Solving Production Scheduling of Egg Production in Hen Farms with Capacity of Slaughterhouse by Heuristic Algorithms

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***Abstract*—Eggs are products subject to domestic supply and demand as well as for export. The demand tends to continually increase, resulting in insufficient production when compared to demand each year. Scheduling production in hen farms is therefore an important issue. Heuristic algorithms have thus been developed under this research study in order to minimize the total cost of egg production. Harvey M. Wagner and Thomson M. Whitin's algorithm was applied in finding the right number of chicks. The solution was then used to allocate pullets and laying hens into houses with reference to the capacity of the slaughterhouse. The number of weeks of planning and the fluctuation of egg demand were the experimental design parameters. The findings indicated a 63% decrease in total cost when compared to the company's current procedures. Scheduling of production at hen farms was suitable to the demands which fluctuate all the time at present. It could also be applied to plan for other age ranges of hens.**

***Index Terms*—Production planning, heuristic algorithms, hen farm.**

I. Introduction

In developing countries, poultry farming has become more popular, owing to the rising demands for eggs and meat. In 2010, the Department of Livestock in Thailand showed that there were 41.8 million laying hens, which was equivalent to an amount of roughly $130 million [1]. Hence, poultry farming should receive more attention in terms of management planning so that it would produce sufficient eggs for the demand in the country. In general, demands for eggs vary with the time period and economic situation. The hen farm production process itself is complicated, and raising laying hens also faces limitations, namely: 1) different age ranges of hens in each farm, 2) the number and size of farms, and 3) the distance between pullet farms and hen farms. Thus, companies should plan an efficient supply chain that creates a balance between the customers' demand and egg production scheduling. Hen farms should be adjusted to accommodate the appropriate number of pullets and respond to the egg demands as well as possible.

Management and methods to solve the problem of supply chain are essential. The first step in analyzing costs considers production planning, ordering and inventory. In 2000, Stephan V. Dijk et al. [2] proposed a management method for a poultry supply chain through consideration of demand and supply chain characteristics. They suggested matching supply and demand and improving information exchange. In 2004, L. Manning and R.N. Baines [3] conducted a study on the key factors of the poultry supply chain. They found that the factors that affect future development of the global poultry meat trade are costs of capital, labor, and concerns over production methods. In planning the supply chain for poultry farming, ordering chicks and managing inventory of eggs are the basis to efficient operation. There are chick ordering methods that will solve the existing problems. 1) Ordering lot-for-lot in order to reduce the complexity of production according to demand [4]. This can be applied to solve problems in ordering input in batch until production is complete. 2) Dynamic ordering as developed by Harvey M. Wagner and Thomson M. Whitin [5] which would lead to lowest ordering and inventory cost. Currently, most industries place their orders in a dynamic pattern [6]. The literature review revealed that most research work has been done on production planning of industries in general. This research therefore proposes scheduling of production with reference to egg demands by involving the ordering of chicks, transportation, and allocating of chickens in farms using heuristic algorithms for developing production scheduling that will minimize total costs.

II. Statement of Problem

This research was conducted on the planning of ordering chicks and scheduling of production of a hen farm company. Three main processes were involved: 1) planning of chick ordering, 2) allocating pullets in farms, and 3) allocating laying hens in farms and transportation to the slaughterhouse (Fig. 1).

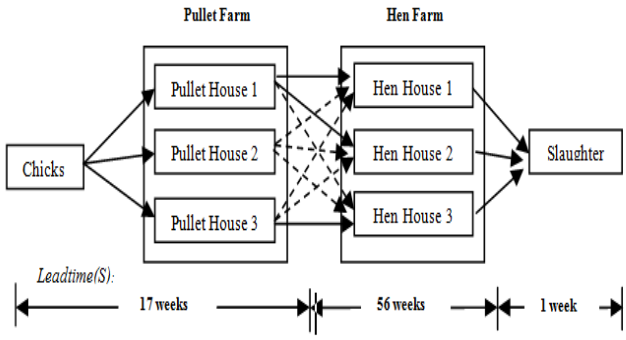

Fig. 1. Flow chart of laying hens of different age ranges

The current case company starts with ordering chicks every week in equal numbers. These chicks are raised in 33

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houses in the pullet farms of contract farmers distributed in various areas from the company. Each farm is of the size suitable to raise 10,000 to 53,000 pullets. Allocating chicks into pullet farms is achieved by putting them in the nearest house first. When the pullets reach 17 weeks, they are moved to hen farms and kept there until they are 75 weeks. Then they are sent to the slaughterhouse. Presently, there are 82 hen houses belonging to the company and contracted farmers. The capacity of each farm ranges from 6,000 to 59,000 hens. Moving hens from the houses means complete removal. Then the pullet houses and hen houses are cleaned within 3 to 6 weeks, respectively, in order to be free from infections. During this cleaning stage, no hens or pullets can be placed in the farm. Slaughter can lead to problems that end in opportunity loss which is caused by a number of practices. First, the sizes of pullet houses and hen houses are different, resulting in imbalanced chicken assignments in the houses. This brings about a loss of opportunities to obtain more eggs. Furthermore, when there is space, younger chickens may be added at a later stage. Then the whole house is destined for the same slaughtering lot, again leading to a loss of opportunity for laying since younger chickens are sent to the slaughterhouse earlier than they should be. The farm owner ends up producing a smaller number of eggs for his customers due to ineffective planning. This study developed heuristics for planning egg production management. Scheduling should respond to demand each week subject to farm limitations in raising and slaughtering. The main objective was minimizing total costs.

III. NOTATION

The heuristic was based on the following indexes, parameters, and decision variables as follows:

A. Indexes

- i Pullet house index i: $i = 1,2,\ldots, I$
- j Hen house index j: $j = 1,2,\ldots, J$
- k Chicken age index k: $k = 1,2,\ldots,RTB$
- t Planning time index t: $t = 1,2,\ldots,T$

B. Parameters

- A Cost of chicks per batch
- EH Number of hatched eggs per week
- H Cost of egg storage per egg
- LS Loss from inability to respond to demand per egg
- RTA Age of pullets before moving to laying hen houses
- RTB Age of laying hens before moving from houses to slaughterhouse
- SCA Cost of opening pullet houses
- SCB Cost of opening hen houses
- Y Percentage of dead chickens and percentage of eggs becoming laying hens
- $CAPA_{i,t}$ Capacity of pullet house i at time t
- $CAPB_{j,t}$ Capacity of hen house i at time t
- $CAPK_t$ Capacity of slaughterhouse at time t
- DE_t Demand for eggs at each time t
- DH_t Number of eggs demanded at each time t
- $DW_{i,j,k}$ Distance from pullet house i to hen house j
- E_t Value based on egg price at time t which is equal to $QB_{k,t} \times PHA_{k,t} \times PE_{k,t}$
- $HB_{i,j,k}$ Number of standing hens from house i in hen house j aged k week at the starting time
- L_t Expense from loss of space per hen at time t
- M_t Expense from mixing chicken ages per chicken at time t
- $PE_{k,t}$ Price based on egg size from hens aged k at time t
- $PHA_{k,t}$ Percentage of hatching of hens aged k at time t

C. Decision Variables

- BG_t Number of eggs that failed to meet demand at time t
- IN_t Number of eggs stored at time t
- OR_t Number of time chicks ordered at time t
- $QA_{k,t}$ Number of pullets aged k at time t
- $QB_{k,t}$ Number of hens aged k at time t
- WD_g The appropriate ordering time - g^{th} time

The total cost comprised the cost of planning for chicks ordering cost that are equal to $(QB_{k,t} \times A) + (IN_t \times H) + (BG_t \times L_t)$, cost of planning of chick assignment to pullet level, which consists of setup cost and fixed cost that are equal to $(SA_{i,t} \times SCA)$, and the cost of planning allocation of pullets to hen farms, with setup cost, fixed cost, and transport cost equal to $(SB_{j,t} \times SCB) + (QA_{RTA,t} \times DW_{i,j})$.

IV. PROPOSED HEURISTICS

The heuristics for solving scheduling production were developed based on the following:

A. Planning for Ordering Chicks

Step 1: Calculate customers' egg demand each week $DH_t = \lfloor DE_t / (Y \times EH) \rfloor$. DH_t - $HB_{i,j,k}$ all through chicken growth period to obtain real chicks requirement.

Step 1.1 If there are enough hens or $DH_t - (IN_{t-1} + QB_{k,t}) \leq 0$, store the remaining eggs to supply during the next period.

Step 1.2 On the contrary, if the number of hens is not sufficient or $DH_t - (IN_{t-1} + QB_{k,t})$ is more than zero, then order $QA_{1,t}$ at $DH_t - (IN_{t-1} + QB_{k,t})$ quantity.

Step 2: From Wagner's and Whitin's heuristic, order chicks during suitable time WD_g by calculating reverse order at OR_{t-1} quantity. If the calculation does not meet the need adjust E_t. Follow the above steps in the subsequent periods until the chickens reach RTB weeks. Then calculate with the number of stored eggs at time $t-1$ before calculating the needs for more chicks until time T. Then plan chicks ordering cost.

B. Planning of Chicks Allocation to Pullets

Step 3: Consider $max\{QA_{1,t}\}$ to allocate chicks to possible houses by looking at L_t with $CAPA_{i,t}$ previously vacant at any time t, and at M_t in case the house assigned previously contains pullets of different ages. Then select the lowest scores to houses from the following sub-procedures:

Step 3.1 In case space is left unused in houses during the previously considered time (L_t), then set the score for the opportunity cost of leaving space in the house $|QA_{k,t} - CAPA_{i,t}|$, and add up the two scores.

Step 3.2 In case chickens are mixed in the houses with space during the previously considered time (M_t), then set the score for the opportunity cost from mixing pullets in the house with remaining space during the previously considered time $|QA_{k,t} - CAPA_{i,t}|$.

Step 3.3 In case there are no pullets in the houses previously considered, then calculate only $|QA_{k,t} - CAPA_{i,t}|$.

Step 4: Check $QA_{k,t}$- $CAPA_{i,t}$ in order to allocate chicks at time t in house $CAPA_{i,t}$.

Step 4.1 In case $QA_{k,t}$- $CAPA_{i,t} \leq 0$, chicks are allocated at time t in house $CAPA_{i,t}$ selected in Step 3 and consider the number of chicks to be ordered at any next time t.

Step 4.2 In case $QA_{k,t}$- $CAPA_{i,t} > 0$, consider $QA_{k,t}$ to allocate chicks at time t to house $CAPA_{i,t}$. Allocation ends when $CAPA_{i,t} = 0$ or $QA_{k,t}$- $CAPA_{i,t} = 0$. Then consider ordering chicks at any time t by selecting $max\ \{QA_{1,t}\}$ except the selected time.

Step 5: Calculate the cost of planning chick assignment to pullet level.

C. Planning of Pullets Allocation to Laying Hens

Step 6: When pullets reach RTA weeks, they are all transported to hen farms. The houses are cleaned for three weeks. Then consider $max\ \{QB_{RTA,t}\}$ from process (2), which is similar to planning for pullets. Then select the lowest score in allocating pullets to hen houses from the following three sub-procedures:

Step 6.1 In case of (L_t), set the weight of $|QB_{k,t}$- $CAPB_{j,t}|$ $\times$ $DW_{i,j}$ at new time $CAPB_{j,t}$ as there is no chicken in the house during the time considered nor opportunity cost from leaving space in the house.

Step 6.2 In case of (M_t), set the weight of $|QB_{k,t}$- $CAPB_{j,t}|$ $\times$ $DW_{i,j}$ at new time $CAPB_{j,t}$ when laying hens have been allocated to houses during the considered time. And consider the opportunity cost from mixing hens of different ages in the houses with space left during the previously considered time.

Step 6.3 In case there are no hens in the house previously considered, calculate only $|QB_{k,t}$- $CAPB_{j,t}|$ $\times$ $DW_{i,j}$.

Step 7: Check $QB_{k,t}$- $CAPB_{j,t}$ to allocate pullets at time t to house $CAPB_{j,t}$.

Step 7.1 In case $QB_{k,t}$- $CAPB_{j,t} \leq 0$, allocate pullets at time t in house $CAPB_{j,t}$, as selected in Step 6 and consider the number of pullets in any time t.

Step 7.2 At new time $QB_{k,t}$- $CAPB_{j,t} > 0$, consider $QB_{k,t}$ to pullets at time t to house $CAPB_{j,t}$. Allocation ends when $CAPB_{j,t} = 0$ *or* $QB_{k,t}$- $CAPB_{j,t} = 0$. The number of pullets from the next pullet house at time t is based on the next step and $max\ \{QB_{RTA+1,t}\}$.

Step 8: Calculate the cost of planning allocation of pullets to hen farms.

D. Slaughtering When Chickens Reach Appropriate Age

Step 9: When the hens reach RTB weeks, $QB_{k,t}$, they are transported to the slaughterhouse. The houses are cleaned for six weeks. The slaughterhouse considers $CAPK_t$. $Max\ \{QB_{RTB,t}\}$ will be slaughtered first. If it does not meet the criteria, $QB_{RTB,t}$ will be allowed to stay in the hen farm. This results in a higher cost. Calculate the total cost of planning.

V. Experimental Design and Results

The developed heuristics were compared to the solutions from the real procedures which were based on factorial design. The combination experiments were conducted in five replicates. The parameters taken into account included the number of planning weeks (75, 100, and 150 weeks); fluctuation of demands (20%, 40%, and 60% of egg demands, which was at average of 1,293,600 eggs per week). The total samples were 45 and the reacting results were shown in the percentage of improvement which is presented in Equation 1, when RC is the real situation case and HC is the case from the heuristic algorithms.

$$\%improvement = (RC - HC)/RC \times 100 \qquad (1)$$

TABLE I: Experimental Design and Results.

No.	Factor		Total cost in the best case [Million Baht]		% improve ment
	# weekly plan	% uncertainty of demand	*RC*	*HC*	
1 – 5	75	20	558.41	366.75	34.3
6 - 10	75	40	990.20	340.47	65.6
11 –15	75	60	1,279.27	379.01	70.4
16 –20	100	20	717.54	382.26	46.7
21 –25	100	40	1,125.37	387.79	65.5
26 –30	100	60	2,031.43	404.48	80.1
31 –35	150	20	1,055.29	407.98	61.3
36 –40	150	40	1,975.83	479.29	75.7
41 - 45	150	60	1,287.86	420.54	67.3
		Average	1,224.58	396.51	63.0

Table I shows a 63% improvement from planning the scheduling of hen farms when the data was analyzed by the ANOVA method. The percentage improvement differed significantly from the real situation practices at 95% reliability level and p-value less than 0.05. The parameter explaining this difference was the fluctuation of demand at an average of 40% and the customers' demand for eggs fluctuating between 924,000 to 2,156,000 eggs per week, which yielded the highest average improvement. The number of planning weeks did not differ significantly.

VI. Summary

This research developed heuristic algorithms for solving scheduling of egg production in hen farms, where complexity lies in the ordering of chicks. Wagner and Whitin's heuristic algorithms were adapted for this purpose. Chick ordering planning was performed in advance. Allocating of pullets and hens into houses faced limitations in the farms. It had to be in accordance with the capacity of the houses so there would be no need to open a new house and to avoid mixing chickens of different ages in the houses. This would reduce the opportunity cost from slaughtering young hens that are still able to lay eggs. Scheduling of egg production is suitable for the situation where there is flexibility of egg demand, and can be applied to all weeks in the plan. The improvement from the experiment was 63%. However, the meta-heuristic should be further developed in future research in order to obtain the best answer.

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