SELECTION OF THE SENSORS FOR THE ENVIRONMENTAL CONTROL SYSTEMS OF PIG-HOUSING IN TEMPERATE ZONE

Dong-Il Chang, Professor
and
Hong-Hee Chang, Graduate Research Assistant
Department of Agricultural Machinery Engineering
Chungnam National University
Daejeon 305-764, Korea

ABSTRACT

This study was conducted to select the sensors for measuring temperature, relative humidity, and air velocity among the major environmental factors affecting the pig productivity as a part of the study for the optimum production system model development of pig-housing. The study results are summarized as the follows:

Two sensors, HMP233L and HANI, were tested for measuring temperature and relative humidity. Test results were analyzed by the statistical methods. And the sensor, HMP233L was selected as a proper sensor for temperature and relative humidity measurement.

An air velocity sensor was tested. Test results showed that its accuracy was low and incongruent for the air velocity measurement when it was lower than 4m/s.

Key Word : Environmental control system, Pig-housing, Sensor

INTRODUCTION

In view of the difficult economic situation such as WTO and high wages, for the livestock industry, it is necessary to prepare the international competitive power by the efficient mechanization and automation which can reduce the production costs. And for the sake of it, an optimum production model should be developed to synthesize the production and management systems of livestock. Pigs are used to use the energy produced by the feed when the environmental temperature is under the lower critical temperature and their productivity is declined in the heat environment. The reproductivity of female pig is decreased in proportion to the period of exposure to heat environment. For the boar, the quality of sperm and the fertilization of artificial insemination are deteriorated in the short span of the high thermal stress(D'Arece et al., 1970).

According to Choi(1989), the increasement of relative humidity can only decrease the productivity of livestock under the high air temperature.

For the pigs weighing 40-170kg, if the air velocity was increased from 0.2m/s to 1.5m/s in the environmental temperature ranges of 10-32℃, the feed requirements for the unit increment of weight was increased and the average weight increment per day was decreased. But, in the environmental temperature ranges of 35-38℃, if the air velocity was increased, the rate of weight increment was improved(Bond et al., 1965).

Since the gases of HCl and NH_3 have the effect on loss of appetite, the productivity of pigs is declined in the gaseous environment. Also, NH_3 has the effect on reduction sexual maturity, and HCl increases the abortive birth(Nordstrom and Maquitty, 1976).

Hence the major environmental factors such as temperature, relative humidity, air velocity, and noxious gases should be controlled.

The effects of several types of pig housing on the productivity and economics were studied for the pig farms in the Indiana State of U.S.A. of which climate conditions were similar to the Korean weather. According to performance results, the windowless pig housing having partially slotted floor was most economical among the tested pig-housings(Kadlec et al., 1966).

Therefore, this study was carried to develop an optimum environmental control model for controlling temperature, relative humidity, air velocity, and noxious gases of the windowless pig-housing. The concrete objectives of this study were as the followings:

1) To select the sensors for measuring temperature, relative humidity, and air velocity among the major environmental factors affecting the productivity of pigs.

2) To perform a selection examination for the sensors studied, and decide the most suitable sensors for controlling the environment of pig-housing.

MATERIALS AND METHODS

1. Major environmental factors and sensors to be selected

The major environmental factors affecting the productivity and health of pigs are temperature, relative humidity, noxious gases(NH_3, CO_2), and ventilation rates (air velocity). Temperature was reported as a most important factor among them. Therefore, those factors are considered as the factors to be controlled in this study, and sensors for measuring them were determined to be examined. The specifications of such sensors made in the inside and outside of the country were compared and investigated with each other based on the several conditions such as national climate conditions, environment of pig-housing, optimal breeding conditions. Then one or two kinds of sensors were decided to be tested for each environmental factors. They are HMP233L and HANI for temperature and relative humidity, and NTK for air velocity. Their specifications are shown in Table 1, 2, and 3.

2. Experimental equipment and measurement system

1) Instrumentation for temperature and relative humidity

In order to maintain that temperature and relative humidity were constant, an environment chamber (Woo Joo Science Ltd. : Model THC-C-1) was used. By this chamber, temperature could be controlled from -50℃ to 100℃; and 25 - 95% for relative humidity. The stability of temperature control was ±0.5℃; and ±3% for RH.

Probes of temperature and relative humidity sensors were installed at inside of environmental chamber, and signal processing circuits were set up at outside of it. As a reference point, a liquid-in-glass thermometer and a wet bulb and dry bulb psychrometer were installed in the environment chamber.

2) Instrumentation for air velocity

For measuring air velocity, an ASME flow nozzle of 300mm diameter and a probe of air velocity sensor were installed at the center of a cylinder. Then an inclined-tube manometer(Okano Co., Japan; Model KM) was connected to flow nozzle to measure the pressure difference. The air flow rates were varied by a speed variable motor(2.2kW, IMC-30B)

3) Measurement systems

The measurement system for this study was consisted as Figure 1, and the measurement software was programmed by C language.

RESULTS AND DISCUSSION

1. Performance of temperature sensors

The test results of temperature sensors are shown in Table 4 and 5. In these tests, as a reference point, a liquid-in-glass thermometer was used. Since there were temperature deviation between the reference points and the measured results of two kinds of sensor, HMP233L and HANI, two sensors were calibrated and tested. Then the test results were analyzed by the paired sample t-test statistically. Its results showed that there were no significant differences among the measuring methods.

The relationships of the estimated value and the observed value of HMP233L and HANI were analyzed for temperature by the linear regression and R^2 values were 0.9735 and 0.9652, respectively. Therefore, it was turned out that both sensors were proper to measure temperature of pig-housing. But, the standard deviations of two sensors were compared in this study, which were 0.265 for HMP233L and 0.529 for HANI. Based on the lower standard deviation value, HMP233L was selected as a proper sensor for temperature measurement.

2. Performance of relative humidity sensors

The test results of relative humidity sensors are shown in Table 6 and 7. In these tests, as a reference point, a wet bulb and dry bulb psychrometer was used. Since there were relative humidity deviation between the reference points and the measured results of two kinds of sensor, HMP233L and HANI, two sensors were calibrated and tested. Then the test results were analyzed by the paired sample t-test statistically, too. Its results showed that there were no significant differences among the measuring methods.

The relationships of the estimated value and the observed value of HMP233L and HANI were analyzed for relative humidity by the linear regression and R^2 values were 0.9404 and 0.8980, respectively. Therefore, it was turned out that both sensors were proper to measure relative humidity of pig-housing. But, the standard deviations of two sensors were compared in this study, which were 4.215 for HMP233L and 5.886 for HANI. Based on the standard deviation value, only HMP233L was selected for relative humidity sensors.

3. Performance of air velocity sensors

The test results of relative humidity sensor are shown in Table 8. Considering the required air velocity of inside of pig-housing was less than 1m/s, the accuracy of NPK air velocity sensor was too low for air velocity less than 4m/s to measure it. Therefore it was analyzed that the sensor NPK would be not proper to measure the air velocity. For air velocity measuring, other types of sensor will be tested more to find a suitable one.

CONCLUSIONS

This study was conducted to select the sensors for measuring temperature, relative humidity, and air velocity among the major environmental factors affecting the pig productivity as a part of the study for the optimum production system model development of pig-housing. The study results are summarized as the follows:

1) Two temperature sensors, HMP233L and HANI, were tested for their performances. The R^2 values were 0.9735 and 0.9652 for the relationships of the inputs and the outputs of sensors, respectively. The standard deviations were 0.265 and 0.529, respectively. Therefore, the sensor, HMP233L was selected as a proper sensor for temperature measurement.

2) Two relative humidity sensors, HMP233L and HANI, were tested for their performances. The R^2 values were 0.9404 and 0.8980 for the relationships of the inputs and the outputs of sensors, respectively. The standard deviations were 4.215 and 5.886, respectively. Therefore, the sensor, HMP233L was selected as a proper sensor for relative humidity measurement.

3) An air velocity sensor was tested. Test results showed that its accuracy was low and incongruent for the air velocity measurement when it was lower than 4m/s.

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Table 1. Specifications of the temperature sensors

Item	Model	
	HMP233L	HANI
Accuracy	±0.1℃(at +20℃)	±0.3℃(at -10~+50℃)
Response time(90%)	About 15 seconds (at +20℃)	-
Measuring range	-40~+80℃	-10~+50℃
Temperature dependence of output	±0.005℃/℃	-
Operating temperature range	-40~+60℃	-20~+60℃
Analogue outputs	DC 4~20mA and DC 0~5V	DC 0~5V
Relationship between environmental factor and output signal(voltage)	T = 25V - 45 where, T = temperature(℃) V = voltage(V)	T = 15V - 25 where, T = temperature(℃) V = voltage(V)

Table 2. Specification of the relative humidity sensors

Item	Model	
	HMP233L	HANI
Accuracy	maximum achievable accuracy when calibrated against high quality, certified humidity standards : ±1%RH(0~90%RH) ±2%RH(90~100%RH when calibrated against salt solutions(ASTM E104-85) : ±2%RH(0~90%) ±3%RH(90~100%RH	±3%RH(at 30~90%)
Response time(90%)	About 15 seconds(at +20℃)	-
Measuring range	0~100%RH	0~100%RH
Operating temperature range	-40~+60℃	-20~+60℃
Analogue outputs	DC 4~20mA and DC 0~5V	DC 0~5V
Relationship between environmental factor and output signal (voltage)	RH = 25V - 25 where, RH = relative humidity(%) V = voltage(V)	RH = 25V - 25 where, RH = relative humidity(%) V = voltage(V)

Table 3. Specification of the air velocity sensor

Item	NTK duct type anemometer
Accuracy	Linearity : ±2.5% F.S.(at 25℃) Direction dependency : ±3% F.S.(horizontal to surface) Temperature dependency : ±3% F.S.
Response time(90%)	About 5 seconds
Measuring range	0~20m/s
Operating temperature range	0~50℃
Analogue outputs	DC 4~20mA and DC 0~10V
Relationship between environmental factor and output signal(Voltage)	Vel = 5V - 5 where, Vel = velocity(m/s) V = voltage(V)

Table 4. Results of performence test of temperature sensor HMP233L (Unit : ℃)

Reference temp	2.8	5.5	10.7	13.0	13.8	16.1	20.0	20.0	21.9	25.6	30.6
Temp from equation	1.9	5.0	10.4	11.9	13.0	15.4	19.2	19.4	21.3	25.4	30.2
Calibrated temp	2.5	5.6	11.0	12.5	13.6	16.0	19.8	20.0	21.9	26.0	30.8
Revised equation	T = 25V - 44.4 (r squared = 0.9735) where, T = temperature(℃); V = voltage(V)										
Results of statistical analysis	Not significant (standard deviation = 0.265)										

Table 5. Results of performence test of temperature sensor HANI (Unit : ℃)

Reference temp	2.8	5.5	10.7	13.0	13.8	16.1	20.0	20.0	21.9	25.6	30.6
Value from equation	3.4	5.2	11.0	11.8	13.2	15.8	20.0	20.2	21.5	26.0	32.2
Calibrated temp	4.2	6.0	11.8	12.6	14.0	16.6	20.8	21.0	22.3	26.8	33.0
Revised equation	T = 15V - 24.2 (r squared = 0.9652) where, T = temperature(℃); V = voltage(V)										
Results of statistical analysis	Not significant (standard deviation = 0.529)										

Table 6. Results of performence test of relative humidity sensor HMP233L (Unit : %)

Psychrometric RH	45.8	49.7	52.3	60.3	64.0	65.3	67.5	71.3	71.6	82.9	93.0
RH from equation	32.9	39.4	42.5	47.4	52.8	59.4	57.2	66.8	64.9	81.3	91.8
Calibrated RH	39.9	46.4	49.5	54.4	59.8	66.4	64.2	73.8	71.9	88.3	98.8
Revised equation	RH = 25V - 18 (r squared = 0.9404) where, RH = relative humidity(%); V = voltage(V)										
Results of statistical analysis	Not significant (standard deviation = 4.215)										

Table 7. Results of performence test of relative humidity sensor HANI (Unit : %)

Psychrometric RH	45.8	49.7	52.3	60.3	64.0	65.3	67.5	71.3	71.6	82.9	93.0
RH from equation	32.5	42.1	46.3	52.0	57.7	59.4	59.6	64.0	64.2	64.7	68.9
Calibrated RH	40.9	50.5	54.7	60.4	66.1	67.8	68.0	72.4	72.6	73.1	77.3
Revised equation	RH = 25V - 16.6 (r squared = 0.8980) where, RH = relative humidity(%); V = voltage(V)										
Results of statistical analysis	Not significant (standard deviation = 5.886)										

Table 8. Results of performence test of wind velocity sensor NTK (Unit : m/s)

Manometer	1.00	1.60	1.90	2.03	2.28	2.50	2.71	2.99	3.33	3.49	3.64
NTK	-3.15	-0.70	0.49	1.28	1.60	1.62	1.62	1.63	1.62	1.61	1.63

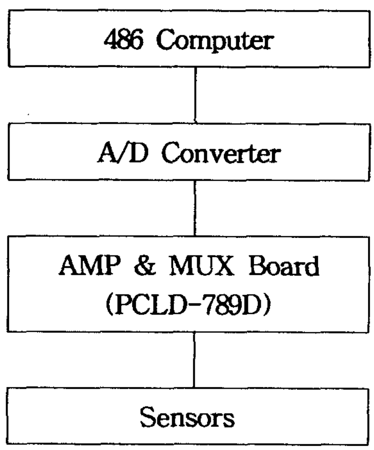

Fig. 1. Measurement system