Calculation of supplementary heat required in a broiler house in Kahramanmaraş region (Turkey)

Berechnung des zusätzlichen Wärmebedarfs in einem Broilerstall in der Region Kahramanmaraş (Türkei)

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Introduction

Animal proteins have great important in solving nourishing problems. Broiler breeding is important because it is more economical than the other animal nutrient supply. Besides, it provides proteins to human beings in a shorter time period than the others do. Chicken production in Turkey was 617,895 tons in 1998, and 80 percent of chicken was produced by broiler enterprises. The chicken meat consumption was 3.84 kg per capita in 1990 and it increased to 9.53 kg in 1998 (BÜLBÜL et al. 1999). In broiler production, besides genetic structure of the broiler, quality of feeding, control of diseases, proper breeding methods, and environmental conditions inside broiler houses are also very important factors. All these factors influence broiler development. Among the environmental factors, temperature has to be 305.0-306.0 K during the first two weeks. It should be decreased by 275.5-276.0 K per week and come down to 294.0 K in 4th and 5th weeks. Chicks are grown up in a location divided by a plastic curtain from the first week to the end of the fourth week. After the fourth week, the plastic curtain is removed and chicks are separated into the broiler house according to their growth rate (LIDLEY and WHITAKER 1996).

Environmental condition inside broiler houses is the most important factor influencing broiler development and yield. Environmental conditions that are above or below the optimum limits negatively affect performance. The highest performance can be obtained with less feeding from broiler living between optimum limits (OSBALDISTON and SAINSBURY 1963; ERNST 1995). In order to obtain the highest performance, temperature of broiler houses should be kept in optimal level by reducing heat loss and using supplementary heating when needed (ANONYMOUS 1987).

The requirement of supplementary heat in broiler houses will vary in accordance with the insulation of broiler house, animal heat production as a function of age and density of chicks and growing season. Moreover, the climatic conditions of the region the broiler house is planned for has to be taken into consideration. Kahramanmaraş region has Mediterranean climatic conditions with hot and dry summers, and rainy and warm winters. High wind speed (4.9 - 6.7 m sn⁻¹) and high numbers of blowing (288 - 432) in summer are typical characteristics of this region. This study was conducted to determine optimal environmental conditions inside the broiler house with a local heating system by calculating the required supplementary heat in W. This was accomplished by determining crucial months within the year and calculating the required supplementary heat in order to prevent excessive temperature.

Material and Method

In order to plan a natural ventilated broiler house with a capacity of 10,000 birds and to provide optimum environmental conditions, various project criteria were used to calculate required supplementary heat. In the project no heating systems as ovens or gas heaters were used. An area of 0.075 m² per chick was considered according to WOOLLEY (1965) and BROWN et al. (1977). Accepting a width of 10 m net space (ÖZEN 1992; ERNST 1995), the length of broiler house was calculated as 81.4 m. The following considerations were also made: Minimum 0.29 m³ of inside air volume per chick (ALAGÖZ 1983), 2.75 m glass wool in market, a 6 cm glass wool was chosen instead. In order to examine the relationship between insulation and required supplementary heat, insulation material in four different widths (3, 6, 8 and 10 cm) was used and required supplementary heat, insulation material on the roof was calculated as 4.22 cm to provide heat and humidity balance in the planned broiler house. Since there was no 4.22 cm glass wool in market, a 6 cm glass wool was chosen instead. In order to examine the relationship between insulation and required supplementary heat, insulation material in four different widths (3, 6, 8 and 10 cm) was used and required supplementary heat for each width was calculated. This equation can be written in the form:

\[ Q_m = Q \] (1)

\[ Q_m \geq q_y + q_h \] (2)

where \( Q_m \) is sensible heat released by the animals in W, \( Q \) is total heat loss in W, \( q_y \) is heat loss from structural elements (roof, wall, window, door) in W, and \( q_h \) is heat loss through ventilation in W.
Equation 2 may not provide heat balance all the time. There is a heat deficit if $Q_m$ is less than $q_y + q_h$. In that case, heat loss is inevitable and supplementary heat is required to raise broiler house’s temperature in optimal level. There is surplus heat if $Q_m$ is greater than $q_y + q_h$. This extra heat should be removed by ventilation. Heat loss ($q_y$) from structural elements can be calculated by using the equation (CIGR WORKING GROUP 1984; ALBRIGHT 1990):

$$q_y = \sum U A \Delta t$$  \hspace{1cm} (3)

where $\Sigma U$ is the coefficient of conductance of structural elements (Wm$^{-2}$K$^{-1}$), $A$ is the surface area of structural elements in m$^2$, $\Delta t$ (ti-to) is the difference between inside (ti) and outside (to) temperature of broiler house (K).

The coefficient of total heat conductance of structural elements ($U$) was calculated by using following equation.

$$U = \frac{1}{\sum_{i=1}^{n} \frac{d_i}{k_i} + \frac{1}{f_i}}$$ \hspace{1cm} (4)

where $f_i$ and $f_o$ are the surface coefficients of inside and outside heat conductance of structural elements in Wm$^{-2}$K$^{-1}$, $d$ and $k$ are width of structural elements in m and thermal conductivity in Wm$^{-1}$K$^{-1}$, respectively.

In order to determine whether there is condensation inside the surface of structural elements, surface temperature should be calculated by using the following equation:

$$t_s = t_i - \frac{U}{f_i} (\Delta t)$$ \hspace{1cm} (5)

where $t_s$ is the inside surface temperature of structural elements in K, $f_i$ is inside conductance of wall surface in Wm$^{-2}$K$^{-1}$.

After the broiler house had been planned, the probability of temperature (some month’s average temperature for long term was given in Fig. 1) and relative humidity to estimate heat and humidity balance in the broiler house was calculated by “Weibull method” (TÜLÜCÜ 1988). To apply this method, long term monthly temperature and relative humidity data were used. As a result of this calculation, the coldest and warmest months were determined as crucial months with a contingency of 80 percent. Thus, broiler growing periods coinciding these critical months were determined.

Broilers are produced in six periods within a year. Optimum heat and humidity requirements of broiler change weekly. For this reason, general heat balance equation was used to calculate supplementary heat for two 8-week periods (BALABAN and ŞEN 1982). One of these periods included the coldest crucial month, and the other included warmest crucial month in a year. Water content of inside the broiler house was 70% (MATON et al. 1985). Various degrees of temperature, sensible heat, total heat, water content, and broiler weight were obtained from Table 2 (ANONYMOUS 1996).

Required supplementary heat for first two weeks was calculated for floor areas of 0.03 m$^2$ per chick. In the third and fourth week 0.05 m$^2$ per chick was used and an area of

<table>
<thead>
<tr>
<th>Structural Elements</th>
<th>Used Structural Elements</th>
<th>Area of Structural Elements (m$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1-2 weeks</td>
</tr>
<tr>
<td>Floor</td>
<td>Hard core and 2.5 cm concrete skim</td>
<td>329.3</td>
</tr>
<tr>
<td>Walls</td>
<td>40x20x20 cm briquette, both side 2 cm plaster</td>
<td>168.0</td>
</tr>
<tr>
<td>Roof</td>
<td>4 mm asbestos, 6 cm glass wool</td>
<td>364.8</td>
</tr>
<tr>
<td>Door</td>
<td>Wood</td>
<td>2.2</td>
</tr>
<tr>
<td>Window</td>
<td>Wooden frame, 3 cm glass</td>
<td>49.5</td>
</tr>
<tr>
<td>Curtain</td>
<td>1 mm PVC curtain</td>
<td>38.4</td>
</tr>
</tbody>
</table>

Table 1. Information about structural elements of the planned broiler house.

Daten über die strukturellen Elemente des geplanten Broilerstalls

Figure 1. Monthly average temperature for long term (temperature values of these four months were given, because January and August are crucial months and rearing was continued to the middle of February and September)

Monatliche Durchschnittstemperaturen auf Langzeitbasis (Temperaturen für die genannten Monate werden angegeben, nachdem Januar und August kritische Monate sind und die Haltung bis Mitte Februar bzw. September fortgeführt wurde)

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The required supplementary heat in broiler houses was the difference between the heat loss from structural elements and ventilation, and the heat emitted by the chicks. The amount of heat loss from structural elements varies according to the difference between indoor and outdoor temperatures and the insulation thickness. The amount of required supplementary heat was calculated by using 3 cm, 6 cm, 8 cm, and 10 cm thick glass wool on the roof of broiler house and the results were given in Tables 3 and 4. The required heat by chicks for January corresponding to the above glass wool thickness for 8 weeks was calculated as 30963-38163, 28514-35714, 27744-34944, 27254-34454 W, respectively. Table 3 shows that if rearing is started on January 1st, there will be a need of heating for all thickness of the glass wool during the 8 weeks period. If rearing is started on August 1st, there will be no need of heating except in the third week of the growing period. Since the chicks do not produce any heat in the first week and they prefer relatively higher temperature in the first two weeks, supplementary heat for the first two weeks might be required. This supplementary heat was calculated for each of 3, 6, 8, and 10 cm thick glass wool and yielded to 3887, 3913, 3921 and 3926 W (week 1-2), respectively (Table 4). Results showed that as thickness of insulation increased supplementary heat requirement decreased to 580-2898 W in winter season and 5-25 W in summer season.

Discussion

There was no requirement of supplementary heat in the first two weeks of August production (Table 4). If hourly measured outside temperature values were available (ÖZTÜRK 1993) and long term monthly average temperature and humidity with 80% probability in the establishment of heat–humidity balance in broiler house were not taken under consideration, supplementary heat might be required in this period of time. THOMASON et al. (1987) reported that chicks should be reared under a controlled environmental temperature because they could not easily adapt themselves to temperature changes for first two weeks, and they could not emit any heat within this period.

Results

The warmest and coldest crucial months in Kahramanmaraş were determined as July, August (301.8 K) and January (279.3 K), respectively (Table 2).

Total heat conductance coefficients for walls, doors, windows, and curtains were 2.08, 4.07, 6.98, and 6.03 Wm⁻²K⁻¹, respectively. The coefficients for 3, 6, 8 and 10 cm roof glass wool were calculated as 0.88, 0.53, 0.42 and 0.35 Wm⁻²K⁻¹, respectively.

Maximum heat conductance coefficients of the structural elements were calculated as 2.15 Wm⁻²K⁻¹ in the critical coldest month by using a 70% inside relative humidity of broiler house, and outside temperature value that was predicted from the mean of long term monthly outside temperature with 80% probability. Inside temperature values were obtained from Table 2 (ANONYMOUS 1996). Heat conductance coefficients for walls and roof were estimated as 2.08 and 0.53 Wm⁻²K⁻¹. It was determined that no condensation is expected on the surface of wall and roof since the calculated heat conductance coefficients were smaller than the maximum heat conductance coefficients. It was also determined that used insulation for roof only was enough to supply optimum inside environmental conditions.

Since there was no difference between cost and thermal conductivity of double layer polystyrene foam with 2.5 cm and 6 cm glass wool and since glass wool is stronger than polystyrene foam, glass wool was chosen in this study. When total cost is considered based on thickness of the polystyrene foam, glass wool was chosen in this study. The total cost of the 6 cm thick glass wool is cheaper than 3, 8, and 10 cm glass wool (Gencoğlan 2000).

The required supplementary heat in broiler houses was the difference between the heat loss from structural elements and ventilation, and the heat emitted by the chicks.
During these two weeks period, a broiler house should be designed with enough heating equipment. The limits of minimum and maximum temperature inside the broiler house for this time period should be 300–303 K and 305–308 K, respectively. Although our research results reveal that there is no need of supplementary heat in the first two weeks, it should be provided whenever inside broiler house temperature decreases below 300 K (Table 3 and Table 4).

The most important reason of high supplementary heat in the third week of August might be due to inside broiler house temperature (297 K) that was taken directly from the literature (Table 2). This situation would not appear if the third week inside broiler house temperature was 300 K instead of 297 K. This value could not be changed since selected literature showed that there is a need of supplementary heat for Kahramanmaraş region.

The coldest and warmest crucial months were determined considering inside broiler house temperature of 297 K. Therefore, values taken from the literature are not appropriate for some critical months and heat and humidity values should be measured in critical months. As a result, these measured parameters can be easily used to provide optimum environmental conditions inside broiler houses.

### Table 3. Heat and humidity-heat balance in the broiler house with 10,000 birds capacity, and supplementary heat according to the thickness of insulation material when production started on January 1

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Weight (kg)</th>
<th>Total Heat Production (W)</th>
<th>Total Moisture Production (g/h)</th>
<th>Heat Losses From (HLF)</th>
<th>Heat Production (W)</th>
<th>Total Energy (W)</th>
<th>Door (W)</th>
<th>Window (W)</th>
<th>Wall (W)</th>
<th>Curtain (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>4500</td>
<td>22000</td>
<td>1502.73</td>
<td>11632.20</td>
<td>7843.08</td>
<td>203.26</td>
<td>7930.14</td>
<td>5249.39</td>
<td>8834.16</td>
<td>4093.13</td>
</tr>
<tr>
<td>3</td>
<td>26000</td>
<td>50000</td>
<td>5138.75</td>
<td>31015.93</td>
<td>9451.27</td>
<td>158.49</td>
<td>8834.16</td>
<td>4093.13</td>
<td>8834.16</td>
<td>4093.13</td>
</tr>
<tr>
<td>4</td>
<td>42000</td>
<td>73500</td>
<td>18329.18</td>
<td>60627.42</td>
<td>5179.51</td>
<td>86.85</td>
<td>4841.32</td>
<td>2243.13</td>
<td>8834.16</td>
<td>4093.13</td>
</tr>
<tr>
<td>5-6</td>
<td>50000</td>
<td>80000</td>
<td>20779.22</td>
<td>59520.00</td>
<td>6596.10</td>
<td>280.34</td>
<td>6465.23</td>
<td>1942.50</td>
<td>8834.16</td>
<td>4093.13</td>
</tr>
<tr>
<td>7</td>
<td>67500</td>
<td>112500</td>
<td>29220.78</td>
<td>83700.00</td>
<td>6596.10</td>
<td>280.34</td>
<td>6465.23</td>
<td>1942.50</td>
<td>8834.16</td>
<td>4093.13</td>
</tr>
<tr>
<td>8</td>
<td>80000</td>
<td>130000</td>
<td>37766.23</td>
<td>96720.00</td>
<td>6596.10</td>
<td>280.34</td>
<td>6465.23</td>
<td>1942.50</td>
<td>8834.16</td>
<td>4093.13</td>
</tr>
</tbody>
</table>

qt = total heat production, Wa = Total water-steam production, Qh = Loss of humidity caused by ventilation, qwin = Loss of humidity through windows, qd = Loss of humidity through doors, qw = Loss of humidity through walls, qc = Loss of humidity through curtains, Qs = supplementary heat, Uc = Heat conductivity constancy.

### Summary

In this study, a naturally ventilated broiler house with a capacity of 10,000 birds was planned in the south part of Kahramanmaraş/Turkey where Mediterranean climatic conditions prevail. After a local heating system had been installed in the house, quantity of supplementary heating requirement in crucial months was calculated in order to provide the most convenient environmental conditions without waste of supplementary heating. The breeding period of the broilers took 8 weeks.

The coldest and warmest crucial months were determined as January with 279.3 K and August with 301.8 K, respectively, with an 80% contingency based on long-term climatic data analysis. A 6 cm thick glass wool sheet was used as insulation material on the roof for heat and humidity balance. Rearing was initiated in the first week of Janu-
The weekly required supplementary heat from the first week to the end of the eight week was as follows: 32747, 32747, 32846, 33879, 28514, 28514, 35194 W and 35714 W, respectively. When the breeding was started in the first week of August, chicks needed 3913 W supplementary heat for the first two weeks but they did not require any supplementary heat for the remaining weeks. Furthermore, supplementary heat quantities were also calculated for 3, 8 and 10 cm glass wool sheets. As result of these calculations, as the thickness of the insulation material increased, the amount of the supplementary heat decreased to 580-2898 (31836.15-31256.47)-(35645.48-32747.08) W in winter and to 5-25 (3925.91-3920.80)-(3912.78-3887.24) W in summer season.

Table 4. Heat and humidity-heat balance in the broiler house with 10.000 birds capacity, and supplementary heat according to the thickness of insulation material when production started on August 1

<table>
<thead>
<tr>
<th>Weeks</th>
<th>Weight (kg)</th>
<th>Total Heat Pro. (Wkg⁻¹)</th>
<th>Total Moisture Pro. (Wg⁻¹)</th>
<th>Min. Ventilation Discharge Q (m³h⁻¹)</th>
<th>Heat Losses From (HFL)</th>
<th>Ventilation Qh (W)</th>
<th>Window qw (W)</th>
<th>Door qd (W)</th>
<th>Wall qw (W)</th>
<th>Curtain qc (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>0.1</td>
<td>4500</td>
<td>22000</td>
<td>5301.20</td>
<td>361.54</td>
<td>69.10</td>
<td>1.79</td>
<td>69.87</td>
<td>46.25</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>0.4</td>
<td>26000</td>
<td>50000</td>
<td>-65789.47</td>
<td>107684.21</td>
<td>-2563.06</td>
<td>-42.98</td>
<td>-2395.71</td>
<td>-110.00</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>0.7</td>
<td>21000</td>
<td>73500</td>
<td>35167.46</td>
<td>-21585.79</td>
<td>-961.15</td>
<td>-16.12</td>
<td>-898.39</td>
<td>-416.25</td>
<td></td>
</tr>
<tr>
<td>5-6</td>
<td>1.0</td>
<td>30000</td>
<td>95000</td>
<td>18886.68</td>
<td>5152.29</td>
<td>628.20</td>
<td>26.70</td>
<td>615.74</td>
<td>185.00</td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>1.5</td>
<td>45000</td>
<td>135000</td>
<td>26838.97</td>
<td>7321.67</td>
<td>628.20</td>
<td>26.70</td>
<td>615.74</td>
<td>185.00</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>2.0</td>
<td>60000</td>
<td>180000</td>
<td>35785.29</td>
<td>9762.23</td>
<td>628.20</td>
<td>26.70</td>
<td>615.74</td>
<td>185.00</td>
<td></td>
</tr>
</tbody>
</table>

Key words
Broiler house, heat-humidity balance, required supplementary heat, insulation material

Zusammenfassung
Berechnung des zusätzlichen Wärmebedarfs in einem Broilerstall in der Region Kahramanmaraş (Türkei)


Stichworte
Broilerstall, Wärme-Feuchtigkeits-Bilanz, zusätzlicher Wärmebedarf, Isolationsmaterial
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