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Abstract
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Keywords
Chick, Airtransport, Thermal-environment, Stress, Ventilation, Mortality

Disciplines
Agriculture | Bioresource and Agricultural Engineering

Comments
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PHYSICAL CONDITIONS AND MORTALITIES ASSOCIATED WITH INTERNATIONAL AIR TRANSPORT OF YOUNG CHICKS

H. Xin, S. R. Rieger

ABSTRACT. Transport conditions and mortalities of day-old breeding chicks associated with eight shipments from central Iowa to Asia were delineated. The chicks were shipped in commercial cardboard shipping containers with the dimensions of 61 L × 46 W × 18 H cm and 88 chicks/container. The chicks were delivered by bus from the hatchery to the originating airports and from the receiving airports to the destination farms. During air transport, the chicks were situated in the cargo compartment of commercial passenger aircrafts.

Transport time consisted of 13 to 18 h of flying time, 27 to 57 h of ground operation, 42 to 72 h in total journey. Both dead-on-arrival and the first seven-day mortality were found to be proportional to transport duration. Relative humidity inside the chick containers averaged 44% at 33°C on the ground, but only 19% at 31°C during flight. Container temperatures declined from 35°C to 28°C in 100 min during departure and increased from 28°C to 38°C in 75 min during arrival. Stressful temperatures of 37°C or higher averaged 4.5 h during the journey and tended to occur around departure and following arrival. However, no apparent functional relationship was detectable between the stressful temperature period and chick loss. Air temperature inside the container averaged 9°C and 4°C warmer than the ambient during flight and ground operation, respectively. Air-exchange rates through the containers were estimated to be 3.67 and 9.03 m³·h⁻¹·kg⁻¹ during flight and ground operation, respectively. These air-exchange rates exceeded the literature recommended minimum ventilation rates for air transport of chickens. Barometric pressure averaged 100 kPa on the ground and 84 kPa during flight. The results suggested that under the present transport conditions, efforts should be made to limit transport time within 45 h to alleviate excess mortalities. Furthermore, an improved shipping container needs to be investigated to overcome adverse transport conditions. Keywords. Chick, Airtransport, Thermal-environment, Stress, Ventilation, Mortality.

Day-old breeding chicks at the value of $45 to $50 each are being shipped in increasing numbers from the United States to international destinations such as China and Japan. The shipments, ranging from 4,000 to 10,000 chicks ($180,000 to $450,000 value), are transported with commercial passenger aircraft, where the chicks are situated in the cargo compartment. Experience has shown that chicks associated with shorter transport flights (i.e., those to Europe and South America) arrive in excellent conditions. However, major challenge arises for shipments to distant areas in Asia. It is generally the supply company’s policy to replace or credit the customers for any chick lost during the early seven-day period. More than once, adverse transport conditions (i.e., weather extremes, customs delays and biosecurity procedures) have caused severe mortalities (30 to 50%) such that the company had to replace the entire shipment. Such catastrophic incidences cause devastating economic losses to the company and much inconvenience to the customers.

While prolonged exposure of the chicks to thermal stress and water deprivation is speculated to be responsible for the elevated mortalities, little research data was found to quantify the actual transport conditions and their effects on chicks. Nevertheless, certain research related to poultry transportation has been documented. The previous research examined heat tolerance of one-day old chicks (Henken et al., 1987); broiler mortalities during transportation to processing plants (Bayliss and Hinton, 1990; Warriss et al., 1992); effects of post-hatch holding time on mortality and subsequent early performance of broiler chicks and turkey poults (Pinchasov and Noy, 1993); and thermal stress and environment during broiler transportation (Kettlewell, 1989; Webster et al., 1993; Kettlewell and Mitchell, 1994).

The objective of this study was to characterize transport conditions of day-old breeding chicks to distant international destinations regarding journey duration, thermal conditions, and chick mortalities.

PROCEDURE

CHICKS AND TRANSPORTATION METHODS

Day-old breeding chicks were delivered in a temperature-controlled chick bus from the hatchery located in central Iowa to the international airport in Chicago, Illinois, or Minneapolis, Minnesota. Following a period of
“storage” inside the airport warehouse, the chicks were loaded into the cargo compartment of the commercial passenger aircraft for departure. Thereafter, the chicks followed the itinerary of the commercial flight including plane transfer. After arriving at the final airport, the chicks were conveyed by bus to the destination farm.

Cardboard transport containers with dimensions of 61 L x 46 W x 18 H cm and excelsior bedding were used for all the shipments (fig. 1). Each container was divided into four compartments and held a total of 88 chicks. Circular ventilation openings of 1.6 cm in diameter were embedded in the sidewalls, dividers, and lid of the container (128 openings in the sidewalls and 92 in the lid). Moreover, six foam-block spacers (two along each length side and one along each width side) were used to provide a minimum of 10-cm, side-by-side spacing between the container stacks. The purpose of the spacers was to facilitate air exchange through the containers. Depending upon the quantity of chicks shipped, multiple stacks of 5 to 10 containers were used during the transport.

ENVIRONMENTAL AND PERFORMANCE MEASUREMENTS

Air temperature, relative humidity (RH) and barometric pressure were continuously measured and recorded at 5-min averages with programmable miniature electronic dataloggers. For internal measurements, the temperature sensor (thermistor) was taped near the top of the container divider, and the RH sensor (capacitive film) was extended from the perforated lid into the chick zone. For external measurements, temperature, RH, and pressure sensors were mounted on the spacer block. During bus and plane loading, the container with internal sensors was located in the second top layer of the central stack, where the temperature was considered to be the highest. The container with external sensors was located in a perimeter stack, with the sensors exposed to ambient air. The dataloggers were either mailed or carried back from the customer farms and data were retrieved to a computer. Dead-on-arrival (DOA) and seven-day mortality (SDM) were recorded on the farm. No attempt was made to measure the body mass loss of the chicks during transport. However, a laboratory test involving 6,160 off-line chicks (i.e., chicks with opposite sex to what the customer wanted) was conducted to evaluate body mass loss of chicks following a 72-h, post-hatch holding under room conditions of 24°C and 45 to 55% RH.

CALCULATION OF AIR-EXCHANGE RATE THROUGH THE CONTAINERS

The following heat balance equation (ASAE Standards, 1994) was used to estimate average air-exchange rate through the containers:

\[ N q_s = \rho C_p Q \Delta T + \Delta T \sum_{i=1}^{n} \frac{A_s}{R_s} \]  

(1)

where \( N \) is the number of chicks per container, 88; and \( q_s \) is sensible heat output per chick, \( W \), calculated as:

\[ q_s = \phi \cdot q_t \cdot \delta \]  

(2)

where

\[ \phi = \text{fraction of total heat output as sensible heat, 0.85 (Longhouse, 1968, as cited by ASAE Standards, 1994)} \]

\[ q_t = \text{total maintenance heat production per chick in the thermoneutral zone, } W, \text{ calculated as (CIGR, 1984):} \]

\[ q_t = 7 \cdot M^{0.75} \]  

(3)

where

\[ M = \text{body mass of the day-old chick, averaging 0.038 kg/chick (based on laboratory measurements of the same type of chicks)} \]

\[ \delta = \text{correction factor for ambient temperature of the form (Strom, 1978):} \]

\[ \delta = 4 \cdot 10^{-5} (-T_1 + 30)^3 + 1 \]  

(4)

\[ \rho = \text{density of the air (1.14 kg·m}^{-3} \text{ at 100 kPa pressure and 0.97 kg·m}^{-3} \text{ at 84 kPa)} \]

\[ C_p = \text{specific heat of the air (1 kJ·kg}^{-1}·K^{-1}) \]

\( Q = \text{air-exchange rate through the container (m}^3·\text{h}^{-1}·\text{kg}^{-1}) \]

\[ \Delta T = \text{average temperature difference between the inside and the outside of the container (i.e., } T_i - T_o), (°C) \]

\[ A_s = \text{surface area of a particular container surface (m}^2); \]

\[ A_{\text{sidewalls}} = 0.354; A_{\text{lid}} = 0.256; A_{\text{bottom}} = 0.279 \]

\[ R_s = \text{thermal resistance of a particular container surface, } M^2·K·W^{-1} \text{ (including air films of 0.12 on each side of the surface); } R_{\text{sidewalls}} = 0.44; A_{\text{lid}} = 0.44; A_{\text{bottom}} = 0.88 \]

RESULTS AND DISCUSSION

Data from eight shipments during the months of July through October 1994 were analyzed. Table 1 shows the general transport information. All shipments were made to China except for no. 7 which was made to Japan.

TRANSPORT TIME AND MORTALITIES

As can be noted in table 1, although the actual flight time to China lasted only 15 to 18 h, the ground time varied from 27 to 57 h. Consequently, the total transport
Table 1. General transport data for shipments of breeding chicks to Asia*

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Chicks (h)</th>
<th>Flight (h)</th>
<th>Ground (h)</th>
<th>DOA</th>
<th>7-Day Mortality, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. 1</td>
<td>07/05/94</td>
<td>6,103</td>
<td>62.8</td>
<td>17.0</td>
<td>45.8</td>
<td>4.92</td>
</tr>
<tr>
<td>No. 2</td>
<td>07/12/94</td>
<td>6,767</td>
<td>46.0</td>
<td>17.0</td>
<td>29.0</td>
<td>2.33</td>
</tr>
<tr>
<td>No. 3</td>
<td>07/19/94</td>
<td>9,168</td>
<td>48.5</td>
<td>17.0</td>
<td>31.5</td>
<td>1.18</td>
</tr>
<tr>
<td>No. 4</td>
<td>07/22/94</td>
<td>5,500</td>
<td>45.0</td>
<td>18.3</td>
<td>26.7</td>
<td>0.55</td>
</tr>
<tr>
<td>No. 5</td>
<td>08/17/94</td>
<td>6,051</td>
<td>52.0</td>
<td>15.8</td>
<td>36.3</td>
<td>0.62</td>
</tr>
<tr>
<td>No. 6</td>
<td>08/30/94</td>
<td>8,360</td>
<td>54.0</td>
<td>16.7</td>
<td>37.3</td>
<td>3.25</td>
</tr>
<tr>
<td>No. 7</td>
<td>10/03/94</td>
<td>4,586</td>
<td>41.5</td>
<td>12.6</td>
<td>28.9</td>
<td>1.26</td>
</tr>
<tr>
<td>No. 8</td>
<td>10/25/94</td>
<td>6,560</td>
<td>72.0</td>
<td>15.3</td>
<td>56.8</td>
<td>11.43</td>
</tr>
</tbody>
</table>

* All shipments were made to China except for no. 7, which was made to Japan.
† Time period from leaving the hatchery to arriving at the destination farm.
‡ Time period when the chicks were flying in the aircraft.
§ Time period when the chicks were on the ground.
‖ Number of dead-on-arrival birds at the farm; seven-day mortality includes DOA.
# There was an extended delay at the Beijing airport customs and in shipment to the destination farm.

Time ranged from 45 to 72 h. This large variation in total transport time resulted from the combination of different flight schedules, delays in customs and biosecurity procedures, and various travel distances between the final airports and the destination farms. The relationships of transport time (h) versus mortalities (DOA and SDM) are presented in figure 2, and of the following forms:

\[
\text{DOA} (\%) = -13.89 + 0.324 \cdot h \quad (R^2 = 0.82) \quad (5)
\]

\[
\text{SDM} (\%) = -55.80 + 1.378 \cdot h \quad (R^2 = 0.81) \quad (6)
\]

The positive relationship between DOA and transport time found in this study was consistent with the result of Warriss et al. (1992) who reported higher DOA incidence for broilers on longer journeys. Moreover, SDM (%) and DOA (%) (fig. 3) were related by the following equation:

\[
\text{SDM} = 3.53 + 4.17 \cdot \text{DOA} (\%) \quad (R^2 = 0.95) \quad (7)
\]

Equations 4, 5, and 6 can be used to help the supply company estimate mortalities based on transport time, and plan for the quantities of replacement chicks upon knowledge of DOA.

**THERMAL AND CLIMATIC CONDITIONS DURING TRANSPORT**

An example of the barometric pressure, temperature and RH profiles during transport is presented in figure 4. The transport conditions were partitioned for during-flight and on-the-ground periods of the journey (tables 2 and 3). As shown in table 2, the average container temperature ranged from 26° to 34° C during flight and from 31° to 35° C on the ground. Although the pooled mean air temperatures over the journey periods were lower than the upper critical temperature (UCT) of 37° C for day-old chicks (Henken et al., 1987), there were times when UCT was exceeded. This time period, ranging from 38 to 638 min with an average of 272 min (table 2), occurred around departure and after landing. This outcome presumably resulted from reduced compartment ventilation and temperature control during these periods. Although no apparent relationship was detectable between the high temperature periods and chick losses, efforts should be made to minimize the occurrence of such stressful temperatures.

Perhaps the most intriguing and alarming aspect of the results lies in the quantification of low RH during flight, which averaged only 19% in contrast to 44% on the ground (fig. 4 and table 2). Such low RH would undoubtedly accelerate dehydration and body mass loss of the chicks. Although no data was collected on body mass loss for the transported chicks, a laboratory test involving 6,160 similar chicks showed a 20% loss of initial body mass after a 72-h, post-hatch holding period at 24° C and 50% RH. Pinchasov and Noy (1993) reported a 10% loss of initial body mass after a 48-h, post-hatch holding period.

During each time of departure and arrival, there was a 16 kPa change in barometric pressure (from 100 kPa to 84, and vice versa) (fig. 4). Meanwhile, considerable changes in air temperature occurred (fig. 4 and table 2). On the average, temperature inside the containers decreased by 6.7° C (from 35.4 to 28.7° C) in 100 min during departure; and increased by 9.7° C (from 28.4° to 38.1° C) in 75 min during arrival. The time interval between arrival and departure (i.e., layover period) averaged 5.83 h and at least two layover periods were encountered for each shipment.

**AIR-EXCHANGE RATE THROUGH THE CONTAINERS**

As shown in table 3, temperature difference between the inside and outside of the containers averaged 9° C during
flight and 4° C on the ground. The associated average air-exchange rates through the containers were estimated by substituting the respective average temperature difference (AT) into equations 1 through 4:

1. During flight: \( \Delta T = 9^\circ \text{C} ; Q_{\text{flight}} = 3.67 \text{ m}^3\text{h}^{-1}\text{kg}^{-1} \) (or 0.08 cfm/chick);

2. On the ground: \( \Delta T = 4^\circ \text{C} ; Q_{\text{ground}} = 9.03 \text{ m}^3\text{h}^{-1}\text{kg}^{-1} \) (or 0.20 cfm/chick).

These estimated air-exchange rates were much higher than the suggested minimum ventilation rates of 0.68 and 1.68 m³·h⁻¹·kg⁻¹, respectively (Muller, 1985). Muller assumed the bird microenvironment conditions to be 28° C and 85% RH during flight and 30° C and 90% RH on the ground, with the corresponding inlet air conditions of 8° C and 4° C.
and 10% RH during flight and 28° C and 60% RH on the ground. Muller also concluded that removal of animal heat, instead of CO₂, was the determining factor for minimum ventilation rate. Thus, there seemed to be sufficient oxygen (O₂) supply for the chicks under the present average air-exchange rates. Nevertheless, O₂ and CO₂ levels inside the chick containers need further verification.

CONCLUSIONS

Microenvironments and mortalities including DOA and SDM associated with air transport of day-old breeding chicks to Asia were analyzed. The following observations were noted from eight shipments:

1. The transport journey consisted of 13 to 18 h in flight time; 27 to 57 h in ground time; and 42 to 72 h in total time.
2. Mortalities were proportional to transport time. SDM and DOA were related by the equation of SDM (%) = 3.53 + 4.17 × DOA (%) (R² = 0.95).
3. RH inside the chick containers averaged 44% at 33° C on the ground, but only 19% at 31° C during flight.
4. Considerable temperature fluctuations existed inside the chick containers during departure and arrival. Stressful temperatures of greater than 37° C tended to occur around departure and following arrival, suggesting that special attention be paid during these periods.
5. Temperature difference between the inside and outside of the chick containers averaged 4° C on the ground and 9° C during flight. Based on these temperature gradients, air-exchange rates through the containers were estimated to exceed the recommended minimum ventilation levels for transportation of chickens.

6. Barometric pressure averaged 100 kPa on the ground and 84 kPa in the air.
7. Under the present transport conditions, efforts should be made to limit transport time within 45 h to avoid excess mortalities.

SUGGESTION FOR FUTURE RESEARCH

The effects of low humidity and fluctuating air temperatures on physiology and energetics of the breeding chicks need to be quantified. An alternative, stress-alleviating transport container needs to be investigated for the ever-growing international shipment of breeding stocks.

REFERENCES


