Production vacuum-evaporation unit for increasing humic suspension concentration

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Abstract. Humic preparations belong to natural growth regulators. Humic preparations eliminate the negative effects of factors unfavorable for the development of plants, normalize the processes of intracellular metabolism. Humic substances are adsorbed on the cell wall of the animal organism, increasing the elasticity of its membrane and increasing the surface of the cell, this leads to an increase in the amount of oxygen and metabolism entering it. With the introduction of humic substances in the diet of cattle, the average daily increase in live weight increases by 14.4%. When used as an additive in chickens feed, the average daily increase increases by 11.85%, the weight of the heart, liver, spleen, and gall bladder up to 20.7%. The average daily gain in sucking piglets is increased by 8.3%. A line with a vacuum evaporator was developed to increase the concentration of humic suspension. The installation consists of a heating chamber, a steam pipeline, a steam condenser, a condensate tank, a water-air ejector, a cooler, a water tank, a centrifugal pump, a hot water supply pipe to the heating jacket, a water drain pipe from the shirt, a working water pipe, a pressure gauge, vacuum gauges, a thermometer.

1. Introduction
It is possible to increase crop yields and improve product quality with the help of plant growth and development regulators [1, 2]. Humic preparations are natural growth regulators [3, 4]. They change the course of all physiological and biochemical processes of plants (photosynthesis, respiration, carbohydrate and protein metabolism, transpiration, the intensity of mineral nutrition), morphogenesis, and the rate of passage of phenological phases. In addition, they have anti-stress and antimutagenic properties. The highest effect of the drugs is observed when deviating from the optimum of at least one of the factors of plant growth and development. Humic preparations eliminate the negative impact of factors unfavorable for plant development, normalizing the processes of intracellular metabolism [5]. It is possible to use humic preparations to increase the effectiveness of biological reclamation of contaminated territories [6]. Non-root treatment of plants by Rostcom reduced the content of heavy metals in potato tubers [7].
Engineering support in the implementation of socio-economic and environmental programs of the agro-industrial complex provides for the improvement of technologies and technical means for the production of animal feed and BMVD for farm animals and poultry [8-15]. Humic substances are endowed with a wide spectrum of biological activity, they are adsorbed on the cell wall of animals, increasing the elasticity of its membrane and increasing the surface of the cell, this leads to an increase in the amount of oxygen entering it, and as a result, an increase in metabolic rate and growth processes.

The use of humic substances leads to an absolute increase in live weight, accelerate the growth of animals, increase the safety of offspring, reduce morbidity, as well as increase their body's resistance to adverse environmental conditions. So with the introduction of humic substances in the diet of cattle, the average daily increase in live weight increases by 14.4%. Erythropoiesis (the formation of red blood cells in the body) and the synthesis of immunoglobulins are enhanced, and the activity of leukocyte phagocytosis increases by 10%.

2. Development of an experimental line

2.1 Materials and methods
At the Department of General Chemistry, LLC “SPC” Evrika "of the State Agrarian University of Northern Trans-Urals, a natural humic preparation from peat - ROSTOK was developed and produced [16, 17]. Together with employees of the Eureka enterprise, it was proved that with an increase in the concentration of humic suspension by evaporation at a temperature of 60...65 °C, the beneficial properties of ROSTOK are better preserved than with an increase in concentration in precipitation centrifuges [18].

2.2 Experimental line
Based on a review of literature [19, 20] and search experiments, we developed and patented a line with a vacuum evaporator to increase the concentration of humic suspension [21]. Modification of the experimental line is shown in figure 1 [22–24].
2.3 Line work
A ripened humic suspension is poured into the heating chamber 1, water with a temperature of 80...90 °C is introduced into the jacket of the heating chamber through the nozzle 9, the cooled water is discharged through the nozzle 10. When the suspension temperature reaches 65 °C, a centrifugal pump is turned on to supply water to the air-water ejector 5. A water-airless ejector creates a vacuum of 75...80 kPa in the heating chamber. The steam from the heating chamber is removed through the steam line 2 and condenses in the steam condenser 3. The condensate drains into the tank 4. After the ejector 5, water enters the cooler 6 and is drained into the tank 7. From the tank, the centrifugal pump 8 returns water to the ejector. After increasing the concentration of the suspension to the desired value, the water supply to the jacket is shut off and the centrifugal pump is turned off. The pressure in the heating chamber with atmospheric is equalized. After all operations are completed, the suspension merges. To control the pressure, a manometer 12 and vacuum gauges 13 and 15 are used. To control the temperature, a thermometer 14 is used.

2.4 Calculation method
To calculate the diameters of the nozzle and mixing chamber of a water-air ejector based on literature [25–30], provided that the maximum volumetric coefficient of injection is ensured, we obtained the formula:
\[
f_{p1} = \frac{G_w R_w (273 + t_p)}{3600 (P_n - P_{np})} \left( \frac{\rho_v}{2 (P_p - P_n)} \right)^{1/2}
\]

\(f_{p1}\) – area of the working nozzle, m\(^2\);
\(G_w\) – mass flow rate of injected air, kg/h;
\(P_p\) – water pressure in front of the working nozzle, Pa;
\(P_n\) – pressure of injected air, Pa;
\(\rho\) – density of working water, kg/m\(^3\);
\(P_c\) – pressure after the ejector, Pa;
\(P_{np}\) – saturated steam pressure, Pa.

The diameter of the working nozzle, mm, is determined by the formula:

\[
d_{p1} = 2000 \sqrt{\frac{f_{p1}}{\pi}}
\]

The area, m\(^2\), and diameter, mm, of the mixing chamber are determined by the formulas:

\[
f_3 = \frac{\Delta P_p}{\Delta P_c} f_1.
\]

\[
d_3 = 2000 \sqrt{\frac{f_3}{\pi}}
\]

3. Results and discussion
The results of calculations using the obtained formulas for the diameters of the mixing chamber and the working nozzle are shown in figure 2.

![Figure 2. Dependence of the diameters of the mixing chamber \(d_3\), mm, and working nozzle \(d_{p1}\), mm, from the flow rate of injected air \(G_w\), kg/h.](image)

For example, when the flow rate of injected air is \(G_w = 1\) kg/h, the diameter of the working nozzle is \(d_{p1} = 14\) mm and the diameter of the mixing chamber is \(d_3 = 28\) mm.

A vacuum evaporation unit for increasing the concentration of humic suspension was developed and tested. In the heating chamber, the absolute pressure must be maintained in the range \(P = 20...25\) kPa. The boiling point of the suspension is \(t_n = 65...68\) °C, and the specific heat of water vaporization is \(r = 2350...2336\) kJ/kg.
4. Conclusion
Provided that the maximum volumetric coefficient of injection was ensured, the dependences of the diameters of the working nozzle and the mixing chamber of the air-water ejector as a function of:

\[ G_n \] – mass flow rate of injected air, kg/h;
\[ P_p \] – water pressure in front of the working nozzle, Pa;
\[ P_n \] – pressure of injected air, Pa;
\[ \rho \] – density of working water, kg/m³;
\[ P_c \] – pressure after the ejector, Pa;
\[ P_{sv} \] – saturated vapor pressure, Pa;
\[ t_r \] – working water temperature, ºС;
\[ t_n \] – temperature of the injected air, ºС.

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