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Simulation of the Microclimate in Poultry Structures in Kenya

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Abstract: A computer model based on the thermodynamic principles was developed for simulating the internal temperature responses in a naturally ventilated broiler chicken house. The model used transient thermal analysis with suitable initial and boundary conditions. Developed relationships had the input parameters: outside air temperature; total solar radiation; mass rate of airflow; properties and dimensions of the constructional materials; number of broilers and their average weight as well as the air properties to predict hourly internal air temperature. The mathematical model of the internal temperatures was implemented using a computer program written in Visual BASIC. The program solves analytically the temperatures of the building with the results presented, which compare the model with experimental measurements made in a naturally ventilated poultry house. Experiments were performed using a physical model to test and verify the model at the University of Nairobi, Department of Animal Production at Kabete Campus, between January and May 2009. Results showed no significant difference between the internal air temperatures obtained by simulations and observed measurements. Statistical analysis indicated that the model adequately simulated the internal environment of the building with good linear regression with a coefficient of determination of 0.978.

Key words: Broiler, building, environment, heat transfer, mathematical model, Poultry Sim, ventilation

INTRODUCTION

In Kenya 90% of the poultry keeping is under subsistence systems and contribute to 60% of the eggs and meat produced in the country. It was estimated that poultry population was 25.8 million by 2003 (Menge *et al*., 2005) and had increased to 30 million poultry by 2006 (Gullet and Kisia, 2006), out of which 80% comprises indigenous chicken (*Gallus domesticus*), the rest are improved breed. 19% of the chicken is commercially reared broilers and layers, while 1% is made up of other poultry (ducks, turkeys, geese etc). Commercial chicken consisting of hybrid broilers and layers are kept at the periphery of the main towns such as Nairobi, Nakuru and Mombasa. This is mainly for ease of marketing and procuring of inputs. These commercial chicken make up to 26% of the poultry population. Farmers keep from 100 to 1,000 chickens per batch and in most cases less than 500 chickens. The total egg production per year is approximately 1.182 million and an estimated poultry meat production of 19,058 metric tons per year. Constraints to indigenous chicken production include poor management lack of feed supplementation, lack of disease control measures and inappropriate housing (MARD, 2007).

The environmental conditions inside livestock housings play an important role for improving the performance and welfare of the animals in the farms. Poultry building itself and the ventilation system have to provide an adequate physical environment for the animals. The physical environment inside the poultry buildings is determined by climatic variables, such as temperature, humidity, and air quality, with temperature being the most widely studied variable. Temperature is one of the many aspects of achieving environmental control in poultry buildings (ASAE, 2003). Other aspects include provision of adequate ventilation, illumination, photoperiod, humidity, noise levels and aerial pollutant levels. These variables are affected by the interaction between the outdoor weather conditions and the livestock, building and ventilation system. The most basic and common form of controlling the poultry housing environment is maintaining temperature inside the building within a desired range by adjusting ventilation and heating rates and cooling rate in hot climates. The control actions are based on feedback measurements of ambient temperature collected from one or more locations in the building (Schauberger *et al*., 2000; Hamrita and Mitchell, 1999).

In tropical hot climate areas the reduction of the air temperature inside the animal houses is essential in order to limit the production losses, although difficult to reach especially in closed and crowded buildings. In these circumstances the ventilation and the cooling systems are

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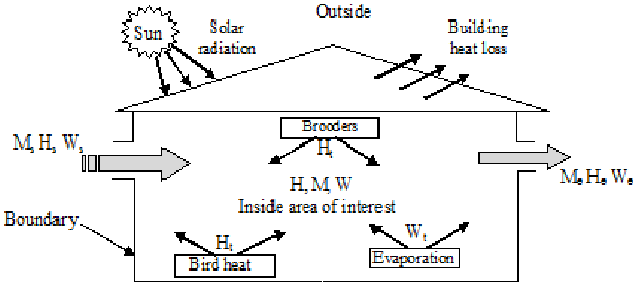


Fig. 1: Heat and moisture balance for a naturally ventilated broiler chicken house air space (Esmay, *et al*; 1986, ASAE, 2003), where: M is mass flow rate of air, kg/h, H_t is enthalpy transfer, kJ/kg, W_t is moisture transfer rate, kg/h. Subscripts *s* and *e* are supply and exhaust air respectively

the crucial points (Bucklin *et al*., 2009). The adequate design of both of them requires the knowledge of the right data, including the prediction of the expected microclimate along the different periods of the year. Inappropriate design, in addition to low quality of the installation and poor maintenance, are some of the causes of the lack of adequate performance of the ventilation and cooling systems, and the unsuitable environment inside the animal housings. The environmental control and the design of a naturally ventilated poultry house are difficult mainly because of controlled variables found outside and inside the structure (Lacy and Czarmick, 2000). This study came up with a mathematical model designed to predict internal temperatures of a naturally ventilated broiler chicken house design with respect to the total heat balance.

Objectives: The specific objectives of the study were:

- To use already established theoretical relationships of thermal balance and the pertinent physical parameters affecting broiler chicken housing to develop a mathematical model for temperature simulation of poultry housing systems in Kenya
- To use computer simulation to solve mathematical model developed in (1) above and
- To use a physical model of the poultry production structure to test and verify model developed.

MATERIALS AND METHODS

Definition of a physical system: To achieve the above objectives, a poultry structure illustrated in Fig. 1 was considered as control volume and the principles of mass and energy conservation applied. The inner surface of the walls, inner surface of the floor, and the ceiling of the structure bound the control volume. Fig. 1 also shows the heat sources and sinks in a poultry building. This physical model reflects the following parameters: building with ventilated side walls; external and internal temperatures; mass of air exchange through the building; conduction heat exchange; solar heat absorption through the roof; sensible and latent heat generated in the building. Fermentation heat production and the heat stored in the building construction materials are neglected. The broiler chicken housing air space is treated as a control volume. The climates from which the chicken are protected from, determine the degree of environmental control to be provided by the structure. Thermal comfort of the chicken is a function of: Air temperature, air velocity, relative humidity, air quality, growth of micro organisms etc.

Development of the mathematical model: The mathematical model is based on energy and mass balance. The model simulates the transient environment inside a poultry house. The energy exchanges due to thermal radiation, latent heat, sensible heat, and ventilation are incorporated (Rajput, 2008; Mendes *et al*., 2001).

For transient state conditions the equation can be cast as:

$$Mc_p \frac{dT_i}{dt} = Q_o + Q_p + Q_t - Q_i - Q_s - Q_f \qquad (1)$$

where; T_i is internal temperature, t is time, M is mass of air inside the control volume, c_p is specific heat capacity of air, Q_o is heat taken with ventilation air, Q_p is sensible heat produced within the building, Q_t is steady-periodic heat conducted through the walls or roof (into space), Q_i heat exhausted in the ventilated air, Q_s Steady state heat conducted through walls or roof (out of space), Q_f heat transferred through the floor (out of space).

Ventilation heat exchange: The ventilation rate of a building is the sum of the air flows at all the outlets or inlets (Cooper *et al*., 1998). The overall ventilation heat exchange is given by:

$$Q_v = Mc_p (T_i - T_o) \qquad (2)$$

For steady periodic overall heat is given by:

$$Q_v = Mc_p\,(T_{im} - T_{o.m}) + Mc_p\,(T_{i,n} - T_{o,n})\mathrm{Cos}(\omega_n\theta - \varphi_n) \quad (3)$$

where; $Q_{vo\ is}$ total heat transmitted into the building by ventilation (W), Q_{vi} is total heat transmitted out of the building by ventilation (W), M is mass air flow rate through the building (kg/s), C_p is specific heat (J/kg ºC), T_i is inside temperature (°C), T_o is outside temperature (°C), ω angular velocity of the sinusoidal waves (radians s-1).

Solar heating: Solar heat absorbed at the outside surface of the walls and roof is conducted into the building. This conduction is calculated by first finding the sol-air temperature, T_s is the sol-air temperature used directly to calculate heat fluxes through surfaces in the building. The rate of heat transfer Q_o from external environment to the outside surface of the sunlit wall or roof may be written as (Mutai, 2002).

$$Q_o = h_o\,(T_o - T_{w,o}) + \alpha l \quad (4)$$

where;
h_o is the convective heat transfer coefficient
T_o the temperature of the outdoor air
$T_{w,o}$ is the temperature of the outside surface, α solar absorptivity of the outside surface
I is the combined incidence of solar radiation (direct, diffuse and reflected) upon the surface

The periodic heat flux due to solar heating is given by:

$$(Q_{cd})_{sn} = \sum_{N=1}^{N} A_{wN}\ U_N\,(T_{s,m} - T_{i,m}) + \lambda_n T_{s,n}\,\mathrm{Cos}\,(\omega_n\theta - \psi_n - \Phi_n) - T_{i,n}\,\mathrm{Cos}\,(\omega_n\theta - -\psi_n) \quad (5)$$

where;
Q_{cd} is the heat conducted
A_{WN} is the area of the wall side number N
T is the temperature with subscripts s, m, o and i for sol-air, mean, outside and inside respectively
U is the universal heat transfer coefficient
Ψ is the sun's Zenith angle
Φ is the lag angle; ω angular velocity of the sinusoidal waves (radians s-1)
l_n is the decrement factor

Heat Conducted through the walls and roof: Steady state periodic heat transfer through the wall and roof was considered. The average outside temperature is not expected to equal the average inside temperature. If we assume a structure with thermally homogenous walls and roof and one dimensional heat transfer we have:

$$Q_{cd} = \sum_{N}^{N} =_1 A_{w,N}U_N\ [(To,m - T_{t,m}\,\mathrm{Cos}(\omega_n\theta - \psi_n))] \quad (6)$$

Sensible heat produced by broilers: The sensible heat produced by the broilers is assumed to be linearly related to the inside temperature. By means of multiple linear regression, effect of live weight, inside temperature and relative humidity is given by (Chwalibog and Eggum, 1989) as:

$$HE = 7.97L^{0.75}\ 5.87T_i + 2.38RH \quad (7)$$

where: HE is sensible heat (kJd-1), LW is the live weight, kg, and T_i is the inside temperature in °C.

From the foregoing equation (Nyambane *et al*., 1999) modified to give a transient sensible heating by the broilers as:

$$Q_{se} = (\beta - \gamma T_i)\,ANo = \{\beta - \gamma T_{i,m} - \gamma T_{i,m}\ \cos\,(\omega_n\theta - \psi_n - \Phi_n)\}Ano \quad (8)$$

where; Q_{se} is sensible heat production (W), β is the constant associated with sensible heat production (W), β is $11.92 + 7.8LW^{0.78} - 5.45LW^{0.64}$, LW is the live weight, γ is constant = 0.0408, T_i is the inside temperature, ANo is the number of broilers

Latent heat produced by broilers:

$$Q_{se} = (\beta - \gamma T_i)\,ANo = \{\beta - \gamma T_{i,m} --- \gamma T_{i,m}\ \cos\,(\omega_n\theta - \psi_n - \Phi_n)\}\ Ano \quad (9)$$

where;

$$\beta = 8.42 + 19.63L\omega^{0.64} \text{ and } \gamma = 6.0 \quad (10)$$

Supplemental heating: Supplemental heating was provided during the time of the study, as the weather was too cold for brooding. This heat was estimated (Mutai, 2010) as:

$$Q_{su} = P\theta \quad (11)$$

where; Q_{su} is supplemental heat supplied (W), P is the power rating of the heating element (W), θ is time (s)

The mathematical model: By substituting the various expressions developed earlier into the energy balance equation we obtain (Threkeld, 1970; Mutai, 2010):

$$P\theta + mcT_{o,n}\cos\,(w_n\theta - \psi_n) + \beta\ \gamma - T_{i,m} - T_{i,n}\ \cos\,(w_n\theta - \phi_n) + {=}1A_rU_r\,(T_{s,m} - T_{i,m} + \lambda_n\cos\,(\omega_n\theta - \phi_n\ \Phi_n) - T_{i,n}\cos\,(\omega_n\theta - \phi_n))) + \sum_{n\ =1}^{N} A_{wN}U_N\,(T_{o,m} - T_{i,m} + T_{,on}\cos\,(\omega_n\theta - \phi_n))) - mcT_{i,n}$$

$$-mcT_{i,n}\cos(\omega_n\theta_n-\phi_n)=-\omega^n Mc\sum_{n=1}^{\infty}A_{wN}U_N$$
$$(T_{o,m}-T_{i,m}+T_{o,n}\cos(\omega_n\theta-\lambda_n))-mcT_{i,n}-mcT_{i,n}$$
$$\cos(\omega_n\theta-\phi_n))=-\omega n Mc\sum_{n=1}^{\infty}\lambda_n$$
$$T_{n,o}\sin(\omega_n-\phi_n) \tag{12}$$

For (12) above, the properties are temperature dependent and require that the equation be solved iteratively using suitable computer program.

It can also be broken down to the steady state and steady-periodic equation. The steady state equation is:

$$P\theta+mcT_{o,m}+\beta-\gamma Ti,m+1A_{wN}UN(To,m-T_{i,m})$$
$$-mcT_{i,m}+A_rU_rT_{i,n}+A_rU_r(T_{s,m}-T_{i,m})=0 \tag{13}$$

Average inside temperature can be computed from equation:

$$T_{i,m}=$$
$$\frac{p\theta+m_cT_{o,m+\beta+\sum_{n=1}^{N}A_{WN}UT_{o,m+A_r}}U_rT_{s,m}}{mc+\gamma+\sum_{n=1}^{N}A_{WN}U_{N+}A_rU_r} \tag{14}$$

The steady periodic equation is obtained by subtracting (12) from (13). The remaining terms are:

$$mcT_{o,n}\cos(w_n\theta-\phi_n)-mcT_{i,n}\cos$$
$$(w_n\theta-\psi_n))-\gamma T_{i,n}\cos(w_n\theta-\psi_n)+$$
$$ArUr(\gamma_n T_{s,n}\cos(w_n\theta-\psi_n-\Phi_n)+A_WNU_N$$
$$(T_{o,n}\cos(w_n\theta--\psi_n)-T_{i,n}\cos(w_n\theta-\psi_n))$$
$$+\sum_{n=1}^{\infty}\lambda_n T_{n,o}\sin(w_n-\phi_n)=0 \tag{15}$$

Thus the internal air temperature harmonic coefficient is given by:

$$T_{i,n}$$
$$\frac{mcT_{o,n}\cos(w_{n\theta}\_\varphi_{n)+}A_rU_r(\gamma_nT_{s,n}\cos(w_{n\theta}\_\psi_n\_\Phi_{n))}\cos(w_{n\theta}\_\psi_n\_\Phi_{n)}}{mc+\gamma+\sum_{n=1}^{N}A_{WN}U_N\cos(w_{n\theta}\_\psi))+A_rU_r\cos 9w_n\theta\_\psi_{n)}}$$

$$\frac{A_{WN}T_{o,n}\cos(w_n\theta\_\psi_{n)}}{-w_nMc\sum_{n=1}^{\infty}\lambda_{n.o}\sin(w_{n-\varphi_n})} \tag{16}$$

A computer code (Holmes, 1987) written in Visual Basic was used to implement the formulation for the mathematical model developed in (14) and (16). A computer software PoultrySim was developed based on the mathematical models developed earlier. The software is designed in a way engineers evaluating heating and ventilation of poultry environment can use it. The input parameters are; areas of different constructional materials, universal thermal transmittance for the different materials used, mass flow rate of air, power rating of the heating element, ventilating air, number of broilers and their average live weight. The program requires the outside temperature at an hourly interval to predict hourly internal temperature, mean internal temperature, hourly sol air temperature and mean sol-air temperature. A computer program flowchart for the implementation of the model is appended as Fig. 16 with a graphic User interface interactive dialogue boxes from Fig. 17, 18 through Fig. 19.

Data acquisition and verification by a prototype broiler chicken house: The study was conducted during the between January and May 2009 at the University of Nairobi, Department of Animal production, Poultry Unit, which lies on a latitude of 1º16″ S and Longitude of 36º47″ E on an altitude of 1980 m, with tropical weather characteristics. The building which is already in place partially opens on the side for natural ventilation. Sketches showing dimensions (side view and floor plan) of the house are shown in Fig. 14 and 15; the walls are constructed in concrete block, glass windows, with both steel and wooden doors and iron sheet roof. The house is oriented in east west direction to allow the maximum use of available wind to ventilate the house, and to reduce the amount of radiation entering the house, through the ventilation windows. The house was used as the brooder house housing about 300 chickens at the time of the study.

Experimental investigation: Inside temperature of the poultry house was measured using a data acquisition system (Data Logger, PC-logger 2100 (PC-Logger, 1993) and a thermo hydrograph). A PC-loger 2100 together with software (INTAB Easy View) and a personal computer running on Windows platform was used. This is a versatile and a powerful data acquisition system. The logger measures the full range of industrial analogue signals: +/- 10 V, +/- 1 V and +/-20mA. It is also possible to directly connect thermocouples for temperature measurement. Cold junction compensation and linearization are internally handled by the logger. Thermocouple wires were prepared, and one end connected to the PC-logger 2100 while the other was positioned at the bird level. The thermocouple wires were copper and constantan whose ends were connected such that they could be used to determine the absolute temperature or the temperature difference between two points.Temperature variation between the outside and the inside of the poultry house were measured at hourly interval. Recordings were made directly to the storage media on the host computer (on-line recording) and temporarily to the internal memory in the logger (off-line recording). The arrangement constituted remote experimentation shown in Fig. 13. The components of remote experimentation include: Computer, Data Logger, Sensors (probes) and data cables. Also a thermo hydrograph and a globe thermometer were installed at about 0.3 m above the floor. From the thermo hydrograph, daily minimum and maximum temperatures and relative humidity could be extracted from record sheet. Thermo hydrograph was calibrated on daily basis. The outside air temperature, wind speed at 10 meter height and solar radiation were extracted from weather station records.

Validating the solution for naturally ventilated building: The model is a continuous dynamic model where simulated time advances and endogenous variables are updated each time and required the use of data acquisition systems and computer programming language. Sensitivity analysis was done to evaluate the exogenous variable response relative to simulation results, i.e., to test rigorously the model in terms of mathematical logic and stability.The model was verified to ascertain that the programming logic conforms to the intentions of the model. Comparisons were made between the simulated; the measured and predicted internal temperature by the model to those by the experimental procedures was conducted in order to test the accuracy of the model. Calibration of the model was then done accordingly. This involved adjustment of certain parameters and systematical comparison of simulated results to field observation done to improve model accuracy. After model verification, model validation was done. Model validation is the process by which simulation model results are compared to field data not used previously in calibration process (Loewer, 1994). A comparison of simulation method to the observed data based on Visual Basic program was done. This process compared the simulated model results to the measured data. Results from the simulation and experiments were then subjected to various statistical tests to determine their trends and difference of means using a computer spreadsheet package, Microsoft Excel 2007, Analysis Tool-Pak.R^2 test was performed to statistically compare the value and trend of computed and the observed values. Graphs of observed values were done to check for "closeness of fit" (correlation coefficient). Trends of the results were assessed using the general linear model while the differences between the values at a various points of interest and results determined by paired comparisons using the t-test.

RESULTS AND DISCUSSION

The results of inside temperature predictions using Poultrysim developed with their corresponding measured temperature are illustrated graphically in Fig. 2, 4, 6 and 8. Their statistical comparison of both value and trend between computed and observed values shown in Fig. 3, 5, 7 and 9. The 5-days measured and predicted temperature hourly trend is given in Fig. 10 with comparison of measured outside, inside and predicted inside shown in Fig. 12. The 4-days consolidated relative humidity of the inside of the poultry in Fig. 11. The relationship as depicted in Fig. 2 through Fig. 12, between

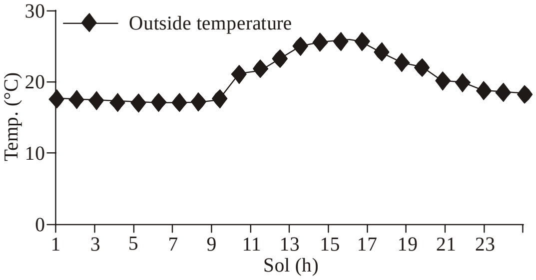


Fig. 2: Comparison of predicted sol-temperature and outside temperature variation with time

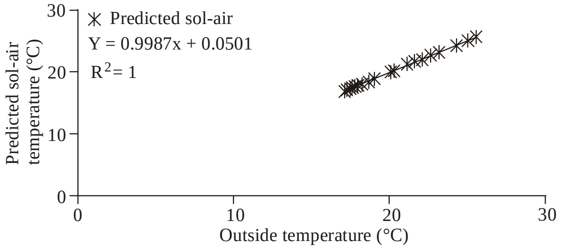


Fig. 3: Correlation of predicted Sol-air temperature versus outside temperature

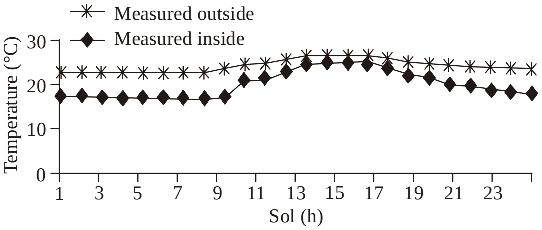


Fig. 4: Comparison of temperatures measured inside and measured outside

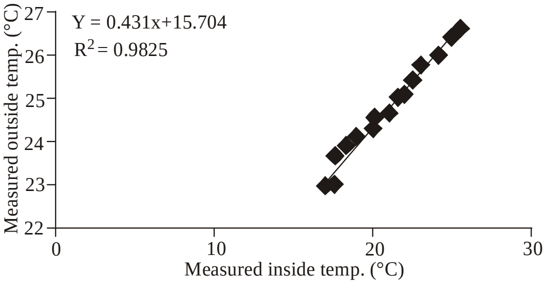


Fig. 5: Correlation of measured inside and outside temperature variation with time

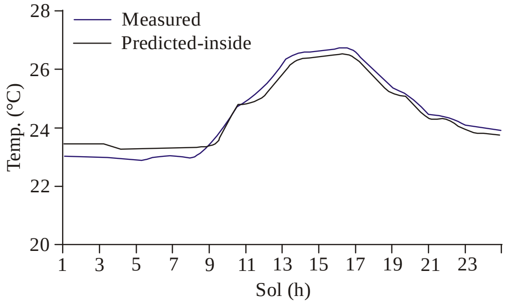


Fig. 6: Relation of predicted inside and measured inside temperature

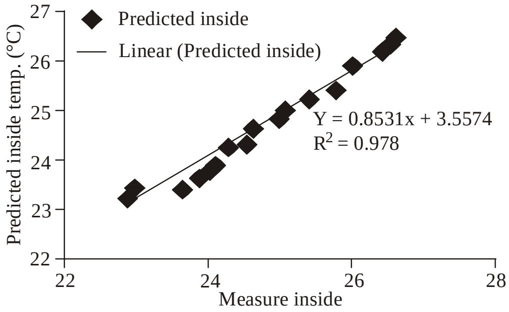


Fig. 7: Correlation of predicted inside and measured inside temperature

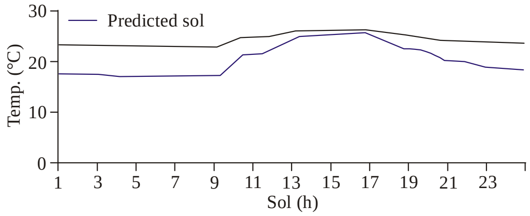


Fig. 8: Comparison of predicted sol-temperature and predicted inside temperature

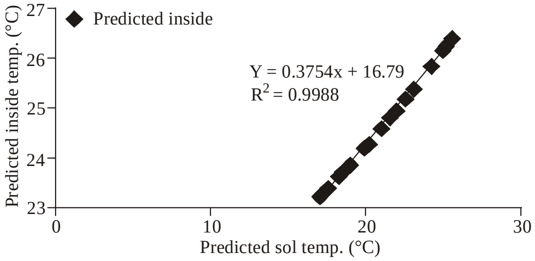


Fig. 9: Correlation of predicted Sol-temperatures and predicted inside temperature

measured and predicted air temperatures, outside and sol-air, as well as relative humidity indicate a non steady state. Diurnal variations produce approximately repetitive 24 h cycle of increasing and decreasing temperature the cycle can therefore be described as periodic. When outside temperature are higher on the outside heat flows

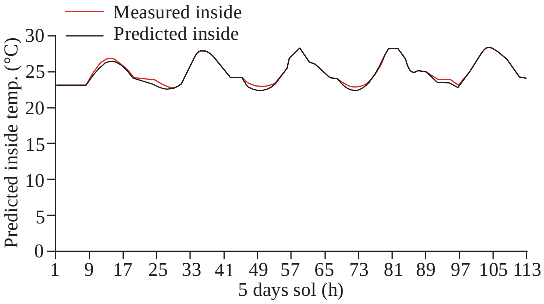


Fig. 10: 5 Days measured and predicted inside temperature hourly trends

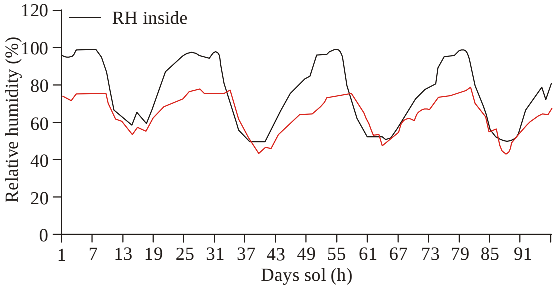


Fig. 11: 4 Days relative humidity trend

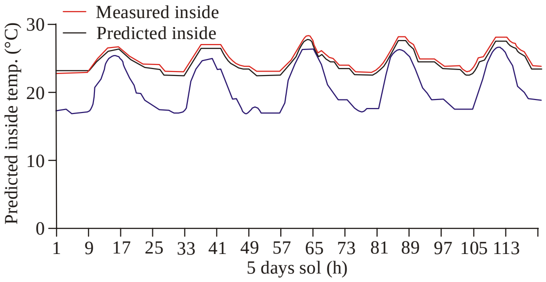


Fig. 12: 5-Days comparison for outside, inside and predicted inside temperature

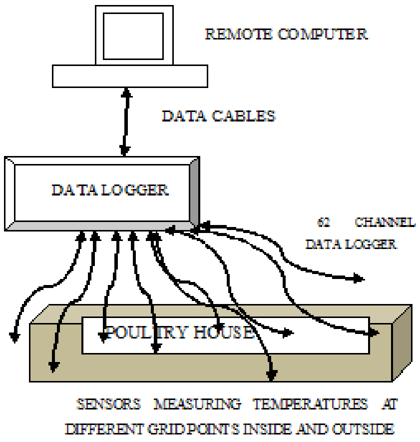


Fig. 13: Remote experimentation using data logger

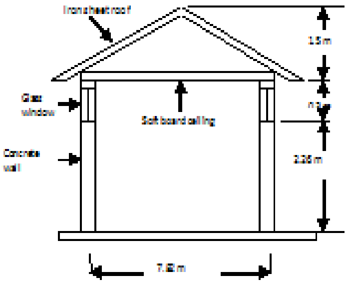


Fig. 14: Poultry structure at Kabete campus

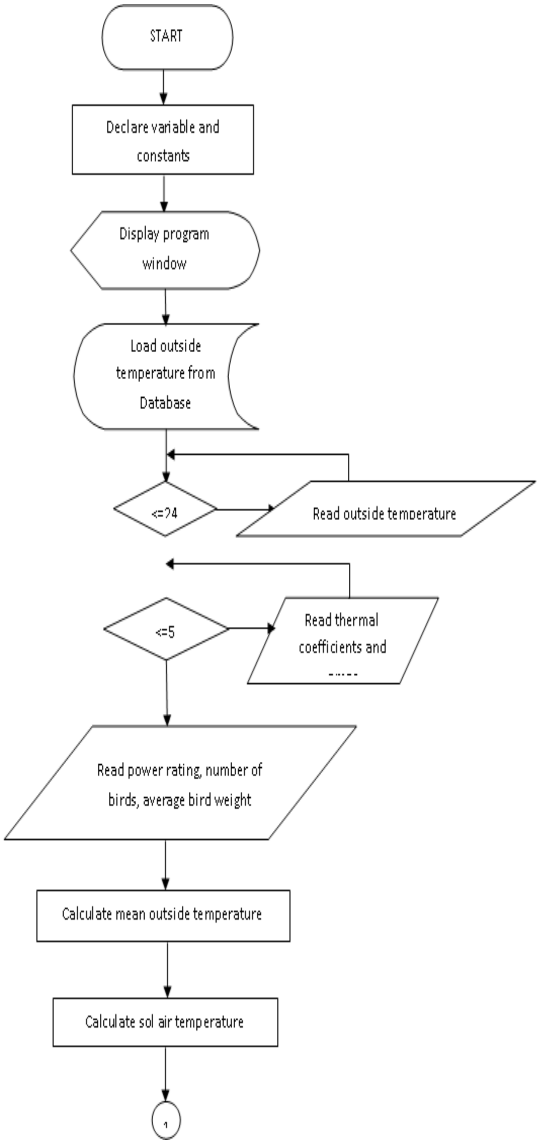


Fig. 15: Floor area of the poultry house at Kabete

from the environment into the poultry house where some is stored therefore thus elevating inside temperature, at night during cool period heat flow is reversed. From

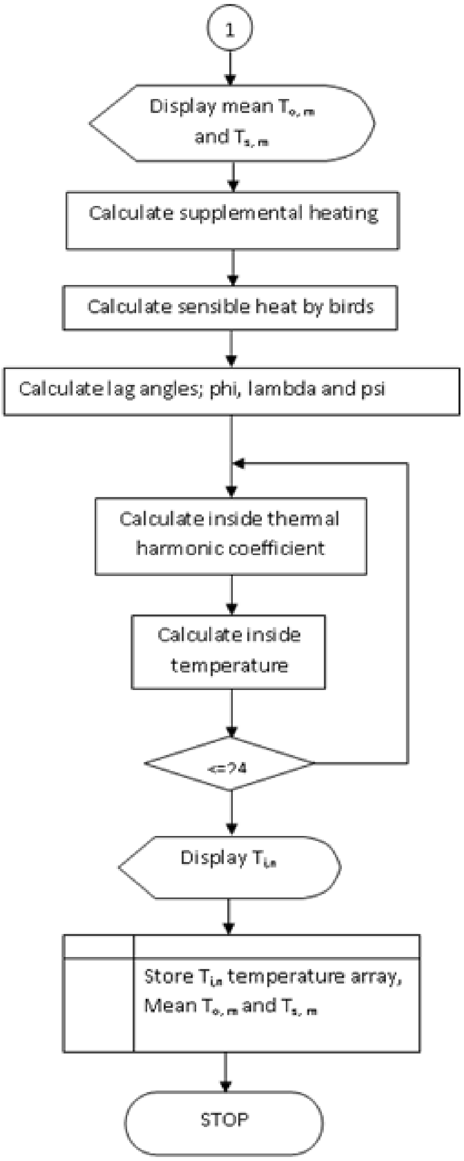
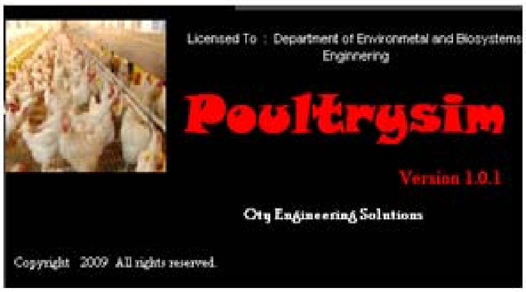


Fig. 16: Program flowchart



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Poultrysim

Version 1.0.1

Oty Engineering Solutions

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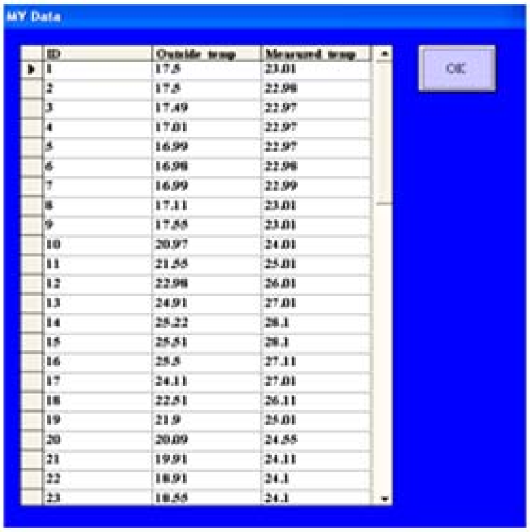
Fig. 17a: Splash screen showing Application and version information

Table 1: Comparison of measured to predicted temperature variation with sol-time for the inside, outside and sol air

		Temperature in ºC		Relative humidity in %		
Sol-bours f rom mid night	Measured inside	Predicted inside	Measured out side	Predicted sol	RH inside	RH outside
0	23.01	2338	17.50	17.52	9899	7751
1	22.98	2338	17.50	17.52	9897	7899
2	22.97	2338	17.49	17.51	9959	78.11
3	22.97	2322	17.01	17.03	100	77.01
4	22.97	2322	16.99	17.01	9999	78.11
5	22.98	2321	16.98	17.00	100	7755
6	22.99	2322	16.99	17.10	100	7999
7	23.01	2326	17.11	17.13	9995	75.01
8	23.01	23.40	17.55	17.57	9751	70.01
9	23.01	24.61	20.97	20.99	95.01	63.11
10	24.01	24.83	21.55	21.57	85.01	57.01
11	25.01	2539	22.98	23.00	80.01	55.11
12	26.01	2618	24.91	2493	75.01	51.10
13	27.01	2631	25.92	25.24	6991	53.05
14	28.01	2643	25.51	25.53	6353	53.01
15	27.11	2643	25.50	25.52	60.01	57.01
16	27.01	25.85	24.11	24.13	50.01	60.01
17	26.11	25.20	22.51	22.53	65.02	68.01
18	25.01	2496	21.90	21.92	75.11	69.01
19	24.55	2428	20.09	20.11	8455	71.11
20	24.11	2422	19.19	19.93	86.01	72.11
21	24.10	23.86	18.91	18.93	93.01	73.11
22	24.10	23.74	18.55	18.57	94.01	73.01
23	24.01	23.62	18.19	18.21	95.01	7099
Average	24.43	24.40	20.25	20.27	86.1	6829
Minimum	24.01	23.26	16.98	17.0	50.01	50.11
Maximum	28.01	26.43	25.51	25.53	100	7899



MY Data

ID	Outside temp	Measured temp
1	17.5	23.01
2	17.5	22.98
3	17.49	22.97
4	17.01	22.97
5	16.99	22.97
6	16.98	22.98
7	16.99	22.99
8	17.11	23.01
9	17.55	23.01
10	20.97	24.01
11	21.55	25.01
12	22.98	26.01
13	24.91	27.01
14	25.22	28.1
15	25.51	28.1
16	25.5	27.11
17	24.11	27.01
18	22.51	26.11
19	21.9	25.01
20	20.09	24.55
21	19.91	24.11
22	18.91	24.1
23	18.55	24.1

Fig. 17b: "My data" form window showing data loaded from the database

Fig. 18: Main form window

Fig. 8 the predicted inside temperature are higher than predicted sol air temperature but show similar trend with low temperature attained form mid night to about 7 am. Maximum temperatures attained between noon and 2 pm. Both outside and sol temperatures exhibit a general trend. From 3 am to 12 noon there is an increase with an increasing rate to a maximum at 2 pm then declines with time. Measured and predicted internal temperatures also exhibit a general trend with peak at 2 pm.

There is a significant difference in average temperatures, except for measured outside verses predicted sol air temperatures. These two comparisons show no significant difference in their means suggesting that the data obtained were closely related (Table 1). Predicted inside temperature values showed same trend as the measured inside temperature but with slight difference resulting from assumptions made and constants used in the mathematical model to the major modes of heat exchange and quantification of the constants. Other forms of heat sources that affect temperature of poultry house

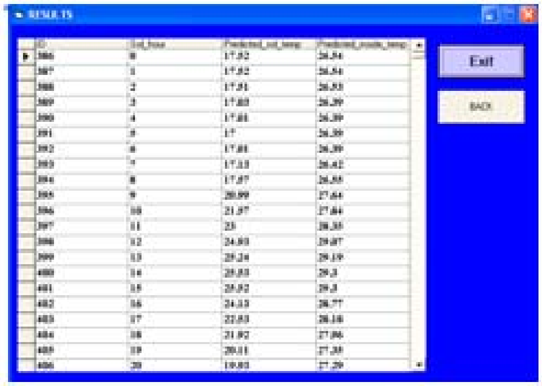


Fig. 19: Results window showing predicted sol-air and inside temperatures

such as convective heat exchange and mass transfer that are not quantified in the model may be affecting the inside temperature of the building.

The statistical measure of coefficient of determination R^2 value of 0.978 shows a good correlation between the observed and simulated internal temperature.

Statistical analysis using t-test as done using MS-Excel Analysis Toolkit taking null hypothesis that the mean difference of measured and predicted temperatures are zero, with 5% level of significance, we can write:H_0:$\mu_1 = \mu_2$ this equivalent to test H_0: D = 0 (No significant difference) H_a: $\mu_1 < \mu_2$ (As we want to conclude that the difference is significant) For 120 values with 119 degrees of freedom (d.o.f) tStat = 0.8048892 we therefore conclude that the difference between the means is insignificant thus accept the hypothesis H_0. Further analysis of previously reported experiments (Mutai, 2002; Nyambane *et al*., 1999; Mendes *et al*., 2001) showed similarly trends. The deviations between internal surface temperatures predicted and measured are due to other factors which might not have been included in the model development such as moisture concentration, gaseous concentrations, building orientation and shadow projection by the roof.

CONCLUSION

Results of the research indicate that it is possible to simulate internal temperature changes in poultry housing using an empirical mathematical model based on thermal balance. The model gives accurate trend of hourly internal temperature. As it was earlier hypothesized it was found that sol-air temperature can be used to give an accurate prediction of the inside temperature than considering outside temperature only. The temperature lift inside the poultry house is primarily determined by ventilation rate, stoking rate and constructional materials. Computer simulation model program POULTRYSIM developed in Visual Basic 6.0 language computes Sol-air temperatures, mean outside temperature and the predicted the hourly inside temperature based on hourly measured outside temperature recording and other pertinent parameters. Statistical comparison of observed or measured inside temperature against predicted give a correlation coefficient R^2 value of 0.978 showing that the model developed is sufficiently accurate.

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