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ECONOMIC ORDER QUANTITY INVENTORY MODEL FOR POULTRY FARMING WITH SHORTAGES, SCREENING, AND AFFILIATED COSTS CONSIDERATIONS

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ABSTRACT

Poultry is the fastest growing subsector, especially in developing countries. Poultry farms, mainly chicken farms producing meat and eggs are highly specialized operations. This study considers poultry farming especially broilers, where the inventory system of new-born poultries is fed to reach the ideal weight for consumers. This field is contemplated to be lucrative since it incurs low costs for maintenance. Legitimate management certifies efficient production and good quality products. An EOQ inventory model for growing items (poultries) is proposed and investigated the various costs of the system. Since the customers prefer for fresh products, it is assumed that shortages are permitted and are completely backlogged. The screening process takes place at the time the broilers are ready to slaughter. The aim of the inventory model is to determine the optimal values for shortage and cycle length that minimizes the total cost of the system. A numerical example is given to illustrate the model framed.

KEYWORDS: *EOQ Inventory Model, Poultry Farming, Broiler Chicken, Screening Cost, Shortages, Vaccination Cost*

INTRODUCTION

Nowadays, agribusiness is developing with great fury in the world among all economic activities, induced mainly due to the increase of population and in the demand for food. For quite a long time, academic researchers have been focussed their research on agribusiness studies. One of the most popular and beneficial agribusinesses is poultry farming. The farms that grow chickens, ducks, turkeys and other birds for meat or egg production are known as poultry farms. In the past, poultry farming involved in raising chickens at the backyard for daily egg production and family consumption was most prevalent. Currently, poultry rearing is a vast business that splits into several operations including hatcheries, pullet farms for meat production or farms for egg production.

Due to the gradual increase of the human population, rising incomes and urbanization, the poultry industry continues to flourish further to meet the demand for poultry goods in world markets. Four decades ago, the poultry zone of contemporary India has shifted from backyard rearing to become organized, scientific and vibrant commercial enterprise. Poultry sector plays a vital role in enhancing the socio-economic condition of rural masses. The significance of poultry farms lies in the quality of products that are provided to humans. Most of the corporations are involved in growing chickens in the farms for the purpose of meat and eggs. Many large farms embellish in rearing broilers for meat production. Broilers are chickens that have a larger body frame and weight than layers which was meant for egg production.

Management of Broiler Chickens

Broilers are not supposed to be grown up in cages. They are raised in large, open structures called grow-out houses. The ventilation system of the poultry house must be well accompanied. To achieve success in broiler farming, ensure that feed is proper and of high quality. They consume more feed and convert them into meat. So, feed management is very essential for the growth of broilers. They take feed and water the whole day and night. The farmer must have to be more conscious in feed and water administration. Another important criteria in the case of poultry management is that make sure to keep away from diseases transmitting via humans, other birds, newly introduced chicks or contaminated equipment. Vaccination is an effective way to curtail the adverse effects of diseases. In the poultry house, some birds may die due to health problems. Dead bird management and disposal can be done with legally accepted practices such as rendering, composting, incineration and burial.

In order to support the growth of poultries, farmers should concentrate mainly on air conditioning and lighting of poultry houses. According to the age and development of the chickens, the electricity demand varies. The need for fuel is also mandatory in all farms. It is used to heat chicken houses, bedding materials, etc. When the broilers reach the ideal weight, they were supposed to slaughter. Some poultry houses were accompanied by slaughterhouse. If not, poultries are packed and sent to the nearby slaughterhouse. Broilers were moved to the holding area of slaughterhouses in wooden or metal crates. Now, the only remains of the poultry house are chicken litter and wood chips initially furnished. This was removed with a skid steer loader rental equipment. The floor was sterilized further to remove the excess litter and prepared for sanitization. The process of sanitization varies subject to the floor type and type of poultry house. To sanitize the poultry house, several disinfectants are used. **The** screening process is undertaken for the grew up broilers before slaughtering to diagnose for any health issues.

The rest of the paper is structured as follows: Section 2 presents the literature review. Section 3 provides fundamental assumptions and notations. Section 4 describes the formulation of a mathematical model. Section 5 illustrates a numerical example. Section 6 concludes the paper. A list of references is also provided.

LITERATURE REVIEW

Researches and studies of inventory modeling have been developed in the last few decades. The first economic order quantity (EOQ) inventory model was proposed by Harris in 1913. This model minimizes the total costs including the holding and the ordering costs. It is assumed that the system faces no shortages. Taft (1918) modified the EOQ inventory model where instead of receiving products in orders at once, he assumed that they are produced at a known rate. Afterward many inventory models were flourished by several researchers and academicians by relaxing the particular boundaries of the system. One of the main contribution addressed by Whitin (1953) who considered the goods that became old-fashioned after a specific period. Ghare and Schrader (1963) studied an inventory system where items decayed exponentially. Covert and Philip (1973) generalized Ghare and Schrader(1963) work and assumed that the deterioration rate could vary during the time. Modified inventory models for perishable products such as vegetable, dairies, batteries, drugs and those dealt with relaxing infinite life cycle were done by Muriana(2016), Dobson et al. (2017), Yan and Wang (2013) and Boxma et al. (2014). Goyal and Giri (2001) studied inventory models of perishable items. Furthermore, many researchers extended inventory models for imperfect products. Rosenblatt and Lee (1986) examined a production system that after some time the manufacturing system alters to out of control and starts to produce imperfect items. Then, Salameh and Jaber (2000) proposed an EOQ/EPQ inventory model with imperfect quality items for the cases that these items are either suitable for other processes or could be sold in a batch after the inspection process. Hayek and Salameh (2001) studied an imperfect production inventory model and examined the rework of produced imperfect quality items.

Moreover, some researchers extended classical EOQ inventory model by considering trade credit policies. The foremost work was done by Goyal (1985) where purchasing costs of the vendor could be paid back with a permissible delay to the supplier. Rajan and Uthayakumar (2017) enhanced an EOQ inventory model with permissible delay in payment where demand and holding costs change as a function of time. Another important criteria the inventory system faces is shortages. Inventory models have emerged on the assumption of permissible shortages. The first study on this concept was executed by Hadley and Whitin (1963) by revising the model of Harris (1913). San-Jose et al. (2015) established an EOQ inventory model with partial back ordering. Focus on inventory models for growing items steadily increases thereafter by researchers. The first systematic research that considers this type of inventory was done by Rezaei (2014) who explored an EOQ inventory model for products that are growing during storage such as livestock, fish farming, and poultry. Such inventory systems focus on the increase in the weight of products during stocking without ordering additional items. Bonney and Jaber (2011) developed an inventory model considering the environmental issues and the impact of these issues in the inventory system. Nobil et al. (2018) studied an economic order quantity inventory model as a case study of a poultry farmer with shortages. Apart from the literature, this paper incorporates several costs such as screening cost, transportation cost, vaccination cost, litter removal cost, energy cost, fuel cost, disposal cost, packaging cost and sanitation material cost in the inventory system.

Notations and Assumption

To formulate the mathematical model, the following notations are used.

.D Demand rate per time unit $\left(\frac{gr}{year}\right)$.

.k Growing rate per chick per time unit $\left(\frac{gr}{chick\times year}\right)$.

.w_0 Approximated weight of new-born items (gr).

.w_1 Approximated weight at the moment of slaughtering (gr).

.Q_t Total weight of inventory at t.

.t_1 Growing period.

.t_2 Consumption period.

.t_3 Shortage period.

.T Length of each period (decision variable).

.y Number of ordered items per period.

.S Shortage quantity per period (gr).

.c Purchasing cost per weight unit $\left(\frac{\$}{gr}\right)$.

$.r$ Feeding cost per weight unit per time unit $\left(\frac{\$}{gr\times year}\right)$

$.h$ Holding cost per weight unit per time unit $\left(\frac{\$}{gr\times year}\right)$.

$.f$ Shortage cost per weight unit per time unit $\left(\frac{\$}{gr\times year}\right)$.

$.A$ Setup cost (ordering cost), cost of preparing nurturing environment per period $\left(\frac{\$}{setup}\right)$.

$.t_s$ Setup time (unit time), time of preparing nurturing environment perperiod $\left(\frac{year}{setup}\right)$.

$.z$ Screening cost per weight unit

$.C_r$ Cost of a crate (wooden or metal)

$.L$ Labor cost for packing

$.n$ Number of crates

$.C_l$ Litter removal cost per cycle.

$.a$ Fixed cost per trip

$.b$ Variable cost per unit transported per distance traveled

$.d$ Distance traveled

$.\gamma$ Cost to dispose of waste to the environment

$.\gamma_0$ Fixed cost per waste disposal activity.

$.\theta$ Proportion of waste produced

$.V_c$ Vaccination cost per cycle

$.F_c$ Fuel cost per cycle

$.E_c$ Energy cost per cycle

$.S_c$ Sanitation material cost per cycle

Assumptions

The assumptions of this model are as follows:

- The inventory system consists of a single product.
- Inventory system considers growing newborn broiler chickens until it reaches the ideal weight preferred by the consumers.
- Shortages are allowed and are fully back ordered.
- Feeding cost and cost for raising items are involved.

- Feeding cost and gained weight are directly related.
- Slaughterhouse is not owned by the poultry farm.

Mathematical Model

This paper extends the work of Nobil et al (2018). Consider an inventory system of growing broiler chickens. y is the number of purchased items for a period from outside suppliers and w_0 is the weight at the beginning of the period (new-born chicks) and w_1 is the weight at the end of the period (ready to sell product). The total initial and final weights are $Q_0 = yw_0$ and $Q_1 = yw_1$ respectively. At the beginning of the consumption period, immediate demands are satisfied and so the inventory level diminishes as $Q_2 = yw_1 - S$.

Consider the following equations given as

$$.t_1 = \frac{Q_1 - Q_0}{yk} = \frac{w_1 - w_0}{k} \tag{1}$$

$$.t_2 = \frac{Q_2}{D} = \frac{yw_1 - S}{D} \tag{2}$$

$$.t_3 = \frac{S}{D} \tag{3}$$

.The cycle length is given by

$$. T = t_2 + t_3 = \frac{yw_1}{D} \tag{4}$$

$$.y = \frac{DT}{w_1} \tag{5}$$

The total cost of the inventory system comprises purchasing cost, holding cost, operational cost, shortage cost, food procurement cost, screening cost, packaging cost, litter removal cost, transportation cost, Disposal cost, vaccination cost, fuel cost, electricity cost, and sanitation material cost. The objective of this inventory system is to minimize the costs involved in the system.

TCU = Purchasing cost + Holding cost + Operational cost + Shortage cost + Food procurement cost + Screening cost + Packaging cost + Litter removal cost + Transportation cost + Disposal cost + Vaccination cost + Fuel cost + Cost of energy + Sanitation material cost.

The inventory total costs per period is given as

$$.TCU = cyw_0 + h\left(\frac{(yw_1 - S)^2}{2D}\right) + A + f\frac{S^2}{2D} + r\left(\frac{y(w_1 - w_0)^2}{2k}\right) + zyw_1$$

$$.+(C_r + L)n + C_l + 2a + bdy + \gamma_0 + \gamma y\theta + V_c + F_c + E_c + S_c \tag{6}$$

Substituting for y from eq. (5), we get

$$.TCU = \frac{Dcw_0T}{w_1} + \frac{hS^2}{2D} - hTS + \frac{hDT^2}{2} + A + f\frac{S^2}{2D} + \frac{Dr(w_1 - w_0)^2T}{2kw_1} + zDT$$

$$. \quad +(C_r + L)n + C_l + 2a + \frac{bdDT}{w_1} + \gamma_0 + \frac{\gamma DT\theta}{w_1} + V_c + F_c + E_c + S_c \tag{7}$$

The inventory total cost per unit time is calculated as

$$.TC = \frac{TCU}{T}$$

$$. = \frac{Dcw_0}{w_1} + \frac{hS^2}{2DT} - hS + \frac{hDT}{2} + \frac{fS^2}{2DT} + \frac{Dr(w_1-w_0)^2}{2kw_1} + zD + \frac{bdD}{w_1} + \frac{\gamma D\theta}{w_1}$$

$$. \ + \frac{1}{T}[A + (C_r + l)n + C_l + 2a + \gamma_0 + V_c + F_c + E_c + S_c] \quad (8)$$

Calculating the partial derivative of the objective function (8) with respect to the cycle length T and setting it to zero, the optimal solution of T is obtained as

$$T = \sqrt{\frac{[(h+f)S^2 + 2D(A + (C_r + L)n + C_l + 2a + \gamma_0 + V_c + F_c + E_c + s_c)]}{hD^2}} \quad (9)$$

Then, the optimal solution of S is obtained by taking the partial derivative of (8) with respect to S and setting it to zero, we get

$$.S = \frac{hDT}{h+f} \quad (10)$$

The optimum cycle length T after substituting S from (10) is

$$.T = \sqrt{\frac{2[A+(C_r+L)n+C_l+2a+\gamma_0+V_c+F_c+E_c+S_c]}{hD\left(1-\frac{h}{h+f}\right)}} \quad (11)$$

Numerical Example

$D = 100{,}000$ g/year, $k = 15{,}330$/chick/g/year, $w_0 = 84$ gram, $w_1 = 1260$ gram, $c = \$0.3$/gram, $r = \$0.8$/gram/year, $h = \$0.4$/gram/year, $A = \$1000$/gram/year, $f = \$2$/gram/year, $z = \$0.0013$/g, $a = \$5$/trip, $b = \$0.01$/unit/km, $d = 250$ km, $\gamma = \$0.2$/cycle, $\gamma_0 = \$1$/unit, $C_r = \$2$/unit, $L = \$1.21$/unit, $n = 20$/cycle, $C_l = \$0.29$/cycle, $\theta = 0.003$, $V_c = \$0.368$/ cycle, $F_c = \$0.418$/cycle, $E_c = \$0.0928$/kWh/cycle, $S_c = \$0.239$/cycle

The optimum solution obtained from eq. (10), (11), (5) and (8) is given as below

$\boldsymbol{T^* = 0.25416}$ **year,** $\boldsymbol{S^* = 4236}$**g,** $\boldsymbol{y^* = 20.17}$**chickens,** $\boldsymbol{TC^* = \$13{,}664.33}$

CONCLUSIONS

Technological advances have revolutionized the role and the structure of the poultry industry in many countries. The increasing demand for poultry products has transformed poultry farming activity into a full-edged industry from a mere household/ backyard activity until recently. This paper discusses the broiler farming where newborns are grown to reach the ideal weight for satisfying customer's demand and further focuses on various costs involved in poultry rearing. The main motto is to optimize the cycle length and shortages by minimizing the total costs of the system.

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