.riigiteataja.ee/ert/act.jsp?id=25048
10. Karhunen J. Kaasut ja pöly eläinsuojiea ilmanväihdoissa. VAKOLAn tiedote 52, Vakola, 1992. - 25 s.
11. Kiviste A. Matemaatiline statistika MS Excel keskkonnas. GT Tarkvara OÜ, Tallinn, 1999. 86 lk.
12. Tuunanen L., Karhunen J. Eläinsuojien ilmanvaihdon mitoitus. Vakolan tutkimusseloistus 39, Vihti, 1984. - 112 s.
13. Maatalouden tuotantorakennusten ilmastointi ja lämmitus. NesteAir-IX suunnitelu, Espoo, 1990. - 5 s.
14. Rosti S. Sianhoito. Mäntän Kirjapaino OY, Helsinki, 1988. - 116 s.
15. Veinla V. Farmide mehhaniseerimine. Valgus, Tallinn, 1986. - 648 lk.
16. Pals A. Loomapidamistehnoloogiate mõju lehmalauda sisekliimale. Magistriväitekiri. Eesti Põllumajandusülikool, Tartu, 2003. - 84 lk.
17. http://www.riigiteataja.ee/ert/act.jsp?id=73153