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POMA-BROILER: A Computer Simulation Model to Evaluate the Optimal Market Age of Broilers

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Abstract: This study presents the POMA-BROILER Model, a computer simulation developed to evaluate the optimal market age of broilers. This model was written in the Visual BASIC programming language and uses the windows operating system. The model was developed from a Sensitivity Analysis Method and is based on the concept that marginal cost must not exceed marginal return. It uses various input data including feed information (Crude Protein (CP), Metabolisable Energy (ME) and feeding stages) an equation for the feed conversion ratio, cost conditions (chicks, feed, labour, water and power, medical treatment, depreciation and miscellaneous costs) and a growth regression equation. The model then compares the calculated results with the range for acceptable market weight. The marginal cost and marginal return are calculated every day to determine the decision-making point for maximum profit. These results could represent a valuable reference for use in adjusting the strategy for broiler production and management.

Key words: Broiler, market age, Simulation Model, production, management, profit

INTRODUCTION

According to the Taiwan Agricultural Yearbook (COA, 2010), Taiwan located in a subtropical area, produced 501,607, 524,059 and 527,906 tons of broiler carcasses, representing 8.94, 8.98 and 8.38% of the total agricultural product value in the years 2008, 2009 and 2010, respectively. Broiler production is the second most valuable livestock industry in Taiwan. Its value is only slightly less than that of the pork industry.

The accuracy and utility of growth models has improved with the ability of modern computers to perform complex calculations rapidly. Researchers have attempted to use a Simulation Model to predict broiler growth and production. Velu *et al*. (1972) proposed a set of regression equations for determining the body composition of young chicks. Emmans (1981a, b) considered genetic condition, ration components, management decisions and environmental factors to build a Poultry Growth Model (PGM) that could predict poultry growth and carcass component changes on a daily basis. Talpaz *et al*. (1986) proposed a Dynamic Optimisation Model for the feeding of broilers. Muramatsu and Isariyodom (1989) established a computer Simulation Growth Model to predict the need for replacement pullets with special reference to seasonal changes in feed intake. Supaporn *et al*. (1988) and Grosskopf and Matthaus (1990) introduced a Mathematical Simulation Model for broiler production processes separately. Burlacu *et al*. (1990) built a mathematical model for energy and protein balance simulation in broilers. Wolynetz and Sibbald (1986a-c, 1990) introduced several methods to predict the major body components of broiler chickens. Emmans (1995) considered several variables relating to feed, environment and management as a basis for the prediction of broiler growth. Wang *et al*. (1995) and Roan and Wang (1996) adopted concepts from Leeson and Summers (1980), Emmans (1981a, b), Zoons *et al*. (1991) and Roan (1991) to construct a computer simulation model to predict broiler growth in Taiwan. Lee *et al*. (1997) presented a study to determine the optimal market weekly age of Taiwan country chickens. Roush *et al*. (2006) compared the Gompertz and Neural Models of broiler growth with neural networks. Ahmad (2009) compared the Gompertz Model, Nonlinear Statistical Model and Neural Network Model of poultry growth.

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Broilers should be sold at an optimal weight. More profit can be achieved if broilers can be sold at an optimal market age and meet consumer preferences and market needs. Because of the fast growth of broilers and the Electro-Slaughter System, the standardisation of broiler production is increasingly important.

If the optimal market age of broilers can be accurately predicted, the operating profits can be increased. Maximum return is always a farmer's production target. The purpose of this study was to build a Simulation Model to evaluate the optimal market age of broilers based on the concept that the marginal costs must not exceed the marginal return.

MATERIALS AND METHODS

The model was written in the Visual BASIC computer programming language and uses the Windows operating system. Seven functions were considered: base, cost, growth function, Feed Conversion Ratio (FCR), market, calculation and analysis with a page dedicated to each function. Each page contained several input items and choices as shown in Fig. 1.

System of functions: The default feed conversion ratio and growth regression equation were taken from the results of Hu (1995) and Roan and Hu (1996):

$$\text{Cock, FCR} = 0.848 + 0.000954\ W$$
$$\text{Hen, FCR} = 0.933 + 0.00103\ W$$

$$\text{Cock, W} = 4567.5 + 49.564\ \text{day} - 0.094\ \text{day}^2 - 65.075\ (\text{ME/CP}) + 0.215\ (\text{ME/CP})^2$$
$$\text{Hen, W} = -525.92 + 32.599\ \text{day} + 0.22\ (\text{ME/CP})^2$$

Where:

FCR = The feed conversion ratio
W = Body weight (g)
Day = The daily age
ME/CP = The ratio of metabolisable energy to crude protein in the feed

Users can also set individual parameters to create new calculation functions to meet their particular needs.

Concepts: The algorithm for this model finds a break-even point to attain the economic regulation of maximum profit so that Marginal Cost (MC) equals Marginal Return (MR). If this break-even point lies within the acceptable market range for weight then this point is the optimal result (Fig. 2a).

If this break-even point is higher than the maximum weight in the acceptable market range for weight, the chickens can only be raised until they reach the maximum weight (Fig. 2b). If this break-even point is lower than the minimum weight in the acceptable market range for weight, the farmer still needs to raise the chickens until they reach the minimum weight (Fig. 2c). The optimal market age is therefore derived according to the optimal result.

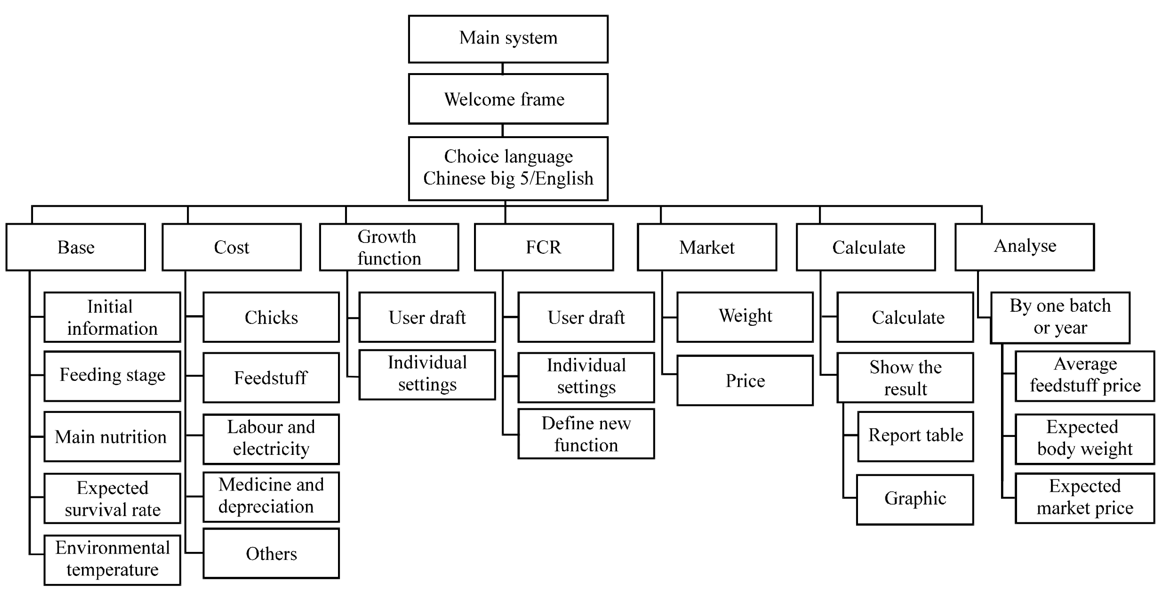

Fig. 1: Framework of the simulation model for predicting the optimal market age of broilers

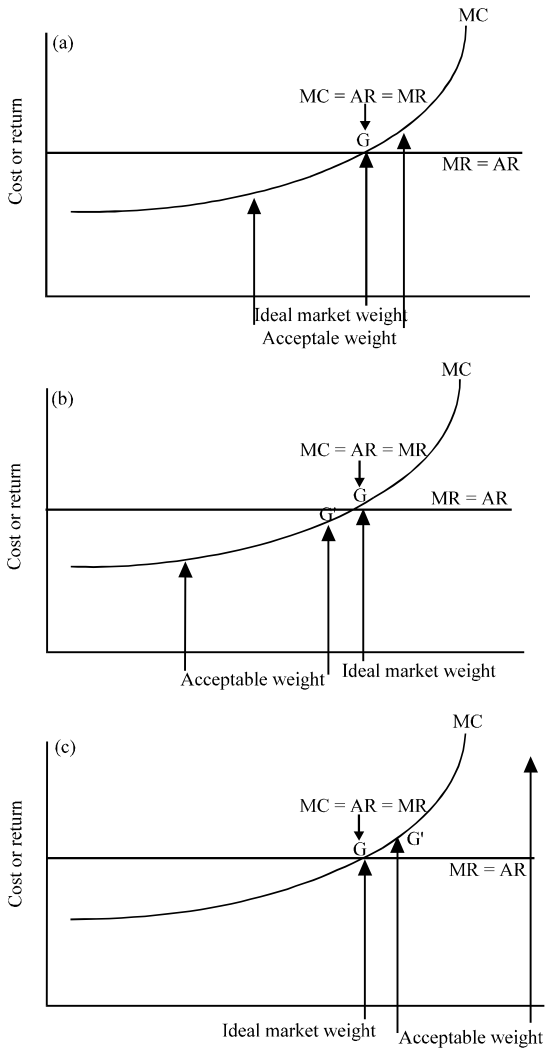

Fig. 2: Determination of the break-even point (G) to find the optimal market weight of chickens. (MC: Marginal Cost; AR: Average Return; MR: Marginal Return)

RESULTS AND DISCUSSION

System description

Base: This page includes initial weight (g), stage by weekly age, daily age or body weight. Users can select one or two stages to change feed and can set the start point, crude protein (%), metabolisable energy (kcal kg^{-1}), expected survival rate (%) and environmental temperature (°C) for this option.

Cost: This page includes chicks, feed, labour, electricity, medicine, depreciation and other costs.

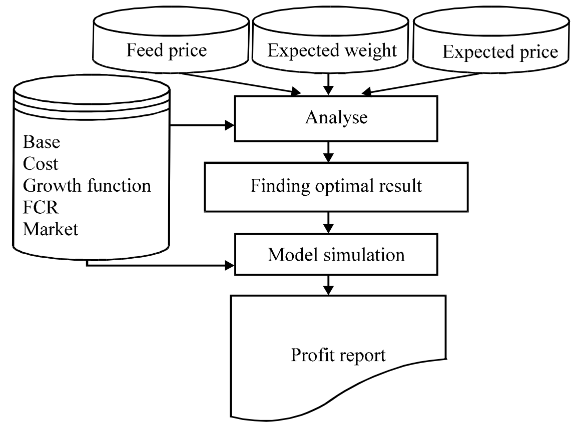

Fig. 3: Framework for the analysis function

Feed conversion ratio: This page includes three parts of the default function, individual settings or a user's own regression equation.

Market: This page includes the ranges of market weight (g) and price (NT$).

Calculation: This page includes the calculated results and displays the results graphically. These reports contain the optimal market age (days), market weight (g), Average Daily Gain (ADG, g), Feed Conversion Ratio (FCR), total feed intake (tons), total feed cost (NT$), total cost (NT$) and net income (NT$/bird).

Analysis: This page analyses the optimal profit for one batch or 1 year. It can also analyse the optimal result based on the average feed price, expected body weight (g) or expected market price (NT$) (Fig. 3) and the codes for the predicted optimal market age of broilers (Table 1) and the codes for the sensitivity analysis (Table 2).

Calculation example

Input base data: This example sets the initial body weight to 56 g and includes 2 stages of change in the weekly feed rations. The first stage starts in the 1st week with 23% crude protein and 3,200 kcal kg^{-1} of metabolisable energy. The second stage starts in the 3rd week with 20% crude protein and 3,200 kcal kg^{-1} of metabolisable energy. The expected survival ratio is 95% and the environmental temperature is 25°C (Fig. 4).

Input cost data: The example assumes that 50,000 birds are raised at a cost of 15 NT$/bird. The resulting total chick cost is 750,000 NT$. The feed costs in the first and second stages are 11.4 and 10.5 NT$ kg^{-1}, respectively. The following costs were defined: labour, 25,000 NT$/month;

Table 1: The code for the predicted optimal market age of broilers

```
For Di = 1 To 365
            If I_option1(2).Value Then
                If w(0) >= Val(I_text(4).Text) Then s = 1
            Else
                If c_day > 0 And Di >= c_day Then s = 1
            End If
            w (1) = gf (0) + gf (1) * Di + gf (2) * Di ^ 2 + gf (3) * MECP (s, 2) + gf (4) * MECP (s, 2) ^ 2 +
gf (5)* MECP (s, 1) + gf (6) * MECP (s, 1) ^ 2 + gf (7)* MECP (s, 2) * MECP (s, 1) + gf (8) * (MECP (s, 2)
/MECP(s, 1)) + gf (9) * (MECP (s, 2)/MECP (s, 1)) ^ 2
           FCR = FCRf (1) + FCRf (2) * w (1) + FCRf (3) * w (1) ^ 2
           sFCR = sFCR + FCR
'          If w(1) < 0 Then w (1) = 0
           ADG = w (1) - w (0)
           sADG = sADG + ADG
           FI (s) = FCR * ADG
           sFI (s) = sFI (s) + FI (s)
           Cost_food (s) = Cost_food (s) + cost_feed (s) * FI (s)
           Cost (1) = Cost (0) + cost_feed (s) * FI (s) + cost_lab + cost_water
           Gain (1) = w (1) * Val (I_text (7).Text)/100 * price
           Income (1) = Gain(1) - Cost (1)
           Write #1, Di, w (1), MECP (s, 1), MECP (s, 2), FCR, ADG, sFI (s), Cost_food (0) + Cost_food (1),
Cost (1), Gain (1), Income (1)
           If w (1) >= W_min Then
                If (Income (1) < Income (0)) Then Exit For
           End If
           If w (1) >= W_max Then Exit For
           w (0) = w (1): Cost (0) = Cost (1): Gain (0) = Gain (1): Income (0) = Income (1)
      Next
      Close #1
      bestDay = Di
      s_OptimDay.Text = bestDay
      s_initWeight.Text = I_text(0).Text
      s_marketWeight.Text = Format(w(1), ####0.000)
      s_AvgW = Format(sADG / bestDay, ####0.000)
      s_avgFCR.Text = Format(sFCR / bestDay, ####0.000)
      s_feedstuff1.Text = Format(sFI(0) * chk_no / 1000000#, ####0.000)
      s_feedstuff2.Text = Format(sFI(1) * chk_no / 1000000#, ####0.000)
      s_feedstuff_total.Text = Format((sFI(0) * cost_feed(0) + sFI(1) * cost_feed(1)) * chk_no / 10000#, ####0.000)
      s_totalCost.Text = Format(Cost(1) * chk_no / 10000#, ####0.000)
      s_chkProfit1.Text = Format(Gain(1), ####0.00)
      s_chkProfit2.Text = Format(Income(1), ####0.00)
      s_batchProfit1.Text = Format(Gain(1) * chk_no / 10000#, ####0.000)
      s_batchProfit2.Text = Format(Income(1) * chk_no / 10000#, ####0.000)
      Exit Sub
```

Table 2: The code for the sensitivity analysis

```
Dim cost_food_max (1) As Double, cost_food_min (1) As Double, step 1 As Integer, step 2 As Integer
      Dim k As Integer, FI (1) As Double
           If c_day = 0 Then
               step1 = Val (a_text0 (2).Text): step 2 = 1
           Else
               step 1 = Val (a_text 0 (2).Text): step 2 = Val (a_text 0 (5).Text)
           End If
           cost_food_min (0) = Val (a_text 0 (0).Text): cost_food_max (0) = Val (a_text 0 (1).Text)
           cost_food_min (1) = Val (a_text 0 (3).Text): cost_food_max (1) = Val (a_text 0 (4).Text)
           file = VB.App.Path + \Analize_Data1.txt
           On Error GoTo Err1:
           Open file For Output As #1
      For k = 1 To step 1
           If step 1 = 1 Then
                Cost_food (0) = cost_food_min (0)
           Else
                Cost_food (0) = cost_food_min (0) + (k - 1) * (cost_food_max (0) - cost_food_min (0))/(step 1 - 1)
           End If
           For j = 1 To step 2
                If step 2 = 1 Then
                     Cost_food (1) = cost_food_min (1)
           Else
```

Table 2: Continue

```
                Cost_food (1) = cost_food_min (1) + (j - 1) * (cost_food_max (1) - cost_food_min (1))/(step 2 - 1)

        End If
        Gain (0) = 0: Gain (1) = 0: Cost (0) = 0: Cost (1) = 0: Income (0) = 0: Income (1) = 0
        w (0) = 0: w (1) = 0: sum_fcr = 0: sh = 0: FI (0) = 0: FI (1) = 0
        For i = 1 To 365
             If I_option 1 (2). Value Then
                  If w (0) >= Val (I_text (4).Text) Then sh = 1
              Else
                  If c_day > 0 And i >= c_day Then sh = 1
            End If
            w (1) = gf (0) + gf (1) * i + gf (2) * i ^ 2 + gf (3) * MECP (sh, 2) + gf (4) * MECP (sh, 2) ^ 2 + gf (5)
* MECP (sh, 1) + gf (6) * MECP (sh, 1) ^ 2 + gf (7) * MECP (sh, 2) * MECP (sh, 1) + gf (8) * (MECP (sh, 2)/
MECP (sh, 1)) + gf (9) * (MECP (sh, 2)/MECP (sh, 1)) ^ 2
            If  w (1) < 0 Then w (1) = 0
            FCR = FCRf (1) + FCRf (2) * w (1) + FCRf (3) * w (1) ^ 2
            sum_fcr = sum_fcr + FCR
            dw = w (1) - w (0)
            Cost (1) = Cost (0) + Cost_food (sh) * FCR * dw/1000# + cost_lab + cost_water
            FI (sh) = FI (sh) + Cost_food (sh) * FCR * dw/1000#
            Gain (1) = w (1) * Val (I_text (7).Text)/100 *price
            Income (1) = Gain (1) - Cost (1)
            If w (1) >= W_min Then
                 If Income (1) < Income (0) Then Exit For
                 If w (1) >= W_max Then Exit For
            End If
            w(0) = w (1): Gain (0) = Gain (1): Cost (0) = Cost (1): Income (0) = Income (1)
        Next
```

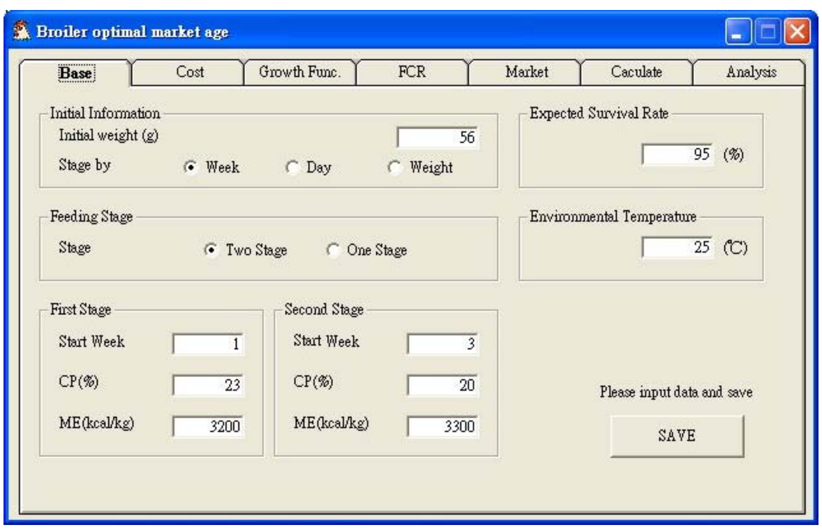

Fig. 4: The base page for the POMA-BROILER System

electricity, 2,200 NT$/month; medicine, 4 NT$/bird; depreciation, 3.5 NT$/bird and other costs, 5 NT$/bird (Fig. 5).

Growth function: The default growth regression equation for cocks was selected in this example (Fig. 6).

Feed conversion ratio function: This example selected the default FCR function for cocks (Fig. 7). Acceptable range for market weight: The acceptable range for market weight was set to 1,600-2,200 g and the market price was 60 NT$ kg^{-1}. All these data were stored and used for calculation by the model (Fig. 8).

Calculation: A result is presented immediately after the calculate button is pressed. This example demonstrates that the optimal market age is 56 days with a market weight of 2,164.30 g, an ADG of 38.65 g and an FCR of 1.80. The feed intake is 36.81 tons for the first stage and 169.0 tons for the second stage. The total feed

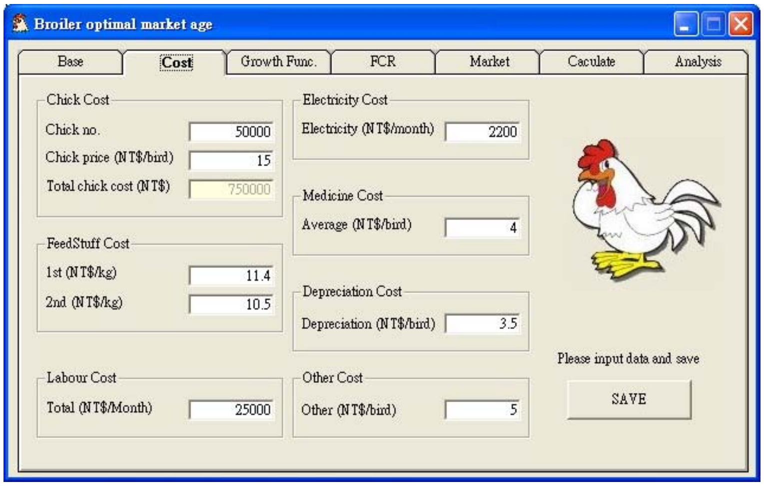

Fig. 5: The cost page for the POMA-BROILER System

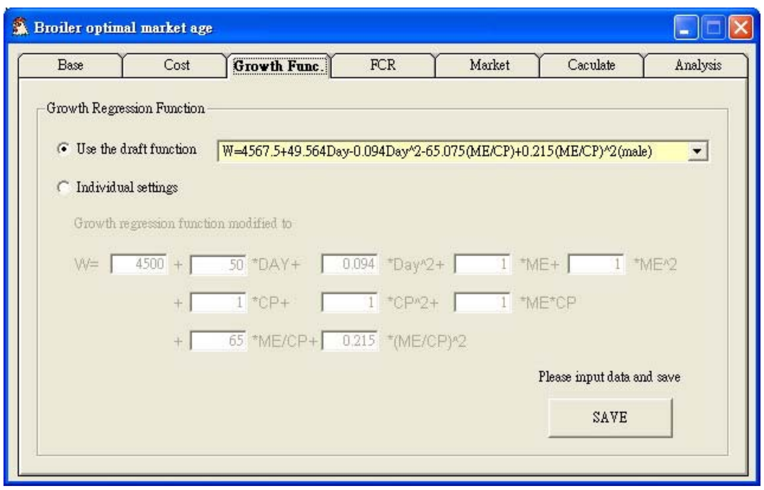

Fig. 6: The growth function page for the POMA-BROILER System

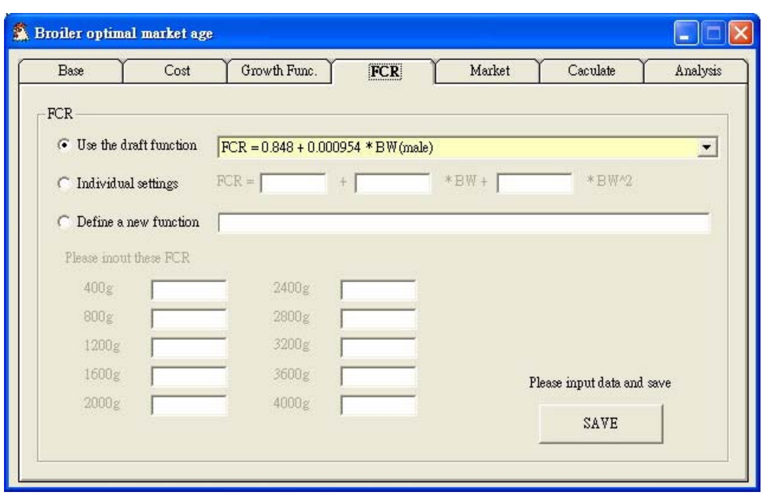

Fig. 7: The FCR page for the POMA-BROILER System

cost is 2,193,450 NT$ and the total cost is 3,619,220 NT$. The gross profit is 123.37 NT$/bird with a net profit of 50.98 NT$/bird, a batch gross profit of 6,168,260 NT$/batch and a batch net profit of 2,549,030 NT$/batch (Fig. 9). The program also displays these results in both table and graph formats.

Analysis: This example selects the optimal annual profit for 1 year and selects the average feed price as the decision point. The price of the two feeds was set to 10-15 NT$ kg^{-1} and a change including five steps was also chosen (Fig. 10). The optimal profit for each combination was accordingly derived (Fig. 11). The predicted results were compared with the recommended NRC (1994) value. Researchers set the growth function and FCR function ourselves according to the following equations:

$$W = 4755.5 + 30.932\ \text{day} + 0.4898\ \text{day}^2 - 65.075\ (\text{ME/CP}) + 0.215\ (\text{ME/CP})^2$$

$$\text{FCR} = 0.98 + 0.00063\ W$$

The comparison shows that the trends for body weight change are quite similar (Fig. 12) and that the trends for changes in feed intake (g/week) are close (Fig. 13). Many factors affect the cost of production and net profit per broiler. However, broiler profit is significantly affected by market weight and market price. Research by Farooq *et al.* (2001) indicated that the market age has a negative effect (p<0.01) on the net profit per broiler but no effect on the cost of production. The reduced net profit per broiler at increased market age could be a result of a poorer FCR and extra management costs due to the prolonged rearing period. The results

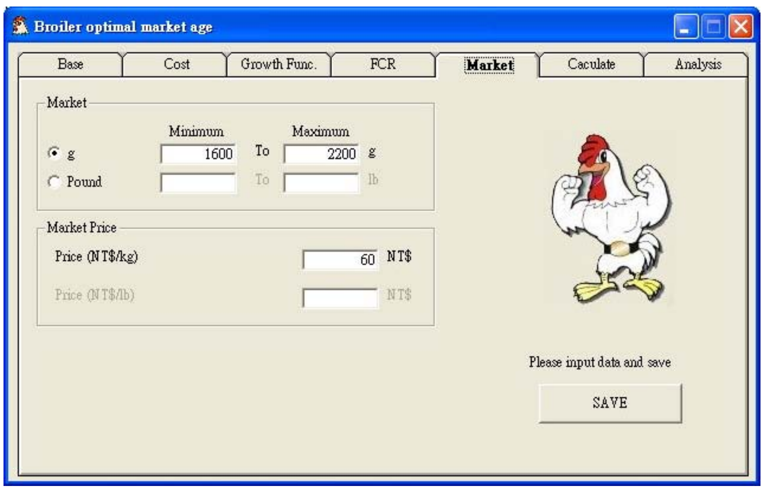

Fig. 8: The market condition page for the POMA-BROILER System

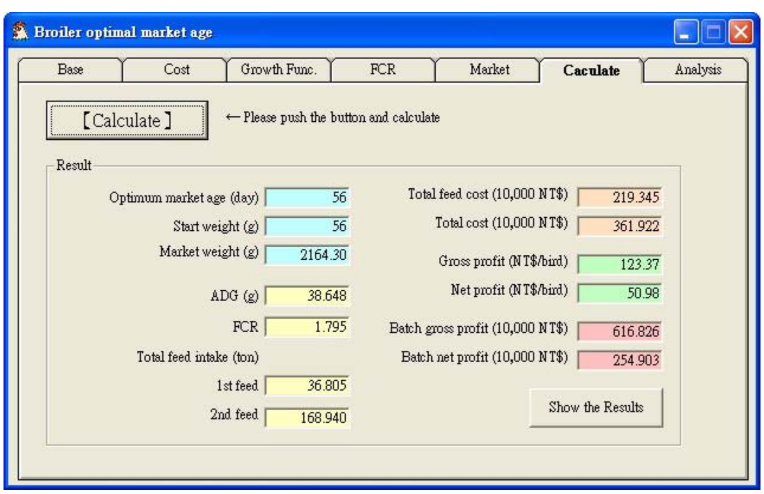

Fig. 9: The results calculation page for the POMA-BROILER System

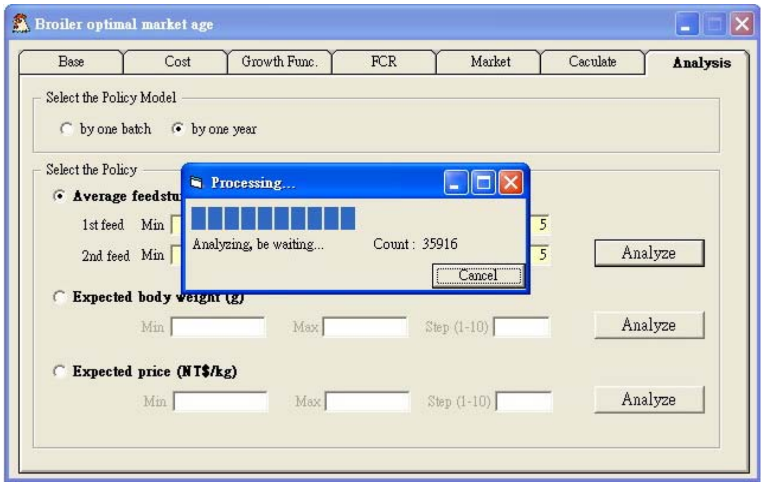

Fig. 10: The sensitivity analysis page for the POMA-BROILER System

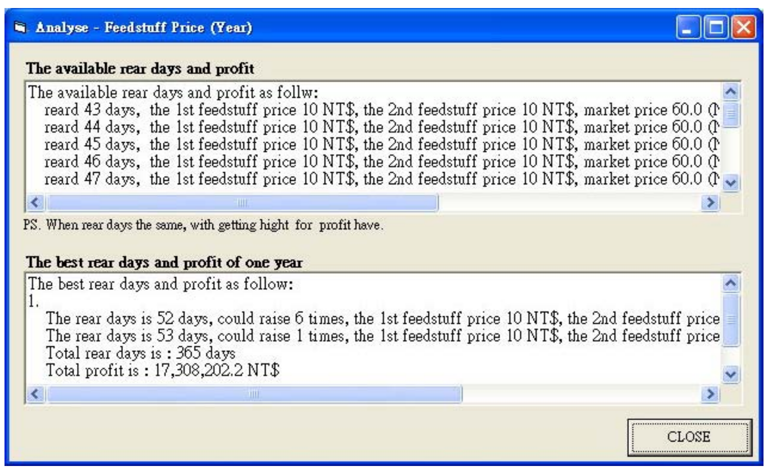

Fig. 11: The analysis results page for the POMA-BROILER System

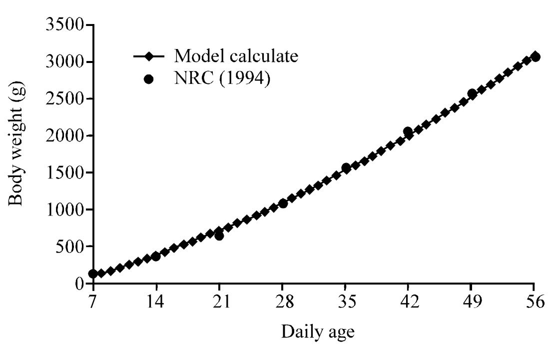

Fig. 12: Comparison of body weight between the model and the NRC (1994) recommendations

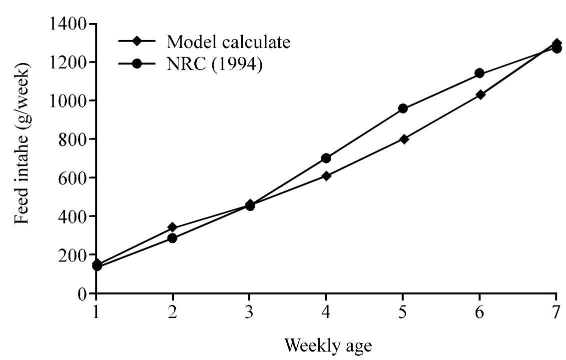

Fig. 13: Comparison of feed intake between the model and the NRC (1994)

obtained by Pestana (1972) appear to indicate that there is no fixed optimum market age. The minimum cost of meat production varied as a function of several factors, especially in relation to the feed price and the growth rate. Sarma *et al.* (1986) reported that economic factors determine the optimal market age of Khaki Campbell ducks. Nakamura *et al.* (1988) used diets with different protein and ME values to find the optimal market age of broiler chickens. Lee *et al.* (1997) reported the optimal market age for Taiwan country chickens in a study performed during the hot and cool seasons to test growth curves, feed efficiency, changes in carcass parts and production costs. All of these studies used different methodologies to identify the optimal market age for poultry production.

Because of broiler growth rates and the use of an Automatic Slaughter System, the carcass size of broilers is increasingly important. It appears to be more profitable to market broilers at an optimal age to meet consumer requirements and obtain an acceptable market weight. Thus if the optimal market age of broilers can be predicted, producers can increase the profits from their production. Because very few researchers have attempted to study the optimal market age of broilers from an economic viewpoint, the aim of this study was to design a Simulation Model to predict the optimal market age of broilers with the intention of increasing profit for farmers.

CONCLUSION

In this study, the demonstration shows that this simulation model is a useful tool for the future production of broilers. Using the model, managers can calculate the optimal market age and analyse the maximum profit decision using different combinations of feed, costs, growth function, FCR function and acceptable market weight. This simulation model provides a consultation tool for adjusting farm production and management to achieve maximum profits.

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