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INTERNAL TEMPERATURE OF DECOMPOSING DUCK CARCASSES IN RELATION TO BOTULISM

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ABSTRACT: Under spring conditions (mean daily maximum 22 C, mean daily minimum 9 C), the temperature within duck carcasses paralleled air temperature for 3 days; on days 4 and 5 the internal temperature rose above 30 C for approximately 30 hr and maximum temperatures of 40–47 C occurred. This coincided with the period of maximum blowfly maggot activity in the carcasses. Carcasses screened from blowflies did not experience this period of high internal temperature. Under autumn conditions (mean daily maximum 13 C, mean daily minimum 1 C), the internal temperature of carcasses paralleled air temperature for approximately 2 wk. Following a warm day (23.5 C), maggots appeared in the carcasses and the internal temperature rose markedly higher than air temperature. Maggots moved into the soil on cold nights and reinhabited the carcasses during the day. The microclimate within maggot-infested carcasses appeared very suitable for growth and toxin production by *Clostridium botulinum* and this phenomenon may help explain the occurrence of botulism outbreaks during cool weather.

INTRODUCTION

Vertebrate and invertebrate carcasses are important in the epizootiology of avian botulism, serving as substrate for growth and toxin production by *Clostridium botulinum*. The optimal temperature for growth of this organism is above 30 C, but toxin production may occur at 20 C (Segner et al., 1971). Some strains may produce small amounts of toxin at 12.5 C, although toxin production is delayed (Haagsma, 1973). Outbreaks of waterfowl botulism occur when weather conditions appear unsuitable for toxin production and we have speculated that the microclimate within carcasses might influence bacterial growth (Wobeser et al., 1983). This report describes observations on the internal temperature of decomposing duck carcasses.

METHODS AND MATERIALS

Spring trials

Three trials were conducted during June 1983. The average temperature for the month was 15.5 C, the mean maximum and minimum daily temperatures were 22.0 and 9.0 C, respectively, and the extreme maximum was 30.0 C (Saskatchewan Research Council, 1983). Adult male ducks of several species were collected by shooting and held in fly-proof containers for 1–3 hr until used in trials. To prevent interference by scavengers, each bird was placed in a 30-cm-square cage made of 2.5-cm wire mesh and then several of these cages were placed within a 1.5-m-square wire pen. This large pen was located in a grassed upland location on the campus of the University of Saskatchewan where it was partially sheltered from the wind, but exposed to the sun. The birds were in dorsal recumbency on the wire bottom of the small cages and in contact with the underlying vegetation and soil. At the start of each trial a puncture wound was made in the skin overlying the thoracic inlet of each duck and the stem of a bimetallic, partial immersion, dial-type thermometer was inserted so that the tip was located in tissue approximately in the center of the body cavity. Thermometers were left in place and temperature was recorded at 4–7-hr intervals for 7 days. Air temperature was measured with a thermometer suspended in a shaded location immediately adjacent to the carcasses.

In Trial A, three northern shovelers (*Anas clypeata* L.) and a blue-winged teal (*Anas discors* L.) were used. A northern shoveler, a mallard (*Anas platyrhynchos* L.) and a gadwall (*Anas strepera* L.) were used in Trial B. The latter three birds were weighed daily during the trial period.

Two mallards and two blue-winged teal were used in Trial C. The procedure in this trial was

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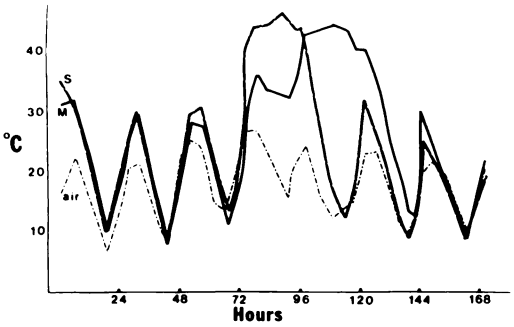

FIGURE 1. Comparison of the temperature within mallard (M) and northern shoveler (S) carcasses to that of air over a 7-day period in June (Trial B).

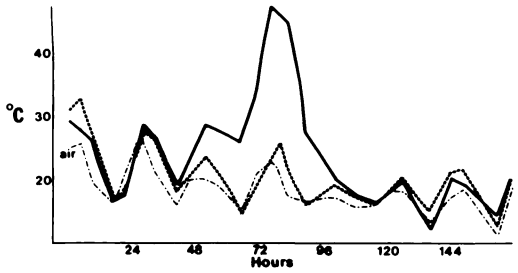

FIGURE 2. Comparison of the temperature within a mallard carcass screened from blowflies (interrupted line) to that of a mallard carcass open to blowflies (solid line) and to air temperature (Trial C).

as outlined above, except that the small cage containing one bird of each species was enclosed completely in fiberglass window screen. The top and three sides of the cage containing the other bird of each species were covered with screen, so that the carcasses were shaded similarly, but blowflies could enter. These carcasses will be referred to as screened and unscreened.

Autumn trial

A single trial was conducted between September 10 and October 8, 1983, using three adult male mallards collected in the terminal stages of botulism from an outbreak in southern Saskatchewan. The birds were killed and handled as described above. Temperatures were recorded only three times daily (early morning, noon, late afternoon) on most days. The mean maximum and minimum daily temperatures during the trial period were 13.0 and 1.1 C, respectively (Saskatchewan Research Council, 1983).

RESULTS

Spring trials

During the first 3 days after placement, the temperature of carcasses in all trials paralleled that of the air, although the carcasses often warmed more slowly during the day and cooled more slowly at night than did the air. The internal temperature of the carcasses was often warmer in late afternoon and cooler in early morning than the air. Beginning on the fourth day, the temperature within all carcasses in Trials A and B, and within the unscreened carcasses in Trial C rose much above, and became somewhat independent of, air temperature (Figs. 1, 2). The internal temperature of these birds first rose above 30 C an average of 82.7 hr (range 75–96) after placement, and remained continuously above 30 C for an average of 29.6 hr (range 25–44 hr). The maximum temperature recorded in each bird ranged from 40 to 47 C, and this maximum temperature was 14 to 32 C higher than air temperature at the time. The maximum measured temperature occurred in late afternoon in seven of the nine birds, at midnight in one, and at 5:20 AM in the other.

The period of elevated temperature coincided with the time during which blowfly maggots were conspicuous in the carcasses and with the liquefaction and disappearance of the soft tissues. This was reflected in the change in weight of the three ducks in Trial B. The average proportion of starting weight of these birds was 97, 97, 92, 79, 59, 33 and 26% on days 1 through 7, respectively. By the sixth day little remained of the carcasses other than skin and skeleton, and at this point the internal temperature approximated air temperature.

The screened carcasses in Trial C did not follow this pattern and continued cyclical daily temperature fluctuations that paralleled air temperature during the entire 7-day trial period (Fig. 2). At the end

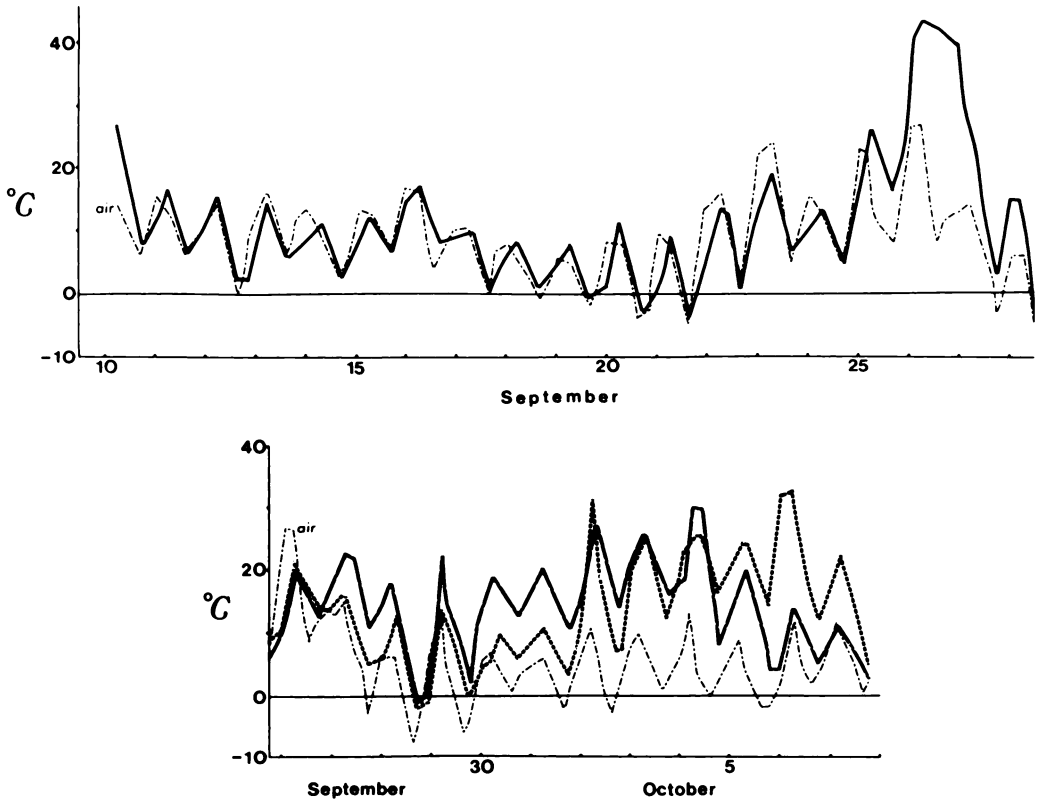

FIGURE 3. Comparison of the internal temperature of mallard carcasses to air temperature under autumn weather conditions: (a) Bird A (see text). The temperature within birds B and C followed a very similar pattern during September 10–25. (b) Birds B and C.

of the trial screened carcasses were still intact.

Flies reared from pupae collected from the soil underlying carcasses in these trials were identified as *Phaenicia sericata* (Mg.) and *Lucilia illustris* (Mg.).

Autumn trial

Between the start of the trial on September 10 and September 23 the weather was cool and cloudy (mean maximum temperature 12.4 C; highest daytime temperature 16 C) and freezing temperatures occurred on six of the 13 nights. During this period the internal temperature of the carcasses approximated that of the air (Fig. 3a) and temperatures of −1 to −3 C were measured in all carcasses in the early mornings of September 21 and 22. September 23 was warm (23.5 C) and sunny and many blowflies were active on the carcasses. On September 25 numerous maggots were seen on one carcass and the internal temperature of this bird (A) began to rise (Fig. 3a). The following day the internal temperature of this bird reached 43 C and remained above 40 C for at least 23 hr, although the overnight air temperature fell to 8.5 C. By the morning of September 28 soft tissues were gone from the carcass and the internal temperature approximated that of the air. The internal temperature of the other two carcasses (B, C) followed that of the air until September 27 and 29, respectively, which were also the first occasions on

which maggots were conspicuous on these birds. The internal temperature of these birds rose and remained somewhat elevated over an extended period of time (Fig. 3b). During this period few or no maggots were evident on the carcasses in the early morning, particularly when the air temperature was below freezing, but large numbers of maggots were present in the soil immediately under the carcasses. By midday maggots were numerous in the carcasses. The soft tissue of these carcasses was consumed by October 8.

DISCUSSION

These trials indicated that the temperature within a decomposing duck carcass may be substantially different from the ambient temperature. A remarkably consistent pattern was found in carcasses under June weather conditions. Carcass temperature followed air temperature closely for 3 days, with only minor variations presumably caused by solar heating during the day and heat transfer to the soil at night. Very high internal temperatures occurred on days 4 and 5 in all carcasses not screened from blowflies. The heat in the carcasses was probably produced at least partially by the metabolic activity of the maggots. The role of microbial decomposition in heat production is unknown although bacteria produce heat (Lamanna et al., 1973). The dense aggregation of maggots within the insulation of the bird's plumage may represent a large thermal mass, perhaps producing an effect similar to that observed in cultures of flour beetles (*Tribolium* sp.) (Pimental, 1958) and in aggregations of some other insects (Willmer, 1982).

The pattern was somewhat different under autumn conditions. The carcasses persisted for about 2 wk without obvious maggot infestation or elevated internal temperature while the weather was cool; however, a short period of warmer weather was followed by obvious maggot activity and elevated carcass temperatures. The results were variable among the three birds in this trial, and no explanation for this variation was evident. However, the internal temperature of all birds was substantially higher than ambient temperature. It appeared that some maggots retreated into the soil overnight and reinhabited the carcass during the day.

We have measured temperatures in excess of 30 C within maggot-infested waterfowl carcasses found in marshes under cool weather conditions, so a similar phenomenon occurs in nature. The microclimate within such a carcass appears suitable for rapid growth of *Clostridium botulinum* and this may provide an explanation for the occurrence of toxin in circumstances in which weather conditions are not optimal for the bacterium. The average period during which the carcass temperature remained above 30 C (29.6 hr) under spring conditions is a minimal estimate, because of the method of measurement, but is adequate for substantial bacterial growth. The findings provide another aspect to the "microenvironment concept" (Kalmbach and Gunderson, 1934; Bell et al., 1955) of the ecology of botulism.

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