Electrotechnology in the production of phytogenic feed additives

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Abstract. In various sectors of the agro-industrial complex, innovations are used to improve production efficiency. For livestock and poultry farming, innovative solutions related to feed additives are especially relevant. A valuable phytogenic additive to the feed rations of farm animals and poultry is hydroponic green fodder obtained by germinating seeds. Off-season obtaining of green forage on a hydroponic basis is associated with significant expenditures of thermal and electrical energy, in connection with which the urgent task is to reduce the energy intensity of production. To increase the energy efficiency of green fodder production, it is proposed to create the necessary conditions for the seeds to realize their potential with the help of methods and means of electrical technology, which make it possible to realize “smart” (controlled) germination and to influence the bioelectric potentials of seeds due to their electrification. As a result of the studies carried out, the maximum charge received by germinating seeds of legumes in the corona discharge field was determined. It was found that the electrification of germinating seeds promotes the activation of growth processes, an increase in the yield and quality of hydroponic green forage, and a decrease in the energy intensity of its production.

1. Introduction

In all sectors of the agro-industrial complex, innovations are used to improve production efficiency. For industries such as livestock and poultry, innovative solutions related to feed additives are especially relevant - special additions to feed rations [1].

Currently, various types of feed additives (phytogenic, mineral and chemical) have been developed, which are divided into technological, food, zootechnical, etc. figure 1).

The main purpose of feed additives is to reduce the cost of keeping animals and improve the quality of products by obtaining balanced, complete and effective feed rations. The result of the use of feed additives is:

• introduction of necessary components into the diet;
• increasing the digestibility of feed;
• activation of the growth and development of farm animals and poultry;
• increasing the survival rate of young animals;
• decrease in morbidity, etc. [2-4], (figure 2).

**Figure 1.** Classification feed additives

**Figure 2.** Appointment feed additives

When choosing feed additives for farm animals and poultry, one should take into account not only their beneficial properties, but also the effect on the human body. Phytogenic additives, in the production of which plants (herbs and spices, extracts and essential oils) are used, are of natural origin, are natural food material, safe and quite effective [2-4].

A valuable phytogenic additive to the feed rations of farm animals and poultry is hydroponic green fodder (GZK) obtained by germinating seeds [9]. On the sixth ... tenth day of cultivation, the chemical composition of GZK differs significantly from the composition of seeds in terms of protein, fat, nitrogen-free extractives, etc. [9], picture 3. In hydroponic green fodder, the amount of vitamins E and B increases significantly, the formation of carotene and vitamin C occurs [9].

When growing GZK on substrates eaten by farm animals and poultry (in particular, on sapropel), the typical technological process undergoes a number of changes: operations are introduced to prepare the substrate and place it on the growing surface; for irrigation, water is used instead of the nutrient solution. Accordingly, the composition of the set of equipment for continuous feed production changes. (figure 4) [9].
Off-season obtaining of hydroponic green fodder is associated with significant consumption of thermal and electrical energy, in connection with which the urgent task is to reduce the energy intensity of production. Increasing the energy efficiency of GZK production implies creating the necessary conditions for the seeds to realize their potential. In this regard, it seems expedient to use methods and means of electrical technology, which make it possible to realize "smart" (controlled) germination and to influence the bioelectric potentials of seeds due to their electrification.

**Figure 3.** Content of chemical components in GZK (compared to the seeds of the original crop).

2. **Materials and methods**
In studies of the process of charging seeds in electric fields, of greatest interest is the assessment of the maximum charge and response of seeds to electrical impact. In this regard, the studies carried out included:
- determination of the maximum charge received by germinating seeds of agricultural crops in the field of corona discharge;
- evaluation of the response of seeds (biomass of hydroponic green forage).
For germinating seeds located on a non-corona electrode, a combined charge is characteristic, consisting of ionic and contact (induction) charging. Limit (maximum) charge \( Q_{\text{max}} \) obtained by germinating seeds was calculated by the formula [10; 11]:

\[
Q_{\text{max}} = Q_{\text{max}}^3 \cdot \mu_k
\]  

(1)

\( Q_{\text{max}}^3 \) - the maximum charge received by the seeds during ionic charging; \( \mu_k \) - discharge rate.

The discharge index was determined using the expression:

\[
\mu_k = \frac{2 \tau \beta + 1 - \sqrt{1 + 4 \tau \beta (1 + \frac{Q_{\text{max}}^2}{Q_{\text{max}}^1} )}}{2 \tau \beta}
\]  

(2)

\( \tau \) - time constant of charging a particle (germinating seed) on the electrode; \( \beta \) - corona intensity; \( Q_{\text{max}}^2 \) - maximum charge received by germinating seeds during contact charging [10; 11].

The time constant for charging germinating seeds was calculated by the formula [10; 11]:

\[
\tau = \frac{\varepsilon_c d_0 + \varepsilon_{cp} (1 - d_0)}{\gamma_c d_0 - \gamma_{cp} (1 - d_0)}
\]  

(3)

\( \varepsilon_0 \) - electrical constant; \( \varepsilon_c \) - relative dielectric constant of germinating seeds; \( d_0 \) - depolarization coefficient; \( \varepsilon_{cp} \) - relative dielectric constant of the medium; \( \gamma_c \) - electrical conductivity of germinating seeds; \( \gamma_{cp} \) - electrical conductivity of the medium.

To calculate the intensity of the corona discharge, we used the expression [10; 11]:

\[
\beta = \rho \kappa / 4 \varepsilon_0
\]  

(4)

\( \rho \) - bulk charge density; \( \kappa \) - ion mobility.

Maximum charge \( Q_{\text{max}}^1 \), obtained by seeds with ionic charging was determined by the formula [7; 8]:

\[
Q_{\text{max}} = \frac{3 \pi \varepsilon_u \varepsilon_c a^2 E}{\varepsilon_u + 2}
\]  

(5)

\( a \) - germinating seed diameter; \( E \) - corona field strength.

During the research, the electrode system "needles on rods - plane" with the following design parameters was used: interelectrode distance 0.10 m; length of needles 0.015 m; distance between needles and rods 0.03 and 0.025 m, respectively [9; 12]. A voltage of 25 kV was applied to the electrodes.

To assess the response of seeds to electrical treatment, a one-factor experiment was carried out to grow hydroponic green fodder. The research was carried out with the seeds of the vetch variety «Nikolskaya» PC1 and peas «Sakharnyy». GZK was grown for 7 days from a mixture of vetch and pea seeds taken in a 1: 1 ratio. Sapropel, which has the beneficial properties of fertilizer and feed additive, was used as a substrate for farm animals and poultry. [13]. The ecological purity of the green mass of feed was determined by the content of heavy metals: cadmium, lead, nickel, arsenic, mercury.

The technological process of growing hydroponic green forage included complex seed preparation: germination and processing in the corona discharge field. When receiving the GZK, the following microclimate parameters were maintained: temperature 18 ... 20 °C, relative humidity 65 ... 70%. The experiment used the method of randomized repetitions; statistical processing of the results obtained was carried out using well-known techniques [14].
Comparison of the energy efficiency of different options for growing hydroponic green food was carried out using the corresponding indicator:

\[ \eta_{ef} = \frac{E_c - E_p}{E_c} \]

\( E_c, E_p \) - energy consumption of production of GZK in control and pilot versions, respectively.

3. Results and discussion
The results of theoretical studies related to the determination of the maximum electric charge acquired by germinating seeds during combined charging on a non-corona electrode in the corona discharge field are given in the table 1.

| № | Electrifying germinating seeds in a corona discharge field | Germinating seeds |
|---|----------------------------------------------------------|-------------------|
|   |                                                          | vetch             | peas              |
| 1 | Maximum charge \( Q_{max1} \), obtained by ion charging, \( \mu \)Кл | 1,52              | 2,04              |
| 2 | Maximum charge \( Q_{max2} \), obtained by contact charging, \( \mu \)Кл | 0,86              | 1,14              |
| 3 | Maximum charge \( Q_{max3} \), obtained by combined charge, \( \mu \)Кл | -0,76             | -1,02             |
| 4 | Charging time constant \( \tau \), мкс | -0,50             | -0,50             |
| 5 | Discharge rate, \( \mu \)к | 0,90              | 0,90              |

Analysis of the results presented in Table 1 allows us to conclude that the germinating vetch and pea seeds acquired a negative charge under the action of combined charging. Ionic charging processes proceeded with a higher intensity than induction charging processes. As a result, germinating seeds on the positive noncoronating electrode were negatively charged. The maximum charge of pea seeds turned out to be higher (in absolute value) than the maximum charge of vetch seeds, which is explained by the differences in their sizes.

The results of experimental studies related to the assessment of the response of germinating seeds to electrical treatment are presented in tables 2; 3. Table 2 shows the results of analysis of variance, in table 3 - the results of the experiment and statistical processing. The yield of GZK obtained from one plot in the control variant (germinating seeds were not exposed to the corona discharge field) was 0.258 ... 0.282 kg. In the experimental version (germinating vetch and pea seeds were processed in the corona discharge field for 3 seconds) 0.287 ... 0.313 kg of hydroponic green forage was obtained from one plot.

Analysis of the results of analysis of variance (Table 2) allows us to conclude that there are significant differences between the options in the experiment. \( F_{\phi} > F_{0.05} \).

| Dispersion | Sum of squares | Degrees of freedom | Medium square | \( F_{\phi} \) | \( F_{0.05} \) |
|------------|----------------|--------------------|---------------|-------------|-------------|
| general    | 0,0023         | 7                  | -             | -           | -           |
| repetitions| 0,0004         | 3                  | -             | -           | -           |
| options    | 0,0018         | 1                  | 0,0018        | 54,054      | 10,13       |
| mistakes   | 0,0001         | 3                  | 3,33·10^5     | -           | -           |

Data processing (Table 3) shows that the maximum harvest of GZK from one plot (germinating seeds were processed in the corona discharge field) was 0.287 ... 0.313 kg. In the experimental version (germinating vetch and pea seeds were processed in the corona discharge field for 3 seconds) 0.287 ... 0.313 kg of hydroponic green forage was obtained from one plot.
Analyzing table 3, we can draw the following conclusion. The experimental version significantly exceeds the standard version (control): the deviation from the standard is greater HCP_{0.05}.

The results of determining the content of heavy metals in the green mass of hydroponic feed are shown in the table 4.

**Table 4.** Content of chemical elements in hydroponic green fodder, micron / kg wet weight.

| №  | Chemical element | Content in the GZK experimental version | Content in the GZK test version |
|----|------------------|----------------------------------------|--------------------------------|
| 1  | Cadmium          | 0.026                                  | 0.029                          |
| 2  | Lead             | 0.430                                  | 0.480                          |
| 3  | Nickel           | 0.420                                  | 0.460                          |
| 4  | Arsenic          | 0.171                                  | 0.190                          |
| 5  | Mercury          | 0.016                                  | 0.018                          |

Analysis of the data given in table 4 allows us to conclude that the content of heavy metals (cadmium, lead, nickel, arsenic and mercury) is below the maximum permissible values. The concentration of these chemical elements in the experimental version was 9.11% lower than in the control version.

Determination of the indicator of energy efficiency of production when comparing various options for growing GZK showed that the energy intensity of production in the experimental version is 11.2% lower than in the control version.

4. Conclusions

Consequently, the treatment of germinating seeds of legumes (vetch and pea) in the corona discharge field allows them to be electrified, which has a positive effect on growth processes, helps to increase yields, improve the quality of hydroponic green forage and reduce the energy intensity of its production. Thus, the use of methods and means of electrical technology in obtaining phytogetic feed additives in production is promising, since it allows increasing energy efficiency and reducing the energy intensity of production.

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