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Influence of Raw Material Ratios and Extraction Conditions on Organic Matter Content in Liquid Organo-Mineral Fertilizers Based on Poultry Manure and Phosphorite Sludge

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Abstract:
Background: This article investigates the process of obtaining liquid organo-mineral fertilizer (LOMF) based on poultry manure (PM) and phosphorite sludge (PS) in the presence of potassium hydroxide (KOH). Methods: Experiments were conducted with PM:PS mass ratios ranging from 95:5 to 65:35 and solid-liquid (S:L) ratios from 1:1 to 1:3. Results: The results indicated that a decrease in the proportion of poultry manure in the raw material and an increase in the extractant volume led to a reduction in the concentration of total organic matter, humic acids, and fulvic acids in the liquid phase. The maximum organic matter content in the liquid fertilizer (12.78%) was recorded under the conditions of PM:PS 95:5 and S:L 1:1. Scientifically substantiated optimal parameters were identified, allowing for the production of high-quality liquid fertilizer while enabling the efficient utilization of solid residues.

Keywords: Poultry manure, phosphorite sludge, liquid organo-mineral fertilizer, humic acid, fulvic acid, extraction, solid residue, optimal parameters.

Introduction

Occupational In recent years, the global agricultural sector has witnessed a rapid transition from chemical fertilizers to organo-mineral fertilizers aimed at restoring soil fertility and cultivating ecologically clean products. Numerous researchers emphasize that the exclusive use of mineral fertilizers leads to soil degradation and a decline in microbiological activity. Consequently, the development of complex fertilizers by enriching organic waste with mineral components is viewed as an effective solution not only for plant nutrition but also for improving soil structure.

Existing studies have deeply analyzed the current state of humic fertilizer production, identifying problems and proposing scientific-technical solutions. Given the rapid development of organic farming and the increasing demand for humic fertilizers, the sharp decline in cattle and poultry waste volumes has made it difficult to fully meet this need. Therefore, the creation of industrial technological lines for producing humic fertilizers based on natural organic raw materials such as peat, brown coal, and sapropel is identified as an urgent task. Research has demonstrated opportunities for modernizing technological lines using modular equipment. Specifically, it has been scientifically proven that the use of hydromechanical cleaners increases the purification level of peat suspension to 97–98%, and grinding brown coal to 50–70 μm using a vibration mill reduces the amount of post-filtration sediment to 1–3% [1-3].

The improvement of technology for obtaining humic organo-mineral fertilizers is scientifically grounded in the context of ensuring food security. Research highlights the declining soil fertility due to intensive harvesting and provides specific data on the insufficiency of traditional organic fertilizers. In this context, humic organo-mineral fertilizers are evaluated as an innovative solution that yields high agronomic effects with low application rates. A key scientific novelty in recent studies involves the development of a functional scheme for a technological device designed to produce "Gumat" brand liquid humic organo-mineral fertilizer and the experimental substantiation of its main parameters. The production process is divided into two stages: raw material preparation and finished product extraction, with clearly defined input-output parameters. Particular attention is paid to the production cycle time, experimentally proven to be 20 minutes, allowing for a line capacity of 150 L/hour (900 L/shift) [4-5].

Furthermore, the efficiency of the agrarian sector is directly linked to maintaining and increasing soil fertility. The separate application of traditional mineral and organic fertilizers has ecological and economic limitations. In this regard, the combined use of organic and mineral components in humic fertilizers creates highly assimilable nutrient forms for plants. In the technological process of LOMF production, input parameters such as water, concentrate, macro- and microelement quantities, temperature, and mixing time are critical, while the volume, composition, and quality of the finished fertilizer serve as output parameters. Studies on the "Gumat++" (type C2) production line have demonstrated practical efficiency. Results show that using humic organo-mineral fertilizers reduces mineral fertilizer consumption, lowers ecological stress, and increases crop yields by 10–30%. This contributes to increased income for producers, improved product quality, and the strengthening of national food independence and economic security [6-8].

The analysis of the literature indicates that the effectiveness of humic and organo-mineral fertilizers is primarily determined by the quantity and quality of organic matter they contain, as well as the bioavailability of these substances. Therefore, selecting scientifically grounded raw material ratios for producing liquid organo-mineral fertilizers from local and low-cost materials, such as poultry manure and phosphorite sludge, is of great importance. Interactions between organic and mineral components may lead to insufficient extraction of organic matter or its binding with mineral components. Simultaneously, studying the direct effect of extraction conditions on the yield of organic substances, particularly humic and fulvic acids, is scientifically and practically relevant. This enables the creation of high-efficiency fertilizers with stable compositions suitable for agriculture.

Materials and Methods. The study utilized phosphorite sludge, a waste product from the enrichment of Central Kyzylkum phosphorites, and poultry manure obtained from a local poultry farm. Phosphorite Sludge (PS): The chemical composition (by weight %) is: P_2O_5 – 11.21; CaO – 42.28; MgO – 0.61; Fe_2O_3 – 1.42; Al_2O_3 – 2.79; SO_3 – 1.46; CO_2 – 20.91; SiO_2 – 12.54. Poultry Manure (PM): The composition (by weight %) is: Moisture – 64.82; Ash – 11.89; Organic matter – 23.29; Humic acid – 1.12; Fulvic acid – 7.41; Water-soluble organic matter – 1.28; P_2O_5 – 1.29; N – 1.21; K_2O – 0.95; CaO – 1.61; Fe_2O_3 – 0.78; Al_2O_3 – 0.96; SO_3 – 0.37; and SiO_2 – 1.98.

In the first stage, poultry manure and phosphorite sludge were mixed in various weight ratios (95:5, 90:10, 85:15, 80:20, 75:25, 70:30, and 65:35) in a laboratory ball mill for 15 minutes until homogenized. Subsequently, to activate the organic and mineral parts and convert humic substances into a soluble state, a 2% aqueous solution of potassium hydroxide (KOH) was used. The Solid:Liquid (S:L) ratio was varied at 1:1, 1:1.5, 1:2, 1:2.5, and 1:3. The process was carried out in a water bath at a temperature of 50–60˚C with constant mechanical stirring (400 rpm) for 90 minutes. This resulted in a dark brown paste-like suspension. The total organic matter content in the resulting suspension was analyzed using standard chemical analysis methods.

Results and Discussion. The analysis revealed a strict dependency of the total organic matter content in the liquid fertilizer separated from the PM-PS-KOH slurry on the raw material weight ratios and the S:L ratio. It was found that as the proportion of PM decreased and the liquid ratio increased, the organic matter content declined.

For instance, at a PM:PS ratio of 95:5 and minimal dilution (S:L=1:1), the maximum organic matter concentration was 12.78%. As the PS content increased, this indicator consistently decreased to 11.91% (at 90:10), 10.26% (at 80:20), and 8.00% (at 65:35). This is explained by the reduction in the share of poultry manure (the main organic component) and the increase in phosphorite sludge, which lacks organic compounds.

Furthermore, increasing the volume of the KOH solution (widening the S:L ratio from 1:1 to 1:3) led to a sharp dilution of organic matter in the liquid phase. In the sample with a PM:PS ratio of 85:15, the value dropped from 11.07% at S:L=1:1 to 4.11% at S:L=1:3 (Table 1).

Table 1.

Dependence of total organic matter content in liquid fertilizer on PM:PS weight ratios and Solid:Liquid ratios.

Weight Ratio (PM : PS)	**Solid:Liquid ratios**				
	1 : 1	**1 : 1,5**	**1 : 2**	**1 : 2,5**	**1 : 3**
	Total organic matter %				
95 : 5	12,78	9,24	7,16	5,85	5,10
90 : 10	11,91	8,49	6,51	5,29	4,58
85 : 15	11,07	7,79	5,92	4,78	4,11
80 : 20	10,26	7,12	5,37	4,30	3,69
75 : 25	9,48	6,50	4,85	3,86	3,30
70 : 30	8,72	5,90	4,37	3,46	2,94
65 : 35	8,00	5,35	3,93	3,09	2,62

According to the analysis (Figure 1), the highest indicator of humic acid was 1.64% at the lowest dilution level (S:L=1:1) and a PM:PS ratio of 95:5. When the ratio changed to 80:20, this indicator decreased to 1.31%, and at 65:35, it fell to 1.03%. Simultaneously, an increase in the extractant volume (2% KOH) reduced the share of humic substances in the liquid phase. For example, in the 90:10 sample, changing S:L from 1:1 to 1:1.5 reduced humic acid from 1.52% to 1.09%, and further to 0.59% at 1:3. A similar trend was observed in the 75:25 sample, where the content dropped from 1.21% (at 1:1) to 0.42% (at 1:3). The lowest humic acid content (0.34%) was recorded at PM:PS 65:35 and S:L 1:3, which is nearly a 4.8-fold decrease compared to the initial 95:5 (1:1) sample.

The variation in fulvic acid content depends on both indicators. The results show values ranging from a maximum of 9.31% (at PM:PS 95:5, S:L 1:1) to a minimum of 1.90% (at PM:PS 65:35, S:L 1:3). Analysis of the process revealed that every 5% increase in the phosphorite sludge share reduced the fulvic acid content in the liquid phase by an average of 0.4–0.8%. For instance, at S:L 1:1, shifting from 90:10 (8.68%) to 85:15 (8.07%) resulted in a 0.61% decrease.

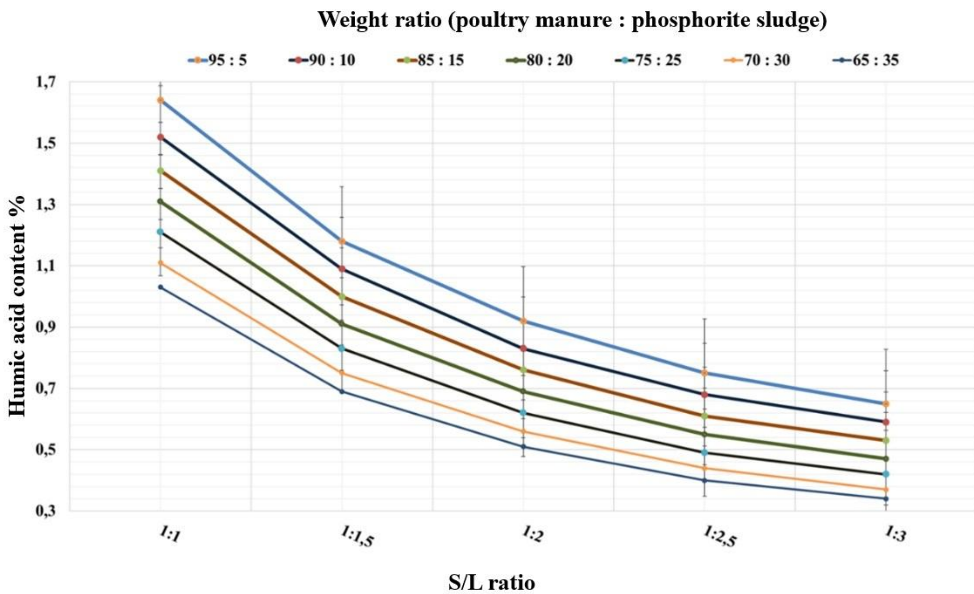

Figure 1. Dependence of humic acid content in liquid fertilizer on PM:PS weight ratios and S:L ratios.

The effect of dilution (S:L) in alkaline extraction was even more pronounced. The initial change from S:L 1:1 to 1:1.5 caused an average 25–30% decrease in fulvic acid content; in the 80:20 sample, it dropped from 7.48% to 5.19%. Further dilution (1:2 to 1:3) continued the proportional decrease. This reduction is explained by the high solubility of fulvic acids in water and alkali, but their specific weight decreases rapidly as solution volume increases. Additionally, increased phosphorite sludge enhances the interaction of mineral components with fulvic acids, potentially binding them.

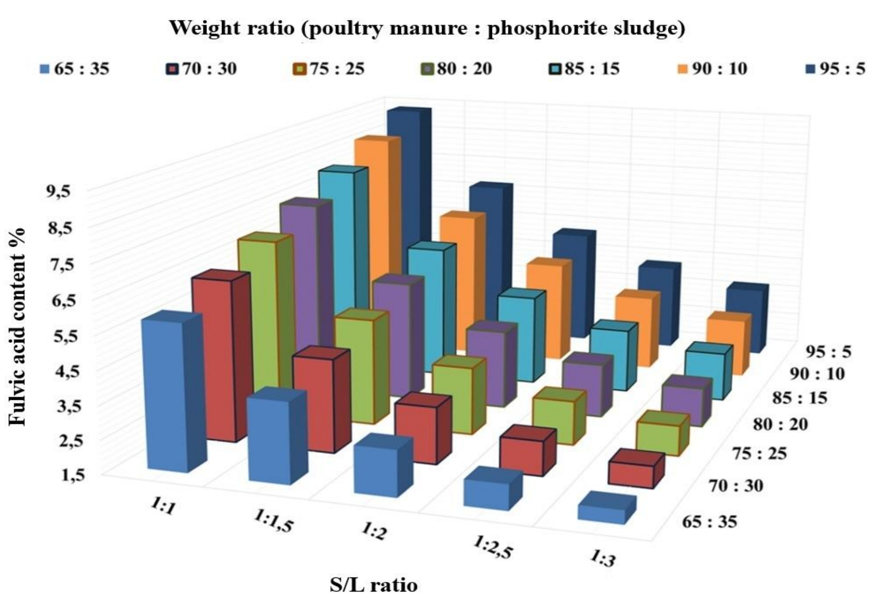

Figure 2. Dependence of fulvic acid content in liquid fertilizer on PM:PS weight ratios and S:L ratios.

The content of Water-Soluble Organic Matter (WSOM) is directly related to raw material weight ratios and extraction conditions. Analysis shows that WSOM was highest (1.84%) in the initial sample (PM:PS 95:5, S:L 1:1) and minimal (0.37%) at 65:35 and S:L 1:3. Every 5% increase in phosphorite sludge decreased WSOM concentration by an average of 0.10–0.13%. This indicates that the water-soluble fraction is primarily formed by low-molecular-weight organic compounds in poultry manure. Regarding the extractant volume, shifting from S:L 1:1 to 1:1.5 reduced the WSOM share by approximately 27–33%. For the 85:15 sample, the value dropped from 1.59% to 1.12%. In subsequent dilution stages, the rate of decrease stabilized slightly.

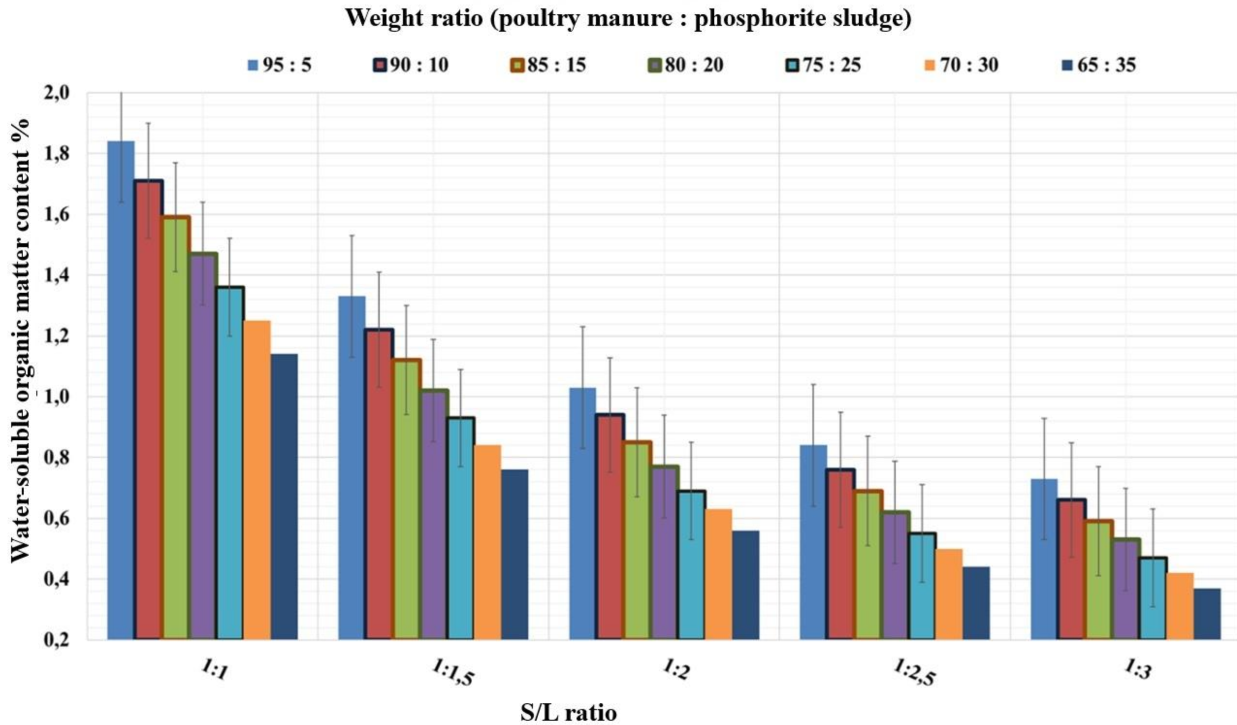

Figure 3. Dependence of water-soluble organic matter (WSOM) content in liquid fertilizer on PM:PS weight ratios and S:L ratios.

Conclusion

The research scientifically substantiated the optimal technological parameters for obtaining liquid organo-mineral fertilizer from poultry manure and phosphorite sludge using potassium hydroxide.
High concentrations of organic substances in the liquid phase (Total organic matter: 12.78%, Humic acid: 1.64%, Fulvic acid: 9.31%, WSOM: 1.84%) are observed at a PM:PS ratio of 95:5 and an S:L ratio of 1:1.
Increasing the phosphorite sludge content up to 35% and increasing the alkali volume (S:L 1:3) results in an average 3–4 fold decrease in organic matter concentration.
Considering the biological activity and economic efficiency of the liquid fertilizer, the PM:PS ratio of 85:15 and the extraction condition of S:L = 1:1.5 were selected as optimal. In this regime, a sufficient amount of humic and fulvic acids (1.00% and 5.68%, respectively) is preserved in the liquid phase. This approach aligns with waste-free technology principles, creating opportunities to obtain high-value-added products from secondary mineral raw materials.

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