J. Field Ornithol., 60(2):190–196

AN INEXPENSIVE DEVICE FOR MEASURING PUNCTURE RESISTANCE OF EGGS

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Abstract.—The avian eggshell provides mechanical protection. However, the physical properties that determine an eggshell's strength are presumably a compromise between different selective pressures. Establishing the relative importance of pressures affecting eggshell strength requires that resistance of the eggshell to breakage be measured accurately. Here I describe a simple device for measuring puncture resistance, one of the most frequently used indices of eggshell strength. This device consists of a Pesola balance which is used as a source of force, a pressure bar, which transmits force generated by the Pesola balance to the egg placed on a support table, and the bell assembly which signals when the shell is punctured. The puncture resistance tester is inexpensive, requires little skill to construct, and is easy to use. It yields sufficiently accurate data on puncture resistance of eggs, and its use for studies of eggs of different sizes requires only minor modification.

UN ARTEFACTO PARA MEDIR LA RESISTENCIA DE LOS HUEVOS A LAS PERFORACIONES

Resumen.—El cascarón del huevo de las aves provee protección. Sin embargo, las propiedades físicas que determinan la fortaleza del cascarón son supuestamente el resultado de diferentes presiones selectivas. Establecer la importancia relative de las presiones que afectan la fortaleza del cascarón requiere que la resistencia de este a romperse se mida con exactitud. Aquí se describe un artefacto sencillo para medir la resistencia a perforación, uno de los índices de fortaleza del cascarón mas utilizados. Este artefacto consiste de una balanza Pesola que se usa como la fuente de fuerza, la vara de presión que transmite la fuerza generada por la Pesola al huevo colocado sobre una base firme, y el timbre que indica cuando el cascarón es perforado. El artefacto propuesto es barato, fácil de construir y de usar. El artefacto rinde información sobre la resistencia a perforación del cascarón con suficiente exactitud y su uso en studios con huevos de diferentes tamaños solo require modificaciones sencillas.

The avian eggshell provides mechanical protection to the egg's contents, supplies calcium to the developing embryo, acts as a barrier to microorganisms, and facilitates gas exchange between the egg and its environments without excessive dehydration (Board 1982). To ensure adequate mechanical protection, the eggshell must be strong enough to minimize breakage during egg-laying and incubation, but weak enough to permit successful hatching. The physical structure of eggshells that determines their mechanical properties thus presumably represents a compromise between two selective forces. In some cases, however, birds may be subjected to additional selective pressures that may favor much stronger shells. For instance, Brown-headed Cowbirds (*Molothrus ater*) lay eggs with thicker shells than other icterids (Blankespoor et al. 1982, Hoy and Ottow 1964, Spaw and Rohwer 1987) which may greatly increase their resistance to puncture ejection attempts by some hosts (Spaw and Rohwer 1987).

Studies of eggshell adaptations depend on the availability of techniques that will provide reliable data on eggshell strength.

The maximum pressure an egg can withstand before it breaks depends upon the various physical properties of eggshells (e.g., shell thickness, density, porosity, shape). Tests of eggshell strength include: (1) compression resistance (i.e., the strength required to crush an egg between a fixed and a moving surface); (2) puncture resistance (i.e., the force required to penetrate the shell with a small punch); and (3) impact resistance (i.e., shell resistance to the force generated by dropping an object from different heights; Voisey and Hunt 1974). Of the three types of strength tests, the impact resistance tests are most complicated and least accurate (Voisey and Hunt 1974).

In 1987 I compared the puncture resistance of cowbird eggs to that of several other icterids of similar size. The purpose of this paper is to describe an instrument that I designed to measure puncture resistance of eggs.

DESCRIPTION OF THE PUNCTURE TESTER

Several complex and rather expensive electronic instruments have been designed by poultry scientists to measure shell strength of chicken eggs (see Voisey and Hunt 1974). Generally, these instruments are not readily available to ornithologists studying eggs. For this reason I designed a simple, mechanical puncture tester that will yield accurate data on eggshell puncture resistance. The instrument (Fig. 1) consists of four main components: (1) the spring-operated Pesola balance that is used as a reliable and accurate source of force; (2) the pressure bar that transmits force generated by the Pesola balance to the egg; (3) support for the egg; and (4) the bell assembly which signals when the shell is punctured. In the following description capital letters refer to parts shown on Figures 1–3.

The Pesola balance (Fig. 1; A) is suspended on a steel rod (diameter 10 mm; B), which is in turn pushed into a slot in the base of a microscope stand. Two control knobs allow both coarse and fine adjustments in height (C). The microscope stand was selected because it allows slow and smooth increases in pressure as the Pesola balance is raised gradually.

The pressure bar (Fig. 1; D) is a 50 cm long aluminum bar (6 × 25 mm). Exactly in the middle of this bar, a small hole is drilled (diameter 3 mm) which is used to hinge the bar to a support stand (E). The hinge (F) is made of piano wire (diameter 2.5 mm; length 80 mm), shaped as shown in Figure 2, and pushed tightly into two holes (diameter slightly less than 2.5 mm) pre-drilled approximately 40 mm apart and 175 mm above the base of the support stand (Fig. 2). The pressure bar must move freely around the wire (oil will reduce friction) and both sides of the bar must be of equal length and weight. If one end is heavier and rotates, filing it down will be necessary. A short piece of wire (diameter 1.2 mm, length 20 mm; G) with a loop at the end is pushed into a hole (diameter 1.2 mm or slightly smaller) drilled through the pressure bar 5 mm from its right end. This wire is used for attaching the Pesola balance to the

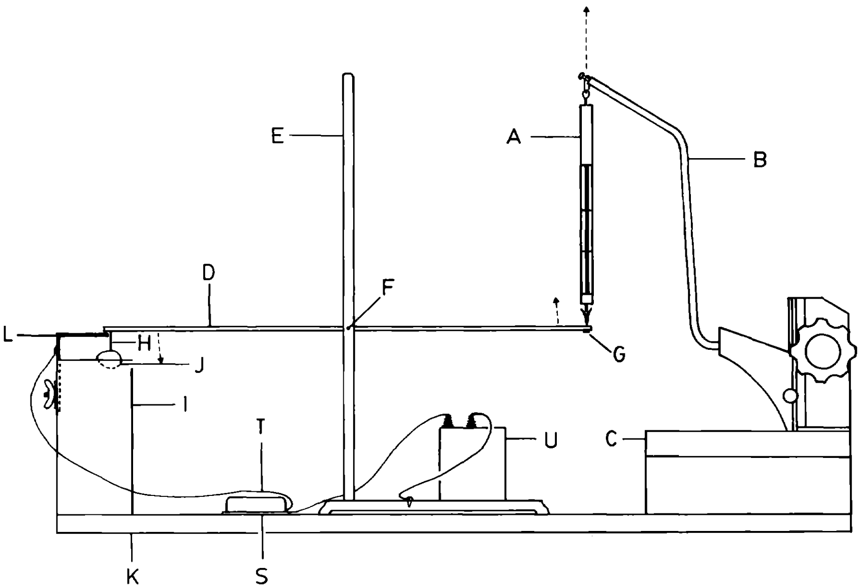

FIGURE 1. Lateral view of the instrument designed to measure puncture resistance of eggs. The instrument consists of the spring-operated Pesola balance (A), the pressure bar (D) attached to the stand (E), support for the egg (I), and the bell assembly (S,T,U). See text for description and function of individual parts referred to with capital letters.

pressure bar through the spring-loaded clip provided with the balance. The punch (Fig. 1; H) is made of a piano wire (diameter 1.2 mm, length 20 mm) which is pushed into a hole (diameter 1.2 mm or slightly smaller) drilled through the pressure bar 5 mm from its left end. The lower end of the punch used for puncture resistance tests must be filed flat. The position of the two wires in the pressure bar should be secured with equivalent amounts of epoxy glue.

The egg support (Fig. 1; I) is a block of wood (165 × 50 × 30 mm) with a small depression (diameter 10 mm, depth 4 mm; J) for an egg to prevent the egg from rolling away. It is attached to a base plate (K) of plywood (about 300 × 1000 mm). A modified metal bracket (length 80 mm; L) is used as a restrainer, allowing the punch to just puncture the egg but preventing it and the pressure bar from crushing the egg. Bracket modifications are shown in Fig. 3. The top must be shortened to 55 mm, and a 25 mm long and 7 mm wide slit (M) drilled in the bottom bracket part allows the restrainer to be adjusted up or down. Lastly, a hole is drilled (diameter 4 mm; N) for attaching the bell wiring with a metal screw and a slit cut (6 mm wide, 8 mm long; O) at the top end of the bracket for the punch. The bracket restrainer slides in a notch (length 80 mm, with 20 mm; depth 2 mm; P) and can be locked in position by

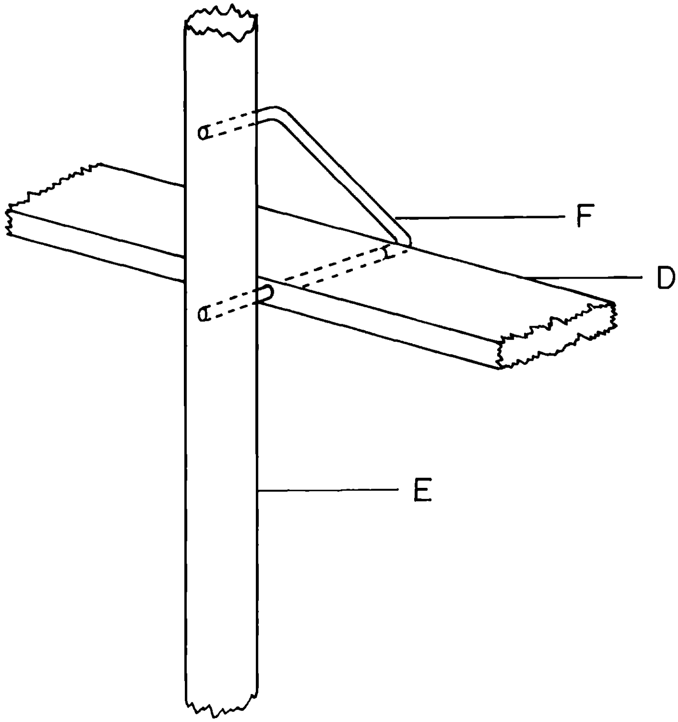

FIGURE 2. Detail of the mechanism (F) hinging the pressure bar (D) to the rod of the support stand (E).

tightening the butterfly nut (Q) which presses a washer (R) against the egg support block (I).

The bell assembly (Fig. 1) consists of the bell (S), wiring (T), and a battery (U). The bell is wired so that the positive output is attached to the base of the support stand (E). Another wire is then attached by a metal screw to the bracket restrainer (L), and connected to the bell. The negative battery output is wired directly to the bell. The steel support stand, aluminum pressure bar, steel punch and metal bracket act as an electrical circuit. The bell is turned on when the punch punctures an eggshell and the pressure bar establishes contact with the metal bracket. The audible signal makes it possible for one to continue raising the pressure on the egg slowly while continuously reading the pressure generated by the Pesola balance.

OPERATING THE PUNCTURE TESTER

The Pesola balance is lowered by turning the coarse control knob of the microscope stand. As a result, the punch is raised well above the egg support, leaving enough space for inserting an egg.

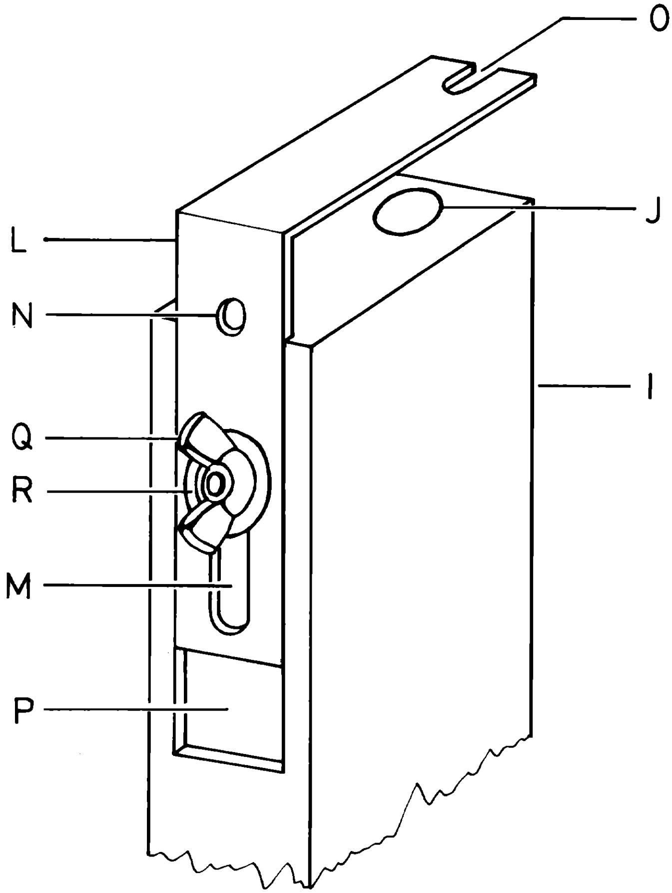

FIGURE 3. Detail of the egg support (I) with bracket restrainer (L). See text for description and function of individual parts referred to with capital letters.

An egg to be tested is placed in the depression on the egg support. The Pesola balance has to be raised slightly by turning the microscope stand control knob so that the punch just touches the egg surface but does not exert any measurable pressure on the egg (i.e., the balance pressure reading is O). The height of the restraining bracket (L) is then adjusted by loosening the butterfly nut (Q) and sliding the bracket restrainer up or down to position it about 1 mm below the end of the pressure bar with the punch (the bracket restrainer and the pressure bar must not be in contact). The bracket restrainer is fixed in position by tightening the butterfly nut (Q). The egg is then carefully positioned so that the punch is perpendicular to the surface of the egg.

Once the egg is in position, the pressure on the egg (transmitted through the punch) has to be slowly increased by raising the Pesola balance until the punch breaks through the shell (at that point the pressure bar will contact the bracket restrainer, thereby closing the electric circuit and activating the bell). The pressure exerted on the egg during the balance manipulation has to be under continuous observation. The Pesola reading at the time the bell rings indicates the pressure needed to puncture an egg (in g/1.13 mm^2). The rate of increasing the pressure on eggs tested should be constant between eggs (raising the balance slowly will yield more accurate results).

Following puncture of the egg, the balance has to be lowered which results in raising the punch above the egg. The same egg can then be rotated for another test (3 or more puncture tests can be performed on one egg, depending on its size), or a new egg may be inserted for a new test. The punch should be cleaned if it broke through the egg membranes.

With a single egg three puncture tests should be conducted. Because of a relatively high variation in pressure required to puncture an egg, the mean from several measurements will provide a more reliable measure. This variation in puncture resistance of individual eggs is evidently caused by varying eggshell thickness and by a slightly different position of an egg on the support and of the punch on the egg during consecutive puncture tests.

To establish the accuracy of the puncture tests, I placed the punch at the end of the pressure bar on an electronic balance. By slowly raising the 100 g Pesola balance of the puncture tester, I increased pressure on the electronic balance. I then repeated the test with a 300 g Pesola balance that would be used for testing larger eggs. The readings I obtained (to the nearest gram for a 100 g Pesola balance, and 2 g for a 300 g Pesola balance) were identical for the two balances. The instrument thus provides reliable data on strength required to puncture eggs.

Pesola balances of different capacities can be used for studying eggs of different sizes. For small passerines such as the Yellow Warbler (*Dendroica petechia*) a 100 g balance is needed, whereas a 300 g balance is needed for eggs of larger passerines such as the Red-winged Blackbird (*Agelaius phoeniceus*). Pesola balances of greater capacities would have to be used for eggs of larger birds. Larger eggs would also require minor adjustments in the egg support table, restraining bracket, and the size of the egg depression.

This instrument could also be used, with minor modifications, to study the compression resistance of eggshells. This type of test measures the strength required to crush an egg between a fixed and a moving surface. This could be done by removing the punch, installing an egg support with a flat surface (i.e., without a depression), and installing a stronger Pesola balance.

To conclude, the puncture resistance tester is a simple and inexpensive device that can be constructed with a minimum amount of skill. This device is easy to use and will yield reliable data on puncture resistance of eggs. Finally, the device can easily be adjusted for testing eggs of various sizes by installing Pesola balances of the appropriate capacity and by modifying the egg support.

ACKNOWLEDGMENTS

I would like to thank J. V. Briskie, E. H. Burtt, Jr., A. Isabelle, M. Milks and an anonymous reviewer for helpful comments on the manuscript. Andre Richer kindly offered assistance with construction of the puncture resistance tester. This work was supported by a NSERC operating grant to J.P.

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Received 9 Feb. 1988; accepted 24 Sep. 1988.