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Enhancing smart farming through egg-incubation technology: A micro-study in lira city, mid-north Uganda

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Abstract: **A visit to TAF Agri-Tourism Farm, located in Anyomorem parish, Lira City East Division revealed that an incubator is used for the production of local chicken and is being commercialized. Reportedly domesticated around 5,000 BC in Southeast Asia, chicken is globally kept and as of 2018, with the introduction and use of modern solar-powered, electricity-powered or fuel powered incubators, the number of chickens increased to about 23.7 billion. In sub-Sahara Africa, and Uganda (which had about 1,274 incubators as of 2014), most farmers still hold-on to the traditional reproduction of chicks as opposed to using incubator. The ZFF Thermal Air Hova-Bator was preferred by TAF Agri-Tourism Farm due to its economical and efficient benefits. The outcome of these aspects were found to be major: that this type of incubator which has a temperature and humidity regulator needs to be placed in a dark room without open windows in order to control light; and that it is able to incubate and hatch a maximum of 200 chicks and any one round of hatchery period. In the incubator, eggs are turned frequently between 4-17 days and thereafter locked completely until they are hatched. After hatching, chicks are transferred to the brooder, and later to a growing wing. Upon maturity, excess cockerels are sold-off. The farm management uses internet to advertise or receive payments but make a physical delivery of chicken to its customers.**

Keywords: **Egg incubation, chicken, smart farming, TAF agri-tourism, brooder.**

1. INTRODUCTION

Millette (2020), noted that a rudimentary incubator used in chicken production has been in existence and practice from about 400 BC when Ancient Egyptians used the cylindrical building or oven that had a fire lit at the bottom from which the eggs were reportedly placed in a woven basket on an inverted cone that was partially covered in ashes. Before the use of an incubator, poultry were reproducing naturally. Perry-Gal (2015) defined an incubator as an apparatus that is used to regulate environmental conditions such as temperature, humidity and turning for successful hatching of the fertile eggs placed in an enclosure. Scientifically, an incubator is a device that aid in keeping eggs warm at a particular temperature range and humidity with a turning mechanism to hatch those eggs (Finer & Holberton, 2002). The first scientific incubator, according to Becker & Gassmann (2006), was a Reaumur's incubator which was designed in 1747 and gave the specifications of a well-defined meaning of an incubator: "the art of hatching and rearing domestic birds of all species in all seasons, either by means of the heat of manure or by means of ordinary fire". Building on this experience, Becker & Gassmann (2006) hinted that a coal lamp was invented in 1879; and that the first commercial machine was made in 1881.

Meunier (2000) pointed that in 1922, the innovation into an electrically powered incubator was made in the USA which greatly encouraged the growth of large scale commercial hatcheries. In describing this incubator, Meunier (2000) explained that it was an apparatus used to regulate environmental conditions such as temperature, humidity and turning for successful hatching of the fertilized eggs which were placed in an enclosure for about 21 days. This electrically powered incubator was expected to play the role similar to that of the hen in its natural state, and was programmed to

allow the eggs to incubate while eliminating all the external threats that could possibly harm the eggs. As noted by Millette (2020), as of January 2019, the use of modern solar-powered, electricity-powered or fuel energy-powered incubators have increased the global broiler meat production to 84.6 million tonnes with the largest producers being the United States (20%), China (16.6%), Brazil (15.1%) and the European Union 11.3%. Between 2000 and 2010, egg production was growing globally at around 2% per year, and the global egg production was expected to reach 65.5 million tonnes in 2013 which was aimed at surpassing all the previous years. In Italy, the Agricola Italiana Alimentare, a member of Grupo Veronesi which is Italy's largest poultry producer undertakes the production of over 350 million birds in over eight production facilities with each producing around half a million tons of chicken and turkey meat annually (Storey, 2007). The company also produces more than 1 billion eggs each year. According to Dohner (2001), in the United Kingdom , the "2 Sisters Food Group" which is one of the U.K.'s largest food producers, produces its stock using artificial incubators and delivers supplies of about one-third of all poultry products consumed in the country, and slaughters 317 million birds annually.

In sub-Saharan Africa, more chickens are kept than any other type of poultry, with over one billion birds being raised each year as a source of meat and eggs (Evans, 1993). Traditionally, such birds are kept extensively in small flocks, foraging during the day and housed at night. In most developing countries like Kenya, women often make important contributions to family livelihoods through keeping poultry (Crawford, 2019). UBoS Report (2016) points that in Uganda, there were 1,274 incubators as of 2014, and that commercial poultry production was being boosted by the use of incubators, although the farms are virtually concentrated in Central region with very few farmers practicing it in up-country locations. The report further indicates that an estimated 23 million chickens were being kept in Uganda. The rising urbanization especially in Central Uganda has led to the bulk of production being in larger, and more intensive, with farm locations being close to where the feed is grown or near to where the meat is needed, and result in cheap, safe food being made available for urban communities.

In Lango sub-region, in spite of the emergence of few commercial poultry farmers using incubators, free-range poultry husbandry in which the birds can roam freely outdoors for at least part of the day is a very common practice (UBoS, 2016). Often, the birds have access to natural conditions and can exhibit their normal behaviours. Modern-day incubators come in all shapes and sizes, and the abundance of options can be overwhelming at times. Some of the notable types, according to Yousaf and Chaudhry (2008), include the Vivo-Home Mini Digital Egg Incubator which is a compact and lightweight life-giving gadget. As such, this device is an excellent choice for science teachers or parents who want their kids to learn about the egg hatching process. Sherwin & Nicol (1993) stated that nurturing and taking care of the chicks is a great way for children to develop responsibility and love for animals, after all. So, let's see how this tiny incubator behaves in action. The Vivo-Home Mini Incubator is suitable for any species, which means that you can incubate the eggs from ducks, pigeons, or quails. Depending on the size of the eggs, a farmer is able to place from nine to 12 eggs in the incubator. Adjustable dividers can also help with positioning and placement of the eggs. Nonetheless, the essential component of this model is the LED display, which provides real-time data; Kemanner Seven-Egg Digital Incubator which is also a compact and portable digital incubator.

With the ability to hatch seven chicken eggs, the KEMANNER Digital Incubator is a typical household unit. However, this is only one of the available variations of this incubator. You can also buy larger KEMANNER models, which can incubate 48 or even 56 eggs. The distinguishing feature of this incubator is the dome-shaped transparent cover on the top, which provides users with 360-view, allowing you to keep an eye on the hatching process from all sides; the Magic Fly Digital Egg Incubator which is a reliable device that can incubate up to 24 chicken eggs at once; the Opps Décor Intelligent Egg Incubator which is a high-end model will allow you to hatch as many as 48 chicken eggs; the Taimiko Automatic Egg Incubator which has a sleek and modern, but there is more than meets the eye with TAIMIKO, for instance, this portable egg incubator will let you hatch 10 chicken eggs with a high success rate.

Incubators are generally used for the production of different poultry. 'Poultry' can be defined as domestic birds or fowls that include chickens, turkeys, geese, ducks, guinea fowl, and doves that are raised for the production of flesh, eggs, feathers or entertainment (Al-Nasser, 2007). The domestication of poultry is believed to have taken place around 5,000BC to 3,000BC, notably in Southeast Asia. Having descended from the red jungle fowl of Asia with some additional input from grey jungle fowl, chickens have traditionally held their characteristics of a very fleshy red combs and wattles on their heads with the males or cocks usually having a larger and more exaggerated plumage bold colour than females or hens (Molino, A.B 2009). Chicken farming is specifically believed to have reached the Indus Valley in around 2,000 B.C;

and reaching Egypt at around 1,750 BC (Al-Nasser, 2007). Kept largely for their eggs and meat globally, a large number of breeds of chickens have been established to be kept on a commercial basis and this needed to be supported by an incubator. By 1800^{S}, chickens began to be kept on a larger scale, and the United Kingdom started a high-output poultry farms at around 1920. With a total population of 23.7 billion as of 2018, up from more than 19 billion in 2011, there are more chickens in the world than any other bird due to the advent and use of artificial incubators (Patwardhan & King, 2017). Since 2010, approximately 16 billion birds are raised annually for consumption making poultry to be the second most widely eaten type of meat in the world, accounting for about 30% of total meat production worldwide (Crawford, 2019).

The smart farming technology adopted by TAF agri-tourism farm

There are many technologies in use by TAF Agri-Tourism Farm: the temperature and humidity sensor installed in the chicken rooms, the automatic piped-line drinkers, and the artificial incubator. For the purpose of the student's assignment, I chose the incubator.

a) *Chicken incubator:* The farm attendant helped to explain that an incubator is literally a device that is powered by fuel, solar or electricity to help in the hatching processes of poultry species like ducks, chicken, turkey, doves, and geese. In this farm, the attendant explained that an incubator is specifically used for chicken reproductive purposes only.

b) *Type of incubator used in this farm:* According to the attendant, there are many types of incubator, and that the management plans to procure a metallic coated incubator. Currently, this farmer uses the ZFF Thermal Air Hova-Bator which is a free-standing incubator made of a plastic material and white in colour with a dimension of 46.35 x 46.35 x 13.08 inches in length, width and height, respectively.

The high demand for local chicken and their products encouraged the farm a management to undertake incubation project. The choice of Thermal Air Hova-Bator is based on the fact that it is most economical and an efficient incubator because it is cheap to buy; the heated air flows out the exhaust vents on top and draws fresh air through the bottom vent; includes two small windows on top for easy viewing of eggs and hatching chicks; and can be safely used for different poultry varieties. Having visited the Netherlands and many other European countries on a New Vision agricultural-sponsored trip, Tom Anyii, the proprietor of TAF Agri-Tourism Farm considered diversifying his bee-keeping business with both fish-pond and poultry farming. According to the proprietor, the idea of this enterprise was to provide both forward and backward linkages to other enterprises, for instance chicken droppings are mixed with other ingredients to prepare feeds for the fish; and that the demand for products from local chicken is very high and fetches higher prices than the genetically modified chickens. A strong reason that motivated the student to consider this farming technology is its ability to promote the production and consumption of local chicken and its products as opposed to the production and consumption of exotic breed of chickens.

The researchers identified four major aspects which were covered during the field visit in association with the selection and use of artificial incubator in TAF Agri-Tourism Farm: the major features or characteristics of the artificial incubator selected or preferred by the farmer; the eggs incubation and hatching processes; feeding and growth process for the chickens; and marketing processes. The student use a multiple approaches to gather data and information from this farmer, including observation, discussion and an in-depth interview. All the three approaches were concurrently applied, although discussion and interviews over-rode observation during the study. In essence, discussion refers to dialogues or conversation, whether asked or not based on a specific topic being shared by two or more people (Crawford, 2019). In the farm, discussions were held to ascertain the origin of 'a dream to establish an incubator in the chicken farming'. On the other hand, interview refers to a one-on-one question and answer session held between two or more people on a pre-determined issue or a specific issue that needs an in-depth answer or explanation. The advantage of using discussion and interview during this visit was that the two methods created a true rapport between the student and the farm attendant which made it possible for a free interaction during the entire visits. It was however, a disadvantage in that both methods were time consuming given that the same attendant was needed by other farm customers for different purposes or reasons at the same time the student also needed him. To mitigate this, the students would use that interruptions or interrupted time to carry on with observation methods which was undertaken to ascertain some of the factual issues raised during discussion and interview time.

2. THE OUTCOMES

This section coves the results of discussion, interview and observation made during the field visit at TAF agri-Tourism Farm. It includes the findings from: the major features or characteristics of the incubator used by the farmer; the eggs incubation and hatching processes; feeding and growth process for the chickens; and marketing processes of chicken or its products.

The major features of the technology

This sub-section presents the characteristics of ZFF Thermal Air Hova-Bator incubator. According to the Farm Attendant in charge of chicken department, this incubator, which hatches between 200 chicks at any one round of hatchery, is believed to have originated from France although its manufacturing has now gone global; and that the ZFF Hova-Bator has been wide recognized for over 30 years as the world's best small incubator. This incubator has a heat source that is controlled by a switch and has a way to add humidity to the air inside of the incubator. This incubator also has a chamber in which water can be added to the water reservoir as necessary to maintain the humidity. The hatching rate for this incubator stands at about 80-95%, depending on many factors like the fertility rate of eggs before their placement in the incubators; and temperature control. Among some of the important aspects to be considered when a farmer plans to have a higher hatching rate are: the ability to expose egg-laying hens to cocks, proper packing or placement of eggs in the incubator, a fan to circulate air in the incubator, an automatic egg turner to turn the eggs periodically or manually doing it, an installing a device to ensure the digital display for temperature, humidity, and hatch day countdown.

The incubator is always set up to run for at least 24 hours prior to setting the hatching eggs inside in order to allow the environment inside the incubator to stabilize. Another important aspect with the incubator is its location in the room. The incubator ought to be placed or put in a room that maintains a constant temperature; free from drafts; away from windows and direct sunlight; and in a very safe and strong room where other parties cannot bump or disturb it during the 21 day incubation period. The farm attendants were quick to note that some eggs may not hatch but hinted that it is safe to say that all viable eggs have the potential to hatch. If a lower hatch rate is attributed to reluctance of the farm attendants or operator of the incubator. If you have an abundance of eggs, then the choice of eggs becomes a matter of culling the least desirable, the cracked, damaged and dirty eggs. And assuming an attendant is choosing eggs that have been fully fertilized. The eggs in this instance tend to be collected and placed in an incubator all at once so that they can hatch at the same time because these eggs are always stored in a cool dry place of about 50-60 degrees Fahrenheit. Eggs that are always collected must not be stored for more than a month because they will begin losing their viability and will definitely reduce the hatch rate.

Eggs Incubating and hatching Processes

Guided by my constant urge for clearance, the management team of the farm noted that chicken reproduction cycle can either be done naturally or artificially with a minimum of 21 days for the eggs to hatch. For any reproduction to take place, the hen lays a fertilized egg which hatches into a new chick. In a natural reproduction setup, the proprietor of TAF Agri-Tourism Farm explains that after laying the eggs, the hen typically sits on them until they hatch, calling it 'the brooding period for the hen'. The hen usually cares for the chicken for several weeks and then starts losing her interest in them as they grow. By then, she also gets ready to lay the next batch of eggs. In an artificial nature of chicken reproduction, he contends that hens only do one thing: "lay the fertilized eggs as many as possible because these eggs are taken away on a daily basis to be put in an incubator. In this type of chicken reproduction, hens can lay as many as 300 eggs in one year". To ensure that the eggs are fully fertilized, TAF Agri-Tourism Farm management have built a fence around the courtyard to allow these egg-laying hens mix freely with cocks which are intentionally designed to help in the fertilization of eggs laid. Usually numbering about 60-100 eggs, the farm attendants collect these eggs every morning and evenings to be placed in the incubator. Before these eggs are loaded into the incubator, he explains that the incubator is set fully to ascertain that it is ready for the eggs. Issues examined during this time are the temperature regulation for forced-air incubator using a fan to ensure a range of 99-100 degrees F; and still-air incubator without a fan which can be at a range between 100 and 101^0 F.

Using a pencil, the farm attendants always mark each egg with letters 'T' to mean 'top' on one side of the shell, and 'B' to mean 'bottom' on the other end in order to enable visualization and a proper egg-rotation for perfections of egg-turning during incubation period. The eggs are packed in a cardboard egg-carton that is put in the same room where the incubator

is placed for temperature acclimatization. After few hours in the incubation room, the eggs are properly arranged in the incubator. Within seven days in the incubator, a few blood vessels could be seen radiating in the eggs; and by the fourteenth day, the embryo is much larger with an egg hardly seen through using candling. Between 14-17 days, the farm attendant keep on turning the eggs in the incubators after every eighth hour while also monitoring or controlling both the temperature and humidity. Between the 18th day to 20th day, the farm attendants always keep the incubator closed until after all chicks have hatched and dried off. This, according to the interviewee is based on the fact that by the eighteenth day, the chicks are nearly fully developed and will begin positioning themselves inside the egg to prepare for hatching. In this period, the humidity can be increased to about 65-70% while also preparing the brooder to receive or host the chicks.

By the 21st day, hatching begins and can take a full 24 hours for all chicks to complete the hatching-process. Once the chicks are completely dry and fluffy, the incubator can be opened to remove the chicks which are placed in a waiting brooder. The farm attendants always clean and disinfect the incubator. According to the farm manager, chicken incubation can successfully occur in their incubator because they always provide the correct, and a well-controlled environment for the developing chick inside the machine throughout the 21 days. Temperature regulation is the most critical factor for a successful hatch. Variations of more than 1°C (34 °F) from the optimum temperature of 37.5 °C (99.5 °F) will reduce hatch rates. Humidity is also important because the rate at which eggs lose water by evaporation depends on the ambient relative humidity. Evaporation can be assessed by candling, to view the size of the air sac, or by measuring weight loss. A relative humidity is always increased to around 70% in the last three days of incubation to keep the membrane around the hatching chick from drying out after the chick cracks the shell. Lower humidity is usual in the first 18 days to ensure adequate evaporation. The position of the eggs in the incubator can also influence hatch rates. For best results, eggs should be placed with the pointed ends down and turned regularly for at least three times per day until one to three days before hatching.

The farm manager hinted that the farm Director was in the final stages of acquiring a new incubator. He contends that in the modern days, many commercial incubators are industrial-sized with shelves holding tens of thousands of eggs at a time, with rotation of the eggs a fully automated process. The farm has also acquired smaller incubators that can be hired by the farm neighbours as home-based incubators which are boxes holding from 6 to 75 eggs; they are usually electrically powered, but can also be heated with an oil or paraffin lamp.

Feeding and growth of the chicks

Day old chicks are fed chick starter feed; Layer pullet chicks need 18 to 21% protein chicken starter. This type of chicken feed is usually high in nutrients, about 23% CP for starter feed for broiler chicks. Newly hatched chicks ages 0-10 weeks should be fed a chick starter diet with a protein level between 10%-20%. These rations are formulated to provide proper nutrition for growing baby chickens. Within twenty four hour, according to the farm attendants, a chick is termed as a day-old-chick and can tentatively survive without either water or any feed! However, a farm attendant contends that chicks should always have water and food at their disposal; and that what is important is that within the first month, temperature in the brooding area is always kept in the range of 95-100 degrees Celsius but after a month, temperature can be reduced by about 5 degrees. Between 2-4 weeks after birth, the chicks will have started developing feathers. Due to the appearance of these feathers for warmth, they can then be moved to a normal chicken houses. By the eighth weeks the chicks will grow adult plumage and can be fed a mixture made for growing chicks which is termed as the 'growers-mash'.

Marketing

According to the farm attendant, chickens and other unfertilized eggs are highly demanded for their nutritious content. The local chicken eggs are a common food and one of the most versatile ingredients used in cooking. They are important in many branches of the modern food industry. The most commonly used bird eggs are those from the chicken, duck, and goose eggs. Eaten as hard-boil or crushed to be cooked, eggs especially from the local hens have ready market in Lango sub-region.

a) *Prospective customers:* The management of TAF Agri-Tourism Farm uses smart technology in marketing of its different farm products. Currently, the customers include: the surrounding households; individual consumers from within Lira City or neighbouring districts of Kole, Pader and Lira district; and eating houses and hotels in Lira City. Both the cockerels; and excess eggs which are not due for reproduction are packed in egg-trays to be sold-off.

b) *Mode of advertisement:* Using smart phones, and laptop computers, the management has created a network or links with users of Facebook, WhatsApp and other social media forums to advertise for the availability of chicken products in this farm. The use of short message services, radio or television announcements, and print media are also embraced by the farm management to advertise for the availability of chicken products.

c) *Mode of payments:* Payments for these products are also electronically made through their bank accounts given out to the public or specifically to their customers; and can also be made through mobile phone services like the mobile money for MTN subscribers or Airtel money for AIRTEL subscribers. Due to COVID-19, the management has decided to minimize physical cash transaction, although it is not wholly impossible to avoid it completely.

d) *Mode of delivery:* Both the chicken and eggs which meant for sale are packed in the egg-trays which are always of plastic type and the deliveries of product are of two fold in that the intending buyers can walk to TAF Agri-Tourism Farm to get their supplies, or the management can arrange for an effective and effective transportation of the products to those who bought them.

3. CONCLUSION

The domestication of poultry by ancient farmers might have targeted many benefits like eggs and meat production, feathers, and entertainments in form of cock-fighting and birds' songs by quail. The introduction and use of incubators by many chicken farmers have led to the increase in chick production. Through the Internet of Things, smart farming in chicken production therefore encompasses the use of technology in aiding chicken production processes like hatchings, feeding, growth and marketing by any prospective chicken farmer.

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