Microclimate influence investigation on broilers industrial production intensification by information technology methods

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Abstract. The article contains regression mathematical models that describe the effect of mechanical and automatic microclimate control systems on the growth and development of Arbor Acres broiler chickens in Sayan broiler agro-industrial complex in conditions of on-ground keeping. The following microclimate parameters are considered: temperature, humidity, illumination. Cramer-Welch, Wilcoxon criteria are used to test the statistical hypothesis of homogeneity of the two considered samples. The Chow test is taken on the possibility of constructing two different mathematical models of the same type that describe the patterns of development of simulated indicators. Statistical estimates of the significance of the constructed models and factors included in the models are calculated. The Fisher criterion is checked to see the differences in the constructed models and choose a more acceptable one to describe the effect of the microclimate on the production of young birds. The results of regression analysis are interpreted in relation to the subject area under study. Graphical visualization of analysis of initial and output data of built models is performed. Factors are ranked by degree of their effect on the resulting index using elasticity coefficients and share of their influence. The main production indicators are calculated according to the results of population cultivation - average daily growth, absolute growth, relative growth rate, liveability. The article calculates the economic effect in one complete cycle of broiler chickens growing.

1. Introduction

The paper evaluates the mechanical and automatic microclimate control systems influence on the Arbor Acres cross broiler chickens growth and development in the Sayan Broiler agro-industrial complex conditions (the Irkutsk region a diversified enterprise) with outdoor housing using mathematical statistics methods, applied mathematics and the STATISTICA 10.

The Arbor Acres Cross was developed by the Hubbard French-British-American company Isa as a crossing result of the broilers breed lines: Cornish and White Plymouth Rock.

By the life first month, with optimal maintenance, broilers reach two kilograms in weight. Since that time, the weight gain is accelerating, and by the life fortieth day, the broiler is gaining about two and a half kilograms.
The Arbor Acres Cross broiler chickens are very thermophilic, for their comfortable stay it is necessary to create a special microclimate in the shops: maintain the air a certain temperature and humidity, its speed, control the harmful gases content, the room dustiness, illumination, noise level [1, 2, 3].

2. Research methods
To study the various environmental parameters influence on the Arbor Acres Cross broiler chickens growth and development, two-floor housing units with different microclimate control systems were selected [4, 5]: maintaining a microclimate control (mechanical method) and maintaining the microclimate experimental (automatic method).

After sanitizing, filling with bedding material (sawdust), gassing and warming up the air environment, guided by the temperature and humidity standards established at the enterprise, the Arbor Acres Coss chickens were settled in the buildings on June 1, 2020 (table 1).

**Table 1.** Data on the broiler chickens settlement.

| Name                              | Landing rate heads, pcs. | Heads number, pcs. | Stocking density heads/m² | Average weight at check-in, g. | Keeping term, days |
|-----------------------------------|--------------------------|--------------------|---------------------------|-------------------------------|-------------------|
| Control shop (maintaining the microclimate mechanical method) | 39250                    | 31801              | 19.6                      | 41                           | 41                |
| Experimental workshop (maintaining the microclimate automatic method) | 44928                    | 37668              | 20.5                      | 41                           | 41                |

When the chickens were moved into the control building, the air temperature, humidity, and illumination intensity average values were, respectively, 33°C, 53%, 60 lx, and in the experimental – 33°C, 50%, 60 lx. In the first case, measurements were carried out in the building different parts (beginning, middle, end) at the birds level. In the second, the parameters were set in automatic mode on the Fancom microclimate control computer, taking into account the sensors readings installed in the building.

Previous studies by various authors have focused on the chickens' diet, mainly on the feed and nutritional supplements quality and balance, and on the broiler rearing zoo-hygienic conditions. Feeding at growth different stages is one of the key factors in broiler production, i.e. depending on the development stage, broilers require nutritional components a certain amount and ratio, first, the proteins content and their biological value are controlled. It is known that proteins primarily affect poultry productivity, with the main emphasis on identifying amino acid deficiencies [6]. In addition, the vitamins, macro-and microelements balance plays an important role in the diet, their deficiency directly causes a decrease in poultry productivity, leads to culling and mortality [7].

For feeding the poultry in both buildings, a full-value diet adopted at the enterprise was used (table 2).

Poultry health is the broiler production most important element, and poor health has a negative effect. In this regard, the veterinary service specialists continuously monitor the livestock diseases early detection and treatment.

Regular checks show that there are two leaps in mortality in the broiler herd: the first is associated with the post-vaccination syndrome (high stress on the body); the second is precutting (sudden death syndrome: internal organs do not have time to grow behind the skeleton and muscles due to the fast production time).
Table 2. Recipe for a complete ration for broiler chickens for the Arbor Acres Cross.

| Ingredients                   | Rations for 1 feed ton, % |
|-------------------------------|---------------------------|
|                               | 5-10 days | 11-18 days | 19-24 days | 25-31 days | 32-41 days |
| Soybean meal                  | 28.3      | 21.6       | 21.6       | 21         | 16.3       |
| Meat and bone meal            | 2         | 3          | 3          | 3          | 3          |
| Sunflower cake                | 4         | 6          | 6          | 6          | 6.5        |
| Premix P5 2.5%                | 2.5       | -          | -          | -          | -          |
| Premix P5 1.5%                | -         | 1.5        | -          | -          | -          |
| Premix P6 1.5%                | -         | -          | 1.5        | 1.5        | 1.5        |
| Wheat                         | 58.46     | 62.45      | 62.45      | 63.62      | 67.76      |
| Limestone                     | 1.3       | 1.2        | 1.2        | 0.8        | 0.5        |
| Sunflower oil                 | 3         | 3.5        | 3.5        | 3.5        | 4          |
| Calcium Monophosphate         | -         | 0.5        | 0.5        | 0.3        | 0.2        |
| Lysine                        | 0.07      | 0.05       | 0.05       | 0.05       | 0.05       |
| Threonine                     | 0.03      | -          | -          | -          | -          |
| Vitamin B4 (choline)          | 0.01      | 0.1        | 0.1        | 0.04       | -          |
| Vitamin B7 (biotin)           | 0.001     | -          | 0.1        | 0.1        | 0.001      |
| Manganese Sulfate             | 0.015     | -          | -          | 0.005      | 0.03       |
| Sodium Sulfate                | 0.1       | -          | -          | -          | -          |
| Probiotic Maxus GI            | -         | -          | -          | 0.03       | -          |

The livestock safety is a normative indicator, which consists of statistical data on its culling, which average value, for the Sayan Broiler agricultural holding, is taken equal to 93.7%. For the control and experimental shops, the livestock safety was 92.56% and 95.39%, respectively.

It was found that the microclimate parameters have no less influence on the broiler chickens vital parameters than the feeding ratio [8].

3. Results and discussion

When studying the factors affecting poultry production intensification, as a rule, most scientists use biological research methods involving mathematical and statistical analysis (observation method, experimental method, monitoring, variation statistics, etc.) [9]. However, the article authors suggested that the microclimate influence on the broiler chickens growth can be studied using the regression analysis methods, which reveals the factors relationships type and structure under consideration, as the information processing methods one. This will make it possible to identify the microclimate statistically significant indicators that affect the chickens live weight increasing effectiveness and give the study a biological interpretation results.

Before proceeding with the mathematical models' construction describing how changes in certain controllable (exogenous) microclimate parameters will affect the output characteristic values - a bird live weight (endogenous), it is advisable to use modern statistical methods to check the initial data homogeneity. To formalize the differences absence in the samples elements characteristics: the change in the birds' weight and the microclimate parameters in the control and experimental buildings, the F. Wilcoxon and Cramer-Welch criteria were used.

Testing the two considered independent samples homogeneity statistical hypothesis showed the characteristics coincidence. The Cramer-Welch test was 1.06, the Wilcoxon test was 0.81, which is less than the critical value equal to 1.96.

Due to the samples' regression homogeneity, the question arises about the same type using models possibility to describe the simulated processes. The answer to this question is given by Chow's test regression coefficients equality in two samples. The null hypothesis was tested using the F statistic. The calculated value is 8.49, which is more than the critical value of 2.5. This made it possible to conclude
that it is possible to construct two different similar mathematical models describing the simulated indicators development patterns.

Based on empirical data (observations number-41) on changes in the bird weight and the microclimate parameters in the control and experimental buildings in the studies course, two linear multiple regression models (superscripts for variables: 1 - control building 2 - experimental) of the chickens live weight dependence were built ($y$) from temperature ($x_1$), humidity ($x_2$), illumination ($x_3$):

$$
\hat{y}_1^1 = 41.09 - 111.96x_{1t}^1 + 56.14x_{2t}^1 + 14.82x_{3t}^1,
$$

$$
\hat{y}_1^2 = 1451.84 - 126.59x_{1t}^2 + 37.84x_{2t}^2 + 14.97.
$$

The factors included in the model are statistically significant, which is confirmed by $t$-statistics.

The models' verification shows their statistical significance, which is confirmed by $F$-statistics, along with this, the determination coefficients indicate that 97.66% of the variability in the Arbor Acres Cross broiler chickens weight is determined by the first model microclimate influence and 98.09% - the second.

The models performed regression analysis results interpretation:

A bird live weight dependence on temperature is the opposite; with an increase in temperature by one degree, a bird weight decreases by an average of 112 g in the first model and by 126.6 g in the second with other factors fixed levels. Indeed, it was experimentally found that with an increase in the air temperature in the premises up to 35$^\circ$-40$^\circ$C, the bird's body temperature rises by a 0.5-1.0$^\circ$C relative to the norm, which, in turn, increases water consumption by 2-3 times, reduces the activity of digestive enzymes and leads to muscle and bone tissues mineral depletion;

A bird live weight dependence on humidity is direct, with an increase in humidity by one per cent, a bird weight increases by an average of 56 g in the first model and by 37.8 g in the second with other factors fixed levels. It is well known that insufficiently humid indoor air reduces livestock productivity and can lead to stress reactions: poultry health deterioration, infectious diseases spread increased risk, increased mortality, curbing weight gain, etc.;

A bird live weight dependence on the illumination intensity is direct, with a change in the illumination intensity by one lux, a bird weight increases on average by 14.8 g in the first model and by 14.97 in the second with other factors fixed levels.

To check the initial process description quality and accuracy by the two constructed models, the two-sided Fisher criterion was applied, which makes it possible to compare alternative models and make a choice in one or the other favour. The Fisher criterion calculated value turned out to be 1.98, which is more than the critical value of 1.72. Therefore, the choice should be made in the second model favour, which describes the indicators' quantitative relationships in the experimental building. Additionally, this conclusion is confirmed by comparing the constructed models found average approximation errors, for the first model it was 9.37%, for the second - 7.01%.

The quantitative regularities analysis and the microclimate indicators influence dependence on the modelled factor to lead to the need to rank them according to the influence degree on the bird average weight using the elasticity coefficients and the factors that influence shares: temperature has the greatest influence, then humidity, the least influence is the illumination intensity.

The factors that influence assessment included in the model on the key indicator, carried out using regression analysis, is consistent with the experiment data conducted by the authors (weighing every 7 days and daily microclimate indicators recording). Undoubtedly, the most important factors that have a significant impact on increasing poultry productivity are the microclimate indicators (temperature, humidity and light intensity) in poultry houses. Which deviation from the established norms leads to a decrease in productivity, as well as to an increase in the feed, water, labour and funds cost for the technological equipment repair, and a decrease in the poultry buildings operation duration.

The $F$ - statistics use confirms the fact - in the second model, the quantitative characteristics are better compared to the first, which is consistent with the main production indicators based on the cultivation results (table 3).
Table 3. Main production indicators based on the broiler chickens rearing results.

| Indicators                        | Control building | Experimental building |
|-----------------------------------|------------------|-----------------------|
| Weight at the growing beginning, g| 41               | 41                    |
| Weight at the growing end, g      | 2222             | 2308                  |
| Absolute gain, g                  | 2181             | 2267                  |
| Average daily gain, g             | 54.53            | 59.18                 |
| Relative gain,%                   | 192.7            | 193.0                 |
| Safety, %                         | 92.56            | 95.39                 |

The final indicator characterizing the livestock products production efficiency, in particular poultry farming, is the economic effect - an absolute indicator measured in monetary units.

In addition to the economic effect absolute value, it is necessary to know its relative value, comparing the result with the obtaining it costs. The annual economic effect, as well as the achieving its costs, is the basis for calculating economic efficiency - an indicator determined by the economic effect ratio and the costs that generated this effect. Closely related to these economic indicators is the cost recovery concept.

Microclimate control automation has led to an increase in income by 30.21% for the Arbor Acres Cross growing broiler chickens one cycle, which is estimated at 13,540,939.19 rubles per year, while the total costs in the experimental shop will be 4,050,126 rubles per year. The implementation estimated economic effect will be equal to 9,490,813 thousand rubles per year, including 37.93 rubles per one head per cultivation cycle, and economic efficiency - 234.33% per year. Ultimately, the costs will pay off after three growing cycles (table 4).

Table 4. The main economic indicators based on the growing broiler chickens results.

| Indicators                        | Control building | Experimental building |
|-----------------------------------|------------------|-----------------------|
| At the growing beginning, heads   | 31801            | 37668                 |
| Withdrawn from growing, heads     | 29435            | 35932                 |
| Survival rate, %                  | 92.56            | 95.39                 |
| Received for slaughter, heads     | 29066            | 35749                 |
| Carcass weight, g                 | 1629.80          | 1725.50               |
| Products received, kg             | 47371.77         | 61684.90              |
| Additional product yield, kg      | 135.15           | 135.15                |
| Income from the products sale for one growing cycle, rubles | 6,402,294.28 | 8,336,714.17 |
| Income from the products additional output sale for one growing cycle, rub., rubles | - | 1,934,419.88 |
| Batches (cycles) number per year  | 7                | 7                     |
| Estimated proceeds from the additional output sale per year, rubbles | - | 13,540,939.19 |
| The microclimate control equipment cost, rubles | 645,648 | 3,934,926 |
| Equipment maintenance cost per year, rubles | 93,600 | 115,200 |
| Estimated economic effect for the year, rubles | - | 9,490,813.19 |
| Estimated economic efficiency per year% | - | 234.33 |
| Return on costs, cycle            | -                | 3                     |

4. Conclusion
For the first time, on the data obtained basis at the Sayan Broiler enterprise, using the regression analysis methods, we studied the microclimate indicators influence on the Arbor Acres Cross broilers production intensification during their floor keeping under mechanical and automatic microclimate systems.
The main production indicators based on the livestock rearing results, calculated in the study course, are fully consistent with the microclimate indicators influence performed regression analysis results on the Arbor Acres broilers production intensification in one complete growing cycle.

The main economic indicators based on the Arbor Acres Cross growing broiler chickens results on the Sayan Broiler example confirm the need to introduce production processes automation in poultry farming.

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