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ANTIOXIDANT AND BIOLOGICAL ACTIVITY OF VITAMIN C-ENRICHED HUMATES IN OAT SEED GERMINATION

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Abstract. Agricultural practice requires preparations that combine safety, efficacy, and a readily available vitamin component. Humic substances are attractive carriers for such products because they can be obtained from abundant domestic feedstocks at comparatively low cost and can be deployed at scale in both agricultural and environmental technologies.
In this work, humic compounds were enriched with ascorbic acid and examined in a sequence of chemical, technological, and biological tests. Their antioxidant behavior was first characterized by voltammetry; the resulting preparations were then applied in an oat-seed germination assay.
The study was designed to prepare vitamin C-modified humates and determine how these products influence seed germination.
Keywords: humic substances, redox activity, ascorbate enrichment, vitamin-modified humates, seed germination.

СҰЛЫ ТҰҚЫМЫНЫҢ ӨНУІ КЕЗІНДЕГІ С ДӘРУМЕНІМЕН БАЙЫТЫЛҒАН ГУМАТТАРДЫҢ АНТИОКСИДАНТТЫҚ ЖӘНЕ БИОЛОГИЯЛЫҚ БЕЛСЕНДІЛІГІ

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Аңдатпа. Ауылшаруашылық тәжірибесі қауіпсіздікті, тиімділікті және оңай қол жетімді витаминдік компонентті біріктіретін препараттарды қажет етеді. Гуминді заттар мұндай өнімдердің тартымды тасымалдаушысы болып табылады, өйткені оларды отандық шикізаттың мол қорынан салыстырмалы түрде арзан бағамен алуға болады және ауылшаруашылық және экологиялық технологияларда кеңінен қолдануға болады.
Бұл жұмыста гуминді қосылыстар аскорбин қышқылымен байытылып, химиялық, технологиялық және биологиялық сынақтар тізбегінде зерттелді. Олардың антиоксиданттық әрекеті алдымен вольтамметриямен сипатталды; содан кейін алынған препараттар сұлы тұқымының өнуін талдау кезінде қолданылды.
Зерттеу С дәрумені модификацияланған гуматтарды дайындауға және бұл өнімдердің тұқымның өнуіне қалай әсер ететінін анықтауға арналған.
Түйін сөздер: гуминді заттар, тотығу-тотықсыздану белсенділігі, аскорбатты байыту, витаминді-модификацияланған гуматтар, тұқымның өнуі.

АНТИОКСИДАНТНАЯ И БИОЛОГИЧЕСКАЯ АКТИВНОСТЬ ГУМАТОВ, ОБОГАЩЁННЫХ ВИТАМИНОМ С, ПРИ ПРОРАСТАНИИ СЕМЯН ОВСА

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Аннотация. Современная сельскохозяйственная практика нуждается в препаратах, сочетающих безопасность, эффективность и легкодоступный витаминный компонент. Гуминовые вещества представляют собой перспективные носители для таких препаратов, поскольку они могут быть получены из доступного отечественного сырья при сравнительно низких затратах и применяться в широких масштабах как в сельскохозяйственных, так и в природоохранных технологиях.

В данной работе гуминовые соединения были обогащены аскорбиновой кислотой и исследованы посредством комплекса химических, технологических и биологических испытаний. Сначала их антиоксидантные свойства были охарактеризованы методом вольтамперометрии, после чего полученные препараты использовали в опытах по проращиванию семян овса.

Целью исследования являлось получение гуматов, модифицированных витамином С, и определение влияния этих препаратов на прорастание семян.

Ключевые слова: гуминовые вещества, окислительно-восстановительная активность, обогащение аскорбатом, гуматы, модифицированные витаминами, прорастание семян.

MAIN PROVISION

Vitamin C-enriched sodium and potassium humates are prepared and evaluated for antioxidant activity and their effects on oat-seed germination. Voltammetric measurements confirm a detectable antioxidant response associated with ascorbic acid enrichment, while germination assays demonstrate biological activity for both modified humates. The findings support the potential use of vitamin-enriched humic preparations in agricultural applications, although further replicated experiments and statistical validation are required.

INTRODUCTION

A continuing priority in agriculture is the development of safe, effective formulations in which vitamins remain biologically accessible. Humic substances provide a practical basis for such formulations: their feedstocks are widely available, production costs are relatively modest, and the resulting materials are already relevant to agricultural and environmental technologies. Enrichment with ascorbic acid may further improve the antioxidant and biological performance of humates [3, 4].

Accordingly, this work assessed both the antioxidant response of ascorbic acid-modified humic compounds and their influence on the germination of oat seeds.

Two specific tasks guided the investigation:

- to determine whether vitamin-enriched humic preparations alter seed germination;
- to examine how variation in the processing conditions affects the resulting response.

Research gap. Although humic substances have been widely investigated as plant-growth stimulants and as carriers of biologically active compounds, limited information is available on humates directly enriched with vitamin C. In particular, the relationship between their electrochemically determined antioxidant properties and their biological effects on seed germination remains insufficiently understood. Therefore, there is a need to develop vitamin-modified humic preparations and evaluate their redox activity and plant-growth effects under controlled experimental conditions.

This work addresses this gap through the preparation and combined chemical and biological evaluation of ascorbic acid-enriched sodium and potassium humates. Cathodic voltammetry was used to identify their antioxidant response, while oat-seed germination assays were performed to assess biological activity. The results provide preliminary evidence that 0.01 N vitamin C-enriched humates exhibit antioxidant properties and support oat-seed germination.

Novelty statement. The novelty of this work lies in the combined electrochemical and biological assessment of sodium and potassium humates enriched with ascorbic acid. The study demonstrates a detectable antioxidant response and preliminary biological activity in oat-seed germination, supporting the development of vitamin-modified humic preparations for potential agricultural applications.

Materials and Methods

Electrochemical measurements were obtained with a computer-controlled TA-2 voltammetric analyzer. Cathodic voltammetry was selected, with electrochemical O_2 reduction serving as a model of the corresponding oxygen-reduction processes in cells and tissues. Sodium, potassium, and ammonium humates, together with modified humates containing vitamins and macro- and microelements, were tested by recording changes in the limiting current as their concentration varied. Both catalytic and antioxidant responses were registered in this system. The instrumental conditions were as follows:

a three-electrode cell; electrode activation for 120 s; an initial potential of −0.4 V; a scan from 0.0 to −0.8 V at W = 30 mV/s; solution stirring for 10 s followed by a 20 s settling period; 10 mL of background solution at 0 V; phosphate buffer at pH 6.86; an EVL-1M3.1 Ag/AgCl auxiliary electrode; an SPE indicator electrode; and a 0.5 mL aliquot (V).

Results

Changes in voltammetric wave height during the observation period are summarized in Table 1.

A separate germination trial was used to establish the biological response to humates enriched with ascorbic acid.

Oat seeds were arranged on filter paper in Petri dishes and maintained at 20 °C after moistening with extracts of the ascorbic acid-modified humates. Ten replicate dishes were prepared. Distilled water replaced the humate extract in the control. Each day, the papers received the appropriate test or control liquid and the dishes were aerated. On day 7, the root fraction was separated from the green biomass of the germinated seedlings [2, p. 84].

Table 1. Variation in voltammetric wave height with time

Variation in voltammetric wave height with time			
T, min	***J1, μA***	***J2, μA***	***J3, μA***
0	24.151	23.824	25.298
3	24.135	23.920	25.457
6	24.182	23.934	25.419
9	24.602	24.006	25.547

The calculated critical T values for the three responses (R1–R3) are reported in Table 2.

T, min	R1	R2	R3
0	0.000	0.000	0.000
12	-0.019	-0.008	-0.010

The electrochemical reduction of O_2 was also evaluated theoretically. This analysis defined quantitative criteria for confirming an extremum and yielded rate constants for reactions involving reactive oxygen radicals. When ascorbic acid was incorporated into the humic compounds, a detectable antioxidant response appeared [1, p. 32].

Figures 1 and 2 illustrate the voltammetric responses produced by 0.01 N potassium and sodium humates, respectively.

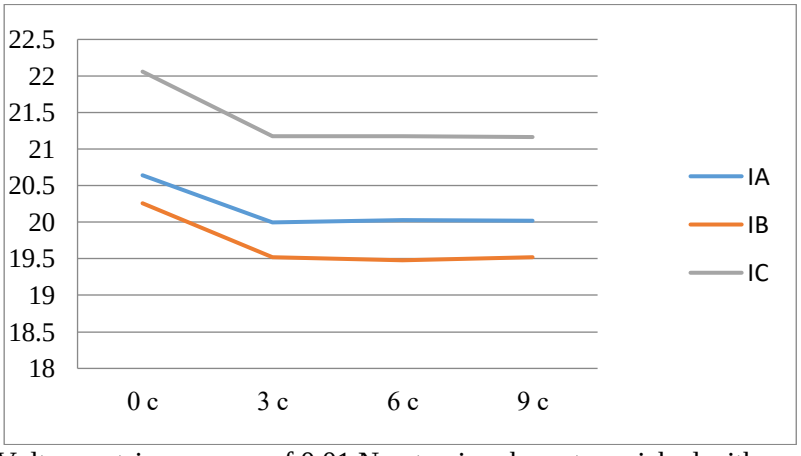


Figure 1. Voltammetric response of 0.01 N potassium humate enriched with ascorbic acid

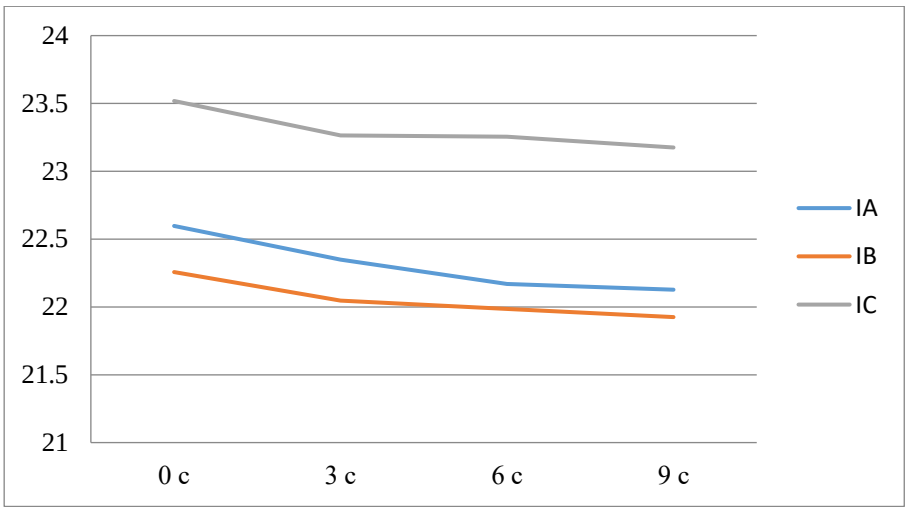


Figure 2. Voltammetric response of 0.01 N sodium humate enriched with ascorbic acid

Figure 3 depicts how the limiting current changed as concentration increased.

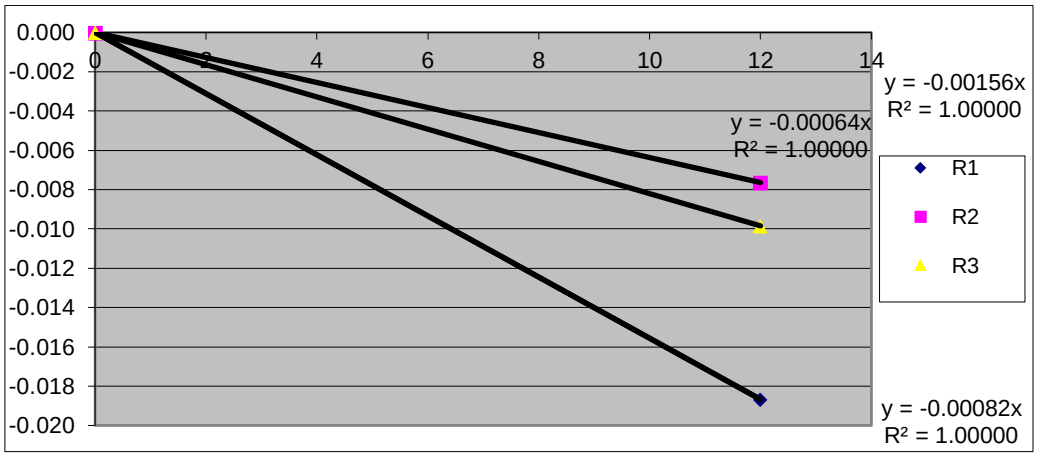
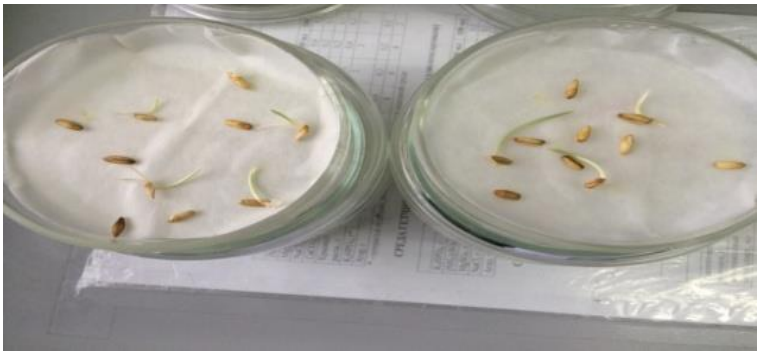


Figure 3. Relationship between limiting current and concentration

Figure 4. Oat-seed germination in the distilled-water control



The germination pattern recorded after exposure to 0.01 N sodium humate containing ascorbic acid is presented in Figure 5.

Figure 5. Oat seedlings treated with 0.01 N sodium humate enriched with ascorbic acid

Table 3 compiles the germination observations for oat seeds exposed to ascorbic acid-modified sodium and potassium humate solutions.

Table 3. Germination counts for oat seeds treated with ascorbic acid-modified sodium and potassium humates

Sample No.	K+AA		Na+AA	
	Count	%	Count	%
1	5	40	4	40
2	0	60	6	60
3	5	40	4	40
4	6	60	6	60
5	2	30	3	30
6	8	60	6	60
7	5	50	5	50
8	5	40	4	40
9	6	70	7	70
10	4	50	5	50
∑Δ	4.6 4.6±1.1	50	5 5±1	5

DISCUSSION

Conventional antioxidants primarily act by terminating oxidation chains: they capture reactive radical species and convert them into radicals of lower reactivity. Oxidative propagation can also be restrained by compounds that break down hydroperoxides, thereby limiting the generation of new free radicals. Because effective inhibition may occur at only 0.01–0.001 N, measurable oxidation products can be absent during an initial delay, commonly termed the induction or retardation period. Interactions among components are also important; in a mixture, one antioxidant—or another accompanying substance—may amplify the protective effect of another [5, 6].

The summary values in Table 3 differ only slightly between treatments. Sodium humate produced a reported mean of 5 ± 1 seedlings, whereas the potassium-humate treatment yielded 4.6 ± 1.1. This pattern is compatible with biological activity in both modified humates. Nevertheless, several counts do not correspond consistently to the percentages listed in the table, and no pooled quantitative result is provided for

the control. These limitations preclude a robust estimate of treatment magnitude; the observed effect should therefore be interpreted as preliminary until it is supported by additional statistical testing.

In Kazakhstan, the use of humic compounds in animal nutrition has become an active area of investigation. The present work addresses the less extensively studied preparation of humic materials enriched with vitamin C. Further experiments will characterize these products in greater detail by voltammetry and will track their concentrations with a CTA voltammetric analyzer.

CONCLUSION

Under the conditions tested, 0.01 N sodium and potassium humates enriched with ascorbic acid showed both antioxidant and biological responses. The germination assay yielded reported means of 5 ± 1 seedlings for the sodium preparation and 4.6 ± 1.1 for the potassium preparation. A firm conclusion will require complete quantitative control data, formal statistical evaluation, and confirmation in a larger replicated experiment**.**

Author Contribution Statement (CRediT Taxonomy): Conceptualization (lead), Methodology, Investigation, Formal Analysis, Validation, Data Curation, Writing – Original Draft. P. Szatkowski: Methodology, Supervision, Visualization, Writing – Review & Editing. Both authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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REFERENCES

[1] . Zaikovsky A.V., Shendrik T.G., Saranchuk V.I. Structural Transformations of Saline Coals During the Isolation of Humic Acids // Solid Fuel Chemistry. – 2011. – No. 4. – P. 137.

[2] Komissarov I.D., Loginov L.F. Structural Scheme and Modeling of Humic Acid Macromolecules // Humic Preparations: Scientific Papers. – Tyumen: TSAA Publishing House, 2011. – Vol. 14. – P. 142.

[3] Canellas L.P., Olivares F.L., Okorokova-Façanha A.L., Façanha A.R. Humic Acids Isolated from Earthworm Compost Enhance Root Elongation, Lateral Root Emergence, and Plasma Membrane H+-ATPase Activity in Maize Roots // Plant Physiology. – 2002. – Vol. 130, No. 4. – P. 1951–1957. – DOI: 10.1104/pp.007088.

[4] Zandonadi D.B., Canellas L.P., Façanha A.R. Indolacetic and Humic Acids Induce Lateral Root Development Through a Concerted Plasmalemma and Tonoplast H+ Pumps Activation // Planta. – 2007. – Vol. 225. – P. 1583–1595. – DOI: 10.1007/s00425-006-0454-2.

[5] Shalata A., Neumann P.M. Exogenous Ascorbic Acid (Vitamin C) Increases Resistance to Salt Stress and Reduces Lipid Peroxidation // Journal of Experimental Botany. – 2001. – Vol. 52, No. 364. – P. 2207–2211. – DOI: 10.1093/jexbot/52.364.2207.

[6] Athar H.-u.-R., Khan A., Ashraf M. Exogenously Applied Ascorbic Acid Alleviates Salt-Induced Oxidative Stress in Wheat // Environmental and Experimental Botany. – 2008. – Vol. 63, No. 1–3. – P. 224–231. – DOI: 10.1016/j.envexpbot.2007.10.018.