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DESIGN, CONSTRUCTION AND TESTING OF AN OPTICAL DEVICE FOR THE DETERMINATION OF EGG FERTILITY

B. A. ADEWUMI, I. A. FUWAPE and A. M. AROGUNJO

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ABSTRACT

This study reports the design, construction and testing of an optical device to determine the fertility of poultry egg at early age. The device consists of optical components such as condenser lens, objective lens, eyepiece lens and a source of light, all encased in a wooden frame. It has a total length of about 1m and produces an inverted image with a magnification of 5.02. The internal structure of the egg could be viewed with the naked eye through the eye piece. The device was tested using ten (10) incubated eggs for 7 days. Result showed that the device could detect fertile eggs within the first three days of incubation. This device therefore has an advantage over the conventional candler which could detect fertile eggs between the fifth and seventh day and is recommended for egg candling in the poultry industry.

Keywords: Candling, Fertility, Optics, Device, Poultry.

INTRODUCTION

The introduction of large scale electric, forced convection incubators and hatchery units have greatly assisted rapid multiplication of chicks and expansion of the poultry industry(Aremu and Shaiwoye,1993; Adewumi and Oduniyi,1999). One major outstanding problem in the poultry industry which has constantly attracted serious attention is the determination of egg fertility (Wells and Belyavin,1987; Panda,1995). Optics has been found to be a very useful science in the non destructive method of determining egg fertility(Adewumi,2000). The candler is the optical device commonly used in the determination of egg fertility to date. Since the introduction of the National Mark Scheme in 1929, egg candling has played a very fundamental role in the quality evaluation of both table and hatchable eggs (Overfield,1974). However, the candler is unable to clearly detect the developments in hatchable eggs under incubation until the seventh day(Olufemi and Robert,1979). Hence, the first candling to identify fertile egg is mostly done between the seventh and nineth day depending on the species of egg(Panda,1995; Olufemi and Robert,1979). This has a serious implications on the hatchery economy as identified by Adewumi (2000). He suggested that it is best to detect infertile eggs within the first three days of incubation to ensure an efficient hatchery economy.

The stages of development of an incubated hatchable egg was monitored by breaking the egg shell and microscope was used to observe the development of the embryo.

The stage of development between the first and twenty one day for fowl egg is as shown in fig.1 (Wells and Belyavin,1987; Olufemi and Robert,1979; Ayivor and Hellins,1986) The size of the embryo is so small that it cannot be clearly seen by the common candler at early age. Hence a more precision optical instrument may be required.

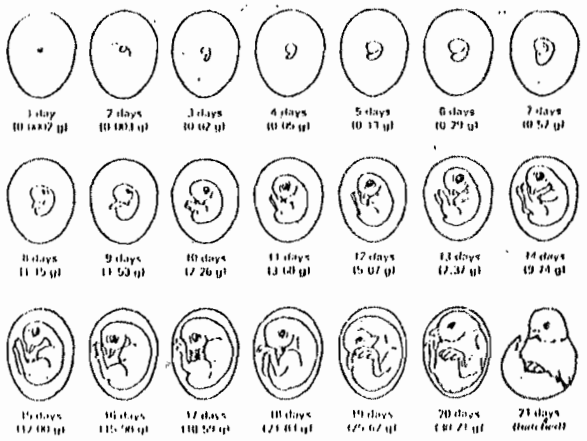

Fig. 1: Stages in the development of the embryo of the domestic fowl. (Adapted from Cornell University, *Rural Science* Leaflet. September 1939)

A number of factors affect the penetration of light through the egg, among which the shell colour, yolk colour and light intensity are very important(Anthony,1980). The intensity, I, of light is proportional to the square of the amplitude of its electric vector (a) as indicated in equation 1(Brill,1980).

$I = Ka^2$ ----------(1)

where k is a constant.

A perfectly transparent medium permits the passage of a beam without any change in intensity other than that caused by the convergence of the beam and the total radiant energy emergent from

B. A. ADEWUMI, Department of Agric. Engineering, Federal University of Technology, Akure Nigeria
I. A. FUWAPE, Department of Physics, Federal University of Technology, Akure, Nigeria
A. M. AROGUNJO, Department of Physics, Federal University of Technology, Akure, Nigeria

such a medium equals that which enters it. Whereas the emergent energy from the absorbing medium is less than that which enters, and in the case of highly opaque medium it reduces practically to zero(Brill, 1980).

If the intensity, I, to which a monochromatic parallel beam is attenuated after traversing a thickness (d) of the medium and I_o is the intensity of the beam at the surface of incidence (corrected for lens by reflection from this surface), the variation of the intensity throughout the medium is given by

$I = I_o e^{-\alpha d}$ ..... (2)

and in logarithm form

$\text{Log}_{10} (I_o/I) = \alpha d/2.303$ .....(3)

where α = absorption coefficient of the material.

A number of devices that utilizes the principle of reflection and refraction in optics include the spectacles, motion pictures projector, satellite - borne infra-red camera, microscope, telescope, scanner, projector lantern, and condenser system. These devices extend the scope of our human vision beyond the visible range (Halliday and Resnick, 1992). While some of those optical instruments produce real images, the others produce virtual images. In most cases, these optical instruments incorporate compound lenses consisting of a number of individual lenses combined together.

The design technique for optical system include the trial and error method, algebraic method, combined method and computer aided technique (Begunov, 1988). The design of optical system consists of two essential stages. At the first stage, the designer determines the number of the optical elements required for the system. The second stage is the determination of the optical value of design parameters. Ideally, optical objects should produce point images. Geometrical aberrations are minimized and eliminated by proper solution of optical system configuration and the creation of optical elements during the design optimization process (Finchman and Freeman, 1980) .

Candling has proved uneconomical for large scale hatchery (Adewumi, 2000). It is therefore essential to find a more sensitive, reliable, accurate and effective alternative to candling in order to improve the economy of mechanized hatchery. An experimental electronic alternative to candling was reported by Overfield (1974).

This device uses high resolution cameras resistant to blooming with optimum spectrum for viewing eggs passing along conventional conveyor at normal speed. The picture of the egg and its content is projected on a television screen in a control room. This device is however very expensive and is yet to be commercialized. The main objective of this study therefore is to develop a simple and affordable alternative device for the determination of the fertility of incubated hatchable egg at early age.

EQUIPMENT DESCRIPTION AND DESIGN

The optical devices basically consist of a source of light, and converging lenses arranged in a wooden frame. An incandescent lamp with a power rating of 100W was used as the light source. Three converging lenses were used, one as a condenser, another as an objective lens and the third as an eyepiece. Fig. 2 shows the schematic diagram of the device. The lenses are arranged in such a way that a final magnification of 5.02 was produced.

The condenser (a converging lens) of focal length of 22.5cm was selected to ensure an image with a short image distance. It is placed between the light source and the object. It is 4cm away from the lights source and 25cm to the objective lens. It gathers the light rays from the source and redirects or focuses them on the object. The objective lens is placed between the object and the eyepiece and it also has focal length of 15cm It produces a real, inverted and enlarged image. The distance between the objective lens and the eye piece is 45cm. The final magnification of image produced by the

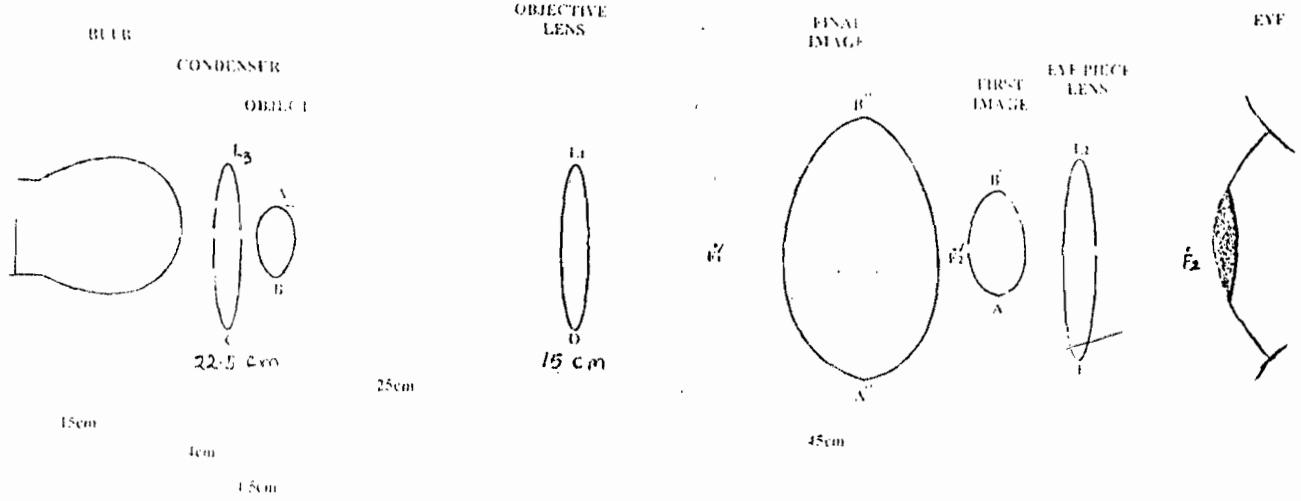

Fig. 2: The schematic diagram of the device

objective lens is done by the eyepiece lens which is a combination of two converging lenses with focal length of 20.5cm and 22.5cm respectively producing a resultant focal length of 10.7cm. The image produced by the eyepiece lens is larger, virtual and inverted.

The design of the device was base on lens equation. Equation 4 gives the relationship between the object distance(S), image distance (S^1) and focal length (f) for individual lens while equation 5 shows the magnification of the lens

$$1/f = 1/S + 1/S^1 \quad \ldots\ldots (4)$$

$$M = S/S^1 \quad \ldots\ldots (5)$$

Table 1: The daily observations of ten incubated eggs using the optical equipment

DAYS /EGG	1	2	3	4	5	6	7
1	Clear Light red Interior	Dark red Spot Observed	Air space Visible/major Portion dark	Air space visible, darker patch observed within dark region	Air sp smaller, major portion dark.	Air space observed at both sides with dark mid-region.	Air space on both sides with dark ring- like mid-region.
2	Clear Light red Interior	Dark red Spot Observed	Air space Visible/major Portion dark	Air space visible, darker patch observed within dark region	Air space smaller, major portion dark.	Air space observed at both sides with dark mid-region	Air space on both sides with dark ring- like mid-region.
3	Clear Light red Interior	Dark red Spot Observed	Air space Visible/major Portion dark	Air space visible, dark region observed but darker on one side	Air space smaller, major portion dark.	Air space observed at both sides with dark mid-region	Air space on both sides with dark ring- like mid-region.
4	Clear Light red Interior	Dark red Spot Observed	Air space Visible/major Portion dark	Air space visible, dark region observed but darker on one side	Air space smaller, major portion dark.	Air space observed at both sides with dark mid-region	Air space on both sides with dark ring- like mid-region.
5	Clear Light red Interior	Dark red Spot Observed	Air space Visible/major Portion dark	Air space visible, dark region observed but darker on one side	Air space smaller, major portion dark.	Air space observed at both sides with dark mid-region	Blood trace capillary lines observed in the dark region.
6	Clear Light red Interior	Dark red Spot Observed	Air space Visible/major Portion dark	Air space visible, dark region observed but darker on one side	Air space smaller, major portion dark.	Air space observed at both sides with dark mid-region	Air space on one side Black patch within the dark region
7	Clear Light red Interior	Dark red Spot Observed	Clear, no changes	Clear	Clear	Clear	Clear
8	Clear Light red Interior	Dark red Spot Observed	Air space Visible/major Portion dark	Air space visible, dark region observed but darker on one side	Air space smaller, major portion dark.	Air space observed at both sides with dark mid-region	Air space observed at both ends with dark mid-region.
9	Clear Light red Interior	Dark red Spot Observed	Clear, no changes	Clear	Clear	Clear	Clear
10	Clear Light red Interior	Dark red Spot Observed	Air space Visible/major Portion dark	Air space is small major portion is dark	Air space is smaller major portion is dark	Air space observed at both sides with dark mid-region	Blood trace capillary lines observed in the dark region.

The objective lens L_1 was placed 25cm from the object (AB). For the combined lenses of the eyepiece, the magnification (Mc) is given by

$Mc = (S_1^1S_2^1)/(S_1S_2)$ .....(6)

Where S_1, S_2 = Image distances of lenses 1 and 2 respectively

S_1^1 ,S_2^1 = Object distances of lenses 1 and 2 respectively

For combined lens, the resultant focal length of the combined lens (F) is given below as stated in equations 7a and b

$1/F = 1/F_1 + 1/F_2$ ..... (7a)

Or

$F = (F_1F_2)/(F_2 + F_1)$ .....(7b)

Where F_1 , F_2 are focal length of individual lenses 1 and 2 respectively

The object (egg) is placed at a distance 4.5cm from the condenser to ensure the concentration of the converging beam is not focused on the object. This is because the concentration of the beam on the egg could destroy the embryo. The distance of the image formed by the objective lens (S^1) was calculated to be 37.5cm from the objective lens, with a magnification of 1.5

A distance of 45cm was selected between the objective lens and the eyepiece (which is a combination of two length having a resultant focal length of 10.7cm). The image A^1B^1 of the objectives becomes the object for the eyepiece. A virtual image at a distance 25.1cm is formed to the right of the objective lens and has a magnification of 5.02. With this magnification a clear view of the internal content of the egg could be viewed with the naked eye through the eyepiece.

RESULTS AND DISCUSSION

The optical device was used to observe the internal structure of ten hatchable eggs for seven days using a laboratory table incubator (Adewumi,1998; Adewumi and Falayi,1999). The result of the test is as shown on table 1. Egg nos.7 and 9 were "clear" indicating that they were not fertile. Apart from the fact that the instrument could detect the yolk and embryo as red spot at the centre of the egg on the first and second day for hatchable egg, it could clearly identify the airspace on the third day. This demonstrates the ability of the equipment to detect fertile egg within the first three days of incubation.

This equipment therefore has an advantage over the common candler since it could identify both fertile and infertile eggs early enough. The implication is that infertile egg could be replaced early enough and the percentage hatchability and hatchery efficiency of the hatchery could be improved. Hence, the economy of hatching eggs could be improved (Adewumi,2000).

CONCLUSION

The equipment is simple, cheap and compact. It could be improved for commercial production and use in the poultry industry.

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