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Environmental Control for Poultry Buildings in Riyadh Area of Saudi Arabia

Ibrahim M. Al-Helal
Department of Agricultural Engineering, College of Agriculture,
King Saud University, P.O. Box 2460, Riyadh 11451, Saudi Arabia

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Abstract. A study of the environmental control practices and problems for poultry was conducted in Riyadh area of Saudi Arabia. Information was obtained on the building size, labor, material of construction, cooling and heating systems, and automatic control for fifteen commercial poultry buildings. Ventilation rates to control temperature, moisture and ammonia were estimated and evaluated for every building. Also, supplemental heat capacities to maintain the desired indoor temperature were determined. The results showed that the floor space for chickens ranged from 0.052 to 0.061 m^2/bird. Walls and roofs were constructed with metal panels, concrete blocks and insulating materials. Cooling was accomplished by fan and pad evaporative cooling systems. The result obtained from this study indicated that summer ventilation rates were between 0.80-1.51 air exchanges per minute, and between 0.31-0.46 air exchanges per minute for winter. It was predicted that ventilation rates during summer could control moisture and ammonia in all farms, while could not control temperature in 33% of farms. The results indicated that ventilation was necessary during winter to control temperature, moisture and ammonia. During winter days, estimated ventilation rates for temperature control were higher than those required for ammonia and moisture control. However, during winter nights, predicted ventilation rates for ammonia control were higher than those required for temperature and moisture control. Therefore, ventilation rates for ammonia control were considered to be minimum ventilation rates, and to be continuous during night. In such a condition, supplemental heat was required to maintain the building at the desired air temperature. Winter ventilation rates were much higher than those required for moisture and ammonia control. This increased mixing of cold outside air with warm inside air. Therefore, indoor temperature could not be maintained at the desired level during winter season even though thermal outputs for heaters were higher than the predicted supplemental heat capacity. Heat was distributed in the building by discharging hot air directly or through perforated polyethylene duct. Some major problems of environment control were salt precipitation and dust accumulation in the cooling pad, non-uniform temperature in the building, and low efficiency of cooling and heating systems. Some recommendations to improve the performance of the environmental control systems for poultry buildings in Saudi Arabia were presented.

Introduction

Central regions of Saudi Arabia have a desert climate where agricultural buildings require environmental modifications to create a favorable environment that is essential for animal comfort and health. Under a less stressful environment, animals can utilize food more efficiently. The common farm buildings in Saudi Arabia include poultry and dairy houses, and greenhouses. The poultry industry plays an important role in the economy of Saudi Arabia because a huge consumption of chicken is in demand. The poultry industry development represents a main strategic objective of the Saudi government because it increases the income resources and insures food security. As a result, the poultry industry has flourished and large capitals have been invested on it. Poultry industry in Saudi Arabia includes productions of eggs, broilers and chicks. Table 1 shows poultry productions by specialized projects for the period from 1995 to 1998 [1, p. 242-250]. More than 30% of the poultry projects were located in central region of Saudi Arabia [1, p. 242-250].

Table 1. Poultry production by specialized projects in Saudi Arabia for the period from 1995 to 1998 [1, p. 242-250]

Year	No. of eggs*	No. of broilers*	No. of chicks (broilers parents or hatcheries)*	No. of chicks (layer parents hatcheries)*
1995	2391.797	299.9141	347.128437	12.518353
1996	2269.788	304.745177	352.906643	10.849367
1997	2389.550	375.955761	451.332331	18.680110
1998	2475.055	312.052459	401.080900	15.570704

* In million.

Increase of poultry production in Saudi Arabia can be attributed to the development of poultry medicines, vaccines, and feed supplements as well as the use of environmental control devices that provide a suitable environment for poultry growth, production, and health. Poultry buildings in Saudi Arabia have environmental modifications that are essentially used for cooling, ventilating and heating. Fan ventilation system is essentially used to regulate inside conditions including humidity, temperature and ammonia (NH_3) concentration in the building. In buildings during summer, water evaporative cooling systems are used to reduce indoor temperature and increase relative humidity to acceptable levels. Also, during cold months, heat is added to the buildings. Poor ventilation would quickly let to unhealthy conditions in poultry housing. This adversely affects bird performance such as growth rate, feed efficiency, carcass quality, and susceptibility to disease challenge [2]. If ventilation is adequate to control temperature during hot weather, it is adequate to control moisture and other aerial contaminants [3, p. 176]. It was stated that 1.0 air exchange per minute would remove excess heat [4]. Humidity and other air contaminants may increase when the ventilation rate is too low to the point where they dictate minimum ventilation rate. This happens during cold weather when air temperature is far below the optimum level for long period of time. To maintain air temperature at the desired level, supplemental heat is needed. To maintain a safe ammonia level of <25 ppm during the first week for flocks grown on old litter requires ventilation rates 10 times the normal rates needed for moisture control [5]. Minimum ventilation rate for broiler houses to maintain indoor aerial ammonia to within 25 to 30 ppm for growout raised on old litter averaged nine times the normal ventilation rates needed for moisture control on day one, and declined exponentially with bird age during the first two weeks [6].

Poultry producers indicated that environmental control systems have some problems that would increase operational cost and energy consumption. Generally, the environment control problems can be observed in ventilation, cooling and heating systems, and automatic control systems. There is limited information about environmental control practices and problems in poultry buildings in Saudi Arabia. The objectives of this study were to:

1) Discuss and investigate environmental control practices and problems in Riyadh area of Saudi Arabia.
2) Predict day and night ventilation rates for summer and winter seasons based on temperature, humidity and ammonia control.
3) Predict supplemental heat capacity required to maintain the building at the desired indoor temperature.
4) Compare the predicted summer and winter ventilation rates, and supplemental heat capacity with those used in buildings.

The results of this paper can be used to help poultry producers improve bird performance and conserve energy, and to help researchers to find priorities for future research studies. Also, the results included problems facing poultry production in Saudi Arabia.

Methods

A survey of the environmental control for poultry was conducted in Riyadh area of Saudi Arabia. Fifteen randomly selected farms were surveyed during the period of 1999-2000. Information was obtained on the building size, labor, material of construction, automatic control, and cooling, ventilation and heating systems.

The required ventilation rates for temperature control (VR_T) was obtained for the building based on steady-state energy balance assuming heat from mechanical sources (light, motors) is small enough to be ignored. Therefore, Abright [3, p. 159] proposed the following equation to determine VR_T, m^3/s:

$$VR_T = \left[\frac{q_s - \sum UA(T_i - T_o}{C_p \rho (T_i - T_o)} \right] \tag{1}$$

Where:

q_s = sensible heat gain from chickens (W)
U = overall building heat transfer coefficient ($W/m^2\,^oC$)
A = area of the building walls and ceilling (m^2)
ρ = density of air (kg/m^3)
C_p = specific heat of air ($J/kg\,^oC$)
T_i and T_o = temperatures inside and outside the building, respectively (^oC).

The overall coefficient of heat transfer was determined as follows:

$$U = \frac{1}{R_t} \tag{2}$$

Where R_t was total unit area thermal resistance ($m^2\,^oC/W$) and was calculated as follows.

$$R_t = R_{is} + R_1 + R_2 + \ldots\ldots + R_{os} \tag{3}$$

Where:

R_{is} = inside surface unit area thermal resistance ($m^2\,^oC/W$)
R_{os} = outside surface unit area thermal resistance ($m^2\,^oC/W$)
$R_{1,2,\ldots}$ = unit area thermal resistance of each layer making up the building ($m^2\,^oC/W$).

The unit area thermal resistance of each layer was determined as follows:

$$R_{1,2,\ldots.} = \frac{x_{1,2,\ldots..}}{k_{1,2,\ldots..}} \tag{4}$$

Where:

$k_{1,2,\ldots}$ = thermal conductivity of each layer ($W/m\,^oC$)
$x_{1,2,\ldots}$ = thickness of each layer of material building (m)

The required summer ventilation rates when the fan-pad evaporative cooling system is used (VR_{Te}) was obtained by changing ventilation air temperature to the temperature of air leaving the cooling pad (T_{oe}). Then, the calculation of ventialtion rate changed to:

$$VR_{Te} = \left[\frac{q_s - \sum UA(T_i - T_o)}{C_p\rho(T_i - T_{oe})}\right] \tag{5}$$

The temperature of the air leaving the pad was expressed as:

$$T_{oe} = T_o - \eta(T_o - T_{wb}) \tag{6}$$

Where:

η = effecincy of the pad cooling system (%)
T_{wb} = wet-bulb temperature of outside air (^oC).

The ventilation rate for moisture control (VR_m, m^3/sec) was calculated based on steady-state moisture balance as follows [3, p. 165]:

$$VR_m = \frac{m_p}{\rho(W_i - W_o} \tag{7}$$

Where:

m_p = moisture production rate (kg/s)
W_i and W_o = humidity ratios at the inlet and outlet, respectively (kg_{water}/kg_{air}).

The ventilation rate for ammonia control during the two-week brooding period was related to bird age by the following regression equation (R^2 = 0.97) [6]:

$$VR_{NH3} = 134 + 0.2474\ (13\text{-}D)^3 \tag{8}$$

Where:

VR_{NH3} = ventilation rate for ammonia (m^3/h/1000 birds)
D= bird age (day)

A sensible energy balance was used to calculate supplemental heat capacity ($q_{suppl.}$) required to maintain the building at required T_i for cold winter night and when minimum ventilation rate VR_{min} (m^3/sec) is used:

$$q_{suppl.} = C_p\, \rho\ VR_{min}\ (T_i\text{-}T_o) + \Sigma UA(T_i\text{-}T_o) - q_s \tag{9}$$

The minimum ventilation rate (VR_{min}) was the highest of VR_m and VR_{NH3}.

Energy and mass balance models required some numerical values as input values. Table 2 shows input values for the models with their dimensions. The data of outside air temperatures and relative humidities were collected from the solar village in Uuaina, Riyadh area. The values of desired indoor temperature were obtained from the survey. The indoor relative humidity were assumed to be no more than 70%. Thermal conductivity of each layer, and inside and outside surface thermal resistance values were obtained from [8]. Sensible heat gain and moisture production from chickens were obtained from [4].

In this study, the predicted summer and winter ventilation rates, and supplemental heat capacity were compared with those used in buildings. Rated ventilation rates for fans were obtained from the survey results. Then, ventilation rate for a building was found by multiplying the number of fans in each building by rated ventilation rates for each fan. Air exchange rates was found by dividing the volume of air that passed through a unit volume of building in a minute to determine air changes per minute. Required winter ventilation rates for temperature control were calculated using Equation 1. While in summer, Equation 5 was used to calculate required ventilation rates when the fan-pad evaporative cooling system was used. Evaporative cooling effeciency was chosen to be 77% [9]. Equation 7 was used to estimate ventilation rates for moisture control. Ventilation rates for ammonia control were estimated using Equation 8. Supplemental heat for buildings was calculated by applying Equation 9.

Results and Discussion

Labor and structure

In every surveyed farm, there was one or more owner, and a general manager. It was uncommon to find the owner to be a laborer or a manager of the farm. On most farms, a veterinarian always held the responsibilities of the general manager who was responsible for all employees and business. The number of employees ranged from 4 to 17 individuals depending on the farm size. About 50% of the employees were laborers, 15% were veterinarians, and 12% were electricians. All producers indicated that there was no need to hire agricultural engineers. The results of the survey showed that farms that have greater than 10 employees had an accountant who held the responsibilities for purchasing materials, handling billing and payments, and bookkeeping.

Table 2. Input parameters used in the simulation models

Parameters	Numerical value	Dimensions
Summer conditions		
Outside air temperature		
Day	45.2	°C
Night	30.0	°C
Outside relative humidity		
Day	4.3	%
Night	30	%
Inside air temperature	26	°C
Inside relative humidity	70	%
Winter conditions		
Outside air temperatures		
Day	15	°C
Night	4.0	°C
Outside relative humidity		
Day	15	%
Night	70	%
Inside air temperature	34	°C
Outside relative humidity	70	%
Inside surface thermal resistance	0.12	m^2.C/W
Outside surface thermal resistance	0.044	m^2.C/W
Evaporative cooling efficiency	77	%
Sensible heat gain from chickens	3.6	W/kg
Moisture production rate	10	gm_{water}/kg.hr

Results showed that the number of poultry buildings per farm varied from 3 to 16 buildings. The width of the buildings varied from 11.4m to 15m, and the length varied from 100 m to 150 m. The area of each building ranged from 1140 to 2250 m^2. About 40% of the surveyed farms had poultry buildings with areas greater than 10000 m^2. Chickens were grown in each building for 5 to 6 weeks before marketing. The confined floor space for chickens was varied from 0.052 to 0.061 m^2/bird. It has been recommended by [7, p. 515.1] that chickens require 0.093 m^2/bird for 4 to 10 week-old birds.

Buildings were constructed from footing, foundations, walls and roofs. The foundation was the link between the building and the ground, and was set on a poured concrete footing. A concrete footing was set to a minimum depth of 1m below ground surface to provide a level surface for a concrete masonry (block) foundation wall that was 1 m above ground surface. Walls with a width of 0.2 m were built of two metal boards connected by metal ties and separated by 0.14 m of an insulating material. Walls height varied from 2 to 3 m. The type of roof framing was a gable roof with a ridge height varied from 3 to 5 m.

Ventilation and cooling

Growing poultry under only ventilated buildings in an arid climate throughout summer poses problems such as high temperature and low relative humidity. For this reason, producers in all surveyed farms used mechanical fan ventilation and pad evaporative cooling system for summer cooling. Hot outside air was drawn in through a wet pad. The type of pad materials used for evaporating water were cross-fluted cellulose pads. They were installed vertically so that the pad was wetted by distributing water over the pad top. There were different designs for the placement of fans, cooling pads and heaters as shown in Fig. 1. Fans and pads were located on side-walls.

The total area of pads ranged from 40 to 60 m^2, and their heights ranged from 0.5 m to 2m. The distance between the ground and fans was 0.6 m. One square meter of pad was required for an average of 0.056 m^3/s of ventilation. Water was delivered to the top of pads by a pump, and returned to the water return tank. In all farms, no filter was installed for controlling salt and dust buildup in the cooling pads.

The desired air temperature inside the building was varied between 26 and 34^oC according to the age of birds. Table 3 shows desired indoor temperatures from week one until the completion of growing period (week six).

Measurements of air temperatures in the building were accomplished hourly on 56% of farms and daily on 44% of farms either manually by a dry bulb thermometer or automatically by a temperature sensor and a computer. On about 15% of the surveyed farms, the indoor relative humidity was measured daily in the building and was between 30% and 40% during summer, and between 50% and 90% in winter. No measurements were made for carbon dioxide and ammonia concentrations inside the buildings.

Table 3. Set point temperatures inside the building

Age, week	Indoor temperature, ^oC
1	32-34
2	30-32
3	28-30
4	26-28
5	26
6	26

Table 4 shows number of fans, rated ventilation rate for each fan, summer and winter ventilation rates for all farms, and predicted ventilation rate for temperature, moisture and ammonia control. The number of fans in each building varied between 6 and 14 fans. There were two types of fans used for ventilation; small fans (24 inches in diameter) had a rated ventilation rate of 6.67 m^3/s, and larger fans (36 and 48 inches) had rated ventilation rates of 9.72 to 11.39 m^3/s. About 80% of the surveyed farms used large fans for ventilation, while only 20% used small fans.

Table 4. Number of fans, rated ventilation rate for each fan, summer and winter ventilation rates for all farms, and predicted ventilation rate for temperature, moisture and ammonia control

Farm No.	No. of fans/house	Rated Ventilation rate/fan, m^3/s	Ventilation rate/house (m^3/s)		Air exchange rate per minute		Predicted ventilation rate/house, m^3/s								Predicted ventilation rate for ammonia control (m^3/s)
							Summer (with evaporative cooling)				Winter				
			Summer	Winter	Summer	Winter	Temperature control		Moisture control		Temperature control		Moisture control		
							Day	Night	Day	Night	Day	Night	Day	Night	
1	8	10.00	80.00	25.56	1.45	0.46	72.97	16.46	15.16	46.48	3.96	2.33	2.66	2.92	3.59
2	6	11.39	68.34	28.61	0.90	0.38	82.17	18.45	16.97	52.03	4.40	2.58	2.98	3.26	4.02
3	8	11.39	91.12	30.56	1.14	0.38	87.9	19.71	18.13	55.57	4.69	2.74	3.18	3.49	4.29
4	6	11.39	68.34	25.56	0.99	0.37	74.05	16.52	15.16	46.48	3.89	2.26	2.66	2.92	3.59
5	6	11.39	68.34	23.33	1.11	0.38	67.72	15.08	13.84	42.44	3.54	2.06	2.43	2.66	3.28
6	8	11.11	88.88	24.44	1.51	0.42	70.88	15.80	14.50	44.46	3.71	2.16	2.55	2.79	3.43
7	10	11.11	111.1	30.00	1.42	0.38	87.93	19.44	17.80	54.56	4.50	2.58	3.12	3.42	4.21
8	10	9.72	97.2	46.67	0.80	0.38	135.5	30.17	27.68	84.87	7.08	4.11	4.86	5.32	6.55
9	12	6.67	80.0	24.44	1.00	0.31	71.16	15.81	14.50	44.46	3.70	2.14	2.55	2.79	3.43
10	14	6.67	93.38	24.33	1.44	0.36	67.99	15.1	13.84	42.44	3.52	2.04	2.43	2.66	3.28
11	6	11.11	66.66	24.32	1.49	0.41	71.80	15.80	14.50	44.46	3.71	2.16	2.55	2.79	3.51
12	8	11.11	88.88	30.00	1.30	0.38	87.90	17.44	17.80	54.56	4.50	2.58	3.12	3.42	3.50
13	10	9.72	97.2	43.67	0.80	0.38	125.5	27.17	27.68	84.87	7.08	4.11	4.86	5.32	6.41
14	8	10.00	80.0	24.49	0.98	0.31	71.10	15.81	14.50	44.46	3.70	2.14	2.55	2.79	3.78
15	14	6.67	93.38	23.36	1.44	0.36	68.00	15.1	13.84	42.44	3.52	2.04	2.43	2.66	3.21

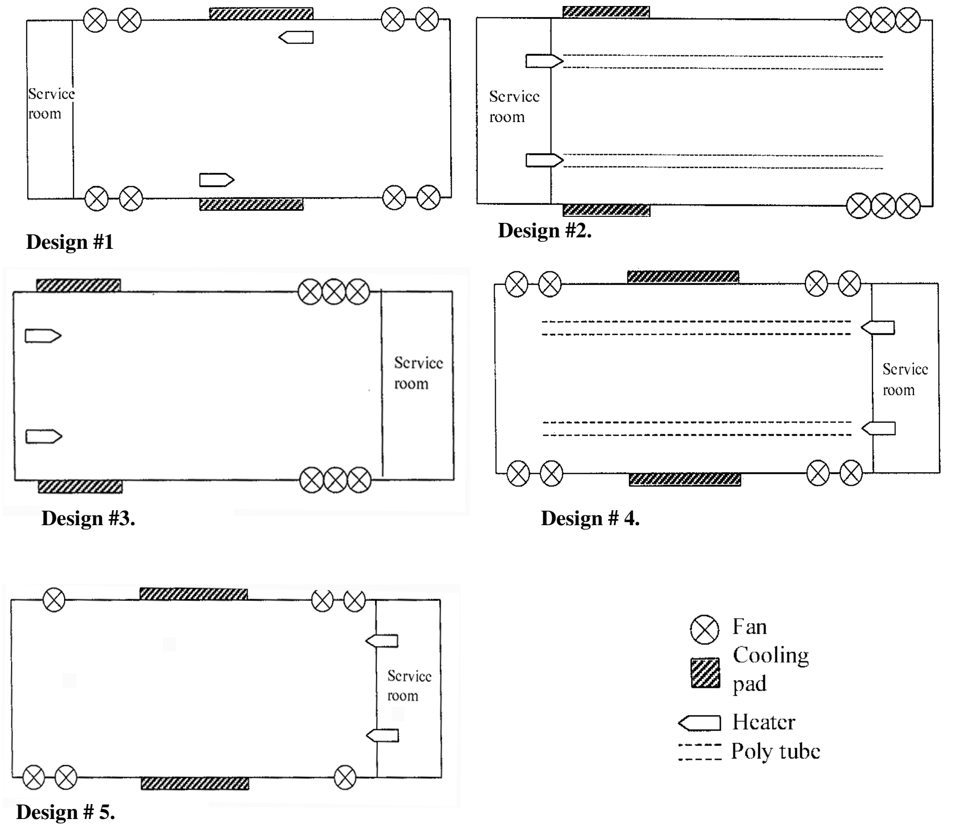

Fig.1. Different designs for the placement of fans, cooling pads and heaters for poultry buildings in the surveyed farms.

Fans were run at their full capacities during summer months to remove excessive heat from the building. Lower ventilation rates were used throughout winter to introduce fresh outside air into the building to remove moisture, gases and odors. As shown in Table 4, summer air exchange rates were ranged from 0.8 to 1.51 air exchanges per minute, while during winter they were ranged from 0.31 to 0.46 air exchanges per minute. Winter ventilation rates were based on 2.67 m^3/hr per kg of body weight, which was 48% higher than the recommended rate of 1.4 m^3/hr per kg [10, p. 97]. It can be seen in Table 4 that winter ventilation rates were much higher than predicted ventilation rates for temperature, humidity and ammonia control. High winter ventilation rates can increase mixing of cold outside air with warm inside air, thus indoor temperature cannot be maintained at the desired level.

Table 4 shows clearly that fan-ventilation systems were capable of controlling moisture and ammonia during summer in all farms. This was simply because ventilation rates required for controlling moisture and ammonia were less than rated ventilation rates for fans. Inside air temperature during summer days can be controlled by fan-pad systems in 67% of farms, while in 33% of farms, rated ventilation rates for fans were lower than the required rates for temperature control. This could reduce the efficiency of cooling system, which in turn reduces the differences between outside and inside temperatures.

It is obvious from Table 4 that ventilation rates for temperature control were predicted to be positive during day and cold night because sensible heat production from birds was high enough to heat air in the building. Table 4 shows that day ventilation rates for temperature control were higher than those required during night. This was because air during winter nights enters at cooler temperature. Also, it can be seen from table 4 that even when it was cold outdoor, ventilation was necessary to control moisture and ammonia. During winter days, estimated ventilation rates for temperature control were higher than those required for ammonia and moisture control. However, during winter nights, predicted ventilation rates for ammonia control were higher than those required for temperature and moisture control. Therefore, ventilation rates for ammonia control were considered to be minimum ventilation rates, and to be continuous during night. In such a condition, supplemental heat was required to maintain the building at the desired air temperature.

Heating systems

In all surveyed farms, heaters were used during winter. Heating system was made up of a fuel burner, heat exchanger, distribution system and controls. Fuel can be Diesel, Gas and Kerosene. The survey showed that in 55% of farms, heat was distributed by discharging hot air directly into the building, and in 45% of farms, heat was distributed through perforated polyethylene duct as shown in Figure 1. There were two types of heaters in terms of thermal output; one had a rated thermal output of 93 kW, and other had a rated thermal output of 116 kW. The number of unit heaters varied from 1 to 3 units per building. About 40% of producers used heaters with a thermal output of 116 kW, and 60% used heaters with a thermal output of 93 kW. In 50% of farms, heaters were indirect fired air heaters where fuel and the air stream were totally separated. The exhaust gases did not go into the building, as they were exhausted out through the flues. On 50% of farms, the exhaust gases went into the building, which increased levels of contaminant. Although increasing ventilation rates removed exhausted gases from the building, heating efficiency was decreased and energy consumption was increased.

A summary of the predicted supplemental heat and thermal output from heating systems for all farms are shown in Table 5. The results showed that all farms had heaters with a thermal output higher than the predicted supplemental heat capacity to maintain the building at the desired air temperature of 34^{o}C.

Table 5. The predicted supplemental heat during winter to maintain the inside air temperature at 34^{o}C, and thermal output from heating systems for all farms

Farm No.	Predicted supplemental heat (kW)	Thermal output from heating systems (kW)
1	45.2	93.0
2	51.8	93.0

3	55.6	93.0
4	47.8	93.0
5	43.9	116
6	45.9	93.0
7	58.5	93.0
8	88	116
9	46.5	93.0
10	44.6	93.0
11	89.3	116
12	67.4	93.0
13	94.1	116
14	67.4	116
15	90.2	116

Automatic control systems

Automatic control systems were used for ventilation, cooling and heating. The control system consisted of a temperature sensor and a controller. A thermocouple was used to sense air temperature deviations. The sensed change produces a switching action to activate fans, the cooling pad pump and heaters. The control systems provided on/off control, meaning that equipment was operating at a rated output or was not operating at all. About 30% of farms used computers for operation of fans and heaters, and wet pad.

Environmental control problems

The survey showed that there were essential problems in cooling, heating and automatic control systems that could result in reducing poultry production in Saudi Arabia. The problems included low efficiency of the cooling and heating systems, non-uniform temperature distribution, clogging of cellulose pads, and the breakdowns of fans, heaters and controllers.

Ground water (well water) was commonly used for evaporative cooling system to wet cooling pads. The common problem of ground water besides its deficiency was that of salinity. The salt content in the water ranged between 700-1200 ppm. As water evaporates from the pad surface, salts in the water were left behind. Salt build up and dust accumulation destroyed the cellulose and plugged passages in the pad reducing the cooling efficiency. As a sequence of this problem, maintenance became necessary in order to sustain the system capability. Such frequent maintenance damaged the cooling pad. The replacement of the pad increased the maintenance costs for the system. In all surveyed farms, salt build up problems occurred after two or three years of use. Also, the water evaporation rate by the pad was very high because of the low ambient relative humidity that increases the vapor pressure differential.

It was also observed that some air leaked through cracks. This lowers the performance of the evaporative cooler because hot ambient air passing through openings without passing through the wet pads increased indoor temperatures. Dust particles were observed inside buildings when fans were running during summer days.

Some producers complained about the low efficiency of the heating system. This resulted in air temperatures were below the optimum level for many hours per season and non-uniform air temperature distribution. This could be because that location of units and minimum ventilation rates were always determined by guesswork. Also, the air infiltration through cracks reduced the heating system efficiency.

Producers who used design #4 for ventilation indicated that they had no essential problems in cooling and heating. They indicated that this design was built by local manufacturers and was modified based on experience to suite arid climate conditions. Some producers indicated that the vertical distance between fans and ground needs to be adjusted for better cooling performance.

It was observed that in some of the surveyed farms, control systems were out of service, dirty or not calibrated periodically. Some sensors, especially in small farms, were exposed directly to the building environment, which could result in worst control than if placed in an aspirated box.

Conclusions

The following conclusions are drawn based on the results of this study:

1. The confined floor space for chickens (ranged between 0.052 and 0.061 m^2/bird) was less than the recommended floor space of 0.093 m^2/bird.
2. The type of roof framing for the poultry building was a gable roof. Walls with a width of 0.2 m were built of two metal boards connected by metal ties and separated by 0.14 m of insulation.
3. Ventilation rates for most of the buildings were between 0.31-0.46 air exchanges per minute for winter, and between 0.80-1.51 air exchanges per minute for summer. Winter ventilation rates were much higher than those required to control moisture and ammonia. High winter ventilation rates can increase mixing of cold outside air with warm inside air, thus indoor temperature cannot be maintained at the desired level.
4. Fan-pad system was used for summer cooling. Fan-ventilation systems should control moisture and ammonia during summer in all farms, and temperature in most farms.
5. Heating systems were used during winter months. All farms had heaters with a thermal output higher than the predicted supplemental heat capacity. Heat was distributed in the building by discharging hot air directly to the building or through perforated polyethylene duct.
6. Automatic control systems were used for ventilation, cooling and heating. Control systems consisted of a temperature sensor and a controller.
7. Problems on farms included low efficiency of the cooling and heating systems, non-uniform temperature distribution, clogging of cellulose pads, and ventilation and heating breakdown. The performance of the evaporative cooler during summer was reported to be ineffective due to salt build up on the cooling pad.

Recommendations

Based on this study, some improvements in the performance of the environmental control systems for poultry buildings in Saudi Arabia could be obtained including:

1) Sealing the opening and cracks for more efficient cooling and heating systems.
2) The confined floor space for chickens should not exceed the recommended rates.
3) Cleaning of the pads used in the evaporative cooling system would result in lower air temperatures in the building.
4) The house should be cleaned after each growout to reduce ammonia and conserve energy.
5) Monitoring manure gas levels within poultry confinement buildings.
6) Fans and heaters should be maintained in good condition for reducing heat gain and loss.
7) Sensors should be accurately calibrated periodically so that higher or lower than desired temperatures are not maintained.
8) Environment sensors should be placed in an aspirated box for better control.

Further research and analysis are needed including:

1) Study the effects of fans and pad placement on air temperature and relative humidity distributions, airflow patterns, dust mass and gases levels, and odors.
2) Evaluate the effects of ventilation rate on temperature and relative humidity inside the building, and air quality in the ventilated airspace.
3) Study and analysis winter ventilation in terms of energy consumption and air quality.
4) Evaluate the influence of indoor environment variations on body weight and temperature.
5) Study the possibility of desalinating and treating water for more efficient evaporative cooler.
6) Study different materials for pad that could be cheaper and easy to maintain.
7) Evaluate fog cooling as an alternative evaporative cooling system to the fan-and-pad system.
8) Determine the heat requirement for buildings.
9) The required pad area should be studied.
10) Develop new controllers for temperature along with relative humidity.

References

[1] Ministry of Agriculture and Water. *Agriculture Statistical Year Book*. Vol. 12, Riyadh, Kingdom of Saudi Arabia, 1999.

[2] Carlie, F. S. "Ammonia in Poultry Houses: A Literature Review". *World's Poultry Science,* 40 (1984), 99-111.

[3] Albright, L. D. *Environment Control for Animals and Plants*. An ASAE Textbook No: 4. St. Joseph, MI., USA: ASAE, 1990.

[4] Hellickson, M. and J. N. Walker. *Ventilation of Agricultural Structures*. An ASAE monograph No: 6. St. Joseph, MI., USA: ASAE, 1983.

[5] Elliott, H. A. and N. E. Collins. "Factors Affecting Ammonia Release in Broiler Houses". *Transactions of the ASAE,* 32, No. 2 (1982), 413-424.

[6] Xin, H.; Berry, I.L. and Tabler, G.T. "Minimum Ventilation Requirement and Associated Energy Cost for Aerial Ammonia Control in Broiler Houses". *Transactions of the ASAE*. 39, No. 2 (1996), 645-648.

[7] Midwest Plan Service (MWPS), *Structure and Environment Handbook*. 11th ed. Ames, IA, USA: Midwest Plan Service, 1983.

[8] ASHRAE. *Handbook of Fundamentals*. Atlanta, GA, USA: American Society of Heating, Refrigerating and Air Conditioning Engineers, 1993.

[9] Al-Helal, I. M. and Al-Twejree, H. "Evaporative Cooling Efficiency for Palm Dates Fiber Pads and Cross-flutted Cellulose Pads under Arid Conditions" (In Arabic). *Misr Journal of Agricultural Engineering*, 18, No. 2 (2001), 469-483.

[10] Sammy, M. *Poultry Production for Small and Large Projects - Keeping, Feeding and Diseases* (In Arabic). Cairo, Egypt: Dar Alfekr Alarabi, 2000.

التحكم البيئي لمباني الدواجن في منطقة الرياض بالمملكة العربية السعودية

إبراهيم محمد الهلال

قسم الهندسة الزراعية، كلية الزراعة، جامعة الملك سعود،

الرياض، المملكة العربية السعودية

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ملخص البحث. تم في هذا البحث دراسة طرق ومشكلات التحكم البيئي لمباني الدواجن في منطقة الرياض بالمملكة العربية السعودية. جمعت معلومات عن أبعاد المباني والعمالة ومواد البناء وأنظمة التهوية والتبريد والتدفئة والتحكم الآلي لـ ١٥ مزرعة تجارية. تم تقدير معدلات التهوية اللازمة للتحكم في درجة الحرارة والرطوبة والأمونيا، كذلك تم تقدير حمل التدفئة المطلوب للحفاظ على درجة الحرارة الداخلية المرغوبة، وذلك لجميع المباني. قورنت هذه المعدلات من التهوية وأحمال التدفئة مع تلك المستخدمة في المباني. أوضحت النتائج أن المساحة الأرضية المتاحة للدجاج تراوحت بين ٠,٠٥٢ إلى ٠,٠٦١ م^{٢}/طير. كما تم إنشاء الجدران والأسقف من ألواح معدنية وطوب ومواد عازلة. استخدم نظام التبريد التبخيري ذو المراوح ووسائد التبريد (اللباد) خلال فترات الصيف. معدلات التهوية الصيفية تراوحت بين ٠,٨ و١,٥١ (تبادل هوائي/دقيقة)، بينما تراوحت معدلات التهوية الشتوية بين ٠,٣١ و٠,٤٦ (تبادل هوائي/دقيقة). دلت النتائج المتوقعة أن معدلات التهوية الصيفية يمكن أن تكون كافية للتحكم في الرطوبة والأمونيا في كل المباني، بينما لا تكون كافية للتحكم

في درجة الحرارة في ٣٣٪ من المباني. دلت النتائج المتوقعة كذلك على أن تهوية المباني خلال الشتاء تعتبر ضرورية للتحكم في كل من درجة الحرارة والرطوبة والأمونيا. كما أن معدلات التهوية اللازمة للتحكم في الحرارة خلال النهار في الشتاء كانت أعلى من المعدلات المطلوبة للتحكم في الأمونيا والرطوبة، بينما خلال أوقات الليل كانت معدلات التهوية اللازمة للتحكم في الأمونيا هي الأعلى. لذا فقد تم اعتبار هذه المعدلات هي أقل معدل تهوية مستمر خلال الليل، وفي هذه الحالة لابد من إضافة حرارة للمباني عن طريق أجهزة التدفئة. أظهرت النتائج أن معدلات التهوية المستخدمة في الشتاء كانت أعلى بكثير من المعدلات المطلوبة للتحكم في الرطوبة والأمونيا مما أدى إلى انخفاض درجة الحرارة داخل المباني عن المستويات المطلوبة في الشتاء على الرغم من أن أجهزة التدفئة المستخدمة كانت ذات قدرة حرارية أعلى من تلك المطلوب إضافتها. ويرجع السبب في ذلك إلى دخول كميات كبيرة من الهواء البارد أثناء عملية التهوية. تم توزيع الحرارة داخل المباني إما بدفع الهواء الحار مباشرة أو من خلال أنبوب بلاستيكي مثقب يمر خلال المبنى. أوضحت نتائج البحث أن من أهم مشاكل التحكم البيئي لمباني الدواجن هي ترسب الأملاح وتراكم الأتربة على وسائد التبريد، وعدم انتظام في درجات الحرارة الداخلية، وانخفاض كفاءة أنظمة التبريد والتدفئة. تم في هذا البحث كتابة بعض التوصيات الهامة لتحسين أداء نظم التحكم البيئي لمباني الدواجن في المملكة العربية السعودية.