

# Production Efficiency of Poultry Small-Scale Laying Hen in Indonesia

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## ABSTRAK

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Daya saing usaha ayam ras petelur ditentukan oleh tingkat efisiensi, yang antara lain dipengaruhi oleh: tingkat adopsi teknologi, biaya produksi, dan skala ekonomi. Penelitian ini bertujuan untuk menganalisis kinerja usaha ayam ras petelur skala kecil. Lokasi penelitian ditetapkan pada daerah sentra produksi ayam petelur, yaitu Kota Payakumbuh di Sumatera Barat, Kabupaten Blitar di Jawa Timur, dan Kabupaten Sidrap di Sulawesi Selatan. Pengumpulan data dilakukan dari bulan April sampai Juli 2017. Data primer dikumpulkan melalui wawancara kepada 50 orang peternak dan 12 poultry shop di semua lokasi penelitian. Analisis tingkat efisiensi menggunakan *software* DEA (*Data Envelopment Analysis*), dan kelayakan usaha menggunakan analisis finansial. Hasil penelitian menunjukkan bahwa: (1) berkembangnya teknologi budi daya ayam ras petelur belum direspon peternak dengan baik, sehingga tingkat produksi dan kematian ayam masih di bawah standar; (2) secara relatif, tingkat efisiensi usaha ayam petelur di Sidrap dan Payakumbuh lebih baik dengan nilai lebih mendekati satu dibandingkan dengan usaha ayam petelur di Blitar, dimana ketidakefisienan tersebut disebabkan penggunaan input yang berlebih; dan (3) usaha ayam ras petelur skala kecil layak secara finansial, dimana faktor yang menentukannya adalah harga pakan dan harga telur. Rekomendasi kebijakan yang perlu diambil adalah penambahan tenaga pendamping peternak baik dari tenaga *technical service* perusahaan *poultry shop* maupun tenaga penyuluh pertanian. Biaya pakan harus diturunkan sebesar Rp1.000 di Blitar dan Rp57 di Sidrap per kilogram telur yang dihasilkan per siklus produksi. Selain itu, diperlukan alokasi bahan pakan yang baik untuk pelaku usaha di daerah, sehingga rasio harga pakan dan telur optimal.

**Kata Kunci:** *Data Envelopment Analysis* (DEA), Efisiensi, Ayam petelur

## ABSTRACT

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Competitiveness of layer business was determined by the level of efficiency, which was influenced by the level of technology adoption, production costs, and economy of scale. This study was carried out from April to July aim to analyse the performance of small-scale layer poultry farming. The study site was in the layer production centre, namely in Payakumbuh West Sumatera, Blitar East Java and Sidrap South Sulawesi. Primary data were collected through interviews with 50 farmers and 12 poultry shops at all study sites. Analysis of the efficiency level is using DEA (Data Envelopment Analysis) software and business feasibility using financial analysis. The following were the main research findings: (1) the development of layer farming technology had not been responded well by farmers so that the production level and mortality of chickens were still below standard; (2) relatively, the level of layer poultry farming efficiency in Sidrap and Payakumbuh was better than in Blitar with a value closer to one, where the inefficiency was due to the use of excessive inputs; and (3) small-scale layer poultry farming was financially feasible, where the determining factors were feed and eggs price. The study recommended the need to add both technical service staff from poultry shops and local agricultural extension workers. Feed costs should be reduced by IDR 1,000 in Blitar and IDR 57 di Sidrap per kilogram of eggs produced per period. In addition, an accurate and better allocation of corn for feed was needed to optimise the ratio of feed and egg price optimal.

**Key Words:** Data Envelopment Analysis (DEA), Efficiency, Layer

## INTRODUCTION

For a business to survive and reach a liable economy, the products must be competitively produced, and some efforts are carried out efficiently. Tangenjaya (2010) stated that efficiency is crucial for the poultry industry to achieve competitiveness affected by production costs, the economy of scale, business

climate, vertical integration and the ability to adopt new technologies. Efficiency is greatly influenced by the size of input costs (Paly 2015). One way to improve cost efficiency is by vertical integration to increase value-added and economy of scale (Arli et al. 2012; Karthikeyan & Nedunchezian (2013).

Production cost of laying hens is influenced by the number and price of production items used that consist

of feed, DOC or pullet, drug-vaccine-disinfectant (DVD), labour, and others (Paly 2015; Saliu et al. 2015; Muhamad & Rizal 2017). Feed is the highest production cost, reaching 71% of the total cost (Ramadhani 2018), 78% (Santoso et al. 2017), and 79% of total costs according to Ulfa et al. (2014). Meanwhile, egg production is not only influenced by the amount of feed consumption but also by age, health, genetics and its local environment (Ramadhan et al. 2018). In unfavourable environmental such as low health status and poor farm management status will increase feed ration conversion. At the same time, the number of eggs produced become lower (Utomo 2018), therefore, will get smaller efficiency.

Meanwhile, to determine input efficiency to produce outputs level or to achieve technical efficiency can be determined by using various methods such as the Cobb-Douglas production function (Yenibehit et al. 2019; Paly 2015; Muhamad & Rizal 2017), the frontier production function (Elpawati et al. 2018; Saliu et al. 2015; Fadwiwati et al. 2014) and Data Envelopment Analysis-DEA (Herawati 2015; Sari et al. 2014). The problem is that the first two methods are a stochastic quantitative approach. This approach practically has three weaknesses, namely: (1) it must meet several requirements before and after estimating; (2) the estimation results are related to statistical criteria, namely the significance of the relationship between the dependent and independent variables at a certain level; if the relationship is insignificant, it is not relevant for interpretation; and (3) difficult to apply to farms that have more than one outputs (Saliu et al. 2015; Paly 2015; Muhamad & Rizal 2017; Diyoga 1999). In contrast, DEA has advantages, including (1) measuring several outputs and inputs; (2) overcoming problem of small samples size; (3) different units and number of input and output variables; and (4) not necessarily require assumption as a functional relationship between variables (Herawati 2015; Cook et al. 2014).

Based on the advantages previously mentioned, the DEA method was applied to analyse production performance or technical efficiency of laying hens. This research was focused on-farm business, to analyse the production performance and profitability of small-scale layer chicken farming. These research findings will formulate policy analysis to develop a small-scale layer poultry industry.

## MATERIALS AND METHODS

### Study location

The study site was located in three provinces of layer production centre in Indonesia, Payakumbuh city in West Sumatera, Blitar regency in East Java, and

Sidrap regency in South Sulawesi. This study use stratified of laying population, so the production centers divided into three classes: high class with population above 15 million, middle class 10-15 million, and the lower class 5-10 million. Data on layer population refers to the Animal Husbandry Statistics Book (Ditjen PKH 2016).

### Data sources

The data were collected during the period of April – July 2017. Primary data was collected through interview with respondents of 50 farmers, 12 poultry shop owners and 9 committee members of farmer groups in 3 location using structured questionnaire, while secondary data were collected from various related agencies as well as from internet.

### Data analysis

Production efficiency will be calculated using Data Envelopment Analysis (DEA) method as measuring an efficiency calculation technique based on linear programming, which is used to calculate the relative performance efficiency of various businesses (Coelli 1996; Emrouznejad & Cabanda 2015). This method was used to measure the relative efficiency level of layer poultry of all types of farms in each location.

Relative efficiency was measured by constructing hypotheses, which locations were most efficient from various farm in the research areas through assigning an average weight for each input in each farm unit. Relative efficiency levels of each layer farming can be calculated and compared by assigning weights to each input and output, and its total weighted output then were divided by the total weighted inputs (Emrouznejad & Cabanda 2015), as presented in the formula ( 1).

$$j^{\text{th}} \text{ farm efficiency} = \frac{\sum_{r=1}^n O_r Y_{rj}}{\sum_{i=1}^m V_i X_{ij}} \dots\dots\dots(1)$$

Where  $O_r$  is weight for output r,  $Y_{rj}$  is number of output r for farm j,  $V_i$  is weight for input I,  $X_{ij}$  = number of inputs i for farm j n is number of outputs, m is number of inputs, and j is number of farms

In this study have four inputs and two outputs. The inputs used were: (x<sub>1</sub>) feed cost (Rp / kg eggs / business cycle); (x<sub>2</sub>) the number of hens (birds); (x<sub>3</sub>) Drug-Vaccine-Disinfectant (DVD) cost per kg of eggs produced per cycle (Rp / kg eggs / cycle); (x<sub>4</sub>) labor cost per kg of eggs produced in one business cycle (Rp / kg eggs / cycle). For outputs were: (y<sub>1</sub>) chicken productivity (kg eggs / birds / cycle); (y<sub>2</sub>) Egg production per farm (kg eggs / cycle).

The level of technical efficiency was calculated using the Variable Returns to Scale (VRS-TE) with input-oriented, where it is assumed that decision maker unit (DMU) is the farmer in a constrained state. To determine the weight of each input and output for each effort to achieve the efficiency target for each business, it is done through problem solving as used by Cook et al. (2014) and Anggela (2012) as follows:

$$(e_j) = \frac{\sum_{r=1}^n OrYrj}{\sum_{i=1}^m ViXij} \dots\dots\dots(2)$$

subject to =  $\frac{\sum_{r=1}^n OrYrj}{\sum_{i=1}^m ViXij} \leq 1$ , for each farm (j)  
 $o_r$  and  $v_i \geq 0$

where  $e_j$  is max. efficiency  $f_j$  and  $e_j$  is  $j^{th}$  farm efficiency.

Maximum efficiency of  $j^{th}$  farm ( $e_j$ ), with efficiency constraint of the whole farm was less than one. Variables  $O$  and  $V$  were weighted, and the solution to these problems was the best weighting values for each farm to produce a good relative efficiency level ( $e_j$  value). If  $e_j = 1$ , then a farm (for example farm 1) was relatively efficient against another. But if  $e_j$  was less than one, then one or several other farms were more efficient than farm 1 (Cook et al. 2014; Anggela 2012).

DEA model was a linear programming based (Coelli 1996; Emrouznejad & Cabanda 2015), therefore the objective function has to meet the most important ratio between outputs and inputs, not the nominal of each variable and its weight. Therefore, to achieve the same effect the denominator (inputs) in the ratio was made as a constant and maximize the numerator (outputs). This condition results in input-oriented optimization, where the objective function is to maximize the output weight. The results of this optimization recommend as excess use of inputs in achieving output (Anggela 2012). In the form of linear programming, the above (Max.  $h_0$ ) problems can be changed to:

$$\sum_r OrYrj \dots\dots\dots(3)$$

subject to  $\sum_i VrXij = 100$  (determined)

$$\sum_r OrYrj - \sum_i VrXij \leq 0$$

Data processing was performed using DEA software and has been had been used by Prasetyo (2008) and Sari et al. (2014) in determining supply chain efficiency, and Heidari et al. (2011) in determining the efficiency of broiler farm in Brazil.

Financial analysis was used to find out the performance of layer poultry farming. The information required were: (i) types of inputs and production costs, (ii) type and value of investment, (iii) level of production, and (iv) type and value of revenue. Based

on these data, cost of production and revenue per kilogram of eggs produced can be calculated, along with its R/C ratio and farm profit.

## RESULTS AND DISCUSSION

### Performance of production

According to Sharma et al. (2020), layer performance can be seen from hen day egg production (%), mortality (%), and other factors, namely egg weight, feed intake and feed conversion ratio. Production level of layer is the average percentage of chickens that lay eggs during one cycle. This data was ob

tained from the results of interviews during the survey and recalled data that had happened before. This is determined by the percentage at peak production, and how long the peak production take place. In overall, the average of production level during one production cycle reached 65% (Payakumbuh 68%, Blitar 63%, and Sidrap 64%). These figures were still below the standard issued by Hy-Line Brown, which was 83% (Hy-line International, 2014). Production level in more detail can be seen in Figure 1.

Relatively low egg production in Blitar was caused by higher temperatures in the area compared to the other two locations or regions. This condition was obtained from the results of observations during a survey with an indication of odor, and dry feces in the cage. Heat stress in poultry (above a comfortable temperature of poultry) would cause an increase in body temperature, thereby increasing drinking water consumption and decreasing feed consumption (Tamzil 2014; Kilic & Simsek 2013).

Mortality rate also determines farm performance. This data was obtained from the results of interviews by calculated the number of chickens that died from DOC to sold after non-productive divided by the number of DOC chick-in; or the number of chickens that died from the pullet to sold after non-productive divided by the number of pullets chick-in. The highest mortality rate occurred in Sidrap (13%). %. According to poultry shop owners most farmers still practice traditional system in raising DOC, therefore, a better use of new techniques, especially in raising DOC was needed, beside more intensive maintenance for chicken raising (Table 1). Farmers often ignored DOC housing preparation before chick-in and the time during brooding period. This finding was confirmed by the study of Bethel et al. (2016) in Nigeria, namely in order to increase productivity, the government should intensify farmers' visits and encourage farmers to become active member of local farmer association.

### Technical efficiency

To assess the technical efficiency of layer at the study sites, a variable cost of feed per kg of eggs produced per cycle (Rp/kg of eggs/cycle), the number of laying hens raised (birds), DVD costs per kg of eggs produced per cycle (Rp/kg eggs/cycle), labor costs per kg of eggs produced in one cycle (Rp/kg eggs/cycle) were applied. Results analysis by using input-oriented DEA application as reflected by efficient use of inputs, can be seen in Table 2.

The level of technical efficiency was calculated using Variable Returns to Scale (VRS-TE) model which assumed that the Decision Making Unit (DMU) of farmers was constrained. The average VRSTE value of layer farming was 0.95. Based on location, in Blitar, Payakumbuh and Sidrap, the value of VRSTE were 0.88; 0.99; and 0.99, respectively. Technically Sidrap and Payakumbuh had almost the same level of efficiency and more efficient than Blitar. Likewise, the efficient population of farmers in Sidrap, Payakumbuh and Blitar were 64.7%; 57.1% and 6.3% respectively.

Inefficiency source of small-scale layer farm in Blitar was excessive use of all inputs. One example was the use of drug-vaccine-disinfectant (DVD) with slack value of 21.73. This was because farmers tend to apply drug-vaccine-disinfectant and vitamins to avoid risk (Ilham & Iqbal 2011). Moreover, the fact that the farm cycle of layer is relatively long, negligence in

controlling and preventing disease can be fatal. Technically, Paly (2015) stated that inefficiency in the use of inputs caused by production and productive capacities that had decreased will not be efficient again even though the amount of input remains as before it experienced inefficiency. In other words, if the production curve had decreased, the increase in input given will not increase production.

The Cobb-Douglas log transformation function (Yenibehit et al. 2019), uses the number of birds, medication, the quantity of water, feeding, and the number of employees as input and the number of eggs produced over the production period as the only output. The results showed that the number of birds, medication, and water intake positively and significantly affected egg production. However, it only revealed the effect of independent variables increase and decrease TE, not the TE value.

The estimation with Stochastic Frontier Production Function (SFPF) (Elpawati et al. 2018) provides better outcomes compared to the Cobb-Douglas log transformation function. In addition to the variables affecting production, there is also information on TE value (i.e., 0.8858) and input slacks in poultry egg production. While the DEA model results indicate the excess per unit input, the SFPF model shows the percentage of inputs currently used. This study revealed that 90% of feed and 40% of labor inputs in the production layer are over-utilized.

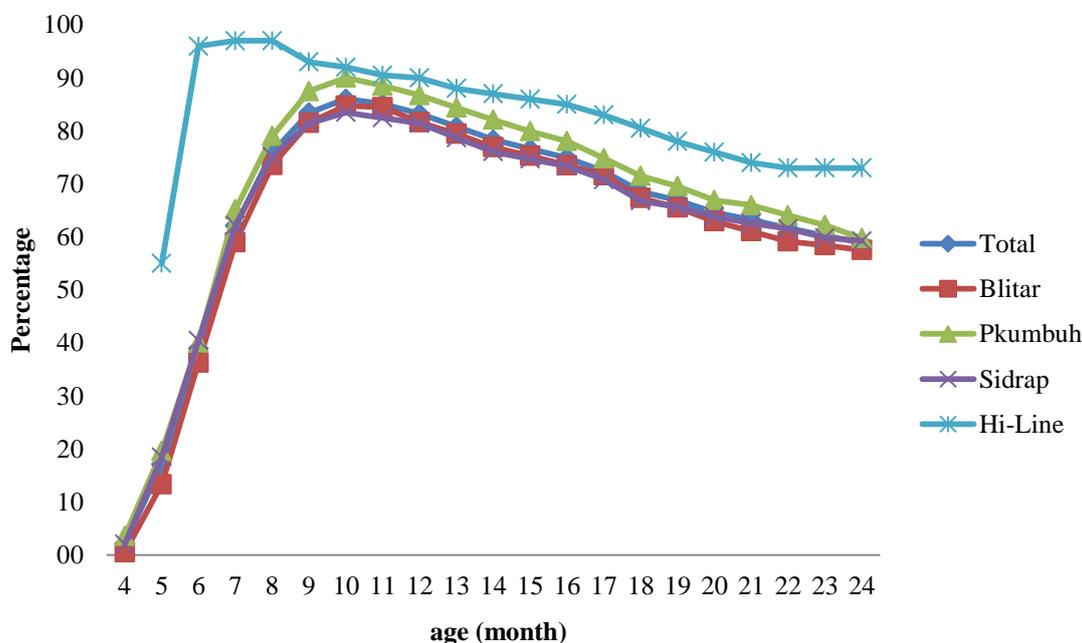


Figure 1. Percentage of chickens that lay eggs during one cycle at study site in 2017 from Primary Data, processed and Hy-line International (2014)

**Table 1.** Average ownership of pullet and mortality rates of pullet in the study site in 2017

| No | Location   | Pullet ownership (birds/farmer) | Dead Pullet (birds/cycle) | % Mortality |
|----|------------|---------------------------------|---------------------------|-------------|
| 1  | Total      | 2,964                           | 237                       | 8.00        |
| 2  | Blitar     | 2,459                           | 156                       | 6.35        |
| 3  | Payakumbuh | 4,518                           | 291                       | 6.44        |
| 4  | Sidrap     | 1,976                           | 263                       | 13.29       |

Source: Primary data (processed)

**Table 2.** Technical efficiency of layer farming at the study sites in 2017

| Location     | VRSTE value         |      |                     |      |         | Slacks Input*             |                                  |                          |                            |
|--------------|---------------------|------|---------------------|------|---------|---------------------------|----------------------------------|--------------------------|----------------------------|
|              | 1                   |      | < 1                 |      | average | Feed<br>(Rp/kg egg/cycle) | Laying hens<br>(birds/<br>cycle) | DVD<br>(Rp/kg egg/cycle) | TK<br>(Rp/kg<br>egg/cycle) |
|              | Number<br>of farmer | %    | Number<br>of farmer | %    |         |                           |                                  |                          |                            |
| Blitar       | 1                   | 6.3  | 15                  | 93.7 | 0.881   | 1,000.98                  | 7.44                             | 21.73                    | 26.97                      |
| Paya- kumbuh | 8                   | 57.1 | 6                   | 42.9 | 0.985   | 0.00                      | 0.00                             | 0.00                     | 15.77                      |
| Sidrap       | 11                  | 64.7 | 6                   | 35.3 | 0.986   | 57.44                     | 0.00                             | 0.00                     | 0.00                       |
| Total        | 20                  | 42.6 | 27                  | 57.4 | 0.950   | 361.54                    | 2.53                             | 7.40                     | 13.88                      |

Source: Primary Data (processed)

\* DVD=drugs, vaccines and disinfectant; TK=labor

**Table 3.** Cost, revenue and profit of layer farming in the study sites, 2017

| No  | Description                     | Blitar | Payakumbuh | Sidrap |
|-----|---------------------------------|--------|------------|--------|
| I   | Cost (Rp/kg egg/cycle)          | 15,659 | 14,332     | 15,014 |
| 1   | Pullet                          | 1,886  | 1,850      | 1,889  |
| 2   | Feed                            | 12,852 | 11,611     | 12,010 |
| 3   | Drug-vaccine-disinfectant (DVD) | 296    | 285        | 225    |
| 4   | Operational                     | 98     | 14         | 14     |
| 5   | Labor                           | 223    | 219        | 291    |
| 6   | Depreciation                    | 304    | 289        | 236    |
| 7   | Packaging                       | 0      | 50         | 320    |
| 8   | Transport                       | 0      | 14         | 29     |
| II  | Egg Production (kg/cycle)       | 89,786 | 178,712    | 64,084 |
| III | Revenue (Rp/kg egg/cycle)       | 16,874 | 18,707     | 17,734 |
| 1   | Egg Selling                     | 15,960 | 17,440     | 16,533 |
| 2   | Old pullet                      | 897    | 1,155      | 1,077  |
| 3   | Manure                          | 17     | 112        | 124    |
| IV  | Profit (Rp/kg egg/cycle)        |        |            |        |
| 1   | Egg                             | 301    | 3,108      | 1,519  |
| 2   | Egg & Old pullet                | 1,198  | 4,263      | 2,596  |
| 3   | Egg, Old pullet & manure        | 1,215  | 4,375      | 2,720  |
| 4   | R/C Egg                         | 1.02   | 1.22       | 1.10   |
| 5   | R/C Egg & old pullet            | 1.08   | 1.30       | 1.17   |
| 6   | R/C Egg, Old pullet & manure    | 1.08   | 1.31       | 1.18   |

Source: Primary Data (processed)

### Farm business

The performance of layer farming can be seen from the profits. The analysis of layer farming in this study area shows in Table 3. Farm profits are not only determined by productivity as a condition of necessity, but also the balance of input prices that determine production costs and output prices which determine the amount of revenue. In this study, layer farm generate revenue from eggs selling, old laying hens selling and manure selling.

Layer farming in Payakumbuh showed better profit than Sidrap and Blitar. In fact, besides farm scale (Table 3) and technical efficiency (Table 4), the price of rice bran in Payakumbuh was relatively cheaper, thus the price of feed was also lower, compared to the two other regions. In addition, egg prices were relatively higher compared to other regions. Details can be seen in Table 5. These findings were better than Nawawi et al. (2017) in Majalengka West Java, which

found that generally the R/C ratio of layer farms was 1.07.

In Payakumbuh and Sidrap, chicken feces can be used as organic fertilizer and as a byproduct of layer farm that provided better economic value than in Blitar. The same thing was also found in other layer farming (Santoso et al. 2017; Abadi et al. 2017). Byproducts of poultry industry that can be processed for a better use and managed with good techniques will reduce environmental pollution and provide an economic value (Mishra et al. 2015).

### CONCLUSION

The development of layer breeding technologies had not been responded well by farmers in the studied locations. Traditional or old method in raising layers was still practiced and often ignore, especially the preparation of DOC housing before chick-in and the accuracy period during brooding. As a result,

production levels were still below standard and mortality rates were still high. In relative terms, the level of technical efficiency of layer in Sidrap and Payakumbuh was better with VRSTE values 0.99 compared to Blitar (0.88). Inefficiency in Blitar was caused by excessive cost of feed and labor inputs. Small scale layer farming was financially feasible in the three locations. Layer farms in Payakumbuh were relatively more profitable. This was partly due to greater farm scale, lower feed prices, and more expensive eggs price than in the other two locations.

Utilization of manure (feces) for organic fertilizer was able to reduce environmental pollution and also provided income, as well as improved farm efficiency and sustainability. Various supports were still needed from both poultry shops (Technical Service) and Extension Workers to make farmers to practice better layer technology. Feed costs should be reduced by IDR 1,000 in Blitar and IDR 57 per kilogram of eggs produced per production cycle. Distribution system of maize and rice bran as the main raw material for small-scale layer poultry farming need better government attention, in order to optimize the ratio of feed and egg prices.

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#### REFERENCES

- Abadi M, Taridala SAA, Nafiu LO. 2017. Evaluasi kelayakan agribisnis ayam ras petelur pada CV. Bintani Poultry Shop Kendari. *Bul Peternak*. 41:355. DOI: 10.21059/buletinpeternak.v41i3.17758.
- Anggela P. 2012. Model pemilihan supplier dengan menggunakan Data Envelopment Analysis (DEA) dan teknik data mining. Depok (indones): Indonesia University.
- Arli, Daryanto A, Hendrawan D. 2012. Strategi peningkatan daya saing rumah potong ayam PT XYZ. *J Manaj dan Agribisnis*. 9:68–76. DOI: 10.17358/jma.9.2.68-76.
- Bethel E, Fani D, Odufa E. 2016. Analysis of technical efficiency of poultry farmers in Cross River State, Nigeria. *Int J Res Stud Agric Sci*. 2:40–45. DOI: 10.20431/2454-6224.0204005.
- Coelli T. 1996. A Data Envelopment Analysis (Computer) Program. Armidale (AUS).
- Cook WD, Tone K, Zhu J. 2014. Data envelopment analysis: Prior to choosing a model. *Omega*. 44:1–4. DOI: 10.1016/j.omega.2013.09.004.
- [Ditjen PKH] Direktorat Jenderal Peternakan dan Kesehatan Hewan. 2016. Statistik Peternakan dan Kesehatan Hewan 2016. Jakarta (Indones): Direktorat Jenderal Peternakan dan Kesehatan Hewan-Kementerian Pertanian RI.
- Diyoga W. 1999. Beberapa alternatif pendekatan untuk mengukur efisiensi atau in-efisiensi dalam usaha tani. *Inform Pertan*. 8:487–497.
- Elpawati, Gabdo BH, Ismail MM, Abdurofi I. 2018. Stochastic frontier production function and efficiency status of poultry layer farms in Malaysia. *Int J Poult Sci*. 17:568–577. DOI: 10.3923/ijps.2018.568.577.
- Emrouznejad Ali, Cabanda E. 2015. Introduction to Data Envelopment Analysis and its Applications. In: Osman I, Anouz A, Emrouznejad A, editors. *Handb Res Strateg Perform Manag Meas Using Data Envel Anal*. USA: IGI Global; 235–255. DOI: 10.4018/978-1-4666-4474-8.ch004.
- Fadwiwati A, Hartoyo S, Kuncoro S, Rusastra I. 2014. Analisis efisiensi teknis, efisiensi alokatif, dan efisiensi ekonomi usaha tani jagung berdasarkan varietas di Provinsi Gorontalo. *JAE*. 32:1–12.
- Heidari M, Omid M, Akram A. 2011. Using nonparametric analysis (DEA) for measuring technical efficiency in poultry farms. *Rev Bras Ciência Avícola*. 13:271–277. DOI: 10.1590/S1516-635X2011000400009.
- Herawati. 2015. Kinerja pemasaran biji kakao di Kabupaten Pasaman, Sumatera Barat. Sekolah Pascasarjana. Bogor (Indones): IPB University.
- Hy-line International. 2014. Hy-line Brown Commercial Layers. Management Guide: Hy-Line Int. West Des Moines, IA.
- Ilham N, Iqbal M. 2011. Factors determining farmers' decision on highly pathogenic Avian Influenza vaccination at the small poultry farms in Western Java. *Media Peternak*. 34:219–227. DOI: 10.5398/medpet.2011.34.3.219.
- Karthikeyan R, Nedunchezian V. 2013. Vertical integration paving way to organised retailing in Indian poultry industry. *IJBMI*. 2:39–46.
- Kilic I, Simsek E. 2013. The effects of heat stress on egg production and quality of laying hens. *J Anim Vet Adv*. 12:42–47. DOI: 10.3923/javaa.2013.42.47.
- Mishra J, Biswas S, Sarangi N, Mishra R, Kumar N, Mishra C. 2015. Efficient utilisation of poultry by-products for economic sustainability - the need of the hour. *Int J Livest Res*. 5:1–9.
- Muhamad S, Rizal A. 2017. Efisiensi usaha peternakan ayam ras petelur di Kabupaten Lombok Timur. *J Ilm Rinjani*. 5:115–131.

- Nawawi A, Andayani S, Dinar. 2017. Analisis usaha peternakan ayam petelur (Studi kasus pada peternakan ayam petelur Cihaur, Maja, Majalengka, Jawa Barat). *AGRIVET*. 5:15–29.
- Paly B. 2015. Efisiensi skala usaha dan intensitas penggunaan input pada ayam ras petelur fase produksi kedua. *JIP*. 2:15–24.
- Prasetyo S. 2008. Analisis efisiensi distribusi pemasaran produk dengan metode Data Envelopment Analysis (DEA). *J Ilmu Tek dan Komput*. 8:120–128.
- Ramadhan M, Mahfudz L, Sarengat W. 2018. Performans ayam petelur tua dengan penggunaan tepung ampas kecap dalam pakan. *J Sain Peternak Indones*. 13:84–88.
- Ramadhani RD. 2018. Analisa usaha peternakan ayam petelur sistem closed house di Rissa Farm Desa Kendalrejo Kecamatan Srengat Kabupaten Blitar. *AVES J Ilmu Peternak*. 11:1–13.
- Saliu L, Abdulrazaq S, Eleke P. 2015. Production efficiency of poultry egg (layer) production in Chikun and Igabi local government areas of Kaduna State, Nigeria. *NJAE*. 6:40–52. DOI: 10.22004/ag.econ.267989.
- Santoso ZB, Sudjani ET, Andaka A. 2017. Analisis biaya produksi peternakan ayam petelur di Kabupaten Tulungagung (Studi kasus di Dofir Layer Farm). *AVES J Ilmu Peternak*. 11:4. DOI: 10.35457/aves.v11i1.319.
- Sari SW, Nurmalina R, Setiawan B. 2014. Efisiensi kinerja rantai pasok ikan lele di Indramayu, Jawa Barat. *J Manaj dan Agribisnis*. 11:12–23.
- Sharma MK, Dinh T, Adhikari PA. 2020. Production performance, egg quality, and small intestine histomorphology of the laying hens supplemented with phytogenic feed additive. *J Appl Poult Res*. 29:362–371. DOI: 10.1016/j.japr.2019.12.001.
- Tamzil MH. 2014. Stres panas pada unggas: metabolisme, akibat dan upaya penanggulangannya. *Wartazoa*. 24:57–66. DOI: 10.14334/wartazoa.v24i2.1049.
- Tangenjaya B. 2010. Global competitiveness of poultry production in South East Asia countries. *Wartazoa*. 20:161–171.
- Ulfa Z, Sarengat W, Santoso S. 2014. Analisis finansial usaha peternakan UD. Balebat di Desa Karang Kobar Kecamatan Sukorejo Kabupaten Kendal. *Anim Agric J*. 3:476–482.
- Utomo DM. 2018. Performa ayam ras petelur coklat dengan frekuensi pemberian ransum yang berbeda. *AVES J Ilmu Peternak*. 11:3. DOI: 10.35457/aves.v11i2.276.
- Yenibehit N, Murshed M, Islam M. 2019. Assessment of technical efficiency of layer production in Mampong Municipality: Stochastic Frontier approach. *Curr Res Agric Sci*. 6:20–28. DOI: 10.18488/journal.68.2019.61.20.28.