2001

An Instrumentation System for Studying Feeding and Drinking Behavior of Individual Poultry

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Abstract

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Keywords

Feeding behavior, Drinking behavior, Automatic instrumentation system, Poultry

Disciplines

Agriculture | Bioresource and Agricultural Engineering

Comments

Journal Paper No. J-18679 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Project No. 3311. Mention of vendor or product names is for presentation clarity and does not imply endorsement by the authors or their affiliations nor exclusion of other suitable products.

This article is from *Applied Engineering in Agriculture* 17, no. 3 (2001): 365–374.

An Instrumentation System for Studying Feeding and Drinking Behavior of Individual Poultry

M. C. Puma, H. Xin, R. S. Gates, D. J. Burnham

Abstract. *This article describes an instrumentation system that was developed to study the dynamic feeding and drinking behavior of individual birds. The system, consisting of 24 feeding and drinking stations interfaced via an RS 485 communication network to a central PC, provides continuous recording of feeding and drinking events. Each feeding/drinking station includes a precision electronic balance (1210–g capacity and 0.1–g resolution) for the feeder and a temperature–controlled drinking water reservoir (1500–mL capacity and 1000– to 1500–mL operating range) whose height and thus volume was sensed with a differential pressure transducer (0 – 2.5 VDC output). The system was tested using growing broiler chickens subjected to constant or cyclic thermal conditions. Sample data are presented to demonstrate how researchers can use the system to examine and understand the effects of environmental modification on feeding and drinking behavior of individual birds. A series of subsequent studies have been planned that will use the system to investigate the interactive effects of environmental and dietary nutrition manipulations on ingestion behavior and poultry performance.*

Keywords. *Feeding behavior, Drinking behavior, Automatic instrumentation system, Poultry.*

Assessment of feeding and drinking behavior is a prerequisite for studying physiology–based controls of feeding and drinking and for evaluating the efficacy and specificity of agents or factors that stimulate or inhibit these behaviors. Studies on poultry have associated feed intake with genetics (Noble et al., 1993b), age or body weight (Picard et al., 1992b; Savory and Maros, 1993; Noble et al., 1993a; Xin et al., 1994), time of feeding or time of day (Kostal et al., 1992; Savory and Maros, 1993; Savory and Mann, 1999), social interaction (Duncan et al., 1970; Kaufman and Collier, 1983; Mills and Faure, 1989; Picard et al., 1992b; Noble et al., 1993a), feeding practice (ad libitum vs. restricted feeding or rationing) (van Rooijen, 1991; Kostal et al., 1992; May and Lott, 1992b; Savory and Maros, 1993; Savory and Mann, 1999), and nutrient content of the diet (Abebe and Morris, 1990a,b; Huey et al., 1982; Morris et al., 1987, 1992; Noble et al., 1993b). Only a few studies (May and Lott, 1992a,b; 1994) associated feed intake with environmental factors, although it has been recognized that operant conditioning or other environmental constraints force chickens to increase duration at the feeder (Kaufman and Collier, 1983; Savory, 1989; Yo et al., 1997).

Much less is known about drinking patterns of individual birds. Savory and Maros (1993) noted that bird water intake was associated with age of the bird, time of the day, and degree of feed restriction. Stereotypical pecking at drinkers was found to be highly variable among birds in restricted feed trials (Kostal et al., 1992). Water consumption of broilers from bell versus nipple waterers, with the birds subjected to high cyclic temperatures, was studied by May et al. (1997). Xin et al. (1994) developed functional relationships between daily water and feed use and age of commercial broilers.

New approaches have been employed to monitor poultry feed and water intake (Hulsey and Martin, 1991; Picard et al., 1992a; Lott et al., 1992; Xin et al., 1993; Yo et al., 1997; Savory and Mann, 1999). Most of these approaches, however, were employed in studying effects of parameters other than environmental factors and for monitoring feeding patterns only. The method used by Xin et al. (1993) involved a computerized measurement and data acquisition system designed to simultaneously collect dynamic environmental information and animal performance data of commercial–scale poultry flocks, including both feed and water use. The system used by Lott et al. (1992) employed load cells connected to a computer to obtain feed and water consumption data. Savory and Mann (1999) measured individual feed intake. Such data can be helpful for assessing physiological and behavioral responses to external stimuli and to quantify variability in such responses. Published studies that report mean responses have provided the basis for much of our present knowledge; how individuals vary in their response may be helpful for understanding inconclusive past results, and to estimate a measure of variance for quantifiable

Article was submitted for review in December 1999; approved for publication by the Structures & Environment Division ASAE in January 2001. Presented at the 1999 ASAE Annual Meeting as Paper No. 99–4209.

Journal Paper No. J–18679 of the Iowa Agriculture and Home Economics Experiment Station, Iowa State University, Project No. 3311. Mention of vendor or product names is for presentation clarity and does not imply endorsement by the authors or their affiliations nor exclusion of other suitable products.

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  ISSN 0883–8542

responses such as eating or drinking amounts, duration and frequency.

The objectives of this research were: (1) to develop an automated instrumentation system for studying individual poultry feeding and drinking behavior, and (2) to test the effectiveness of the system in delineating the interactive effects between the environment and the ingestion behavior of individual poultry.

Materials and Methods

The system involves available industrial electronic and mechanical components with some custom software/hardware integration and design.

Monitoring System for Feeding Events and Feed Consumption

There were a total of 24 feeding/drinking stations in this measurement and control system, divided into four groups of six stations. Each group was located in one of four environmentally controlled chambers (Xin and Harmon, 1996). Each feeding station (fig 1.) consisted of a precision electronic weighing scale (Model CT1200, Ohaus Corporation, Florham Park, N.J.) with a 1210–g capacity and a 0.1–g resolution and a plastic feeder measuring 13L × 13W × 15H cm (5L × 5W × 6L in.). The plastic feeder had a u–shaped access side opening and its bottom was fastened to the electronic scale with VELCRO® strips. In addition to the standard LCD digital weight indicator, each scale had an RS 232 serial interface connected to a custom–built RS232/485 slave communication and analog/digital module (KG Systems, Inc., East Hanover, N.J.). The feeder–scale stations were located on a wooden stand in front of the individual birdcages. The cages, measuring 25W × 46D × 46H cm (10W × 18D × 18H in.), were situated on an adjustable metal frame to maintain proper drinker height for the birds. Aluminum collection trays were placed underneath the cages for fecal collection.

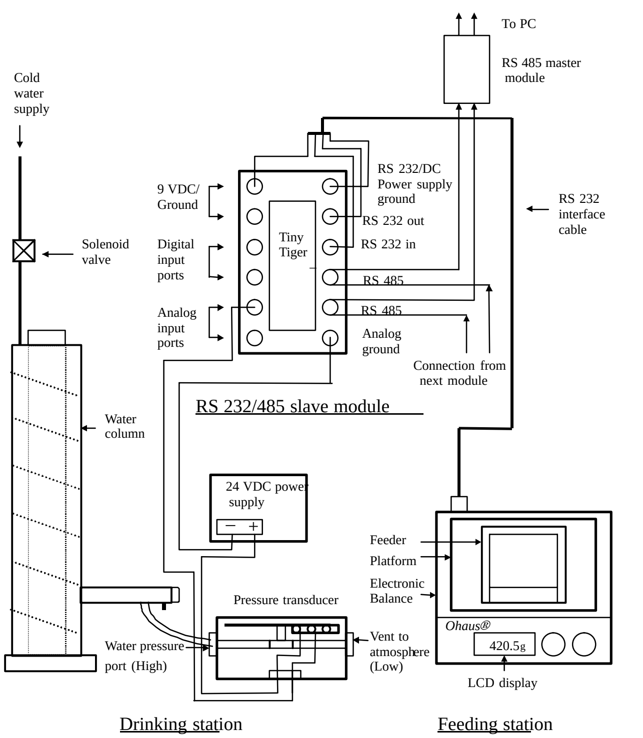


Figure 1. Schematic configuration of individual feeding and drinking station and connections to RS232/485 slave communication module (not drawn to scale).

Monitoring System for Drinking Events and Water Usage

Initial Design of Watering Units and Cooling System

The watering unit initially consisted of a water reservoir made from a 5–cm (2–in.) diameter × 35–cm (14–in.) high insulated, graduated plastic cylinder (Cat. No. E–06137–80, Cole Parmer Co., Vernon Hills, Ill.) and a differential pressure transducer (Model DP8–47YB–B– (*)–A–2, BEC Controls Corporation, Davenport, Iowa) that was connected to the water column (fig. 1). Water reservoir height, measured by the differential pressure transducer (4–20 mA output), was recorded as a voltage on an analog input channel of the RS232/485 slave communication module. Water height was linearly related to transducer output; as configured with a 125–Ω load resistor, a 30–cm (12–in.) water column (approximately 500–mL water) corresponded to 2.5 VDC. A 6.4–mm (0.25–in.) diameter horizontal flexible plastic tube, insulated with glass wool fiber and rubber, supplied water from the column to the nipple drinker.

A coiled copper line cooling system was constructed between the column and its outer insulation to maintain desired drinking water temperature during warmer ambient temperature events. Plastic pipes were used to deliver cooling water from a chiller (Model ER10–1B, Elkay Manufacturing Corporation, Oak Brook, Ill.) to the copper cooling lines. Individual solenoid valves controlled the water flow to each of the cooling lines and thus the temperature of the water reservoir. Solenoid valve operation was controlled with two 16–channel, AC/DC control switches (Model SDM–CD16, Campbell Scientific, Inc., Logan, Utah) in conjunction with a data logger (Model CR10, Campbell Scientific, Inc.). Drinking water temperatures were measured with thermocouples [0.1°C (0.18°F) resolution] (Type T, special limit error, Omega Engineering, Inc., Stamford, Conn.), inserted inside the water column 3 cm above the base.

Modified Watering Units and Cooling System

Testing of the initial watering unit revealed that if birds drank frequently, water flow from the nipple drinkers diminished appreciably with water column height. Rather than maintaining a great re–fill frequency, modifications of the watering units and cooling systems were made. A schematic representation of the modified watering unit is shown in figure 2. The modified water column, 5–cm (2–in.) diameter × 76–cm (30–in.) tall schedule 40 PVC, held approximately 1500 mL (0.4 gal) (fig. 2). The pressure transducers were readjusted by the manufacturer to accommodate the increased water column height and thus pressure. Water flow rate of the modified waterer was measured to range from 33 to 22 mL/min (0.52 to 0.35 gal/h), corresponding to reservoir volume of 1500 to 1000 mL (0.40 to 0.26 gal) or column height of 72 to 60 cm (28 to

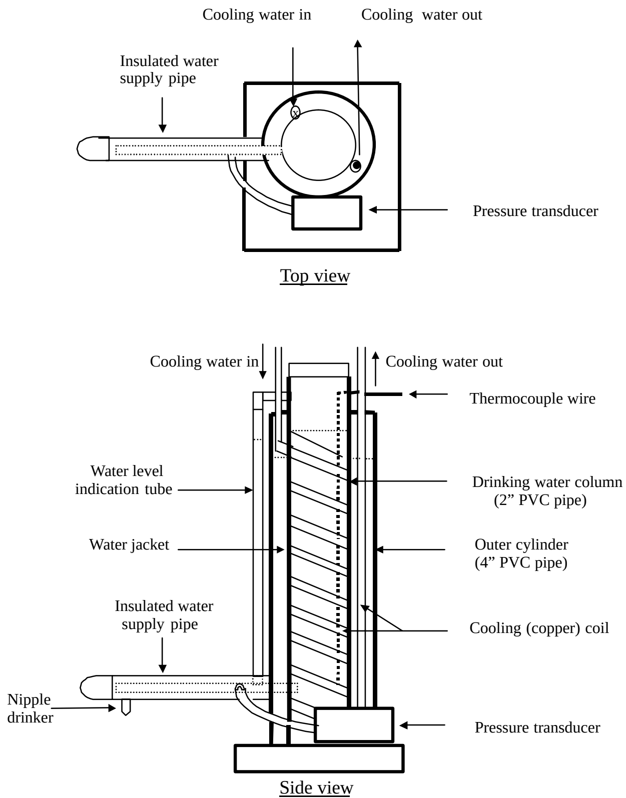


Figure 2. Schematic representation of the modified watering unit (not drawn to scale).

24 in.). A test with growing broilers showed that a flow rate of 22 to 33 mL/min was adequate for providing the daily water use of 300–380 g for 6–week–old broilers under thermoneutrality (Puma et al., 1999). Thus, an operating range of 1500– to 1000–mL water volume was chosen for testing.

A copper cooling line was coiled around the water column as a heat exchanger, and the assembly was then placed inside another 10–cm (4–in.) diameter water–laden PVC cylinder, forming a cooling water jacket (fig. 2). Commercially available, insulated PVC waterlines [1.3–cm (0.5–in.) diameter, 6.0–mm (0.24–in.) wall thickness, with built–in drinking nipples] (Model VP030, Val Watering Systems, Lancaster, Pa.) were used as the drinking water supply pipes for the modified watering units (fig. 2). A plastic inner tube was inserted into the thick–walled water supply pipe to reduce its holding volume and thus purging time of the temperature–controlled reservoir water. The PVC pipes initially used to deliver cooling water from the chiller to the copper cooling lines were replaced with copper pipes to improve cooling water distribution. The exposed surfaces of the watering units and cooling water distribution lines were insulated with aluminum foil–backed bubble insulation [R value = 0.52 m^2 K/W (3 ft^2·°F·h/BTU)].

The 24 watering units with their respective analog to digital converter (ADC) were individually calibrated by decreasing the volume of water in the reservoir columns and recording the ADC counts (1.22 mV/count). A calibration equation for each unit was obtained, allowing measured ADC counts to be used to compute the volume of water remaining in the column.

Data Acquisition System

A schematic representation of the electronic control components and wiring connections of the data acquisition system is shown in figure 3. As described above, the output of the 24–feeding/drinking stations were monitored via RS 232/485 slave modules. An RS 485 master module interfaced the slave modules with a PC and synchronized polling of each slave station at a predetermined time interval (30 s for this study). The master and slave stations were custom–built utilizing a Tiny Tiger™ microcontroller, programmable via the hosting PC, and interfaced to the PC through a Microsoft® Visual Basic (VB) script inside an Excel spreadsheet for data–logging (KG Systems, Inc., East Hanover, N.J.). The Excel data file was automatically saved onto the PC hard drive every 30 minutes.

Another VB script was used to filter out spurious data points in the feed and water weight records. While feeding, the strong impact of the bird’s beak on the feeder occasionally caused instantaneously high feed scale readings to be recorded. As a result, the data consisted of a time series of decreasing feeder weight mixed with feeding impact spikes. The filtering program removed the unwanted spikes and retained only the data points indicative of the feed disappearance. The program compared current feeder weight reading with the previously recorded weight value. If the current feeder weight value was the same or less than the previous value, it was retained. If the current weight was higher than the previous value, it was removed from the filtered record.

The output readings of the pressure transducers exhibited some fluctuations, averaging ±3.6 counts or ±3.6 mL water volume. Hence, the filtering program for the waterer data considered only water volume reduction equal to 3.6 mL or greater. The filtering program used the raw data worksheet and output the filtered data in the same spreadsheet. Air temperature (T_a) and drinking water temperature (T_w) inside each chamber were controlled and recorded with separate CR10 measurement and control units (fig. 3).

System Performance Tests

An experiment was conducted to test the system performance. Twenty–four growing broiler chickens (Hubbard × Peterson) initially 21–days old and with uniform body mass of 0.74 to 0.80 kg (1.6 to 1.8 lb) were selected from a population of 100 birds. The 24 birds were randomly assigned to individual cages and were raised and monitored for the following 3 weeks. The first week (21–27 days of age) served as the acclimation period, whereas the remaining two weeks (28–41 days) as the measurement period. A photoperiod of 23L:1D (midnight to 1 a.m.) was used throughout the trial period. The effects of four T_a regimens on the ingestion behavior of the birds were examined. The T_a regimens were 1) constant thermoneutral T_a of 21.5°C (71°F) in chamber 1 (T1); 2) cyclic T_a of 18–25°C with daily mean of 21.5°C (64–77°F, mean of 71°F) in chamber 2 (T2); 3) constant warm T_a of 30°C (86°F) in chamber 3 (T3); and 4) cyclic T_a of 25–35°C with daily mean of 30°C (77–95°F, mean of 86°F) in chamber 4 (T4). T_w was set at 22°C (72°F) for all T_a regimens. Feed and water were replenished once daily (generally in late afternoon), during which the amount of feed in each feeder was brought to 500 g (1.1 lb) and the amount of water in each reservoir to 1500 mL (0.4 gal).

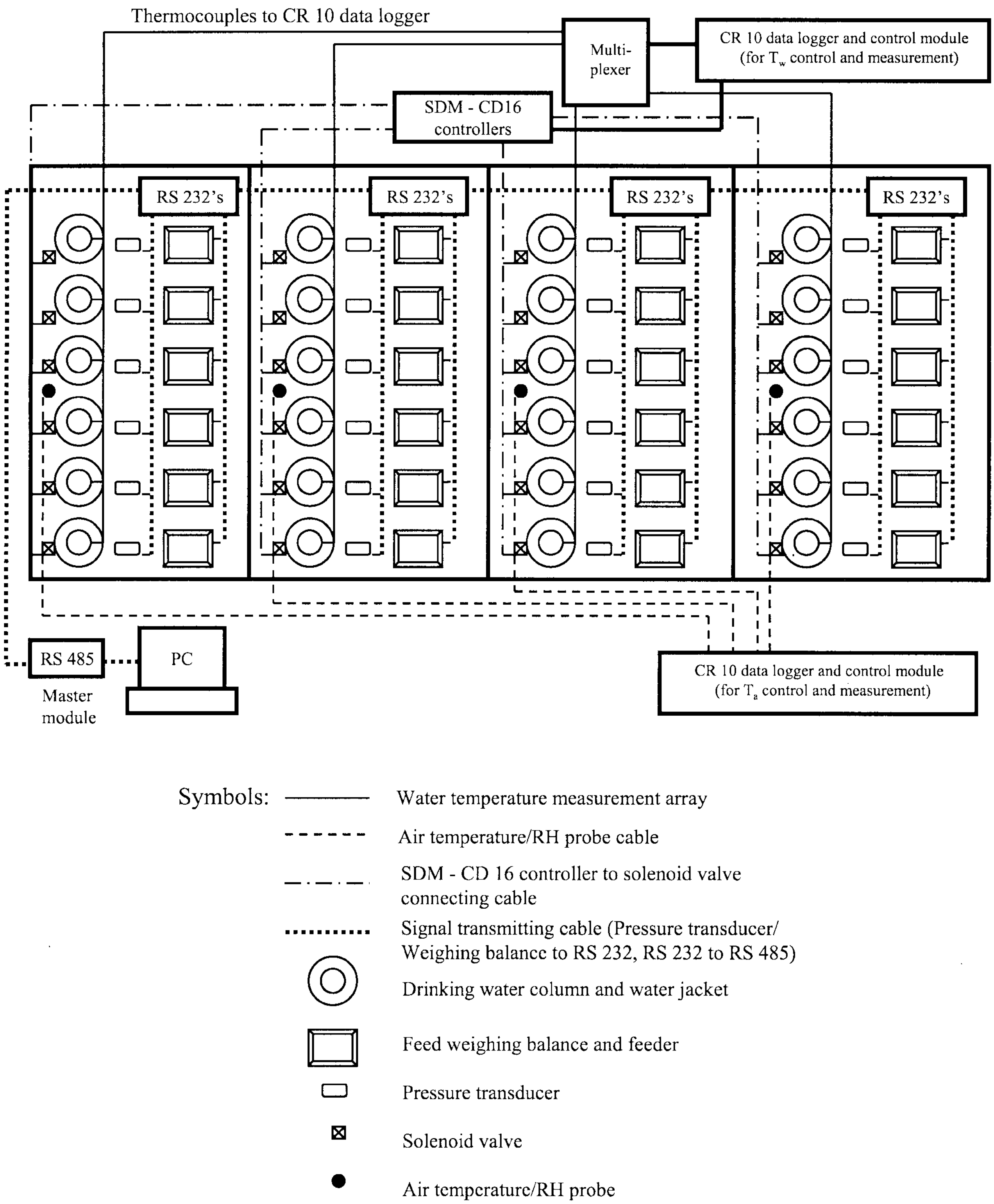


Figure 3. Schematic wiring connections of the measurement and control system for studying feeding and drinking behaviors of individual poultry (not drawn to scale).

Output readings of the feeding/drinking stations were paused for about 30 min during the replenishment, and continuously polled every 30 s during the rest of the time.

The time series of feeder and water readings were filtered first using the VB script described previously. Feeding and drinking events were then quantified to determine the corresponding individual bird feed and water use. Hourly and daily individual feed and water use in each T_a treatment was then determined.

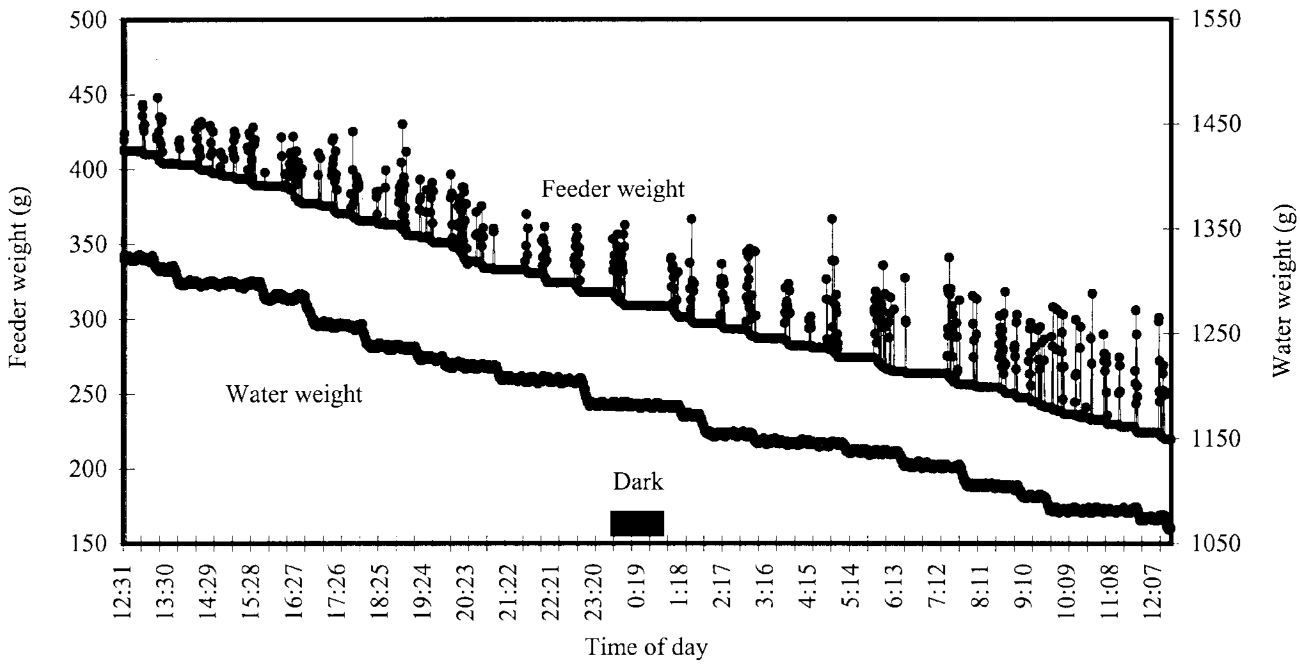


Figure 4. One–day raw data of feeder and water weight (chicken no. 1, 40 days old) [23L:1D photoperiod, T_a = 21.5° C (71° F)].

Bird performance data such as growth rate, feed conversion, and water to feed use ratio for each T_a regimen were also collected (Puma et al., 2000). However, they are not the focus of this article and were omitted from the presentation.

Results and Discussion

T_W remained essentially constant at 22°C (72°F) throughout the trial period for T1, T3, and T4, but was occasionally lower for T2, especially during the lower T_a period of the diurnal cycle. However, maintaining T_W above T_a was not the intention of our system design.

Dynamic Feed and Water Use Data

Representative daily records of feed and water weight data for one bird (chicken no. 1 at 40 days of age) in T1 regimen [T_a of 21.5°C (71°F)] are shown in figure 4. The magnitude of feed pecking, as shown by the spikes in feed weight, ranged from 50 to 100 g (0.11 to 0.22 lb) for the given feeder configuration. The corresponding results of filtered feed and water amount for the same bird are shown in figure 5; and

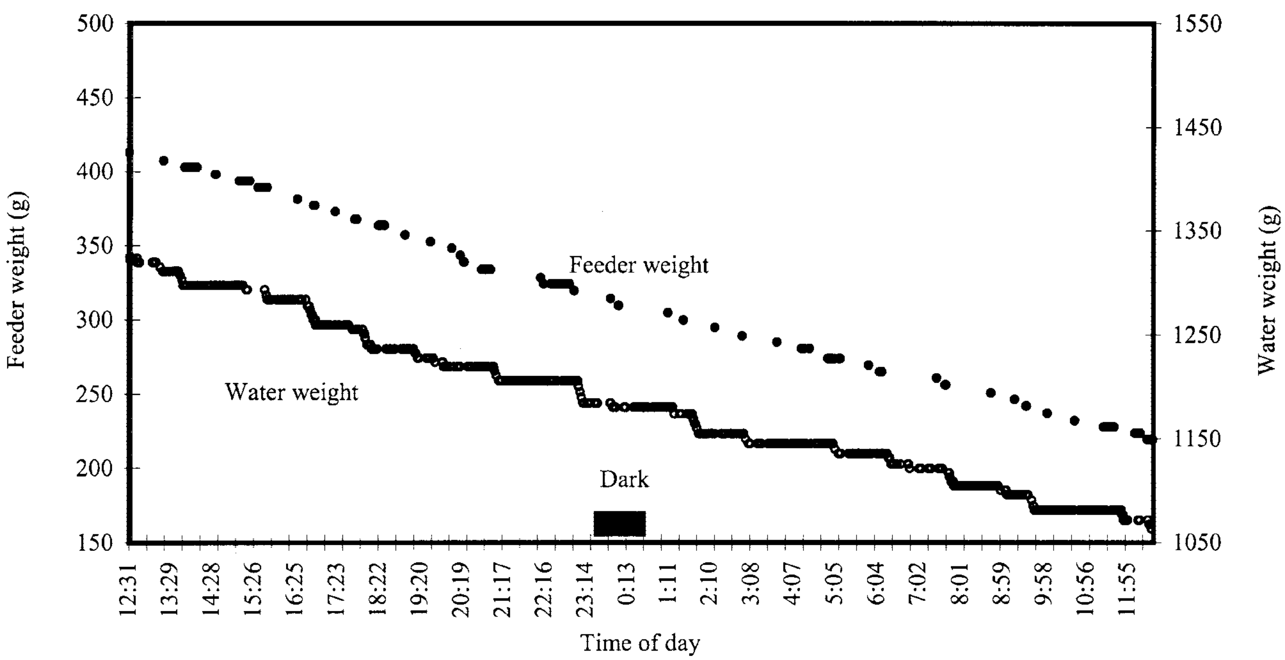


Figure 5. One–day filtered feeder and water weight data (chicken no. 1, 40 days old) [23L:1D photoperiod, T_a = 21.5°C (71°F)].

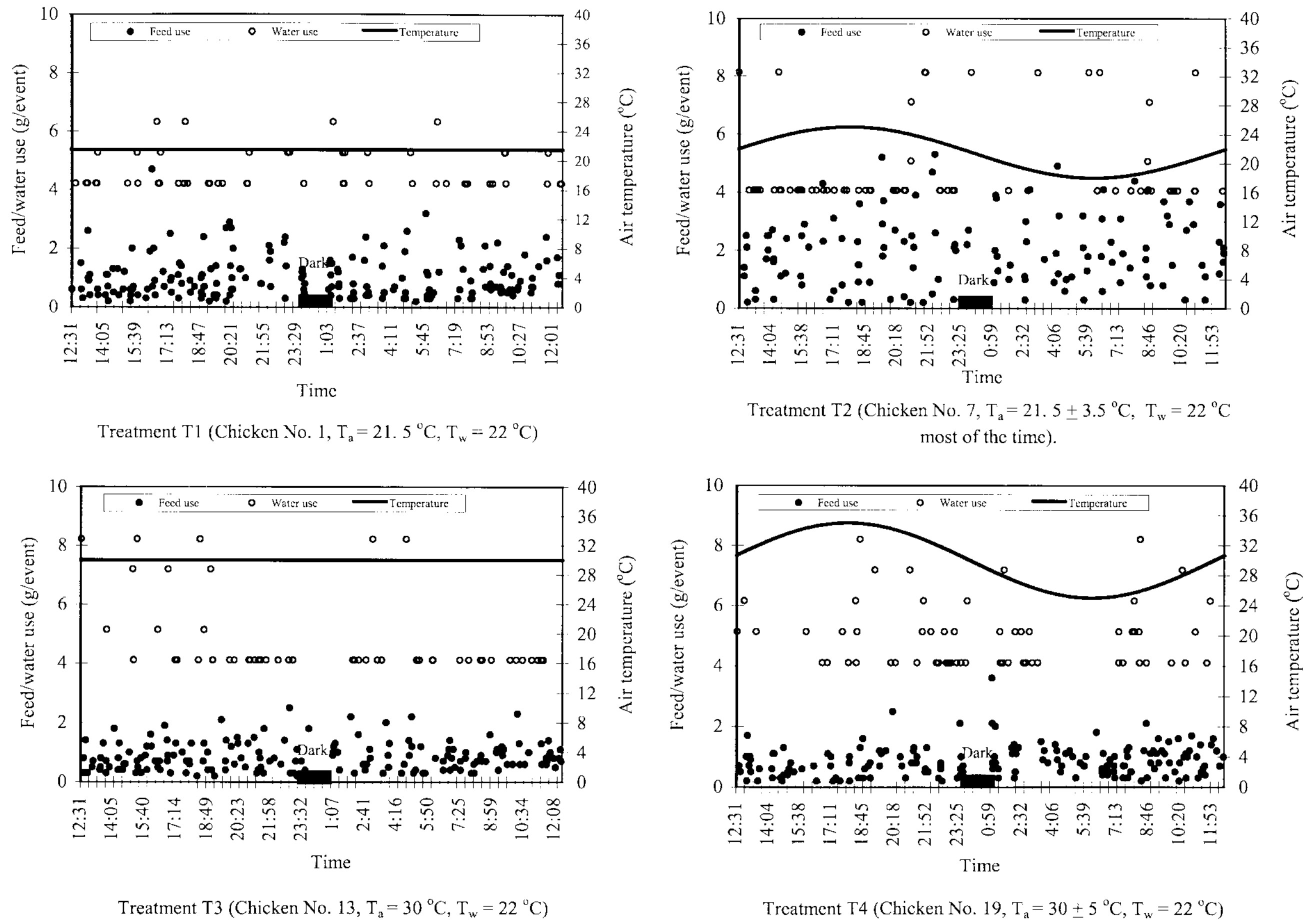


Figure 6. Example feeding/drinking events and feed/water use of 40–day–old broilers subjected to different air temperatures, as determined using the individual bird units described herein.

the dynamic feed and water events by this same bird on day 40 are shown in figure 6 (top left pane). Examples of feeding/drinking events and the corresponding feed and water use for 40–day old birds in the other three T_a regimens are also shown in figure 6. Such data on bird ingestion behavior may provide a scientific basis for better designing and managing feeding and watering equipment in poultry houses, which may lead to enhanced bird well–being.

Individual Variation in Feed and Water Use

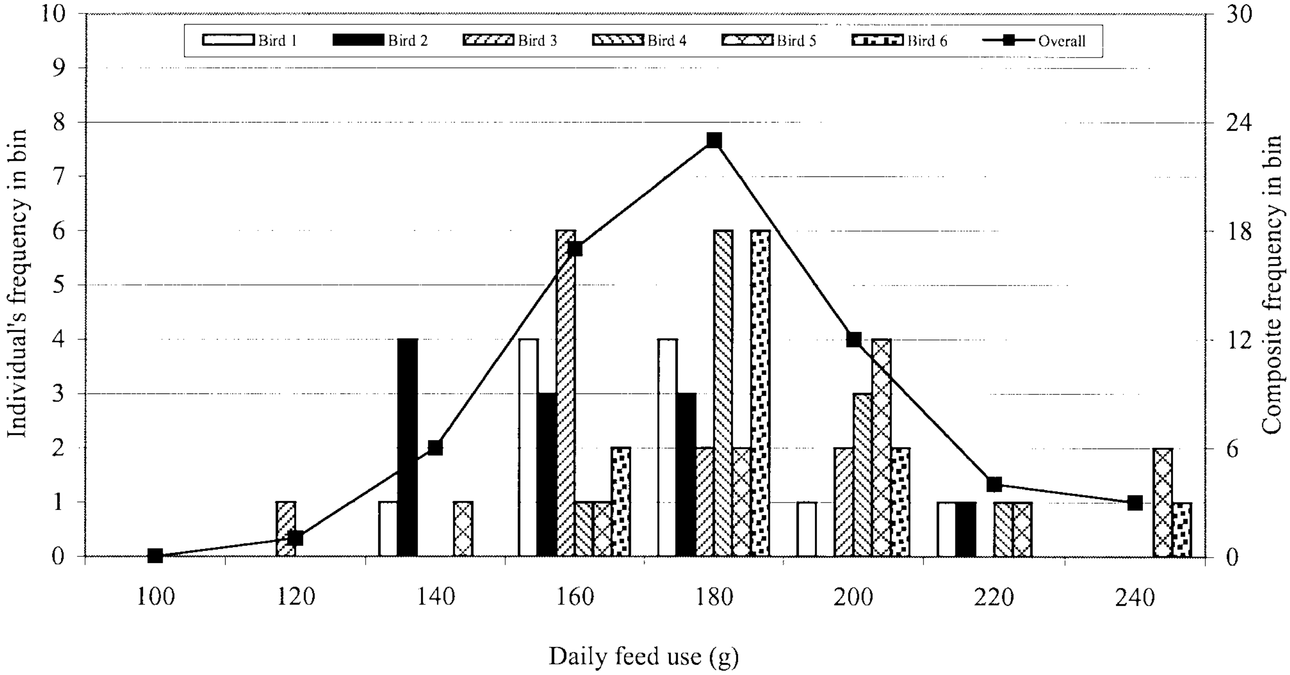
The composite average ingestion behavior of birds in a treatment may mask useful information. To demonstrate the ability of the system to discern individual bird feeding and drinking behavior, sample histograms of daily feed and water use (DFU, DWU) of each bird in T1 (bird 1 to 6) and T3 (bird 13–18) regimens for the growth period of 28–41 days are presented in figures 7–10.

Class intervals of 20 g were used to develop the DFU histograms (fig. 7). The composite trend for each treatment is reasonably symmetric, although the warm T_a treatment (T3) exhibited some positive skew and the thermoneutral treatment (T1) some negative skew. There is about a 50–g difference between the treatment means of DFU. Certain individual birds within each treatment influenced the group means more than the others. For example, DFU for bird 2 in T1 and bird 15 in T3 were responsible for separating the means by about 13 and 7 g, for treatment T1 and T3, respectively. For T1, individual bird DFU consistently spanned 80 to 100 g about the treatment mean. For T3, DFU for birds 13, 14, and 18 spanned a range of less than 60 g, and thus significantly reduced variance for the treatment.

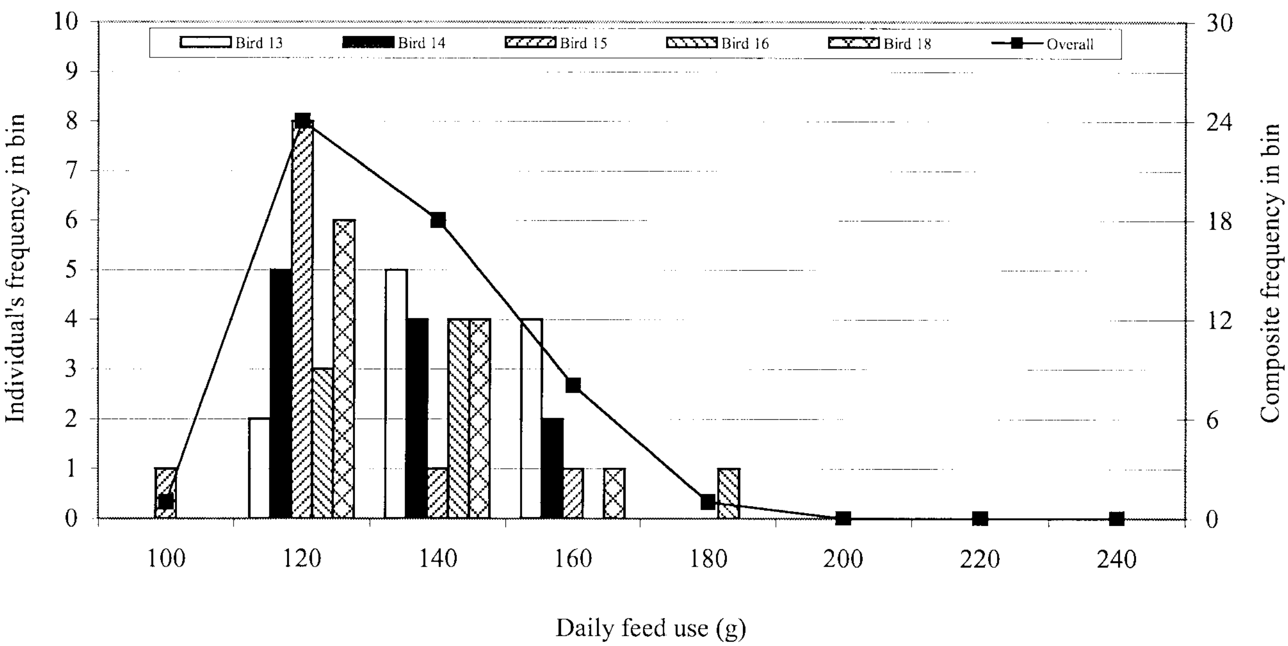
Time series data of individual birds also revealed some interesting trends that were masked by averaging among birds (fig. 8). Most birds in T3 ate less than did those in T1. DFU increased over the two weeks period for T1, but not for T3 (fig. 8). In particular, DFU remained nearly constant for birds 14, 15, and 18 during the entire period, whereas DFU of bird 13 was quite variable.

Histograms for DWU of each bird in T1 and T3 are presented in figure 9. Class intervals of 40 g were used for these histograms. Composite trend for T1 was fairly symmetric; that for T3 showed some positive skew. Difference between the treatment means was about 25 g with the mean for T1 being higher. The lower DWU for birds in the warm condition (T3) was associated with the much lower feed intake. However, the water to feed use ratio was much higher for T3 birds than for T1 birds. DWU among the birds for T1 and T3 (fig. 10) demonstrate uniform drinking behavior, independent of the thermal environment.

An attempt was made to quantify the amount of time the birds spent on ingestion (i.e., eating and drinking) activities. However, it was found that the sampling interval of 30 s used in the testing trials was not frequent enough to produce



T1 (Constant thermoneutral conditions)



T3 (Constant warm conditions)

Figure 7. Histograms of individual and composite bird daily feed use for T1 [constant thermoneutral T_a of 21.5°C (71°F)] and T3 [constant warm T_a of 30°C (86°F)] during the period of 28–41 days of age.

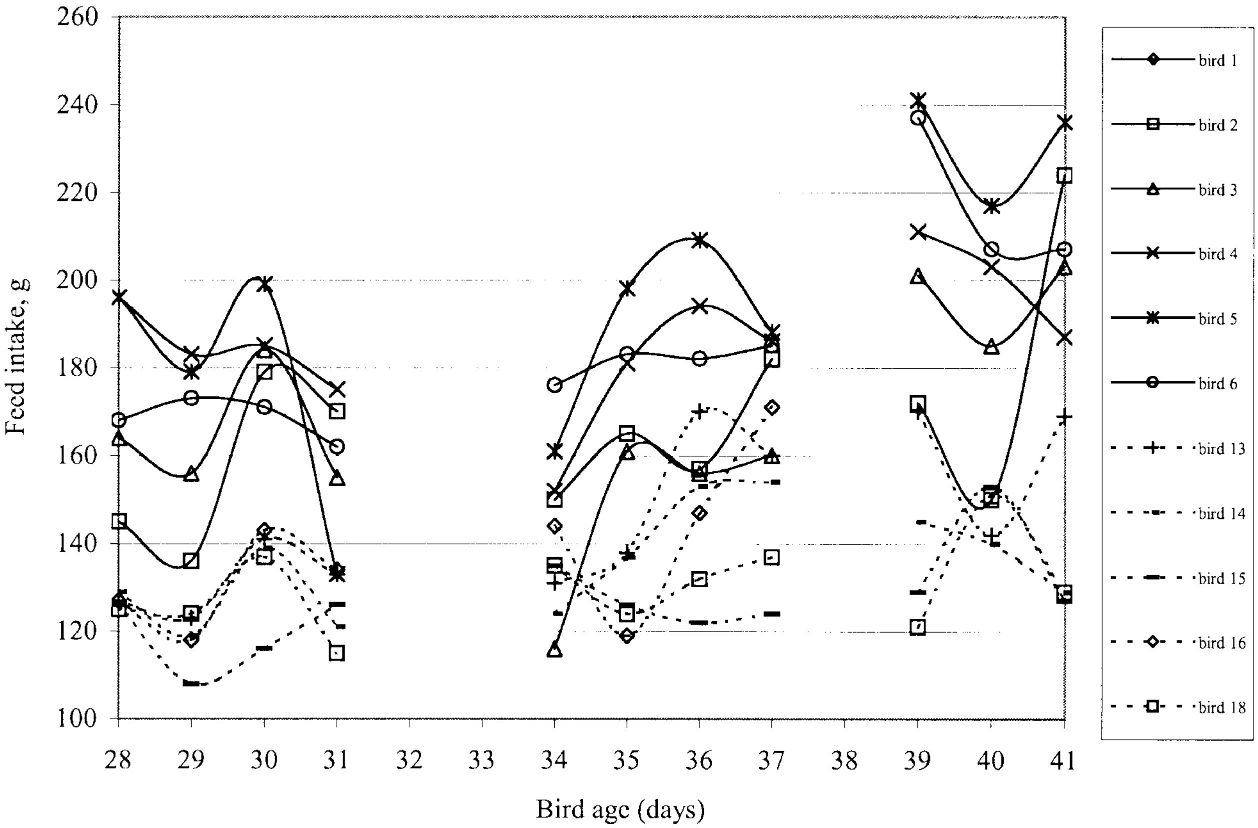


Figure 8. Individual bird's daily feed use variation over time for thermoneutral birds (birds 1–6) and warm environment birds (birds 13–18) during the period of 28–41 days of age.

accurate results. Therefore, information of this nature is not included in this article.

CONCLUSIONS

A system for studying the individual feeding and drinking behavior of poultry was designed, constructed, and tested. The system performance was illustrated with sample feeding and drinking behaviors of broilers subjected to selected thermal conditions. The results demonstrated that the system can characterize dynamic poultry feeding and drinking behavior. Information from such studies may lead to better understanding of thermo–behavioral regulation of birds, biological variations in eating habit among individual birds, and synergistic effects of environmental and nutritional alterations on ingestion behavior and ultimately welfare of the animals.

FUTURE WORK

Future efforts are required to develop a means to achieve higher sampling frequencies (e.g., every 1 s) of the signal outputs from the feeding and drinking stations. Also, reduction of the analog noise in the water measuring circuitry is necessary to further improve the resolution of drinking activity. With these modifications, the system can be used in a series of controlled experiments to quantify the effects of environmental factors and nutrient manipulations on the ingestion behavior and performance of poultry under heat stress conditions.

ACKNOWLEDGEMENTS

Funding for this study was provided in part by Ajinomoto Heartland, Inc., and is acknowledged with gratitude.

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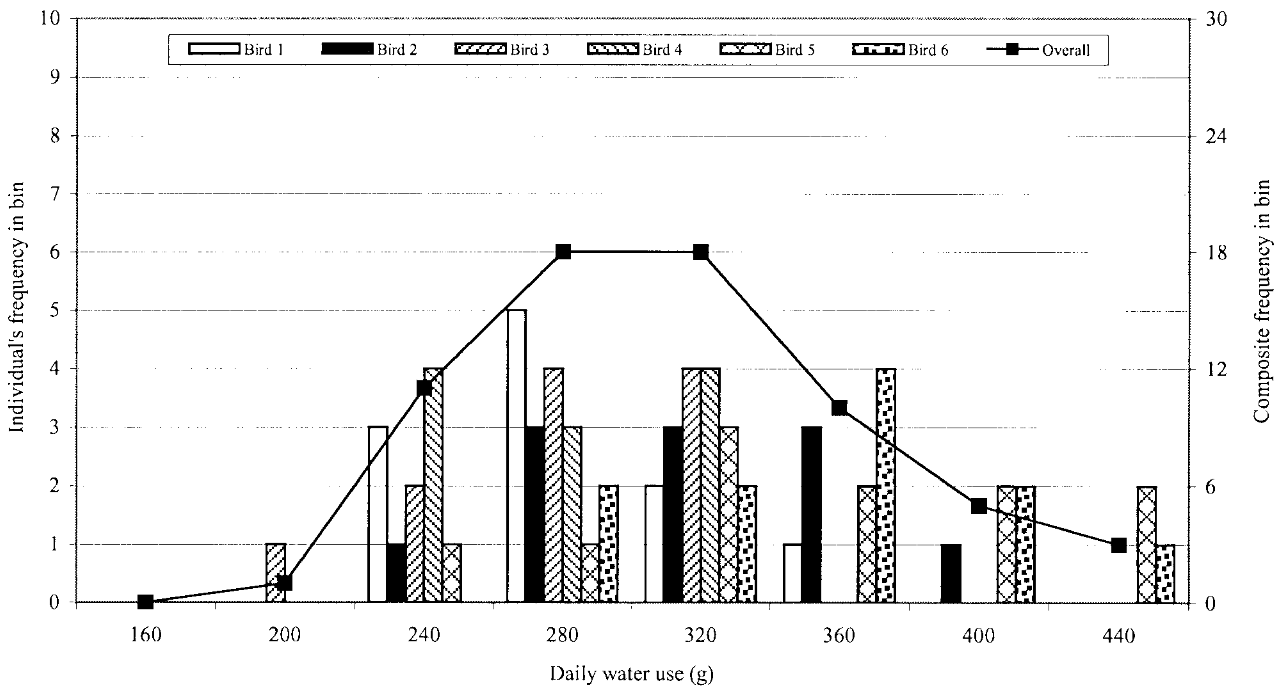

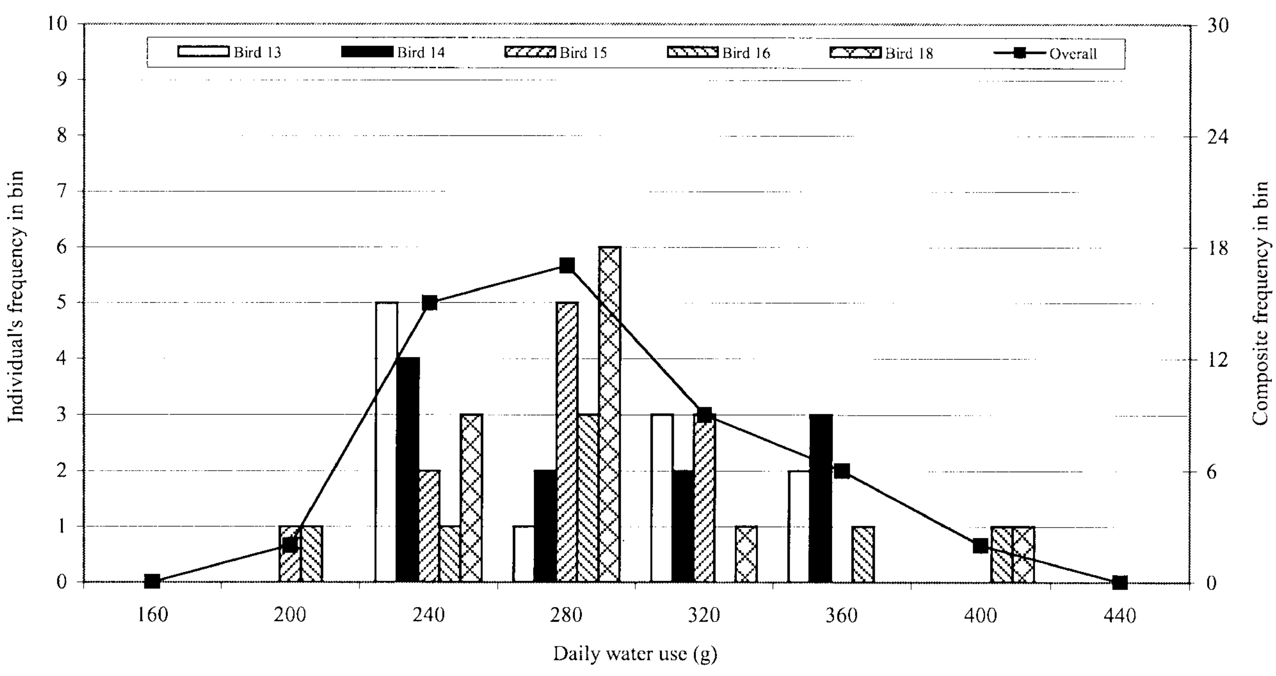

Figure 9. Histograms of individual bird daily water use for T1 [constant thermoneutral conditions, T_a = 21.5°C (71°F)] and T3 [constant warm conditions, T_a = 30°C (86°F)] during the period of 28–41 days of age.

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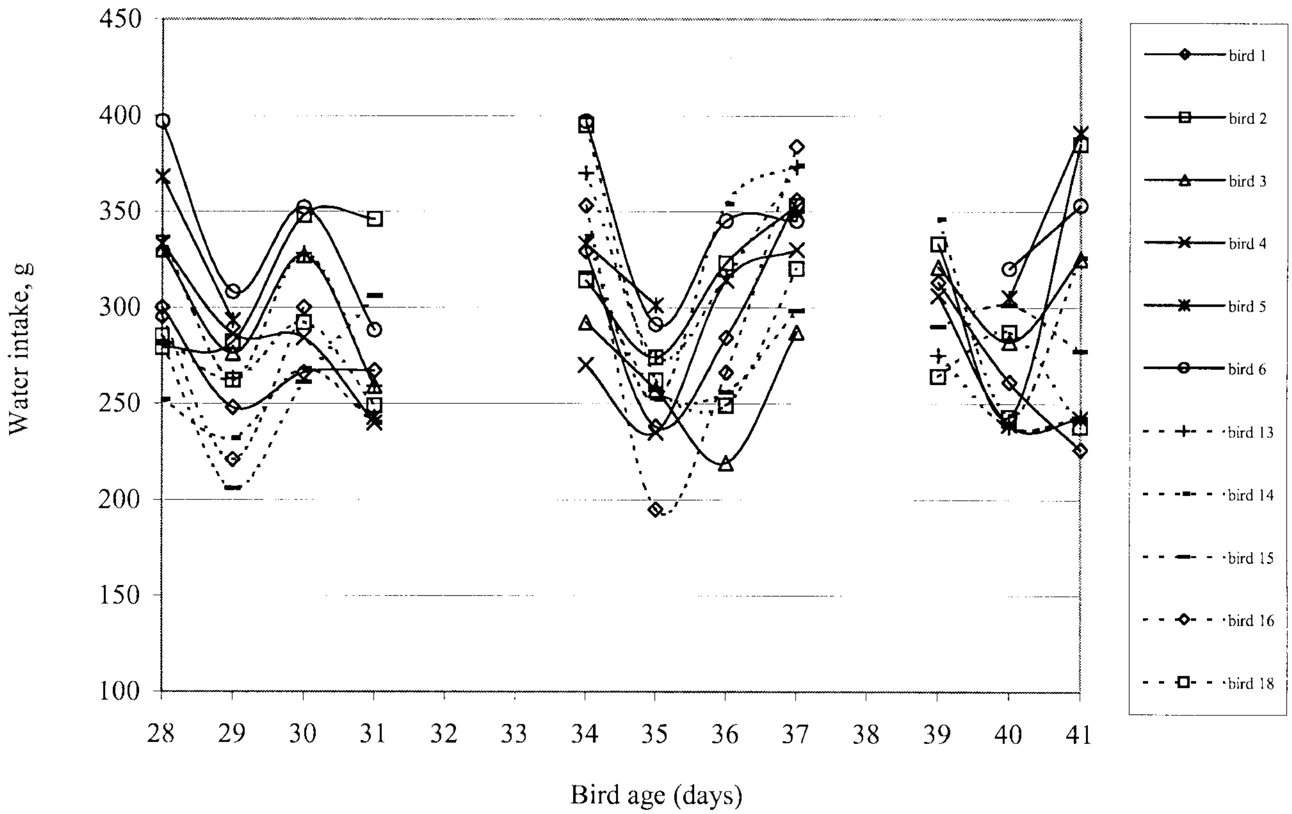

Figure 10. Individual bird's daily water use variation over time for thermoneutral birds (birds 1–6) and warm environment birds (birds 13–18) during the period of 28–41 days of age.

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