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DESIGN AN INTEGRATED INCUBATOR-HATCHER MACHINE TO SUIT SMALL NUMBER OF CHICKEN EGGS

M. K. Afify

ABSTRACT

This study aimed to design a small incubator and hatcher for small number of chicken eggs to suits the requirements of small breeders and poultry houses. The best results in artificial incubation of chicken eggs were achieved with, the careful collection and preparation of clean eggs, the use of a modem automatic turning, circulated forced air incubator with reliable temperature and relative humidity controls.

The results showed that the best egg turning angle was 40° and egg turning times per day was 8 times to record high percent of fertile egg hatching of 95,12 %,low percent of mortality of 4.88%, profit of 70.97 L.E/ cycle and 1206.54 L.E / year, and less energy of 0.388 kW. cycle / chick

INTRODUCTION

The egg is one of nature's most incredible self-contained life capsules. It contains all of the balanced nutrients and, if fertilized, all of the genetic material for the creation of a new life-

Artificial incubation goes back thousands of years when the ancient Chinese and Egyptians operated large hatcheries that were quite successful. Up until ten years ago, most of the scientific information concerning artificial incubation applied to periodical species important to the poultry industry. Presently large commercial poultry incubators fit tens of thousands of eggs at a time and, due to selection, most hatch.

The incubation of exotic bird eggs, usually in small numbers, has recently become a popular way to try and increase production but unfortunately often leads to failure. There is a desire to improve artificial incubation techniques as diets to hand-feed artificial bird's right from

Lec. Agric. Eng., Agric. Eng. Dep., Fac. Agric., Zagazig Univ., Egypt

hatch are becoming available and more breeders are confident that they can raise a baby themselves.

Brown (1979) stated that the topic of incubation could fill a book with many different techniques leading to a successfully hatched egg. Having the right equipment is as important as knowing the process. Temperature, humidity, ventilation, egg turning and sanitation are all important factors in the proper incubation of eggs.

Larue and Hoffman (1981) showed that it is necessary to position eggs in the hatcher so they are held firm, to allow the chick to rotate in the shell without rolling the egg- A freshly hatched chick may still be attached to the allantoic sac by thin vessels which should no longer contain blood and will quickly dry and fall off.

Reininger (1983) recommended that some artificially incubated eggs be cooled once a day to recreate the natural cooling which occurs when the brooding parent leaves the nest to eat.

Flammer (1984) stated that poor fertility and hatchability can be due to a number of factors including poor parental nutrition, stock (old or infirm birds), inbreeding, infection of the egg and improper incubation conditions.

Reininger (1985) mentioned that the production of rare species can be significantly increased by artificial incubation. Eggs normally lost to parental neglect, predation, extremes of environmental conditions, pathogen infection and other calamities can be saved. Many pairs lay a second clutch and in some cases triple clutch to replace eggs that are removed.

Brown (1985) recommended that fertile eggs should be incubated within 7 days after they are laid. The number of eggs that hatch begins to decrease if held too long. If it is necessary to hold the eggs before incubation, keep them at a temperature of 50 to 65 degrees F(10-18C°). Refrigerator temperatures around 45 degrees F (7C°) will kill the embryo. The embryo may resume development if the temperature is above 75 degrees F(22C°) . It is best to have an incubator ready for the eggs when you pick them up.

Cutler and Abbott (1986) found that incubating chicken eggs at a temperature of 3 7.5°C and a relative humidity of 56% produced best results. Temperatures 1.4°C higher or lower than 37.5°C produced very poor hatchability and increased the incidence of abnormalities. He also advised that the rate of embryonic development is dependent on temperature. Incorrect temperature may alter the timing of the hatch and may result in incomplete absorption of the yolk.

Van Der Heyden (1987) claimed that artificially incubating to increase egg production is risky and that many aviculturists have lost more than they've gained by it. This may be due to improper techniques, poor parental nutrition and other factors that can be corrected.

Harrison (1987) declared that foster parents have been successfully used to incubate and raise eggs with the same benefits as artificial incubation. Some species, such as the Monk Parakeet, make better foster parents than others. Possible disease spread, unacceptance by the foster pair and the cost (space) of maintaining them are factors which may make fostering less desirable.

Low (1987) advised towards lower humidity levels and provides little or no water in the incubator. This may be true for very humid areas such as Florida but in all cases the correct humidity must be established by a combination of wet bulb readings and proper egg weight loss.

Metcaife et al (1987) clarified that successful incubation depends on maintaining favorable conditions for hatching fertile eggs- Four major importance factors of are temperature, humidity, ventilation, and turning. Commercial incubators are automated to control all of these factors. With small incubators, some of these factors must be controlled manually. Temperature must be closely regulated, and the thermometer should be at the same level as the eggs. Commercial incubation is accomplished at approximately 99.5 degrees F(37.4C°). Temperature can be controlled within plus or minus 0.1 degrees F(0.06C°) . Small incubators cannot be controlled that closely. If control is within plus or minus 2 degrees F(±1.1C°) , hatching is usually successful. If the incubator does not have a fan to circulate air (still air incubator), the suggested temperature is several degrees higher, about 102 F (39C°).

Wilson and Wilmering (1988) demonstrated that cheaper incubators are available with manual or hand turning but the savings are questionable for several reasons. Eggs should be turned at least three times a day or better still once every two hours for the first 75% of the incubation period. Manual turning may simply require turning or pulling a knob but forgetting to do this will reduce hatchability. Turning eggs directly by hand has many risks including; contaminating the eggs with micro-organisms, damaging the eggs by careless turning, or twisting the embryo by turning in the same direction and forgetting to turn them back . The turning of chicken eggs can be stopped at 16 days (normal incubation period 21 days) without adversely affecting hatchability.

Baker (1988) studied that too low or too high incubation temperature and/or humidity may result in a delayed or early hatch of weak chicks with unrestricted yolk sacs or death as chicks stick to the membranes or drown in excess fluid. A study of 1200 eggs which failed to hatch found 73.3% to be infertile or clear, 14.8% as dead in shell mainly due to infections but also malposition, 11.1% because of early embryo death due to rupture of the yolk, infections or no specific cause, and about 1% due to deformed shells or lack of a yolk, He advised also that staphylo coccus was the most common bacteria found in infected eggs along with Streptococci, E.coli, Coryne bacterium and Pseudomonas in that order of occurrence. This study showed the importance of egg sanitization to achieve maximum hatching rates.

McDanniel (1990) stated that artificial incubation can be frustrating; it can be an art as well as a science- However loses as well as successes provide experience and information on each particular set-up and corrective measures can then be taken. Unfortunately some breeders operate on a trial and Error system, waiting to see if their eggs will hatch under the conditions they have set up and only changing the conditions based on the way the eggs have died. Measuring the rate of egg weight loss and comparing it to accepted ranges can indicate if humidity changes are required before the egg is lost.

French (1997) pointed that the most important incubation factor for determining hatching success must be temperature. While relative humidity, ventilation and turning are important factors that, if not controlled correctly, can have a major impact on hatch. Eggs are not sensitive to small deviations from the optimum in these three factors. This is not the case for temperature, where a change of only 1 °C from the optimum can have a major impact on hatch results

Hamre (1998) recommended to maintain the temperature in the 99-102° F (37-39C°), temperature range 100-101° F. (37-38C°) , if possible. Place the thermometer to measure the temperature at a level or slightly above where the center of the egg will be. Avoid temperatures outside the 97-103° F(36-40C°) range. If the temperature remains beyond either extreme for several days, hatchability may be severely reduced.

-He also added that the moisture level in the incubator should be about 50 to 55 percent relative humidity, with an increase to about 65 percent for the last 3 days of incubation. Moisture is provided by a pan of water under the egg tray. The water surface should be at least half as large as the surface of the egg tray. Add warm water to the pan as necessary. If more humidity is needed, increase the size of the pan or add a wet sponge. Humidity adjustment can also be made by increasing or decreasing ventilation.

Hemes (2001) declared that the eggs must be turned during most of the incubation period, stopping 3 or 4 days prior to hatching. Some incubators have automatic turning features; when using these machines, follow the manufacturer's directions for best results.

Also he added also that all incubators are built with air vents. They are placed strategically to draw fresh air into the incubator and expel stale air and excess carbon dioxide. If the incubator is full of eggs. the need for fresh air will increase as the embryos develop. It may be necessary to open the vents slightly, if possible, late in the incubation period. Take care not to lose humidity if you open the vents. In small incubators, the vents are not adjustable and are designed to be adequate for the entire hatch.

Smith (2001) stated that fairly constant environmental conditions can be maintained in an incubator. Incubators are available in many different models and sizes with capacities ranging from two to thousands of eggs. The larger incubators are rooms in which environmental conditions are carefully controlled- There are two basic types of incubators, forced-air and still-air incubators.

(A) Forced-air incubators have internal fans to circulate the air. Eggs are placed in stacks of trays. The capacity of these incubators is large. Most units have automatic equipment for turning the eggs and spray-mist nozzles for holding proper humidity levels.

(B) Still-air incubators are usually small but may hold 100 eggs or more. They do not have fans. Air exchange is made by escaping warm, stale air at the top and entering cool, fresh air near the bottom. Air circulation, is limited, so only one layer of eggs can be incubated. Incubating temperatures in these machines must be about 2 to 3°F(1-2C°) , above the temperatures in forced-air incubators.

Eggs at various stages of incubation are held in the incubator. The eggs are transferred to the hatcher on the 18th day and held in the hatcher until completely hatched. Clean and disinfect the hatcher after each group of eggs hatches.

This study aimed to design and construct a small integrated incubator and hatcher (one system). This design allows any person to start the breeding in poultry production field easily without high cost.

The capacity of incubator was 120 eggs according to the kind of the chicken eggs.

MATERIALS AND METHODS

Egg composition:

An average-sized egg weights approximately 57 grams. Of this weight, the shell constitutes
11 percent; the white, 58 percent; and the yolk, 31 percent, **Tables (1).** Normally, these proportions do not vary
appreciably for small or large eggs- the analysis of egg composition was done by the animal production labs. , Fac. of Agric. ,Zagazig Univ.

Table (1) The percent components of egg.

Percent	Water	Protein	Fat	Ash
Whole egg	74.20	13.70	11.10	1.00
White	88.80	11.20	00.00	0.00
Yolk	48.60	17.30	33.10	1.00

The incubator and Hatcher unit specifications;

The incubator wall was consisted of three layer, the inner layer made from Galvanize iron plate of 0.3mm thickness and the outer layer was made from wood plate of 0.2 mm thickness . The distance between the two layers was filled by isolating material of compacted glass wool of 25 mm thickness. The density of egg and isolated material was 1200 and 350 kg / m^3 respectively, the temperature inside and outside the incubator were 37.5 and 29 C° respectively,

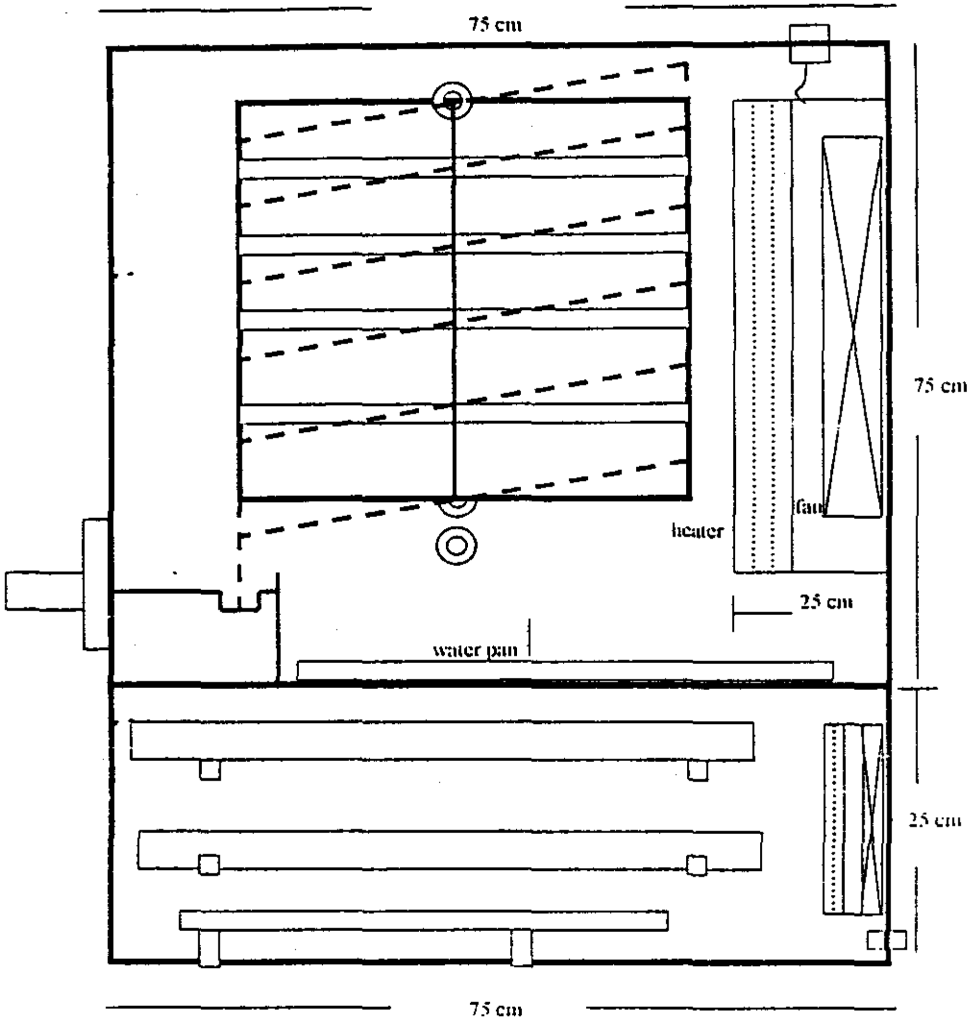
The dimensions of the unit are;

Total length;	75 cm
Total width;	50 cm
Total height;	100 cm

The unit divided into two parts, incubator and hatcher units and separated also by isolated materials

The incubator :

- **Egg trays** : they were made from wooden frame and the bottom from perforated sheet of plastic.



Part no.	Name	No.	Part no.	Name	No.
1	Outer frame	1	10	Heater	2
2	Incubation chamber	1	11	Hatch egg tray	4
3	Hatcher chamber	1	12	Electrical thermostat	2
4	Egg loader	1	13	Thermometer	2
5	Egg tray	2	14	Sensor	2
6	Water pan	2	15	hygrometer	2
7	Fan	2	16	Electrical engine	1
8	crank	1	17	Control panel	1
9	Perforated shaft	1	18	Deflectors	6

Figure (1) The main parts of the incubation-hatcher units

- **Heating system**: consists of heaters to encourage the embryos to develop at a natural rate, the eggs of different species requiring different optimum temperatures
- **Turning system**: at regular intervals, to prevent the egg membranes from sticking to the inside of the shell and to ensure the eggs warming evenly. Egg turning also increases the oxygen intake of the embryo and encourages correct development. Turning the egg needs to be carried out at least twice a day. Because of this, an automatic egg-turning facility for the incubator has a very high priority. The turning system perform its job through crank, perforated shaft through a control panel.
- **Ventilation system**: To ensure a good supply of oxygen and, importantly remove the carbon dioxide produced so that it does not poison the developing ducklings. An appreciate air flow also encourages evaporation of water for essential weight loss of the egg.
- **Water pan**: to control the normal weight loss of the egg that happen during incubation for hatching and to prevent egg shell membranes becoming too dry for hatching, Different humidity levels are needed to be provided at certain stages of incubation, with a very high humidity at the time of hatching.

The incubator specifications;

Total length;	73.5 cm
Total width;	48.5 cm
Total height;	73.5cm
Tray loader length;	40cm
No- of shelves (tray);	4
Distance between trays;	10cm
Distance- between water pan and tray loader;	7 cm
Tray dimensions;	39x35 x6 cm
Distance between fan and heater;	15 cm
Distance between tray loader and heater;	10cm
Distance between tray loader and fan	25 cm

The Hatcher specifications;

Total length;	73.5 cm
Total width;	48.5 cm
Total height;	23.5 cm
Egg tray;	Two egg tray of 70 x 40 cm

The incubators provided with the following instruments;

- **Electrical motor**: to turn the egg tray. The output power of 0.19 kW.
- **Timer**: to adjust the required time to turn the egg tray.
- **Electric blower**: to circulate the air inside the incubator and carrying the following specifications;

Diameter	;	18.6- 18.8 cm
Output power	;	22 Watt
Volt / frequency	;	220 ~ 240 V / 50 – 60 Hz

- **Electrical thermostat:**

Primary experiments showed that the correct position of the thermometer is in the center of the right side of the bottom against rim and facing towards the center when using an automatic turner. The accuracy of the thermostat of 1 C.

- **Thermometer**: to measure the temperature during the incubation and hatching.
- **Heater**: of 2000 Watt used to heat the incubator and Hatcher.
- **Hygrometer**: to measure humidity to prevent unnecessary moisture loss from the eggs. Hygrometer readings are expressed as "degrees, wet bulb," Readings are Converted to relative humidity by using the **(Table 2)**. The wet-bulb thermometer measures temperature the evaporative cooling effect.

Table (2) conversion values of the hygrometer readings to degree.

Relative Humidity	**Dry- bulb(Temperature, C)**			
	37.2	**37.8**	**38.3**	**38.9**
	Wet Bulb Reading for Incubation Temperature			
45%	27.0	27.4	27.9	28.3
50%	28.1	28.5	29,0	29.4
55%	29.2	29.6	30.1	30.6
60%	30.3	30.7	31.2	31.7
65%	31.1	31.7	32.2	32.8
70%	32.1	32.6	33.2	33.7

• **Test procedures :** Primary experiments were done to ensure the best distribution of heat and relative humidity in the incubator and hatcher; 17 thermocouples (Copper Constantan) were used and located into the incubator. The terminals of thermocouples were connected with a temperature recorder through the period of incubation and hatching. The air relative humidity was calculated
according to the previous **Table (2).**

Percent Fertility is the percentage of fertile eggs of all eggs produced.

% fertility = ∑ of fertile eggs / ∑ of total eggs produced or set

Percent Hatchability is the percentage of fertile eggs which actually hatch out as live young.

% hatchability = ∑ of eggs which hatch out / ∑of fertile eggs

Cost calculations:

The cost was calculated according to the fixed and operating variables cost method

• Fixed and operating cost = 10.07 L.E / cycle.

• Electric consumption cost = electric consumption rate / hatching cycle * price per kW. = 44.297 * 0.07 =3.101 L.E / cycle.

• Egg cost = no. of egg * price of one fertile egg.
=120* 0.25 =30 L.E/cycle.

• Total cost = 10.07 + 3.101 + 30 = 43.171 L.E/cycle.

Total cost = electric consumption cost + egg cost + fixed cost + operating cost

Profit = chicken price (one day age) - total cost.

• Chicken price (one day age = 1 L.E / chick.

Annual pro.it = no. of cycle / year * profit / cycle.

• No, of cycle/year =17 cycle/year.

Power and energy requirements:

The consumed power was measured by a watt-meter . The average was 44.297 kW during the period of incubation (21 day).

Results and Discussions

Effect of turning angle and turning times on hatching of fertile egg:

The hatching of fertile egg depends greatly upon the angle of turning egg and turning times er day, between equal periods under the constant conditions of temperatures and relative humidity.

Data in **Table(3)** show increasing hatching with increasing the turning angle gradually rom 20° to 25° to 30° to 35° to 40° then after that with angles of 45° and 50°. It increased from 63.54, 67.47, 70.68, 71.52, and 70.47 % to 80.32, 88.17, 94.30, 95.12, and 93.76 % by increasing the turning angle from 20° to 40° then decreased to 75.00, 80.48, 84.29, 85.40 and 83.17 % as increasing the turning angle to 50° under the egg turning times of 2, 4, 6, 8, and 10 respectively.

Regarding to the times of turning egg per day, the hatching increasing with increase the turning times from 2 to 8. It increased from 63.54 to 71.52%, from 67.04 to 76.33 % , from70.83 to 81.11 %, from73.17 to 84.50 % , from 80.32 to 95.12 %, from 76.67 to 86.39 % , and from 75.00 to 85.40 % under the turning angle of 20, 25°, 30°, 35°, 40°, 45°, and 50°. While reducing to 70.47, 73.77, 78.17, 81.47, 93.76, 84.52, 83.17 % with 10 turning times under the previous conditions of turning angles.

From the above, it is clear that the high percent of hatching eggs was achieved with the turning angle of 40° and turning times of 8 per day to be 95.12 %.

Table (3) Effect of turning angle and turning times on hatching of fertile egg.

Turning times/day	Egg turning angle (°)						
	20	25	30	35	40	45	50
2	63.54	67.04	70.83	73.17	80.32	76.67	75.00
4	67.47	71.47	75.29	78.81	88.17	82.38	80.48
6	70.68	74.98	79.78	82.99	94.3	85.48	84.29
8	71.52	76.33	81.11	84.5	95.12	86.39	85.4
10	70.47	73.77	78.17	81.47	93,76	84.52	83.17

Effect of turning angle and turning times on mortality:

Turning prevents the embryo from fusing with the egg shell membranes. If this happens the embryo will stick to the shell and development can be fatally distorted or the chick may be malpositioned for proper hatching.

Data in **Table(4)** show decreasing mortality by increasing the turning angle gradually from to 25° to 30° to 35° to 40° then increased after that with angles of 45° and 50°. It decreased from 36.46, 32.53, 29.32', 28.48, and 29.53 % to 19.68, 11.83, 5.70, 4.88, and 6.24 % by increasing the turning angle from 20° to 40° then increased to 25.00,19.52,15,71, 14.60 and 16.83 % by increasing the turning angle to 50° under the egg turning times of 2, 4, 6, 8, and 10 respectively.

Referring to the times of turning egg per day, the mortality decreased as increasing the turning times from 2 to 8. It decreased from 36.64 to 28.48%, from 32.96 to 23.67%, from 29.17 to 18.89 %, from 26.83 to 15,50% .from 19.68 to 4.88 %. from 23.33 to 13.61 %, and from 25.00 to 14,60 % under the turning angle of 20, 25°. 30°, 35°, 40°, 45°, and 50°. While increasing to 29.53, 26.23, 21.83, 18.53, 6.24, 15.48, 16.83 % with 10 turning times under the previous conditions of turning angles. From the previous results, it is noticed that the low percent of mortality 4.88 % was recorded with the turning angle of 40° and 8 turning times of per day .

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	20	25	30	35	40	45	50
2	36.46	32.96	29.17	26.83	19.68	23.33	25.00
4	32.53	28.53	24.71	21.19	11.83	17.62	19.52
6	29.32	25.02	20.22	17.01	5.70	14.52	15.71
8	28.48	23.67	18.89	15.50	4.88	13.61	14.60
10	29.53	26.23	21.83	18.53	6.24	15.48	16.83

Effect of turning angle and turning times on cost per cycle:

The incubator works all the cycle time . So, the total cost included the fixed and operating cost, and egg cost calculated to the cycle equal 43,17 L.E / cycle. The expected income or profit represents the chicken price of one day egg (the hatching eggs) minus the total costs.

Data in **Table(5)** show increasing profit by increasing the turning angle gradually from 0° to 25° to 30° to 35° to 40° then reduced after that with angles of 45° and 50°. It increased from 33.08,37.79,41.65, 42.65. and 41.39 L.E/cycle to 53.21, 62.63, 69.90, 70.97, and 69.34 L.E /cycles by increasing the turning angle from 20° to 40° then decreased to 46.83, 53.41, 57.98, 59.31 and 56.63 L.E/cycle by increasing the turning angle to 50° under the egg turning times of 2, 4, 6, 8, and 10 respectively.

Table (5) Effect of turning angle and turning times on profit per cycle of fertile egg.

Turning times/day	Egg turning angle (°)						
	20	25	30	35	40	45	50
2	33.077	37.277	41.825	44.633	53.213	48.833	46.829
4	37.793	42.593	47.177	51.401	62.633	55.685	53.405
6	41.645	46.805	52.565	56.417	69.989	59.405	57.977
8	42.653	48.425	54.161	58.229	70.973	60.497	59.309
10	41.393	45.353	50.633	54.593	69.341	58.253	56.633

Referring to the times of turning egg per day, the profit increasing as increasing the turning times from 2 to 8, It increased from 33,08 to

42.65, from 37.28 to 48,43, from 41.83 to 54.16, from44.63 to 58.23, from 53.21 to 70.97, from 48.83 to 60.50, and from 46.83 to 59.31 L.E / cycle under the turning angle of 20, 25°, 30°, 35°, 40°, 45°, and 50°. While decreasing to 41.39, 45.35, 50.63, 54.59, 69.34, 58.25, 56.63 L.E / cycle with 10 turning times under the previous conditions of turning angles. From the previous results, it is noticed that the high profit was 70.97 L.E / cycle recorded with the turning angle of 40° and 8 turning times of per day .

Effect of turning angle and turning times on profit per year:

The profit per year was calculated to show the importance of investment in incubators especially for small breeders or houses. The incubation period in chicken ended in 21 day, so the incubation period in year approximately equals 1 7 cycles

Regarding to the turning angle in **Table(6)**, the profit increased with the turning angle gradually from 20° to 25° to 30° to 35° to 40° then decreased after that with angles of 45° and 50°. It increased from 652.31, 642.48, 707.97, 725.10, and 703.68 L.E /year to 904.62, 1064.76, 1189.CT: 1206.54, and 1178.80 L.E / year as increasing the turning angle from 20° to 40° then decreasedto796.09.907.89, 985.61, 1008.25 and 962.76 L.E/year increasing the turning angle to 50° under the egg turning times of 2, 4, 6, 8, and 10 respectively.

Table (6) Effect of turning angle and turning times on profit per year of fertile egg.

Turning times/day	Egg turning angle (°)						
	20	25	30	35	40	45	50
2	562.309	633.709	711.025	758.761	904.621	830.161	796,093
4	642.481	724.081	802.009	873.817	1064.76	946.645	907.885
6	707.965	795.685	893.605	959.089	1189.81	1009.89	985,609
8	725.101	823.225	920.737	989.893	1206.54	1028.45	1008.25
10	703.681	771.001	860.761	928.081	1178.8	990.301	962,761

Referring to the times of turning egg per day, the profit increased with the turning times from 2 to 8. It increased from 562.31 to 725.10, from 633.71 to 823.23, from 711.03 to 920.74, from 758,76 to 989.89, from 904,62 to 1206.54, from 830,16 to 1028.45, and from 796.09 to 1008.25 L.E / year under the turning angle of 20, 25°, 30°, 35°, 40°, 45°, and 50°. While reducing to 703.68, 771.01, 860.76, 928.08, 1178.80, 990.30,962.76 L.E/year with 10 turning times under the previous conditions of turning angles.

It is noticed that the high profit was recorded with the turning angle of 40° and turning times of 8 per day to be 1206.54L.E/year.

Effect of turning angle and turning times on power and energy :

The consumed power through the incubation period was 44.297 kW / cycle. Increasing the turning times using the electric motor does not mean increasing the electric consumption because the maximum turning times of 10 times represents 0.056-0.139 part of circle during the time not exceed of 1 - 3 sec.

It is clear from the data in **Table(7)**, that the energy increase with the turning angle gradually from 20° to 25° to 30° to 35° to 40° due to increase the percent of hatching egg then start increasing with angles of 45° and 50° because of decreasing the percent of hatching egg- It decreased from 0.581, 0.547, 0.522, 0.516, and0.524kW.Cycl / chick to 0.460, 0.419,0.319, 0.388, and 0,394 kW. cycle /chick as increasing the turning angle from 20° to 40° then increased to 0.492, 0.459, 0.438, 0.432 and 0.444 kW. cycle / chick as increasing the turning angle to 50° under the egg turning times of 2, 4, 6, 8, and 10 respectively.

Table (7) Effect of turning angle and turning times on energy .

Turning times/day	Egg turning angle (°)						
	20	25	30	35	40	45	50
2	0.58096	0.55063	0.52117	0.5045	0.45959	0.48147	0.49219
4	0.54712	0.5165	0.49029	0.46839	0.41867	0.4481	0.45868
6	0.52227	0.49232	0.4627	0.4448	0.39145	0.43185	0.43794
8	0.51614	0.48361	0.45511	0.43685	0.38808	0.4273	0.43225
10	0.52383	0.5004	0.47223	0.4531	0.39371	0.43675	0.44384

Referring to the times of turning egg per day, the energy decreased the turning times from 2 to 8. It decreased from 0.581 to 0.516, from 0.551 to 0.484, from 0.521 to 0.455, from 0.504 to 0.437, from 0.460 to 0.388, from 0.481 to 0.427, and from 0.492 to 0.432 kW. cycle/ chick under the turning angle of 20, 25°, 30°, 35°, 40°, 45°, and 50°. While increasing to 0.524, 0.500. 0.472, 0.453, 0.394, 0.437, 0.444 kW. Cycle/ chick with 10 turning times under the previous conditions of turning angles,

It is noticed that low energy was recorded with the turning angle of 40° and turning times of 8 per day to be 0.388 kW. Cycle/ chick.

REFERENCES

Baker, J. R. (1988) Poor reproductive performance in exhibition budgerigars: A study of eggs which fail to hatch. Journal of Small Animals Practice. Vol. 29: 562-571.

Bauer, F., S.G. Tullett, and H.R. Wilson (1990) "Effects of Setting eggs Small End up on Hatchability and Post hatching Performance of Broilers." British Poultry Science 31.3-4:715-724,

Brown, A. F. (1979) the incubation book. Saiga Publication company. Survey. Pp: 113.

Brown, A. F., (1985) the incubation book. A. Wheaton, Ltd., Exeter. Pub. by the World Pheasant Assoc.: 322 - 327.

Cutler, BA. and U. K. Abbott (1986) Effects of temperature on the hatchability of artificially incubated cockatiel egg (Nympphicus hollandicus). In: 35"1 Western Poultry Disease Conf. 32-35.

Flamer, K. (1984) Hatching problems in Psittacoses birds. American Federation of Aviculture Veterinary Seminar Proc.: 1-7.

French, N. A. (1997) Modeling incubation temperature: The effects of incubator design, embryonic development and egg size. Poultry Sc. 76: 124 - 133.

Frencb,-N. A. (1998) Overheating chicken eggs: Critical periods during incubation. Proceedings of 10th European Poultry Conf. Jerusalem, Vol. II: 790 - 794.

Hamre, L. E (1998) Hatching and brooding small numbers of chicks. College of Agricultural, Food, and Environmental Sciences. Presentation prepared by Comm. and Ed. Tec. Serv. University of Minnesota Extension Service. In accordance with the Am. Disabilities Act.

Harrison, G. (1987) Reproduction Medicine. Clinical Avian Medicine and Surgery. Aviculture Edition. Pp: 620-633.

Hemes, J. C. (2001) Hatching small numbers of eggs. Extension & Station Communications Oregon St. Uni. 422Kerr Administration.215 - 217

Larue, C. and HoiTman, K. (1981) artificial incubation and hand-rearing of cranes. International Zoo Yrbk. 21:215-217.

Low, R. (1987) Hand-Rearing Parrots and Other Birds. Bland ford Press, Dorset, U.K. : 460.

McDaniel, G. R. 1990. Hatchability: Many factors affect results. Poultry Digest 49 (9): 20, 22, 24, 28, and. 30.

Metcaife, J., M. Stock, and R. Ingermann, (1987) Development of the avian embryo. A. R. Liss, N.Y.:112-115.

Reininger, K. (1983) artificial incubation of bird eggs. Animal Keepers Forum. Vol. 10:418-423.

Reininger, K. (1985) artificial incubation of bird eggs: update. American Association of Zoo Parks and Aquarium Regional Proceed.: 427 - 435.

Scott, T.A., and C. Swetnam (1993) Screening sanitizing agents and methods of application for hatching eggs. II. Effectiveness against microorganisms on the egg shell. Journal of Appl. Poultry Res. 2:7-11.

Smith, T. W (2001) Hatching quality chicks. Ext. Serv. of Mississippi St. Unvi. cooperating with U.S.D.A. Published in furtherance of Acts of Congress, May 8 and June 30, 2001. Pub. 1182.

Van Der Heyden, N. (1987) artificial incubation. Bird World. Vol. 9 (5): 62 - 65.

Wilson, H. R. and R. F. Wilmering (1988) Hatchability as affected by egg turning in high density plastic egg flats during the last half of incubation. Poultry Sc. Vol. 67:685-688.

Wilson, H. R. (1991) Physiological requirements of the developing embryo: Temperature and turning. In Avian incubation, ed. S.G. Tullett, 145-56. Dev. from Poultry Sc. Sympo. No.22 London: Butterworth-Hememann. 125- 127

Summary

This research aims to design an incubator suits the needs of small breeders and house use for the small number of egg birds. It has the advantages of working easily, movable, operating on single – phase A.C., low cost, and simple in construction.

The designed incubator from the type of forced-air incubator provided with a fan to circulate the air and automatic turning. It has the following features:

1. Unit for incubation and another for hatching in one system.
2. The capacity of incubator is 120 of chicken eggs.
3. The temperature of incubation was adjusted to the range from (37.2 - 37.5 C°) and controlled by an electric thermostat.
4. The relative humidity of incubation and hatching was adjusted to the range from 60 - 65% (28.3 - 31.1 C°) and 65 - 70 % (29.44 - 30.56C0), respectively and controlled by hygrometer.

The incubator was tested and the results showed that:

1. The optimum angle for turning egg was 40°.
2. The optimum egg turning times was 8 times.
3. The high percent of hatching of fertile egg was 95.12 % at turning angle of 40° and egg turning times of 8 times per day, and the low percent hatching of fertile egg was 63.54 % at turning angle of 20° and egg turning times of 2 times.
4. Increasing the profit to 214.57 % and decreasing the consumed energy per chick to 66.80 % under the optimum conditions of turning angle of 40° and egg turning times of 8 times per day.

بسم الله الرحمن الرحيم

الملخص العربي

تصميم حضان ومفقس يناسب الأعداد الصغيرة من بيض الدجاج

*محمود خطاب عفيفي

يهدف هذا البحث إلى تصميم حضان ومفقس بنظام دفع الهواء الجبرى ومزود بمروحة وتقليب تلقائي ويشمل على

- وحدة للتحضين وأخرى للفقس
- سعة الحضان ١٢٠ بيضة من بيض الدجاج البلدي المخصب
- تم ضبط درجة الحرارة في المدى (٣٧,٢ – ٣٧,٥) درجة مئوية. ويتم التحكم في درجة الحرارة بثرموستات كهربائي والرطوبة النسبية في المدى ٦٠ – ٦٥ % (٢٨,٣ – ٣١,١) درجة مئوية في مرحلة التحضين.وفى المدى من ٦٥ – ٧٠ % (٢٩,٤٤ – ٣٠,٥٦)) درجة مئوية في مرحلة الفقس. ويتم التحكم عن طريق الهيجروميتر.

تم اختبار الحضان وبين مايلى:

- أفضل زاوية للتقليب ٤٠ درجة
- أفضل عدد مرات للتقليب ٨ مرات / يوم
- تحققت أعلى نسبة فقس للبيض المخصب عند زاوية تقليب ٤٠ درجة، عدد مرات للتقليب ٨ مرات / يوم وكانت ٩٥,١٢ %؛ بينما تحققت اقل نسبة فقس للبيض المخصب عند زاوية للتقليب ٢٠ درجة، عدد مرات للتقليب ٢ مرات / يوم وكانت ٦٣,٥٤ % .واقل نسبة نفوق للأجنة تصل إلى ٤,٨٨ %.
- زيادة الربحية إلى ٢١٤,٥٧ % وتناقص الطاقة المستهلكة للدجاجة الواحدة إلى ٦٦,٨٠% عند زاوية التقليب ٤٠ درجة وعدد مرات التقليب ٨ مرات / اليوم

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* مدرس الهندسة الزراعية – كلية الزراعة – جامعة الزقازيق