YASHIL

IQTISODIYOT&TARAQQIYOT

Ijtimoiy, iqtisodiy, texnologik, ilmiy, ommabop jurnal

2026-YIL / IYUL / 7-SON, II - QISM

ISSN: 2992-8982

https://yashil-iqtisodiyot-taraqqiyot.uz/

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Elektron nashr. 2026-yil, iyul.
II-qism

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Muassis: “Ma’rifat-print-media” MChJ
Hamkorlarimiz: Toshkent davlat iqtisodiyot universiteti, O‘zbekiston Respublikasi Bosh prokuraturasi huzuridagi Iqtisodiy jinoyatlarga qarshi kurashish departamenti

Jurnalning ilmiyligi:
““Yashil” iqtisodiyot va taraqqiyot” jurnali
O‘zbekiston Respublikasi Oliy ta’lim, fan va innovatsiyalar vazirligi huzuridagi Oliy attestatsiya komissiyasi rayosatining 2023-yil 1-apreldagi 336/3-sonli qarori bilan ro‘yxatdan o‘tkazilgan.

MUNDARIJA

MUNDARIJA СОДЕРЖАНИЕ CONTENTS

SOLID PROPELLANT COMPOSITION AND ITS EFFECT ON THE LAUNCH PERFORMANCE OF MODEL ROCKETS

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Abstract. This paper analyzes the composition of potassium nitrate–sugar (KNSU/KNSB) solid propellants widely used in model rocketry and examines catalytic additives that influence their burn rate. Although conventional catalysts such as iron(III) oxide (Fe_2O_3) are well established, this study considers tobacco ash as a potentially cost-effective and environmentally beneficial alternative. Tobacco ash is a waste-derived biomass material containing calcium carbonate ($CaCO_3$), potassium carbonate (K_2CO_3), and trace amounts of metal oxides. Propellant samples prepared under laboratory conditions were evaluated through static-thrust tests and flight simulations. Under the tested laboratory conditions, the tobacco-ash-containing formulations exhibited higher measured burn-rate, thrust, and specific-impulse values than the control and conventionally catalyzed formulations. The observed effect may be associated with the influence of carbonate compounds in the ash on the thermal decomposition behavior of KNO_3 and the kinetics of the exothermic reaction. The findings suggest that tobacco ash may serve as a promising burn-rate modifier and waste-derived catalyst for model-rocket propellants.

Keywords: model rocketry, solid propellant, potassium nitrate–sugar propellant, tobacco ash, biomass-derived catalyst, burn rate, specific impulse.

Annotatsiya. Ushbu maqolada model raketasozlikda keng qo‘llaniladigan kaliy nitrat–shakar asosidagi (KNSU/KNSB) qattiq propellantlarning tarkibi tahlil qilinib, ularning yonish tezligiga ta’sir ko‘rsatuvchi katalitik qo‘shimchalar o‘rganilgan. Temir(III) oksidi (Fe_2O_3) kabi an’anaviy katalizatorlar keng qo‘llanilishiga qaramay, mazkur tadqiqotda tamaki kuli potensial ravishda iqtisodiy jihatdan samarali va ekologik jihatdan foydali muqobil sifatida ko‘rib chiqilgan. Tamaki kuli tarkibida kalsiy karbonat ($CaCO_3$), kaliy karbonat (K_2CO_3) va oz miqdordagi metall oksidlari mavjud bo‘lgan, biomassadan hosil bo‘luvchi chiqindi materialdir. Laboratoriya sharoitida tayyorlangan propellant namunalari statik tortish kuchi sinovlari va parvoz simulyatsiyalari orqali baholangan. Sinovdan o‘tkazilgan laboratoriya sharoitlarida tamaki kuli qo‘shilgan tarkiblar nazorat namunasi va an’anaviy katalizator qo‘shilgan tarkiblarga nisbatan yonish tezligi, tortish kuchi hamda solishtirma impuls bo‘yicha yuqoriroq o‘lchangan ko‘rsatkichlarni namoyon etgan. Kuzatilgan ta’sir kul tarkibidagi karbonat birikmalarining KNO_3 ning termik parchalanish xususiyatlari va ekzotermik reaksiya kinetikasiga ta’siri bilan bog‘liq bo‘lishi mumkin. Olingan natijalar tamaki kulidan model raketalari uchun mo‘ljallangan propellantlarda istiqbolli yonish tezligi modifikatori va chiqindi biomassadan olinadigan katalizator sifatida foydalanish mumkinligini ko‘rsatadi.

Kalit so‘zlar: model raketasozlik, qattiq propellant, kaliy nitrat–shakar propellanti, tamaki kuli, biomassadan olinadigan katalizator, yonish tezligi, solishtirma impuls.

Аннотация. В статье анализируется состав твёрдых ракетных топлив на основе нитрата калия и сахара (KNSU/KNSB), широко применяемых в модельном ракетостроении, а также исследуются каталитические добавки, влияющие на скорость их горения. Несмотря на широкое применение традиционных катализаторов, таких как оксид железа(III) (Fe_2O_3), в данном исследовании табачная зола рассматривается в качестве потенциально экономически эффективной и экологически целесообразной альтернативы. Табачная зола представляет собой отход биомассы, содержащий карбонат кальция ($CaCO_3$), карбонат калия (K_2CO_3) и следовые количества оксидов металлов. Образцы топлива, подготовленные в лабораторных условиях, оценивались посредством статических тяговых испытаний и моделирования полёта. В исследованных лабораторных условиях составы с добавлением табачной

золы продемонстрировали более высокие измеренные значения скорости горения, тяги и удельного импульса по сравнению с контрольным и традиционно катализированными составами. Наблюдаемый эффект может быть связан с влиянием содержащихся в золе карбонатных соединений на характер термического разложения KNO_3 и кинетику экзотермической реакции. Полученные результаты позволяют предположить, что табачная зола может использоваться в качестве перспективного модификатора скорости горения и катализатора из отходов биомассы для топлив модельных ракет.

Ключевые слова: модельное ракетостроение, твёрдое ракетное топливо, топливо на основе нитрата калия и сахара, табачная зола, катализатор из биомассы, скорость горения, удельный импульс.

INTRODUCTION

Model rocketry is an interdisciplinary field of engineering that integrates principles of aerodynamics, thermodynamics, and chemistry. Propellant composition and physical properties play a central role in determining a model rocket's thrust, flight altitude, and operational reliability. One of the most commonly used propellant formulations in amateur rocketry is a solid propellant based on potassium nitrate (KNO_3), in which potassium nitrate is used as an oxidizer, and a carbohydrate, such as sugar or sorbitol, is used as fuel. This composition is usually referred to as KNSU (Potassium Nitrate–Sucrose) or KNSB (Potassium Nitrate–Sorbitol).

During the reaction, KNO_3 breaks down under the action of heat and releases oxygen, which, in turn, enters into an exothermic reaction with carbohydrates, forming products such as nitrogen, carbon dioxide, water vapor, and potassium carbonate. The total thermodynamic indicator of this reaction—the amount of heat emitted—directly determines the specific impulse (Isp) and combustion rate of the fuel.

Burn-rate control is one of the key factors in determining the performance characteristics of a rocket motor. If the burn rate is too low, the motor may not generate sufficient thrust; if it is excessively high, the chamber pressure may exceed the permissible operating range and increase the risk of structural failure. Therefore, catalytic additives used to regulate the burn rate play an important role in both model-rocketry applications and industrial solid-propellant engineering.

The catalytic effect may be associated mainly with two mechanisms: changes in the thermal decomposition behavior of KNO_3 and the formation of heterogeneous reaction sites at the combustion front. Iron(III) oxide (Fe_2O_3) and manganese dioxide (MnO_2) are conventional catalysts that operate through such a mechanism. However, due to the high cost and limited availability of these substances, the search for alternative, inexpensive, and environmentally friendly materials remains a relevant research objective. In this context, the waste product—tobacco ash—was studied as a potential catalyst, since it contains high concentrations of alkali- and alkaline-earth-metal carbonates, including K_2CO_3 and $CaCO_3$, which can accelerate heat transfer by forming a flux (molten phase) during combustion.

LITERATURE REVIEW

Much of the research conducted on model-rocket propellants over the past two decades has focused on optimizing the combustion kinetics of KNSU/KNDX (potassium nitrate–dextrose) compounds. Many authors have shown that the effect of the size and concentration of iron oxide particles on the combustion rate is not linear; rather, the maximum catalytic effect is generally observed at a specific optimal percentage, usually within the range of 1–3%.

In these studies, reducing the particle size of iron oxide to the nanoscale has been reported to enhance catalytic activity, although the use of nanoparticles may increase production costs. Some studies indicate that manganese dioxide (MnO_2) may exhibit a stronger catalytic effect than iron oxide under certain conditions. However, its use may also increase hygroscopicity during processing, potentially affecting moisture resistance and the long-term storage stability of the propellant.

However, in recent years, the number of studies on the application of biomass ash as an alternative functional material in the fields of energy and materials science has been increasing. Notably, alkaline metal compounds derived from agricultural waste and wood ash have been successfully used in various industrial processes—for example, as catalysts in biodiesel production. However, most research in this area has focused mainly on agrochemistry and environmental protection rather than on energy materials.

Thus, the potential of waste biomass ash, particularly tobacco ash, as a catalyst in solid rocket propellant has received limited attention in the available literature. The high calcium carbonate and potassium carbonate content of tobacco ash, combined with its affordability and widespread availability, provides grounds for

considering it a candidate capable of filling this gap. This study represents a preliminary experiment in this direction.

RESEARCH METHODOLOGY

The study was carried out in three stages: component preparation, catalyst incorporation, and propellant-grain casting and drying.

Phase 1: Component preparation. Technical-grade potassium nitrate (KNO_3, purity ≥99%) was ground for 30 minutes using a ball mill under laboratory conditions to form a powder with an average particle size of less than 100 microns. Sucrose was selected as the carbohydrate component because it provides a casting density similar to that of sorbitol and is readily available. KNO_3 and sugar were measured in a 65:35 weight ratio, corresponding to the standard KNSU formula.

Phase 2: Safe incorporation of the tobacco-ash catalyst. Tobacco ash was preheated for 1 hour at a temperature of 300 °C, cleaned of organic residues, and passed through a fine 200-micron sieve. It was then added at three different concentrations—1%, 2%, and 3%— relative to the total propellant mass, making it possible to determine the optimal concentration. Each sample was prepared in a separate batch. For comparison, a catalyst-free control sample and a conventional sample containing a 2% Fe_2O_3 additive were also prepared in parallel.

Phase 3: Casting and drying. The mixture was gradually melted using a low-power heat source at approximately 100 °C while being stirred continuously and was then poured into a cylindrical mold. The propellant grain was cooled slowly for 24 hours at room temperature, followed by drying in a chamber at a reduced humidity level for 48 hours. The density and degree of cracking of each sample were assessed using visual and gravimetric methods.

Two types of tests were performed on the prepared samples: (1) a static stand test, in which the engine was connected to a thrust sensor in a stationary position, and a thrust-time graph was recorded; and (2) a flight test, in which flight-altitude and acceleration data were collected using an engine mounted on a model-rocket airframe.

ANALYSIS AND RESULTS

The measured values differed among the tested formulations among the three main groups: the standard composition, the composition containing the conventional Fe_2O_3 catalyst, and the composition containing the newly proposed tobacco-ash catalyst. The table below presents the average results for each group, based on tests repeated three times.

Table 1. Experimental performance indicators of the tested propellant formulations[1]

Propellant formulation	Catalyst/additive	Burn rate, mm/s	Specific impulse, s	Maximum thrust, N
Control formulation	None	6.4	131	44.8
Fe_2O_3-catalyzed formulation	Fe_2O_3, 2%	8.1	141	57.6
Tobacco-ash formulation	Tobacco ash, 1%	7.5	138	52.3
Tobacco-ash formulation	Tobacco ash, 2%	8.9	146	61.9
Tobacco-ash formulation	Tobacco ash, 3%	9.7	152	67.4

As shown in the table, the formulation containing 3% tobacco ash exhibited higher burn-rate and specific-impulse values than the formulation containing the conventional Fe_2O_3 catalyst. One possible explanation for this result is that calcium carbonate and, particularly, potassium carbonate in tobacco ash may contribute to the formation of a molten phase at relatively low temperatures. This molten phase may increase the contact area between the solid and gaseous phases at the combustion front and thereby improve heat and mass transfer within the reaction zone. In addition, K_2CO_3 may contribute to ion transport and heat transfer in the reaction zone, potentially facilitating the thermal decomposition of KNO_3 and lowering the effective activation barrier of the decomposition process. Consequently, the thermal decomposition of KNO_3 may occur more readily and proceed at a higher rate, contributing to the observed increase in the overall burn rate.

1 Source: compiled by the authors based on the experimental results.

It is also hypothesized that trace iron and copper oxides, together with potassium-containing mineral phases present in tobacco ash, may act as additional heterogeneous catalytic sites and thereby influence radical-chain reactions during combustion. However, further thermal, mineralogical, and spectroscopic analyses are required to confirm the proposed mechanism. The static-thrust test results were consistent with the flight-test observations: the model rocket powered by the formulation containing 3% tobacco ash reached a peak altitude approximately 22% higher than that achieved with the control formulation. This difference may be associated with the higher measured thrust and specific-impulse values of the tobacco-ash-containing formulation.

CONCLUSION AND SUGGESTIONS

The experimental results indicate that tobacco ash may serve as a potentially effective burn-rate-modifying additive in solid propellants intended for model-rocketry applications. Under the tested conditions, the formulation containing 3% tobacco ash exhibited higher measured burn-rate, thrust, and specific-impulse values than both the control formulation and the formulation containing iron(III) oxide. This effect may be associated with the carbonate compounds and trace mineral phases present in the ash, although further thermal and spectroscopic analyses are required to confirm the underlying mechanism.

The low cost, availability, and waste-utilization potential of tobacco ash suggest that it may represent a technically, economically, and environmentally promising alternative additive. Future studies should examine the effects of particle size, chemical and mineralogical composition, batch-to-batch variability, storage stability, and repeated testing under controlled conditions.

REFERENCES

1. Kubota, N. *Propellants and Explosives: Thermochemical Aspects of Combustion*. — 3rd ed. — Weinheim : Wiley-VCH, 2015. — DOI: 10.1002/9783527693481.
2. Chaturvedi, S., Dave, P. N. Solid propellants: AP/HTPB composite propellants // *Arabian Journal of Chemistry*. — 2019. — Vol. 12, No. 8. — P. 2061–2068. — DOI: 10.1016/j.arabjc.2014.12.033.
3. Oommen, C., Jain, S. R. Ammonium nitrate: a promising rocket propellant oxidizer // *Journal of Hazardous Materials*. — 1999. — Vol. 67, No. 3. — P. 253–281. — DOI: 10.1016/S0304-3894(99)00039-4.
4. Davenas, A. Development of modern solid propellants // *Journal of Propulsion and Power*. — 2003. — Vol. 19, No. 6. — P. 1108–1128. — DOI: 10.2514/2.6947.
5. Foltran, A. C., Moro, D. F., Silva, N. D. P. da, Ferreira, A. E. G., Araki, L. K., Marchi, C. H. Burning rate measurement of KNSu propellant obtained by mechanical press // *Journal of Aerospace Technology and Management*. — 2015. — Vol. 7, No. 2. — P. 193–199. — DOI: 10.5028/jatm.v7i2.431.
6. Bharti, M. K., Bansal, L., Chalia, S. Catalytic potential of microsized additives in enhancing the linear burn rate of potassium nitrate–sucrose-based composite solid propellant strands // *International Journal of Energetic Materials and Chemical Propulsion*. — 2021. — Vol. 20, No. 4. — P. 61–77. — DOI: 10.1615/IntJEnergeticMaterialsChemProp.2021038209.
7. Budhwar, A. S., Gautam, A., More, P. V., Pant, C. S., Banerjee, S., Khanna, P. K. Modified iron oxide nanoparticles as burn rate enhancers in composite solid propellants // *Vacuum*. — 2018. — Vol. 156. — P. 483–491. — DOI: 10.1016/j.vacuum.2018.08.013.
8. Sharma, M., Khan, A. A., Puri, S. K., Tuli, D. K. Wood ash as a potential heterogeneous catalyst for biodiesel synthesis // *Biomass and Bioenergy*. — 2012. — Vol. 41. — P. 94–106. — DOI: 10.1016/j.biombioe.2012.02.017.
9. Buragohain, A., Vartic, V., Lalmuanpuii, R., Khawlhring, L., Mamatkulov, K., Arzymanyan, G., Yushin, N., Nekhoroshkov, P., Zinicovscaia, I., Muthukumaran, R. B. Mineralogical characterization of tobacco stalk ash // *Environmental Science and Pollution Research*. — 2026. — Vol. 33. — P. 10777–10794. — DOI: 10.1007/s11356-026-38008-z.
10. Sharma, R. K., Wooten, J. B., Baliga, V. L., Martoglio-Smith, P. A., Hajaligol, M. R. Characterization of char from the pyrolysis of tobacco // *Journal of Agricultural and Food Chemistry*. — 2002. — Vol. 50, No. 4. — P. 771–783. — DOI: 10.1021/jf0107398.

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Ijtimoiy, iqtisodiy, texnologik, ilmiy, ommabop jurnal

Ingliz tili muharriri: Feruz HAKIMOV

Musahhih: Zokir ALIBEKOV

Sahifalovchi va dizayner: Hasan MAQSUDOV

2026. № 7/2

Mazkur jurnalda maqolalar chop etish uchun quyidagi havolalarga
maqola, reklama, hikoya va boshqa ijodiy materiallar yuborishingiz mumkin.
Materiallar va reklamalar pullik asosda chop etiladi.
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““Yashil” iqtisodiyot va taraqqiyot” jurnali 03.11.2022-yildan
O‘zbekiston Respublikasi Prezidenti Adminstratsiyasi huzuridagi
Axborot va ommaviy kommunikatsiyalar agentligi tomonidan
№566955 reyestr raqami tartibi bo‘yicha ro‘yxatdan o‘tkazilgan.
Litsenziya raqami: №046523. PNFL: 30407832680027

Manzilimiz: Toshkent shahar, Mirzo Ulug‘bek tumani
Kumushkon ko‘chasi, 26-uy.

Jurnal sayti: https://yashil-iqtisodiyot-taraqqiyot.uz