



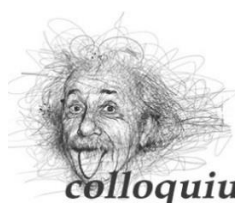
colloquium-journal

ISSN 2520-6990

Międzynarodowe czasopismo naukowe

Art
Medical sciences
Technical sciences
Philological sciences
Pedagogical sciences

№23(288) 2026



colloquium-journal

ISSN 2520-6990

ISSN 2520-2480

Colloquium-journal №23 (288), 2026

Część 1

(Warszawa, Polska)

Redaktor naczelny - **Paweł Nowak**
Ewa Kowalczyk

Rada naukowa

- **Dorota Dobija** - profesor i rachunkowości i zarządzania na uniwersytecie Koźmińskiego
- **Jemielniak Dariusz** - profesor dyrektor centrum naukowo-badawczego w zakresie organizacji i miejsc pracy, kierownik katedry zarządzania Międzynarodowego w Ku.
- **Mateusz Jabłoński** - politechnika Krakowska im. Tadeusza Kościuszki.
- **Henryka Danuta Stryczewska** – profesor, dziekan wydziału elektrotechniki i informatyki Politechniki Lubelskiej.
- **Bulakh Iryna Valerievna** - profesor nadzwyczajny w katedrze projektowania środowiska architektonicznego, Kijowski narodowy Uniwersytet budownictwa i architektury.
- **Leontiev Rudolf Georgievich** - doktor nauk ekonomicznych, profesor wyższej komisji atestacyjnej, główny naukowiec federalnego centrum badawczego chabarowska, dalekowschodni oddział rosyjskiej akademii nauk
- **Serebrennikova Anna Valerievna** - doktor prawa, profesor wydziału prawa karnego i kryminologii uniwersytetu Moskiewskiego M.V. Lomonosova, Rosja
- **Skopa Vitaliy Aleksandrovich** - doktor nauk historycznych, kierownik katedry filozofii i kulturoznawstwa
- **Pogrebnaya Yana Vsevolodovna** - doktor filologii, profesor nadzwyczajny, stawropolski państwowy Instytut pedagogiczny
- **Fanil Timeryanowicz Kuzbekov** - kandydat nauk historycznych, doktor nauk filologicznych. profesor, wydział Dziennikarstwa, Bashgosuniversitet
- **Aliyev Zakir Hussein oglu** - doctor of agricultural sciences, associate professor, professor of RAE academician RAPVHN and MAEP
- **Kanivets Alexander Vasilievich** - kandydat nauk technicznych, profesor nadzwyczajny Wydział Agrotechnologii i Transportu Drogowego, Państwowy Uniwersytet Rolniczy w Połtawie
- **Yavorska-Vitkovska Monika** - doktor edukacji, szkoła Kuyavsky-Pomorsk w bidgoszczu, dziekan nauk o filozofii i biologii; doktor edukacji, profesor
- **Chernyak Lev Pavlovich** - doktor nauk technicznych, profesor, katedra technologii chemicznej materiałów kompozytowych narodowy uniwersytet techniczny ukrainy „Politechnika w Kijowie”
- **Vorona-Slivinskaya Lyubov Grigoryevna** - doktor nauk ekonomicznych, profesor, St. Petersburg University of Management Technologia i ekonomia
- **Voskresenskaya Elena Vladimirovna** doktor prawa, kierownik Katedry Prawa Cywilnego i Ochrony Własności Intelektualnej w dziedzinie techniki, Politechnika im. Piotra Wielkiego w Sankt Petersburgu
- **Tengiz Magradze** - doktor filozofii w dziedzinie energetyki i elektrotechniki, Georgian Technical University, Tbilisi, Gruzja
- **Usta-Azizova Dilnoza Ahrarovna** - kandydat nauk pedagogicznych, profesor nadzwyczajny, Tashkent Pediatric Medical Institute, Uzbekistan
- **Oktay Salamov** - doktor filozofii w dziedzinie fizyki, honorowy doktor-profesor Międzynarodowej Akademii Ekoenergii, docent Wydziału Ekologii Azerbejdżańskiego Uniwersytetu Architektury i Budownictwa
- **Karakulov Fedor Andreevich** – researcher of the Department of Hydraulic Engineering and Hydraulics, federal state budgetary scientific institution "all-Russian research Institute of hydraulic Engineering and Melioration named after A. N. Kostyakov", Russia.
- **Askaryants Wiera Pietrowna** - Adiunkt w Katedrze Farmakologii, Fizjologia. Taszkencki Pediatryczny Instytut Medyczny. miasto Taszkent



SlideShare



INDEX COPERNICUS
INTERNATIONAL



«Colloquium-journal»

Wydawca «Interdruk» Poland, Warszawa

Annopol 4, 03-236

E-mail: info@colloquium-journal.org

<http://www.colloquium-journal.org/>

CONTENTS

ART

Гулиева Н.Н.

ЭКЗОТИКА ВОСТОКА В СЦЕНОГРАФИИ ПЕТРА ОКУНЕВА НА ПРИМЕРЕ БАЛЕТА Ф.АМИРОВА «1001 НОЧЬ» ...3

Guliyeva N.N.

THE EXOTICISM OF THE EAST IN PYOTR OKUNEV'S SCENOGRAPHY AS EXEMPLIFIED BY FIKRET AMIROV'S BALLET "ONE THOUSAND AND ONE NIGHTS"3

MEDICAL SCIENCES

Левченко Д.

ПРИМЕНЕНИЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В ДИАГНОСТИКЕ СТОМАТОЛОГИЧЕСКИХ ЗАБОЛЕВАНИЙ ...8

Levchenkov D.

THE USE OF ARTIFICIAL INTELLIGENCE IN THE DIAGNOSIS OF DENTAL DISEASES8

Сатторова С.А., Кудратова Д. Ш.

РОЛЬ МЕТФОРМИНА В КОРРЕКЦИИ ИНСУЛИНОРЕЗИСТЕНТНОСТИ У ДЕВОЧЕК-ПОДРОСТКОВ С НАРУШЕНИЯМИ МЕНСТРУАЛЬНОГО ЦИКЛА13

Sattorova S.A., Kudratova D.Sh.

THE ROLE OF METFORMIN IN THE CORRECTION OF INSULIN RESISTANCE IN ADOLESCENT GIRLS WITH MENSTRUAL CYCLE DISORDERS13

PEDAGOGICAL SCIENCES

Garibli A.F.

EFFECTIVE PEDAGOGICAL METHODS IN HISTORY TEACHING.....16

Гарибли А.Ф.

ЭФФЕКТИВНЫЕ ПЕДАГОГИЧЕСКИЕ МЕТОДЫ В ПРЕПОДАВАНИИ ИСТОРИИ16

Guliyeva Kh.N.

MODERN TEACHING METHODS: METHODOLOGICAL PRINCIPLES AND APPROACHES.....21

Гулиева Х.Н.

СОВРЕМЕННЫЕ МЕТОДЫ ОБУЧЕНИЯ: МЕТОДОЛОГИЧЕСКИЕ ПРИНЦИПЫ И ПОДХОДЫ21

Abdivohidovna N.T.

DEVELOPING COMMUNICATIVE COMPETENCE IN GERMAN THROUGH THE STEAM APPROACH.....25

TECHNICAL SCIENCES

Kalaida K., Haidai I.

NUTRITIONAL AND ENERGY POTENTIAL OF SWEET PEPPER CULTIVARS AS HIGH-QUALITY PLANT-BASED RAW MATERIALS FOR THE FOODSERVICE INDUSTRY30

Demianov O., Olinichuk A., Verysotska O.,

Yuliuhin V., Vorobiov V., Pervushyn M., Demianova N.

EFFECT OF ELECTRIC-ARC SPRAYING CONFIGURATION ON THE STRUCTURE AND PROPERTIES OF COATINGS PRODUCED FROM Fe–Cr–C–Al FLUX-CORED WIRE.....36

PHILOLOGICAL SCIENCES

Aliyeva T.

ASPECTS OF LITERARY CRAFTSMANSHIP IN THE WORKS OF ƏNVƏR MƏMMƏDXANLI42

ART

Гулиева Наргиз Новруз гызы

докторант Азербайджанской Академии Художеств

<https://doi.org/10.5281/zenodo.22996362>ЭКЗОТИКА ВОСТОКА В СЦЕНОГРАФИИ ПЕТРА ОКУНЕВА НА ПРИМЕРЕ БАЛЕТА
Ф.АМИРОВА «1001 НОЧЬ»

Guliyeva Nargiz Novruz gizi

doctoral student at the Azerbaijan Academy of Arts

THE EXOTICISM OF THE EAST IN PYOTR OKUNEV'S SCENOGRAPHY AS EXEMPLIFIED BY
FIKRET AMIROV'S BALLET "ONE THOUSAND AND ONE NIGHTS"**Аннотация.**

Статья анализирует сценографическое решение балета «1001 ночь» Фикрета Амирова, созданное Петром Окуневым и поставленного на Приморской сцене Мариинского театра. Исследование рассматривает работу как классический пример ориентализма в балетном театре, где восточная эстетика (азербайджанские и арабские мотивы, исламская орнаментика, архитектурные формы восточных дворцов) интерпретируется через призму европейской театральной традиции (классические принципы композиции, академическая выверенность, профессиональное владение пространством).

Анализируется композиционное решение (принцип «театра в театре», центральная стрельчатая арка), цветовую драматургию (контраст бирюзового и золотого), световое решение (имитация масляных ламп, атмосфера ночного дворца) и орнаменту (растительные арабески, геометрические паттерны, марокканские фонари). Стилистически сценография определяется как неоориентализм – современная интерпретация восточной эстетики, характеризующаяся живописностью, театральностью, реализмом с элементами стилизации и роскошью.

Работа демонстрирует культурный синтез и высокий уровень художественного мастерства, представляя собой значимый вклад в историю советского балетного театра.

Annotation.

The article analyzes the scenographic design for Fikret Amirov's ballet "1001 Nights," created by Petr Okunev and staged on the Primorsky Stage of the Mariinsky Theatre. The study examines the work as a classical example of Orientalism in ballet theatre, where Eastern aesthetics (Azerbaijani and Arabic motifs, Islamic ornamentation, architectural forms of Eastern palaces) are interpreted through the prism of European theatrical tradition (classical principles of composition, academic precision, professional mastery of space).

The author analyzes the compositional solution (the principle of "theatre within a theatre", the central pointed arch), color dramaturgy (contrast of turquoise and gold), lighting design (imitation of oil lamps, atmosphere of a night palace), and ornamentation (floral arabesques, geometric patterns, Moroccan lanterns). Stylistically, the scenography is defined as neo-Orientalism—a contemporary interpretation of Eastern aesthetics characterized by picturesqueness, theatricality, realism with elements of stylization, and luxury.

The work demonstrates cultural synthesis and a high level of artistic mastery, representing a significant contribution to the history of Soviet ballet theatre.

Ключевые слова: сценография, балет, ориентализм, Петр Окунев, «1001 ночь», восточная эстетика, культурный синтез, неоориентализм.

Keywords: scenography, ballet, Orientalism, Pyotr Okunev, "One Thousand and One Nights", Eastern aesthetics, cultural synthesis, neo-Orientalism.

В начале XXI века сценография балетных спектаклей на восточную тематику переживает период радикальной трансформации. Традиционные живописные задники и материальные декорации уступают место мультимедийным технологиям, проекционному дизайну и интерактивным пространствам. Однако эта технологическая революция не отменяет, а переосмысливает вопрос культурной аутентичности и способов визуальной репрезентации восточных культур на мировых сценах.

Мировая премьера балета "Тысяча и одна ночь" на музыку азербайджанского композитора

Фикрета Амирова (1922-1984) состоялась в 1979 году на сцене Азербайджанского театра оперы и балета. Премьера балета "Тысяча и одна ночь" состоялась на Международном Дальневосточном фестивале "Мариинский" на Приморской сцене Мариинского театра 14 августа 2020 года. Постановка 2020 года на Приморской сцене Мариинского театра стала новой интерпретацией этого произведения. Постановку осуществил главный балетмейстер Приморской сцены Эльдар Алиев, известный своими спектаклями в Петербурге, в неоклассическом стиле. Художником-постановщиком выступил

Петр Окунев, создавший сценографическое решение, передающее атмосферу восточной экзотики.

Петр Окунев является художником-постановщиком, специализирующимся на создании визуальных решений для музыкальных театральных постановок. Петр Окунев представляет новое поколение российских театральных художников, которые интегрируют современные технологии и мультимедиа в традиционные формы музыкального театра, сохраняя при этом уважение к классическому наследию. Он работает с видеоэффектами, сценографией и художественным светом, создавая современные мульти-медийные решения для оперных и балетных спектаклей. Петр Окунев работает в области видеоэффектов для театральных постановок, художественного света, сценографии музыкальных спектаклей, мультимедийных решений для оперы и балета. Его работы характеризуются современным подходом к визуализации классических произведений, использованием технологий видео-проекции и созданием целостной визуальной концепции спектакля. Сцено-графический стиль работ Окунева отличается классическим подходом к визуальному решению, монументальностью образа, богатством и колористической насыщенностью, созданием красоты зрелища.

Постановка спектакля "Тысяча и одна ночь" представляет собой неоклассическую интерпретацию арабских сказок с использованием национальных музыкальных инструментов и синтезом балетной пластики с восточными танцевальными традициями. Балетмейстер Эльдар Алиев работал в неоклассическом стиле, что предполагало синтез классической балетной техники с элементами восточной пластики, современное хореографическое мышление с неизменным сохранением академических традиций. Сценография Окунева должна была поддерживать этот синтез, создавая визуальную среду, которая не противоречила бы классической балетной эстетике, но при этом передавала восточный колорит.

Балет построен как рассказ Шахерезады царю Шахрияру, где три сказки вставлены в основную историю любви и прощения. В спектакле "Тысяча и одна ночь" зримо представлены три сцены из знаменитых арабских сказок: "Синдбад-мореход и птица Рух"- морская стихия, фантастические существа, "Аладдин и волшебная лампа" - волшебство, восточная роскошь и "Али-Баба и сорок разбойников" - пещеры, сокровища, драматизм. Сценография должна была визуально разделять уровни повествования, создавать переходы между реальностью и сказкой, поддерживать драматургию основной истории, иллюстрировать фантастические миры трёх сказок. В каждой из сказок Шахерезады женская партия олицетворяла красоту, любовь и мудрость. Сценография должна была визуально поддерживать эти темы через романтическую атмосферу, красоту визуальных образов, символику цвета и формы, которые должны были производить эмоциональное воздействие на зрителя.

Ключевой задачей сценографии художника для данного спектакля стало создание декорации, которые передали атмосферу экзотики Востока. Петр Окунев создал декорации, которые передали атмосферу экзотики Востока, погружая зрителя в мир арабских сказок "Тысяча и одна ночь". Каждая сцена требовала своего визуального решения при сохранении общей стилистической целостности спектакля. Пластика восточных танцев гармонично сочеталась с голосами женского хора и солирующим сопрано.

Сценографическое решение стало визуальным эквивалентом музыкальной партитуры Ф.Амирова, сочетающей европейскую оркестровую традицию с азербайджанскими народными мотивами. Визуальное решение гармонично сочеталось со звучанием азербайджанского народного ударного инструмента тара, создавая целостный художественный образ восточного мира. Взаимодействие сценографии и хореографии представляла собой гармонию элементов. Декорации Петра Окунева создавали пространственную среду, в которой пластика восточных танцев гармонично сочеталась с другими элементами спектакля - голосами женского хора и солирующим сопрано.

Сценография Петра Окунева для балета "Тысяча и одна ночь" на Приморской сцене Мариинского театра представляет собой профессиональное и художественно убедительное решение, основанное на классических принципах театральной сценографии, богатстве колористики и визуальной насыщенности, монументальности и масштабности образа. Гармоничный синтез с музыкой, хореографией и вокалом приводит к созданию атмосферы восточной экзотики. Сценография стала неотъемлемой частью художественного целого, поддерживая неоклассический стиль хореографии Эльдара Алиева и создавая визуальную среду для трёх сказочных историй - о Синдбаде-мореходе, Аладдине и Али-Бабе, — рассказанных мудрой Шахерезадой.

Работа Окунева органично вписывается в традицию русского балетного театра, продолжая линию ориентальных спектаклей от "Шехерезады" Бакста до современности, и демонстрирует высокий профессиональный уровень современной российской театральной сценографии.

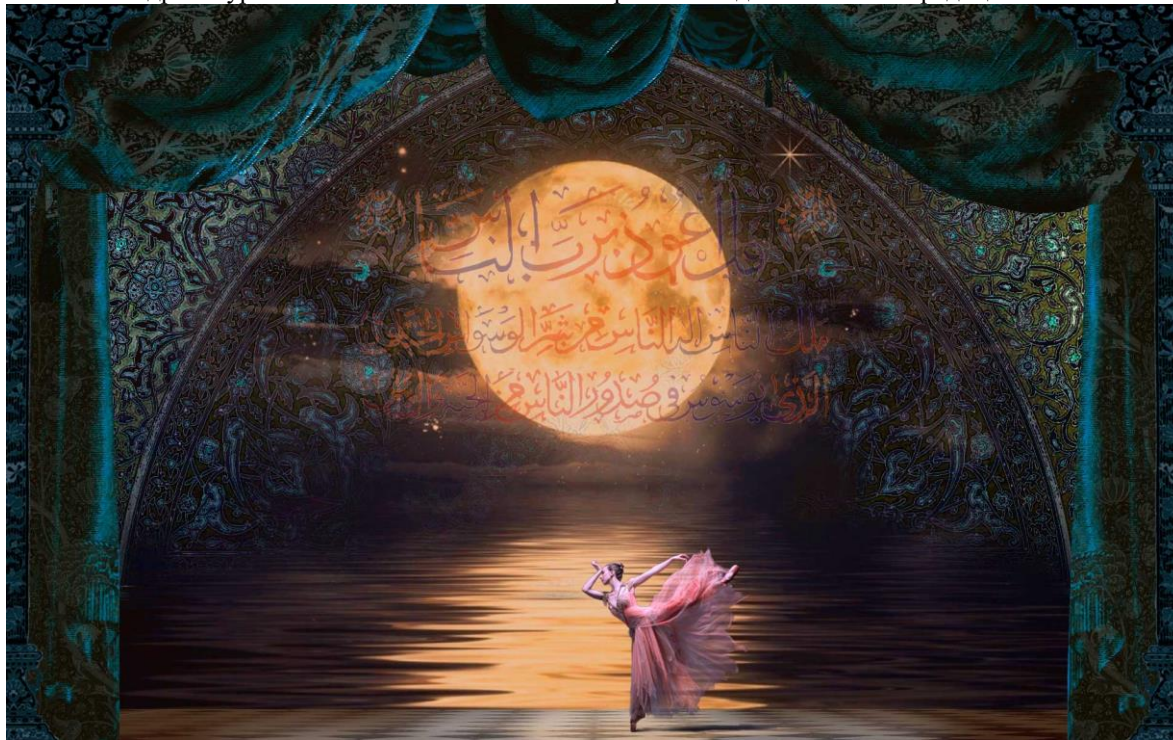
Сценография Петра Окунева стала органичной частью синтетического произведения, где музыка Фикрета Амирова, отличающаяся национальной азербайджанской традицией в синтезе с европейской оркестровкой, хореография Эльдара Алиева, соединяющая собой неоклассический балет с восточной пластикой, сценография Петра Окунева, в творчество которого умело интегрированы классическая школа и восточная экзотика, а также вокал, представленный женским хором и солирующим сопрано, создали гармоничное целое, передающее атмосферу арабских сказок.

Анализ работы Окунева данной постановки позволяет выделить устойчивые визуальные коды, которые международная аудитория считывает, как

"восточные". Это и архитектурные элементы, представленные стрельчатыми арками, куполами, колоннами с капителями, решётками шебеке, дворцовыми интерьерами, и орнаментальные мотивы в виде арабесок, геометрических паттерн, каллиграфии, ковровых узоров, изразцов. Впечатляет и цветовая палитра, избранная для данного спектакля, где доминируют сочетание бирюзы и золота, глубокого синего с серебром, терракоты и охры, пурпура и изумруда. Привлекает внимание также обилие металлических оттенков. Обращает на себя внимание световая драматургия спектакля: тёплое золо-

тистое свечение, воссоздающее атмосферу масляных ламп, сменяется холодным лунным светом, маркирующим ночь как время действия, в то время как игра света и тени через решётки и арки перекликается с мерцанием звёзд и драгоценностей, создавая многослойную визуальную партитуру.

Природные элементы, представленные в данной сценической постановке, включают луну как центральный образ в работе Окунева, звёзды, воду в различных её проявлениях (фонтаны, бассейны, отражения), пустыню и сады, отсылающие к образу райских садов исламской традиции.



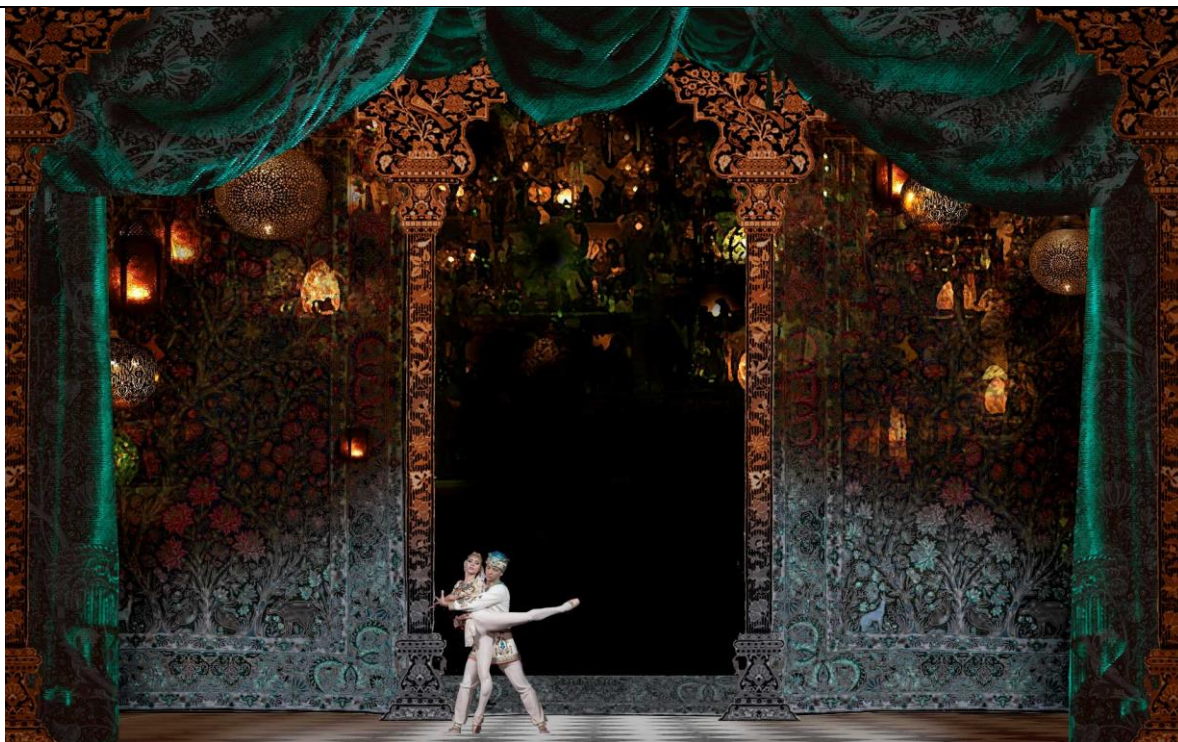
Сценографическое решение одной из сцен спектакля демонстрирует классическую центрическую композицию с осевой симметрией портала и арки, архитектурно отсылающей к михрабу и фиксирующей центр — золотистую луну, вписанную в полукруглую арку согласно принципам сакральной геометрии (круг как символ совершенства и вечности, арка как врата), которую контрапунктически уравнивает динамичная фигура балерины, размещённая по принципу золотого сечения и расклинивающая центр диагональю своей позы, в то время как трёхплановая структура пространства — драпировки переднего плана, орнаментальная арка среднего и вода с луной и каллиграфией дальнего — формирует эффект портала и театра теней.

Постановка Петра Окунева представляет собой синтез традиционной архитектурной формы и цифровых технологий, где материальные элементы (монументальный портал с традиционной орнаментикой, физическая арочная конструкция, текстильные драпировки из бирюзового бархата, водная поверхность) органично сочетаются с цифровыми (проекционная луна с анимированной арабской каллиграфией, динамическая световая среда, LED-

пол с эффектом водной глади, многослойные видеопроекции).

Этот синтез позволяет художнику создать «живую декорацию», в которой каллиграфия трансформируется, рассказывая визуальную историю, луна меняет фазы, цвет и интенсивность свечения, водная поверхность реагирует на движения танцовщиков, а пространство дышит вместе с музыкой и хореографией, обеспечивая трансформативность, символическую насыщенность, иллюзию бесконечности, синхронизацию с музыкой и экономическую эффективность, хотя и не исключая рисков технологической зависимости, потери материальности, отвлечения внимания от хореографии и унификации решений.

Характерный для работ Окунева монументальный традиционный образ, представленный в сцене ниже, предполагает масштабность декораций, создающую впечатление грандиозности, архитектурную выразительность с использованием арок, куполов и колонн, глубину сценического пространства через многоплановость и применение классических композиционных принципов симметрии и ритма.



С точки зрения стилистики сценография данной сцены балета представляет собой неоориентализм — современную интерпретацию восточной эстетики, характеризующуюся живописностью (богатство деталей и цвета), театральностью (подчёркнутая декоративность), реализмом с элементами стилизации (узнаваемые, но обобщённые формы) и роскошью (обилие орнамента, золота, дорогих тканей), которая синтезирует историческую достоверность архитектурных форм, театральную условность через обобщение и стилизацию и романтизацию Востока посредством акцента на роскоши и экзотике.

Данная сценография представляет собой классический пример ориентализма в балетном театре, где восточная эстетика интерпретируется через призму европейской театральной традиции, роскошь и декоративность служат созданию атмосферы экзотики, архитектурные формы обобщены и стилизованы для достижения театрального эффекта, цветовая гамма (бирюза-золото) использует устоявшиеся визуальные коды «восточности», а пространство организовано по принципу «рамы» — театра в театре, что в совокупности свидетельствует о качественной профессиональной работе, демонстрирующей высокий уровень художественного мастерства и глубокое понимание как восточной эстетики, так и законов театральной сценографии.

Орнаментика и декоративные элементы сценографии включают растительные мотивы (арабески, цветочные узоры райских садов, переплетающиеся стебли и листья), геометрические элементы (резные колонны с капителями, структурированные паттерны) и архитектурные детали (марокканские фонари, ажурные решётки, многоярусные капители), выполненные в живописной, проекционной или комбинированной технике.

Световая драматургия, построенная на декоративных светильниках (ажурные фонари, имитирующие масляные лампы), общем освещении (тёплое золотистое свечение, подсветка орнаментов, контровой свет) и световых акцентах (выделение арки, игра света и тени, отражения на полу), создаёт атмосферу ночного дворца, интимности и роскоши, а текстильные элементы (драпировки из бирюзового бархата) формируют глубину и цветовой акцент, что в совокупности создаёт культурный код «восточности» через стрельчатую арку, арабески, марокканские фонари, бирюзово-золотую палитру, роскошь декора и симметричную композицию.

Анализ сценографии Окунева важен в трёх аспектах: методологически он демонстрирует современный подход к восточной тематике, где художественная интерпретация заменяет этнографическую достоверность, создание новой визуальной метафоры — копирование исторических форм, а универсальный язык сохраняет культурную специфику; технологически его работа иллюстрирует эволюцию от материальных декораций к цифровым, открывая новые возможности интерактивности и трансформативности для передачи восточной эстетики; компаративно же сопоставление арабо-персидского подхода Окунева (арабески, каллиграфия, обобщённая архитектура, бирюзово-золотая гамма, проекции) с тюркско-персидской спецификой азербайджанских балетов (ковровые узоры, национальная архитектура, вариативные решения) выявляет различные стратегии культурной репрезентации на мировых сценах.

Сценография интегрировала азербайджанские и арабские мотивы, обеспечивая визуальное соответствие звучанию тара (азербайджанский народный инструмент), воссоздавая архитектурные формы восточных дворцов, используя орнаментальные мотивы исламского искусства и создавая

атмосферу арабских сказок. При этом Окунев работал в рамках европейской театральной традиции, что проявилось в классических принципах сценографии, академической выверенности композиции, профессиональном владении пространством сцены и соответствии канонам балетного театра.

Постановка продолжает традицию диалога культур "Восток-Запад", начатую "Русскими сезонами" Дягилева с их "Шехераздой" и другими ориентальными балетами. Сценография Окунева стала современным прочтением этой традиции.

Постановка балета «Тысяча и одна ночь» демонстрирует жизнеспособность классических форм балетного театра при обращении к восточной тематике. Сценография Петра Окунева показывает, что традиционный подход может быть актуальным и впечатляющим в XXI веке.

Это яркий пример того, как азербайджанское театральное искусство может быть представлено на мировых сценах с сохранением национального колорита и использованием современных выразительных средств.

Литература

1. Астафьева, Т.Ф. Сценография музыкального спектакля / Т.Астафьев – Санкт-Петербург: Композитор - Санкт-Петербург - 2003.
2. Ракитин, В. Ритмы восточной сказки // - Москва: «Декоративное искусство СССР» – 1976.
3. Волшебный Восток. «1000 и одну ночь» покажут в Приморье. https://otvprim.ru/news/volshebnyj-vostok-1-000-i-odnu-noch-pokazhut-v-primore_2020_07_30.
4. Все прелести Востока в одном балете: Приморская сцена Мариинского театра возобновит работу премьерой.
5. <https://vladivostok.bezformata.com/listnews/primorskaya-stcena-mariinskogo-teatra/86144017/>
6. Карпенко, В.Н., Карпенко, И.А., Татаринцев, А.Ю. Сценографическое решение как составная часть художественного хореографического решения // – Тамбов: Грамота: Исторические, философские, политические и юридические науки, культурология и искусствоведение. Вопросы теории и практики - 2016, №3(65) - с.68-71.

MEDICAL SCIENCES

*Левченко Денис**врач стоматолог, MasterDent,**USA, Roseville*<https://doi.org/10.5281/zenodo.22996388>ПРИМЕНЕНИЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В ДИАГНОСТИКЕ
СТОМАТОЛОГИЧЕСКИХ ЗАБОЛЕВАНИЙ*Denys Levchenkov**dentist, MasterDent,**USA, Roseville*

THE USE OF ARTIFICIAL INTELLIGENCE IN THE DIAGNOSIS OF DENTAL DISEASES

Аннотация.

В статье рассматриваются современные возможности применения искусственного интеллекта в диагностике стоматологических заболеваний, включая кариес, заболевания пародонта и патологии твердых и мягких тканей полости рта. Анализируются методы машинного обучения и глубоких нейронных сетей, используемые для обработки медицинских изображений, таких как рентгенограммы, КТ и внутривитальные сканы. Особое внимание уделяется повышению точности ранней диагностики, снижению субъективности клинической оценки и автоматизации принятия врачебных решений. Приводятся данные о высокой чувствительности и специфичности алгоритмов при выявлении скрытых и начальных форм заболеваний. Также обсуждаются ограничения технологий, включая необходимость больших обучающих выборок, вопросы интерпретируемости моделей и этические аспекты использования ИИ в медицине. Делается вывод о значительном потенциале искусственного интеллекта как инструмента, способного повысить качество стоматологической помощи и оптимизировать клиническую практику.

Abstract.

The presented article examines in detail the complex and dynamic role of the oral microbiota in maintaining local homeostasis and the pathogenesis of major dental diseases such as caries and inflammatory periodontal lesions. The biochemical mechanisms of dental biofilm formation and the pathological transition from a symbiotic state to dysbiosis under the influence of various carbohydrate loads, pH changes and decreased immune reactivity are highlighted. Special attention is paid to acidogenic and acidoduric bacteria, in particular *Streptococcus mutans* and representatives of the genus *Lactobacillus*, whose metabolic activity and production of organic acids lead to local demineralization of hard tooth tissues and the development of the carious process. In the context of gingivitis and periodontitis, the influence of specific gram-negative anaerobes of the periodontopathogenic red complex, including *Porphyromonas gingivalis*, *Treponema denticola* and *Tannerella forsythia*, is deeply analyzed. These microorganisms, due to the release of proteolytic enzymes and endotoxins, act as triggers that initiate a cascade of destructive immune-inflammatory reactions, which leads to the destruction of the periodontal ligament and resorption of the alveolar bone.

Ключевые слова: искусственный интеллект, стоматология, диагностика, кариес, заболевания пародонта, машинное обучение, нейронные сети, медицинские изображения, цифровая стоматология, автоматизация диагностики.

Keywords: oral microbiota, dysbiosis, dental biofilm, dental caries, periodontal inflammation, periodontitis, *Streptococcus mutans*, *Porphyromonas gingivalis*, periodontopathogens, microbial homeostasis, preventive dentistry.

Актуальность исследования. Стремительное развитие цифровых технологий и методов искусственного интеллекта существенно трансформирует современную медицину, включая стоматологию. Традиционные методы диагностики во многом зависят от субъективной оценки врача, что может приводить к вариативности результатов и снижению точности выявления ранних стадий заболеваний.

В условиях роста распространенности кариеса, заболеваний пародонта и других патологий полости рта возрастает необходимость внедрения более

точных, быстрых и стандартизированных диагностических инструментов. Искусственный интеллект способен анализировать большие массивы медицинских данных, включая рентгенологические изображения и 3D-сканы, обеспечивая высокую чувствительность и специфичность диагностики. Это делает исследование его применения особенно актуальным для повышения качества стоматологической помощи и оптимизации клинических процессов.

Цель исследования. Целью данного исследования является анализ возможностей и эффектив-

ности применения технологий искусственного интеллекта в диагностике стоматологических заболеваний, а также оценка их влияния на точность выявления патологий, скорость обработки данных и снижение субъективности врачебных решений. Дополнительно ставится задача выявить основные преимущества, ограничения и перспективы внедрения ИИ в повседневную стоматологическую практику.

Материалы и методы исследования. В рамках исследования использовался анализ научной литературы, посвященной применению искусственного интеллекта в стоматологии, включая публикации в международных медицинских и технических базах данных. Рассматривались работы, посвященные использованию алгоритмов машинного обучения и глубоких нейронных сетей для обработки рентгенологических изображений, компьютерной томографии и внутривидео сканов.

Методологическую основу составили сравнительный анализ традиционных диагностических подходов и систем на базе ИИ, а также оценка показателей точности, чувствительности и специфичности диагностических моделей. Дополнительно учитывались данные клинических исследований, в которых применялись автоматизированные си-

стемы распознавания патологий. Такой комплексный подход позволил объективно оценить эффективность и перспективность использования искусственного интеллекта в стоматологической диагностике.

Результаты исследования. Развитие искусственного интеллекта в стоматологической диагностике началось с внедрения базовых компьютерных технологий в медицину во второй половине XX века. На ранних этапах, в 1960-1980-х годах, применялись простейшие экспертные системы, основанные на правилах и логических алгоритмах. Данные системы моделировали клиническое мышление врача и использовались для поддержки принятия решений, однако их возможности были ограничены из-за недостаточной вычислительной мощности и малых объемов цифровых данных.

С переходом к цифровой стоматологии в 1990-е годы началось активное накопление медицинских изображений, включая рентгенограммы и компьютерную томографию. Это создало предпосылки для применения более сложных алгоритмов анализа изображений. В этот период начали использоваться методы машинного обучения, способные выявлять закономерности в данных и помогать в диагностике кариеса, патологий пародонта и аномалий развития зубочелюстной системы (рис. 1).

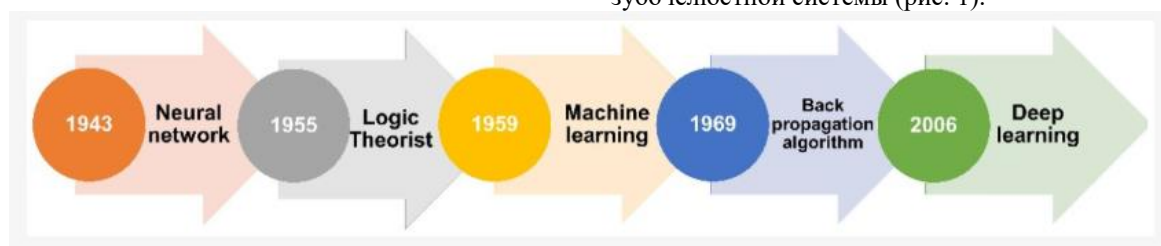


Рис. 1 – Важные этапы в развитии искусственного интеллекта [2]

Существенный прорыв произошел в 2000-2010-х годах с развитием глубокого обучения и нейронных сетей. Появление сверточных нейронных сетей позволило значительно повысить точность анализа медицинских изображений. В стоматологии это выразилось в автоматическом распознавании кариозных поражений, оценке состояния костной ткани и выявлении скрытых патологий на ранних стадиях. Одновременно развивались системы автоматизированного планирования лечения, включая ортодонтические и имплантологические решения.

В последние годы развитие искусственного интеллекта в стоматологии ускорилось благодаря росту вычислительных мощностей, доступности больших данных и внедрению облачных технологий. Современные системы способны не только анализировать изображения, но и интегрировать клинические данные пациента, прогнозировать развитие заболеваний и предлагать персонализированные стратегии лечения. Искусственный интеллект активно внедряется в клиническую практику, повышая точность диагностики, снижая влияние человеческого фактора и оптимизируя рабочие процессы.

Эволюция искусственного интеллекта в диагностике стоматологических заболеваний прошла

путь от простых экспертных систем к сложным интеллектуальным платформам, играющим ключевую роль в современной цифровой стоматологии.

Отметим, что современный этап развития искусственного интеллекта в стоматологии связан с активным внедрением методов глубокого обучения, компьютерного зрения и анализа больших данных. Ключевую роль играют сверточные нейронные сети, которые обучаются на тысячах и миллионах медицинских изображений и способны распознавать патологические изменения с высокой точностью [3]. Эти технологии используются прежде всего для анализа рентгенологических снимков, включая прицельные снимки, панорамные ортопантомограммы и конусно-лучевую компьютерную томографию.

Одним из наиболее распространенных направлений является автоматическая диагностика кариеса. Современные системы, такие как Diagnocat, Pearl или Overjet, анализируют рентгеновские изображения и выявляют даже начальные кариозные поражения, которые могут быть незаметны врачу. Алгоритмы также определяют глубину поражения и помогают оценить необходимость лечения. Это повышает точность диагностики и снижает вероятность пропуска ранних стадий заболевания [1].

В диагностике заболеваний пародонта искусственный интеллект используется для оценки уровня костной ткани и выявления признаков пародонтита. Системы автоматически измеряют расстояние от цементно-эмалевого соединения до уровня альвеолярной кости, что позволяет объективно определить степень разрушения тканей и динамику заболевания. Это особенно важно для долгосрочного мониторинга пациентов.

В области имплантологии ИИ применяется для анализа трёхмерных КЛКТ-данных. Алгоритмы помогают выявлять анатомические структуры, такие как нижнечелюстной канал и гайморовы пазухи, а также оценивать плотность костной ткани. На основе этих данных формируются рекомендации по выбору размеров имплантатов и их оптимальному расположению, что снижает риск осложнений.

Ортодонтия также активно использует технологии искусственного интеллекта. Программы спо-

собны автоматически анализировать телерентгенограммы, определять анатомические ориентиры и выполнять цефалометрические измерения. Кроме того, такие технологии используются для мониторинга хода лечения: анализируя фотографии и 3D-сканы, ИИ способен отслеживать динамику изменений и своевременно выявлять отклонения от запланированного результата. Это снижает необходимость частых визитов к врачу и повышает эффективность взаимодействия между специалистом и пациентом.

Внедрение ИИ в ортодонтию также способствует персонализации лечения, учитывая индивидуальные анатомические особенности каждого пациента, что в конечном итоге улучшает качество и предсказуемость терапевтических результатов (табл. 1).

Таблица 1

Использование технологий искусственного интеллекта в ортодонтии

№	Метод	Характеристика
1	Диагностика	ИИ может анализировать радиографические снимки и 3D-сканирования для выявления ортодонтических аномалий. Алгоритмы машинного обучения могут распознавать паттерны, которые могут быть неочевидны для человеческого глаза.
2	Планирование лечения	С помощью ИИ можно создавать персонализированные планы лечения на основе анализируемых данных о пациенте. Это позволяет более точно предсказывать результаты лечения и оптимизировать процесс.
3	Моделирование результата	ИИ-технологии позволяют визуализировать предполагаемые изменения во время лечения, что помогает пациентам лучше понять процесс и мотивирует их следовать рекомендациям врача.
4	Мониторинг прогресса	Использование мобильных приложений и носимых устройств с ИИ позволяет отслеживать состояние пациента в режиме реального времени. Это может включать автоматизированные напоминания о необходимости ношения брекетов или чистки зубов.
5	Улучшение взаимодействия с пациентами	Чат-боты и виртуальные ассистенты могут отвечать на вопросы пациентов, предоставлять информацию о лечении и советовать по уходу за зубами.
6	Обучение и подготовка	ИИ может быть использован для обучения студентов-ортодонт, предоставляя симуляции, которые позволяют им практиковаться в диагностике и планировании лечения.

Дополнительно развиваются системы, интегрирующие клинические данные пациента, включая анамнез, фотографии и результаты обследований. Такие решения позволяют формировать комплексные диагностические заключения и персонализированные планы лечения. Облачные платформы обеспечивают быстрый доступ к данным и возможность удалённой консультации.

Современные технологии искусственного интеллекта в стоматологии обеспечивают высокую точность диагностики, автоматизацию рутинных процессов и поддержку клинических решений. Их применение уже сегодня существенно повышает качество медицинской помощи и продолжает активно расширяться.

Следует подчеркнуть, что несмотря на активное развитие технологий, внедрение искусственного интеллекта в стоматологическую диагностику сопровождается рядом серьёзных ограничений.

Одной из ключевых проблем является *качество и разнообразие обучающих данных*. Алгоритмы требуют больших массивов размеченных медицинских изображений, однако такие данные часто ограничены, могут быть несбалансированными и зависеть от конкретного оборудования или клиники. Это приводит к снижению точности моделей при использовании в других условиях и ухудшает их универсальность.

Другой важной проблемой является *недостаточная интерпретируемость решений*. Многие модели глубокого обучения работают как «чёрный

ящик», и врач не всегда может понять, на основании каких признаков система сделала вывод. Это снижает доверие специалистов и затрудняет клиническое принятие решений, особенно в спорных случаях.

Существенным ограничением остаются *юридические и этические вопросы*. Ответственность за ошибки диагностики, выполненной с участием ИИ, пока не имеет чёткой регуляции. Также возникают вопросы защиты персональных данных пациентов, особенно при использовании облачных сервисов и передачи медицинской информации.

Технические проблемы включают зависимость от качества изображений. Наличие артефактов, неправильной экспозиции или анатомических вариаций может существенно снизить точность алгоритмов. Кроме того, системы могут хуже распознавать редкие патологии, так как они недостаточно представлены в обучающих выборках.

Экономические и организационные барьеры также играют значительную роль. Внедрение ИИ требует финансовых вложений, обучения персонала и интеграции с существующими медицинскими информационными системами. Не все клиники готовы к таким изменениям, особенно в регионах с ограниченными ресурсами.

Наконец, существует риск *чрезмерной зависимости от технологий*. При некритичном использовании ИИ врач может утратить навыки самостоятельной диагностики, что потенциально снижает качество медицинской помощи при ошибках системы. Несмотря на значительный потенциал, применение искусственного интеллекта в стоматологии требует решения вопросов качества данных, прозрачности алгоритмов, правового регулирования и грамотной интеграции в клиническую практику.

По нашему мнению, решение проблем применения искусственного интеллекта в диагностике стоматологических заболеваний требует комплексного подхода, сочетающего технологические, организационные и правовые меры.

Одним из ключевых направлений является улучшение качества обучающих данных. Для этого необходимо создавать крупные, разнообразные и стандартизированные базы медицинских изображений, включающие данные из разных регионов, типов оборудования и клинических случаев. Важно также внедрять единые протоколы разметки с участием опытных стоматологов, что повысит точность и обобщающую способность алгоритмов.

Для преодоления проблемы «чёрного ящика» активно развиваются методы объяснимого искусственного интеллекта. Такие технологии позволяют визуализировать, какие именно участки изображения повлияли на решение системы, что повышает доверие врачей и облегчает клиническое использование. Дополнительно важно интегрировать ИИ как вспомогательный инструмент, а не замену специалиста, сохраняя за врачом окончательное решение.

Юридические и этические вопросы решаются через разработку нормативной базы, регулирующей использование ИИ в медицине. Это включает определение ответственности сторон, стандарты сертификации алгоритмов и строгие требования к защите персональных данных. Использование методов анонимизации и безопасного хранения информации снижает риски утечки данных.

Также необходимо учитывать вопросы справедливости и недопущения дискриминации, поскольку алгоритмы могут наследовать предвзятость обучающих выборок. Для этого требуется регулярный аудит систем и использование разнообразных и репрезентативных данных при обучении моделей. В совокупности эти меры формируют основу ответственного внедрения искусственного интеллекта в стоматологическую практику, обеспечивая баланс между технологическим прогрессом и соблюдением прав человека.

Технические ограничения могут быть уменьшены за счёт улучшения алгоритмов обработки изображений, включая автоматическую коррекцию качества и адаптацию к различным условиям съёмки. Также важно регулярно дообучать модели на новых данных, чтобы они лучше распознавали редкие и сложные патологии.

Экономические и организационные барьеры преодолеваются через постепенное внедрение технологий, государственную поддержку и обучение медицинского персонала. Разработка удобных интерфейсов и интеграция с существующими медицинскими системами упрощают использование ИИ в повседневной практике.

Наконец, для предотвращения чрезмерной зависимости от технологий необходимо сохранять высокий уровень профессиональной подготовки врачей и развивать критическое мышление. ИИ должен рассматриваться как инструмент повышения точности и эффективности диагностики, а не как автономная система, полностью заменяющая клинический опыт.

Заключение. Применение искусственного интеллекта в диагностике стоматологических заболеваний представляет собой важный этап развития современной медицины, открывающий новые возможности для повышения точности, скорости и доступности медицинской помощи. Технологии ИИ уже демонстрируют высокую эффективность при анализе рентгенологических снимков, выявлении кариеса, заболеваний пародонта и других патологий, снижая вероятность диагностических ошибок и помогая врачу принимать более обоснованные решения.

Несмотря на значительные преимущества, внедрение ИИ сопровождается рядом ограничений, включая зависимость от качества данных, необходимость стандартизации, вопросы интерпретируемости результатов и правового регулирования. Однако при грамотном подходе, включающем развитие объяснимых моделей, совершенствование нормативной базы и подготовку специалистов, эти проблемы могут быть успешно преодолены.

В перспективе искусственный интеллект не заменит стоматолога, а станет его эффективным инструментом, усиливающим клиническое мышление и повышающим качество лечения. Таким образом, интеграция ИИ в стоматологическую практику является не только технологическим, но и стратегическим направлением, способным существенно улучшить уровень здравоохранения и сделать диагностику более точной, персонализированной и доступной для пациентов.

Список литературы

1. Kolarkodi S. H., Alotaibi K. Z. Artificial intelligence in diagnosis of oral diseases: a systematic review // The journal of contemporary dental practice. – 2023. – Т. 24. – №. 1. – С. 61-68.
2. Patil S. et al. Artificial intelligence in the diagnosis of oral diseases: applications and pitfalls // Diagnostics. – 2022. – Т. 12. – №. 5. – С. 1029.
3. Zhu J. et al. Artificial intelligence in the diagnosis of dental diseases on panoramic radiographs: a preliminary study // BMC Oral Health. – 2023. – Т. 23. – №. 1. – С. 358.

*Сатторова Санобар Азамжон кизи**магистрант**Кудратова Дилноза Шарифовна**PhD, доцент**Ташкентский государственный стоматологический институт (ТГСИ), кафедра акушерства и гинекологии, гинекологии детей и подростков*<https://doi.org/10.5281/zenodo.22996404>

РОЛЬ МЕТФОРМИНА В КОРРЕКЦИИ ИНСУЛИНОРЕЗИСТЕНТНОСТИ У ДЕВОЧЕК-ПОДРОСТКОВ С НАРУШЕНИЯМИ МЕНСТРУАЛЬНОГО ЦИКЛА

*Sattorova Sanobar Azamjon kizi**Kudratova Dilnoza Sharifovna*

THE ROLE OF METFORMIN IN THE CORRECTION OF INSULIN RESISTANCE IN ADOLESCENT GIRLS WITH MENSTRUAL CYCLE DISORDERS

Аннотация.

Нарушения менструального цикла у девочек-подростков нередко патогенетически связаны с инсулинорезистентностью (ИР) и компенсаторной гиперинсулинемией, которые через стимуляцию лютеинизирующего гормона и овариального стероидогенеза приводят к ановуляции и гиперандрогении. Метформин, как инсулиносенситайзер первой линии, широко применяется off-label в подростковой гинекологической эндокринологии. В статье на основании анализа литературы обобщены механизмы действия метформина, его эффективность в коррекции ИР и восстановлении менструальной функции у девочек-подростков, а также профиль безопасности препарата в этой возрастной группе.

Annotation.

Menstrual cycle disorders in adolescent girls are frequently linked pathogenetically to insulin resistance (IR) and compensatory hyperinsulinemia, which, through stimulation of luteinizing hormone secretion and ovarian steroidogenesis, lead to anovulation and hyperandrogenism. Metformin, a first-line insulin-sensitizing agent, is widely used off-label in adolescent gynecological endocrinology. Based on a literature review, this article summarizes the mechanisms of action of metformin, its efficacy in correcting IR and restoring menstrual function in adolescent girls, and its safety profile in this age group.

Ключевые слова: инсулинорезистентность, метформин, девочки-подростки, нарушения менструального цикла, гиперинсулинемия, HOMA-IR, пубертат.

Keywords: insulin resistance, metformin, adolescent girls, menstrual cycle disorders, hyperinsulinemia, HOMA-IR, puberty.

Актуальность.

Нарушения менструального цикла выявляются у 20–35% девочек-подростков и являются одной из ведущих причин обращения к детскому гинекологу [8]. Пубертат физиологически сопровождается транзиторным снижением чувствительности тканей к инсулину: показатель HOMA-IR у здоровых подростков закономерно достигает пика в середине пубертата [10]. У части девочек, особенно при избыточной массе тела, это физиологическое состояние трансформируется в стойкую патологическую ИР, которая способствует ановуляции и нарушению ритма менструаций [2, 8]. Рост распространённости ожирения среди детей и подростков закономерно сопровождается увеличением частоты ИР и связанных с ней репродуктивных нарушений, что обуславливает интерес к патогенетической терапии инсулиносенситайзерами, в первую очередь метформином [2, 10].

Цель исследования.

Обобщить и систематизировать данные современной литературы о патогенетической роли инсулинорезистентности в развитии нарушений мен-

струального цикла у девочек-подростков и об эффективности и безопасности применения метформина для коррекции инсулинорезистентности и восстановления менструальной функции в этой возрастной группе.

Материалы и методы исследования.

Проведён анализ научных публикаций в базах данных PubMed/MEDLINE, Google Scholar, Cochrane Library и реестре ClinicalTrials.gov за 2000–2026 гг. по ключевым словам «metformin», «insulin resistance», «adolescents», «menstrual disorders», «HOMA-IR». В обзор включены рандомизированные контролируемые исследования, систематические обзоры, метаанализы и клинические рекомендации, посвящённые применению метформина у девочек-подростков с ИР и нарушениями менструального цикла; исключены работы низкого методологического качества.

Результаты и обсуждение.

Патогенез.

Инсулинорезистентность оценивается преимущественно по индексу HOMA-IR, пороговые значения которого у подростков зависят от стадии пубер-

тата (около 3,2 для пубертатных и 2,9 для постпубертатных) [9]. Гиперинсулинемия усиливает секрецию лютеинизирующего гормона и совместно с ним стимулирует текаклетки яичников к избыточной продукции андрогенов, а также подавляет синтез в печени глобулина, связывающего половые стероиды, увеличивая фракцию свободного тестостерона [2]. Итогом становится хроническая ановуляция и нарушение ритма менструаций — олигоменорея, вторичная аменорея или ациклические кровотечения [2, 8]. Наиболее изученной клинической моделью такой связи является синдром поликистозных яичников (СПКЯ) [8], однако он представляет собой лишь одно из состояний, в рамках которых ИР приводит к нарушению менструальной функции; сходные механизмы вносят вклад в олигоменорею и при алиментарном ожирении без развёрнутой картины гиперандрогении [2].

Механизм действия метформина.

Основной эффект метформина — подавление глюконеогенеза в печени за счёт мягкого ингибирования комплекса I дыхательной цепи митохондрий гепатоцитов и последующей активации АМФ-активируемой протеинкиназы (АМПК) [1]. Активация АМПК снижает синтез липидов, подавляет экспрессию глюконеогенных генов и повышает окисление жирных кислот [1]. Кроме того, метформин повышает периферическую чувствительность к инсулину за счёт усиления транслокации транспортера GLUT4 [1]. Снижение уровня циркулирующего инсулина уменьшает инсулин-опосредованную стимуляцию лютеинизирующего гормона и овариального стероидогенеза, повышает синтез ГСПГ и снижает уровень свободного тестостерона, что создаёт условия для восстановления овуляции и регулярного ритма менструаций [2, 6].

Эффективность.

Метаанализ пяти рандомизированных исследований ($n = 320$, длительность 6 мес.) показал умеренное снижение индекса массы тела и НОМА-IR на фоне терапии метформином по сравнению с плацебо [3]. В 18-месячном плацебо-контролируемом исследовании у 62 подростков 10–16 лет с ожирением и ИР метформин обеспечил достоверно меньшую прибавку индекса массы тела по сравнению с плацебо, однако значимых различий по НОМА-IR получено не было, что подчёркивает вариабельность ответа на терапию [3]. В последующем открытом продлённом исследовании у части этих же подростков сохранялась удовлетворительная переносимость терапии при продолжающемся наблюдении за динамикой массы тела [4].

Влияние на менструальную функцию.

У значительной части подростков с СПКЯ терапия метформином сопровождается нормализацией ритма менструаций и уменьшением клинической гиперандрогении [6]. Сравнительные систематические обзоры показывают, что комбинированные оральные контрацептивы эффективнее обеспечивают регулярность кровотечений, но могут ухудшать метаболические параметры, тогда как метформин и комбинированные

схемы инсулиносенситайзеров демонстрируют более выраженное улучшение овуляторной функции при благоприятном метаболическом профиле [5]. Международные рекомендации 2023 г. по СПКЯ у подростков указывают, что метформин может рассматриваться в первую очередь для коррекции метаболических нарушений и, как дополнительный эффект, — для регуляции цикла, особенно при избыточной массе тела и лабораторно подтверждённой ИР, при этом уровень доказательности рекомендаций остаётся невысоким [7, 8].

Безопасность.

Метформин не вызывает гипогликемии при монотерапии [11]. Наиболее частые нежелательные явления — желудочно-кишечные симптомы (тошнота, диарея, метеоризм), выраженность которых снижается при постепенном титровании дозы и приёме во время еды [11]. Лактацидоз встречается крайне редко и практически не описан в педиатрической популяции; тем не менее перед началом терапии необходима оценка функции почек [11]. При длительном приёме возможно снижение уровня витамина B12, что требует периодического контроля [11]. Применение у подростков носит преимущественно off-label характер и должно сопровождаться постепенной титрацией дозы (с 500 мг/сут до 1500–2000 мг/сут) и обязательным сочетанием с модификацией образа жизни [7].

Заключение.

Инсулинорезистентность играет существенную патогенетическую роль в развитии нарушений менструального цикла у девочек-подростков. Метформин, воздействуя на ключевые звенья этого каскада, демонстрирует умеренную, но клинически значимую эффективность в снижении ИР, нормализации массы тела и восстановлении регулярности менструального цикла, при благоприятном профиле безопасности. Имеющаяся доказательная база пока ограничена по объёму, что диктует необходимость дальнейших многоцентровых рандомизированных исследований с менструальной функцией в качестве первичной конечной точки; решение о назначении метформина должно приниматься индивидуально.

Литература.

1. Rena G., Hardie D.G., Pearson E.R. The mechanisms of action of metformin // *Diabetologia*. — 2017. — Vol. 60, № 9. — P. 1577–1585.
2. Metformin therapy in pediatric type 2 diabetes mellitus and its comorbidities: a review // *Frontiers in Endocrinology*. — 2022. — Vol. 13. — Art. 1072879.
3. Long-term treatment with metformin in obese, insulin-resistant adolescents: results of a randomized double-blinded placebo-controlled trial // *Nutrition & Diabetes*. — 2016. — Vol. 6. — e228.
4. Long-term metformin treatment in adolescents with obesity and insulin resistance: results of an open label extension study // *International Journal of Obesity*. — 2018.
5. Comparative efficacy of metformin and combined oral contraceptives in the management of adolescent polycystic ovary syndrome: a systematic review of randomized controlled trials // *Cureus*. — 2024–2025.

6. Metformin treatment of PCOS during adolescence and the reproductive period // рецензируемый эндокринологический журнал. — 2005. (PMID: 15941616).

7. Teede H.J., Tay C.T., Laven J.J.E. et al. Recommendations from the 2023 international evidence-based guideline for the assessment and management of polycystic ovary syndrome // European Journal of Endocrinology. — 2023. — Vol. 189. — P. G43–G64.

8. Pena A.S., Witchel S.F., Hoeger K.M. et al. International evidence-based recommendations for polycystic ovary syndrome in adolescents // BMC Medicine. — 2025. — Vol. 23. — Art. 151.

9. Da Silva C.C., Zambon M.P., Vasques A.C.J. et al. The threshold value for identifying insulin resistance (HOMA-IR) in an admixed adolescent population: a hyperglycemic clamp validated study // Archives of Endocrinology and Metabolism. — 2023. — Vol. 67, № 1. — P. 119–125.

10. Trends in HOMA-IR values among South Korean adolescents from 2007–2010 to 2019–2020: a sex-, age-, and weight status-specific analysis // International Journal of Obesity. — 2023.

11. Safety issues when prescribing metformin: gastrointestinal adverse effects, lactic acidosis risk and vitamin B12 deficiency // The Journal of Clinical Psychiatry. — 2016. — Vol. 77, № 11. — e1491–e1494.

PEDAGOGICAL SCIENCES

Afag Farahim kizi Garibli

Sumgait State University

Azerbaijan Republic, Baku City

<https://doi.org/10.5281/zenodo.22996418>

EFFECTIVE PEDAGOGICAL METHODS IN HISTORY TEACHING

Афаг Фарахим кызы Гарибли

Сумгаитский государственный университет

Азербайджанская Республика, г. Баку

ЭФФЕКТИВНЫЕ ПЕДАГОГИЧЕСКИЕ МЕТОДЫ В ПРЕПОДАВАНИИ ИСТОРИИ

Annotation.

This article explores effective pedagogical methods in history teaching from the perspective of contemporary educational theory and practice. The study focuses on the role of appropriate instructional approaches in enhancing the quality of history education and promoting students' active involvement in the learning process. Particular attention is given to learner-centred, interactive, problem-based, and inquiry-based methods that facilitate the acquisition of historical knowledge while supporting the development of analytical and critical thinking skills.

The study emphasizes that effective history teaching should extend beyond the transmission of factual information and provide learners with opportunities to analyse historical events, establish causal and chronological relationships, evaluate historical evidence, and interpret different perspectives. In this context, the purposeful application of pedagogical methods is considered an essential factor in fostering students' intellectual engagement and developing their capacity for independent learning.

The article also examines the importance of integrating contemporary pedagogical approaches with established methods of history instruction. The effective combination of instructional objectives, teaching strategies, learning activities, and assessment practices can contribute to a more coherent and meaningful educational process. The study concludes that the systematic and pedagogically justified application of effective teaching methods enhances students' engagement with historical content, facilitates deeper understanding of historical processes, and contributes to improved learning outcomes. Therefore, the development and implementation of effective pedagogical approaches remain important for advancing the quality of history education in contemporary educational settings.

Аннотация.

В статье рассматриваются эффективные педагогические методы преподавания истории с точки зрения современной теории и практики образования. Основное внимание уделяется роли соответствующих методов обучения в повышении качества исторического образования и обеспечении активного участия учащихся в учебном процессе. Особое внимание уделяется личностно ориентированным, интерактивным, проблемным и исследовательским методам обучения, которые способствуют усвоению исторических знаний и одновременно развитию аналитического и критического мышления.

В исследовании подчеркивается, что эффективное преподавание истории не должно ограничиваться передачей фактической информации, а должно предоставлять учащимся возможности для анализа исторических событий, установления причинно-следственных и хронологических связей, оценки исторических источников и интерпретации различных точек зрения. В этом контексте целенаправленное применение педагогических методов рассматривается как важнейший фактор, способствующий интеллектуальной активности учащихся и развитию их способности к самостоятельному обучению.

В статье также рассматривается значение интеграции современных педагогических подходов с традиционными методами преподавания истории. Эффективное сочетание целей обучения, педагогических стратегий, учебной деятельности и методов оценивания способствует формированию более целостного и содержательного образовательного процесса. В результате исследования делается вывод о том, что систематическое и педагогически обоснованное применение эффективных методов обучения повышает заинтересованность учащихся в изучении исторического материала, способствует более глубокому пониманию исторических процессов и улучшению результатов обучения. В связи с этим разработка и внедрение эффективных педагогических подходов остаются важным условием повышения качества преподавания истории в современной образовательной среде.

Keywords: History Teaching; Pedagogical Methods; Teaching Strategies; History Education; Educational Effectiveness

Ключевые слова: преподавание истории, педагогические методы, стратегии обучения, историческое образование, эффективность образования.

INTRODUCTION

History teaching is an important component of contemporary education, as it contributes not only to the acquisition of historical knowledge but also to the development of learners' cognitive, analytical, and critical thinking abilities. The pedagogical significance of history education lies in enabling students to analyse historical evidence, understand causal relationships, interpret different perspectives, and draw reasoned conclusions. Therefore, the effectiveness of history teaching is closely related to the pedagogical principles and instructional methods applied in the educational process.

Contemporary educational theory has gradually shifted from predominantly teacher-centred instruction towards learner-centred approaches. Traditional history teaching, which often emphasizes the presentation and memorisation of factual information, may not sufficiently develop students' analytical and critical thinking skills. Contemporary pedagogy therefore emphasises active participation, independent inquiry, collaborative learning, and meaningful interpretation of educational content. Within this framework, history teaching requires methods that actively engage learners in the examination and interpretation of historical material.

The selection of appropriate pedagogical methods is particularly important because historical content often involves complex events, multiple interpretations, and interactions among political, social, economic, and cultural factors. Learner-centred, interactive, problem-based, and inquiry-based methods provide opportunities for students to examine historical sources, compare interpretations, identify causal relationships, and develop evidence-based arguments. Their effective application can consequently contribute to the development of historical thinking and higher-order cognitive skills.

The effectiveness of a teaching method depends on its alignment with curriculum objectives, content, learners' educational needs, available resources, and expected learning outcomes. Educational technologies and diverse historical resources, including documents, maps, visual materials, timelines, and multimedia content, can further enrich the instructional process when integrated purposefully into pedagogical practice.

Accordingly, this study examines effective pedagogical methods in history teaching and analyses their contribution to the improvement of the educational process. Particular attention is given to learner-centred and active learning approaches, their role in developing historical thinking and analytical abilities, and the pedagogical conditions necessary for their effective implementation. The study proceeds from the premise that the purposeful selection and systematic application of appropriate teaching methods can enhance the quality of history instruction and contribute to more meaningful learning outcomes.

Effective Pedagogical Approaches to History Teaching

The effectiveness of history teaching is determined to a considerable extent by the methodological principles underlying the organisation of the educa-

tional process and by the pedagogical strategies employed to facilitate students' acquisition and interpretation of historical knowledge. Within contemporary educational theory, history is no longer viewed exclusively as a body of factual information to be transmitted and memorised. Rather, history education is increasingly conceptualised as a process of disciplinary learning through which students acquire the capacity to examine evidence, interpret historical developments, establish causal relationships, recognise continuity and change, and formulate historically grounded arguments. In this context, the selection of pedagogically appropriate teaching methods constitutes a fundamental condition for enhancing the quality of history education and promoting meaningful learning outcomes [8; 35-38].

The conventional model of history instruction has traditionally placed substantial emphasis on the systematic presentation of factual knowledge, chronological sequences, historical figures, and significant events. Such knowledge remains indispensable, since an adequate factual and chronological framework provides the basis for subsequent historical interpretation. Nevertheless, the predominance of reproductive learning may restrict students' opportunities to develop higher-order cognitive skills. Contemporary history pedagogy consequently advocates a gradual transition from the passive acquisition of information towards active intellectual engagement with historical content. Learners are expected not merely to remember historical facts, but to examine their origins, contextualise them, evaluate their significance, and establish relationships among historical phenomena. In this regard, learner-centred pedagogy provides an important methodological framework for restructuring the relationship between the teacher, learner, and historical content [3; 15-18].

A learner-centred approach positions students as active participants in the construction of knowledge and assigns the teacher the role of facilitator, methodological guide, and organiser of the learning environment. In history education, this approach can be implemented through independent research, source analysis, structured discussion, collaborative investigation, project work, and analytical tasks. Such activities provide students with opportunities to formulate historical questions, examine alternative explanations, and construct interpretations on the basis of evidence. The pedagogical significance of this approach lies in its capacity to develop learners' autonomy and cognitive engagement while simultaneously strengthening their ability to approach historical knowledge critically [3; 21-24].

Inquiry-based learning represents a particularly significant methodological approach within contemporary history education. Its primary objective is to engage learners in processes of questioning, investigation, evidence evaluation, and interpretation. Rather than receiving historical explanations as predetermined conclusions, students are encouraged to investigate historical problems and arrive at conclusions through the examination of relevant evidence. The inquiry process may involve analysing primary and secondary sources,

comparing historical accounts, identifying contradictions, determining the context in which sources were produced, and assessing the reliability of available evidence. Such activities correspond closely to the disciplinary nature of historical inquiry and contribute to the development of students' historical reasoning [9; 7-12].

The effective implementation of inquiry-based learning requires careful pedagogical planning. Historical questions should be sufficiently challenging to stimulate intellectual investigation while remaining appropriate to learners' cognitive and educational levels. Similarly, source materials should be selected according to their relevance, reliability, complexity, and potential to generate meaningful historical discussion. Students also require methodological guidance in order to distinguish factual evidence from interpretation and to recognise the limitations of particular sources. Wineburg's research demonstrates that historical reading involves specific forms of contextual and evidentiary reasoning and that these practices require explicit instructional development [10; 495-499]. Accordingly, the teacher's role remains essential in providing scaffolding and guiding learners towards increasingly sophisticated forms of historical analysis.

Interactive and collaborative methods constitute another important dimension of effective history teaching. Discussion, structured debate, cooperative learning, group investigation, and oral presentation can create conditions for the exchange and critical examination of ideas. Historical knowledge frequently involves competing interpretations and perspectives, and structured classroom interaction enables learners to encounter viewpoints different from their own. Through such activities, students can formulate arguments, provide supporting evidence, respond to alternative interpretations, and reconsider their initial assumptions. However, pedagogically meaningful interaction depends upon clear learning objectives, carefully formulated questions, appropriate source materials, and effective teacher moderation. Without these conditions, classroom interaction may remain descriptive rather than analytical.

Problem-based learning can further strengthen the analytical dimension of history education. Historical problems may require learners to investigate the causes and consequences of particular events, assess the decisions of historical actors, or explain divergent interpretations of a historical development. Such tasks encourage students to apply previously acquired knowledge to unfamiliar or complex situations and thereby promote higher-order thinking. The framework of historical thinking developed by Seixas and Morton places particular emphasis on historical significance, evidence, continuity and change, cause and consequence, and historical perspectives as essential dimensions of historical understanding [5; 10-14]. Consequently, problem-oriented instruction can provide an effective means of integrating factual knowledge with historical reasoning.

A central objective of these pedagogical approaches is the development of historical thinking. Historical thinking involves a range of cognitive opera-

tions through which learners make sense of the past, including chronological reasoning, contextualisation, analysis of causation and consequence, evaluation of evidence, recognition of continuity and change, and consideration of historical perspectives. Seixas emphasises that historical thinking should constitute a central objective of history education rather than being treated as an incidental outcome of factual instruction [4; 4-8]. From this perspective, the quality of history teaching should be assessed not simply by the quantity of information students can recall, but by their capacity to use historical knowledge in analytical, interpretative, and evidence-based ways.

The systematic use of historical sources is consequently of particular pedagogical significance. Primary documents, official records, correspondence, memoirs, photographs, maps, newspaper reports, and other forms of historical evidence enable students to engage directly with representations of the past. Source-based instruction can develop students' ability to examine authorship, purpose, context, intended audience, perspective, and reliability. The comparison of multiple sources relating to the same historical event is particularly valuable because it demonstrates that historical accounts may differ according to the circumstances and perspectives from which they are produced. Students thereby acquire a more sophisticated understanding of the relationship between evidence and historical interpretation [10; 495-519].

The integration of literary works into history teaching may also contribute to the contextualisation and interpretation of historical processes. Literary texts can provide representations of social structures, cultural values, political circumstances, and individual experiences associated with particular historical periods. For example, selected passages from *The Book of Dede Korkut* may be employed as supplementary material in lessons concerning the social and cultural characteristics of medieval Turkic societies. Likewise, Leo Tolstoy's *War and Peace* may provide a literary perspective for discussing the Napoleonic Wars and early nineteenth-century European society, while Victor Hugo's *Les Misérables* may support the study of nineteenth-century French society, social inequality, and political transformation. Such works can enrich historical learning by presenting aspects of human experience that are not always fully conveyed through conventional historical narratives.

Nevertheless, the pedagogical use of literary texts requires a clear methodological distinction between literary representation and historical evidence. Literary works may contain fictional characters, reconstructed events, symbolic elements, and authorial interpretations and therefore cannot automatically be regarded as documentary sources. Their educational value lies primarily in their capacity to stimulate historical inquiry and facilitate interdisciplinary connections between historical, literary, and cultural knowledge. Comparative activities in which students examine a literary representation alongside documentary and scholarly sources can be particularly productive. Such activities encourage learners to distinguish between factual evi-

dence, historical interpretation, and artistic representation and thereby contribute to the development of critical source literacy.

The growing availability of educational technologies has further broadened the methodological resources available to history teachers. Digital archives, historical databases, interactive maps, virtual exhibitions, digital timelines, and multimedia materials can facilitate access to diverse forms of historical information and evidence. Properly designed technology-supported activities may encourage independent research, visual analysis, collaboration, and inquiry. However, technological innovation should not be equated with pedagogical effectiveness. Digital resources acquire educational value only when they are integrated purposefully into the instructional process and are directly related to learning objectives. Their use should therefore be guided by methodological considerations concerning source selection, learner activity, historical interpretation, and assessment [6; 3-7].

The teacher's professional competence constitutes a further determinant of methodological effectiveness. The application of pedagogical methods cannot be separated from teachers' knowledge of both historical content and instructional practice. Teachers must determine which method is appropriate for a particular learning objective, historical topic, group of learners, and classroom context. Consequently, methodological flexibility is more valuable than adherence to a single instructional model. A combination of explanatory instruction, source-based inquiry, collaborative learning, discussion, problem solving, and independent research may be required within a single instructional sequence.

Assessment practices should correspond to this broader understanding of history learning. Assessment focused exclusively on factual recall provides an incomplete representation of students' historical competence. More comprehensive assessment should also consider students' ability to analyse evidence, contextualise historical information, establish causal relationships, compare perspectives, and formulate coherent historical arguments. Analytical writing, source interpretation, project-based tasks, presentations, structured discussions, and formative assessment can provide opportunities to evaluate these dimensions of learning. Such assessment practices are consistent with the broader pedagogical objective of developing students who are capable of engaging critically and independently with historical knowledge.

The analysis therefore demonstrates that effective history teaching is best understood as a systematic pedagogical process in which diverse instructional methods are selected and combined according to clearly defined educational objectives. Learner-centred instruction, inquiry-based learning, problem-based approaches, interactive and collaborative activities, source analysis, literary materials, and educational technologies can complement one another when they are implemented within a coherent methodological framework. Their common pedagogical purpose is to move history education beyond the reproduction of factual information towards the development of historical thinking, critical analysis, evidence-based reasoning,

and independent interpretation. Research in history education consistently demonstrates the importance of engaging learners with evidence, historical questions, and competing interpretations in the development of disciplinary understanding [4; 4-8; 8; 35-38]. Therefore, the purposeful and context-sensitive application of effective pedagogical methods can contribute to a more rigorous, learner-centred, and intellectually meaningful model of history education.

CONCLUSION

The analysis demonstrates that the effectiveness of history teaching is closely associated with the purposeful selection and systematic integration of appropriate pedagogical methods. Contemporary history education increasingly emphasizes not merely the acquisition and reproduction of factual knowledge, but also the development of students' historical thinking, analytical reasoning, critical evaluation, and interpretative abilities. In this context, learner-centred, inquiry-based, problem-based, interactive, and collaborative approaches provide important pedagogical opportunities for engaging students in the systematic examination of historical processes and the interpretation of historical evidence.

The integration of primary and secondary historical sources, literary texts, visual materials, and digital resources further contributes to the diversification of the instructional process and facilitates a more comprehensive understanding of historical phenomena. However, the pedagogical effectiveness of these resources depends on their methodological appropriateness, contextual relevance, and alignment with clearly defined learning objectives. The teacher therefore remains a key agent in designing learning activities, guiding historical inquiry, and establishing an intellectually stimulating learning environment.

Overall, the findings suggest that an integrated and pedagogically grounded approach to history teaching can enhance students' academic engagement and contribute to the development of transferable cognitive competencies. Effective history education should consequently be understood as a dynamic process that combines substantive historical knowledge with analytical inquiry, critical interpretation, and independent learning. Such an approach can significantly strengthen the educational value of history and support the formation of learners capable of engaging with the past in a thoughtful, evidence-based, and critically informed manner.

References

1. Barton, K. C., Levstik, L. S. *Teaching History for the Common Good*. – Mahwah, NJ: Lawrence Erlbaum Associates, – 2004.
2. Lévesque, S. *Thinking Historically: Educating Students for the Twenty-First Century*. – Toronto: University of Toronto Press, – 2008.
3. Seixas, P. A Model of Historical Thinking // *Educational Philosophy and Theory*. – 2017. – Vol. 49, No. 6. – P. 593–605.
4. Seixas, P., Morton, T. *The Big Six Historical Thinking Concepts*. – Toronto: Nelson Education, – 2013.

5. Voet, M., De Wever, B. History Teachers' Knowledge of Inquiry Methods: An Analysis of Cognitive Processes Used During a Historical Inquiry // *Journal of Teacher Education*. – 2017. – Vol. 68, No. 3. – P. 312–329.

6. Whitehouse, J. A. Historical Thinking: A Framework for Learning and Teaching History // *Educational Practice and Theory*. – 2015. – Vol. 37, No. 2. – P. 51–58.

7. Wineburg, S. *Historical Thinking and Other Unnatural Acts: Charting the Future of Teaching the Past*. – Philadelphia: Temple University Press, – 2001.

*Khayala Natiq gizi Guliyeva**Baku State College of Communications and Transport under Azerbaijan Technical University**Azerbaijan Republic, Baku City*

Orcid ID number: 0009-0005-6793-5710

<https://doi.org/10.5281/zenodo.22996437>**MODERN TEACHING METHODS: METHODOLOGICAL PRINCIPLES AND APPROACHES***Хаяла Нати́з кызы Гулиева**Бакинский государственный колледж связи и транспорта при Азербайджанском техническом университете**Азербайджанская Республика, г. Баку*

ORCID: 0009-0005-6793-5710

СОВРЕМЕННЫЕ МЕТОДЫ ОБУЧЕНИЯ: МЕТОДОЛОГИЧЕСКИЕ ПРИНЦИПЫ И ПОДХОДЫ**Annotation.**

This article examines modern teaching methods from the perspective of methodological principles and contemporary pedagogical approaches. The study focuses on the theoretical foundations of teaching methodology and analyses the ways in which different instructional methods can contribute to the effective organisation of the educational process. Particular attention is given to student-centred learning, active learning, collaborative learning, problem-based learning, project-based learning, and differentiated instruction as significant components of modern teaching methodology. The article highlights the importance of selecting teaching methods in accordance with educational objectives, students' learning needs, the content of the subject, and the specific characteristics of the educational environment. It is argued that the effective application of teaching methods requires not only the appropriate selection of methodological tools but also their purposeful integration into the overall teaching process. The study concludes that modern teaching methodology should be flexible, evidence-based, and oriented towards the development of students' knowledge, skills, critical thinking, creativity, and active participation in the learning process. The findings may contribute to a more systematic understanding of contemporary teaching methodology and provide methodological considerations for improving the effectiveness of educational practices.

Аннотация.

В статье рассматриваются современные методы обучения с точки зрения методологических принципов и актуальных педагогических подходов. Основное внимание уделяется теоретическим основам методики преподавания и анализу возможностей различных методов обучения в эффективной организации образовательного процесса. Особое внимание уделяется личностно ориентированному и активному обучению, обучению в сотрудничестве, проблемному и проектному обучению, а также дифференцированному подходу как важным составляющим современной методики преподавания.

В статье подчеркивается важность выбора методов обучения в соответствии с образовательными целями, учебными потребностями обучающихся, содержанием преподаваемой дисциплины и особенностями образовательной среды. Отмечается, что эффективное применение методов обучения предполагает не только правильный выбор методических инструментов, но и их целенаправленную интеграцию в общий процесс преподавания.

В результате исследования делается вывод о том, что современная методика преподавания должна быть гибкой, опираться на научно обоснованные подходы и быть ориентированной на развитие знаний и навыков обучающихся, их критического мышления, творческих способностей и активного участия в образовательном процессе. Результаты исследования могут способствовать более системному пониманию современной методики преподавания и служить методологической основой для повышения эффективности образовательной практики.

Keywords: teaching methods, teaching methodology, methodological principles, pedagogical approaches, educational process, instructional strategies

Ключевые слова: методы обучения; методика преподавания; методологические принципы; педагогические подходы; образовательный процесс; стратегии обучения.

INTRODUCTION

The rapid transformation of contemporary education has significantly influenced the principles, approaches, and methods used in the teaching process. Changes in educational needs, the increasing diversity of learners, the development of new pedagogical approaches, and the growing emphasis on learning outcomes have created a need to reconsider traditional approaches to teaching methodology. In this context,

teaching methods are no longer viewed merely as techniques for transmitting knowledge; rather, they represent an important methodological component of an educational process aimed at developing learners' cognitive, practical, communicative, and analytical abilities.

Teaching methodology encompasses a system of principles, methods, techniques, and organisational approaches that determine how educational content is presented, how learning activities are structured, and how

interaction between teachers and learners is established. The appropriate selection and application of teaching methods are therefore essential for ensuring the effectiveness and coherence of the educational process. A teaching method cannot be considered effective independently of the educational objectives, content, learner characteristics, available resources, and specific learning environment in which it is applied.

Modern educational theory increasingly emphasises active participation, learner autonomy, collaboration, critical thinking, problem-solving, and the practical application of knowledge. Consequently, methods such as active learning, collaborative learning, problem-based learning, project-based learning, differentiated instruction, and student-centred learning have become important components of contemporary teaching methodology. These approaches seek to move the teaching process beyond the passive transmission of information and encourage learners to become active participants in constructing and applying knowledge.

At the same time, the increasing variety of available teaching methods creates an important methodological challenge: the selection of an appropriate method for a particular educational context. The effectiveness of a method depends not only on its theoretical value but also on the way it is adapted to learning objectives and implemented in practice. Therefore, methodological competence requires teachers to understand the principles underlying different teaching methods and to make informed decisions concerning their selection, combination, and application.

The relevance of studying modern teaching methods is also associated with the need to improve the quality and effectiveness of education. A systematic methodological approach enables teachers to establish a more purposeful relationship between educational objectives, teaching activities, learner engagement, assessment, and expected learning outcomes. From this perspective, contemporary teaching methodology should be understood as a flexible and dynamic system capable of responding to changing educational requirements.

The purpose of this article is to examine modern teaching methods from the perspective of their methodological principles and approaches. The study focuses on the conceptual foundations of contemporary teaching methodology, the main characteristics of modern teaching methods, and the factors that influence their effective selection and application. Particular attention is given to the relationship between teaching objectives, learner needs, instructional strategies, and educational outcomes.

The article contributes to the broader discussion of teaching methodology by emphasising the importance of a systematic and context-sensitive approach to the selection and implementation of teaching methods. Understanding these methodological principles can support the development of more effective educational practices and contribute to the continuous improvement of the teaching and learning process.

Modern Teaching Methods and Methodological Approaches

Modern teaching methods represent an important component of contemporary educational methodology and reflect the changing objectives, requirements, and principles of the teaching and learning process. Unlike traditional approaches that primarily emphasise the transmission and reproduction of knowledge, contemporary teaching methodology increasingly focuses on learners' active participation, independent thinking, problem-solving abilities, collaboration, and practical application of acquired knowledge [1; 2]. In this regard, teaching methods should be regarded not simply as a set of instructional techniques but as an organised system of pedagogical actions directed towards achieving specific educational objectives.

Teaching methodology is closely associated with the relationship between the teacher, learner, educational content, and learning environment. According to Richards and Rodgers, teaching methodology involves a systematic relationship between theoretical assumptions about language and learning and the procedures and practices through which teaching is implemented [3; 16-17]. Although their discussion primarily concerns language education, this methodological principle can be extended to teaching more broadly: the selection of a teaching method should be determined by clearly defined educational objectives and an appropriate understanding of how learning takes place.

One of the major characteristics of modern teaching methodology is the transition from teacher-centred instruction towards learner-centred approaches. Learner-centred education places greater emphasis on students' participation in the learning process and recognises individual differences in learners' abilities, needs, interests, and learning styles. Weimer argues that learner-centred teaching involves a reconsideration of the traditional distribution of responsibility between teachers and students and encourages learners to assume greater responsibility for their own learning [4; 75-76]. Consequently, the teacher increasingly performs the role of organiser, facilitator, and guide rather than functioning exclusively as a transmitter of information.

Active learning constitutes another significant methodological direction in contemporary education. Bonwell and Eison define active learning through learners' involvement in activities and their subsequent reflection on what they are doing [5; 2-3]. From a methodological perspective, active learning may include discussion, group work, problem-solving activities, case analysis, peer learning, debates, simulations, and other forms of purposeful learner engagement. Such methods create opportunities for students to process information, apply concepts, exchange ideas, and develop higher-order cognitive skills.

Problem-based learning is also considered an important contemporary methodological approach. It organises the learning process around meaningful problems that require learners to analyse information, identify possible solutions, and apply relevant knowledge. Barrows emphasises that problem-based learning places students in an active position in the learning process and encourages them to develop both knowledge and problem-solving skills [6; 482-483]. Thus, the

methodological value of this approach lies not only in the acquisition of subject-specific knowledge but also in the development of analytical and independent learning abilities.

Project-based learning represents another approach that integrates theoretical knowledge with practical activities. It allows learners to investigate a particular problem or topic over a period of time and produce a specific outcome. Thomas identifies several central characteristics of project-based learning, including the centrality of projects, learner autonomy, constructive investigation, and the connection of learning activities with real-world contexts [7; 3-4]. From the perspective of teaching methodology, project-based learning is particularly valuable because it promotes cooperation, responsibility, creativity, and the practical application of knowledge.

Collaborative learning also occupies an important position within modern teaching methodology. It is based on structured interaction among learners and encourages them to work together towards common educational objectives. Johnson, Johnson, and Smith emphasise the importance of positive interdependence, individual accountability, promotive interaction, and social skills in effective cooperative learning [8; 3-4]. Therefore, collaborative methods can contribute not only to academic development but also to communication, interpersonal interaction, and teamwork.

Differentiated instruction provides another methodological framework for responding to differences among learners. Tomlinson explains differentiation in terms of adapting teaching to learners' readiness, interests, and learning profiles [9; 1-3]. This approach requires teachers to vary instructional content, learning processes, activities, and expected outcomes according to learners' individual characteristics. Consequently, differentiation can be considered an important methodological principle for creating more inclusive and flexible educational environments.

The effectiveness of modern teaching methods depends substantially on their appropriate selection and contextual application. No single teaching method can be considered universally effective for all educational situations. The choice of a particular method should take into consideration the objectives of instruction, the nature of the subject matter, learners' age and educational background, class size, available resources, time constraints, and expected learning outcomes [2; 8-10]. Effective teaching therefore requires methodological flexibility and the ability to combine different approaches according to the specific requirements of the educational context.

An important methodological principle is the alignment of teaching methods with learning outcomes. Biggs and Tang emphasise the importance of constructive alignment, whereby teaching and learning activities and assessment are designed in accordance with the intended learning outcomes [10; 74-76]. This principle suggests that the selection of a teaching method should not be based merely on its popularity or novelty. Instead, the method should directly support the knowledge, skills, competencies, or attitudes that learners are expected to develop.

Digital technologies have further expanded the range of contemporary teaching methodologies. Digital learning environments, online collaboration tools, multimedia resources, virtual learning platforms, and interactive applications provide additional opportunities for organising learning activities. However, the integration of technology should be pedagogically justified. Technology itself does not guarantee effective learning; its educational value depends on how effectively it is incorporated into the methodological structure of the teaching process [11; 5-7].

Overall, modern teaching methodology can be understood as a flexible and systematic framework that combines different instructional methods according to educational objectives and contextual requirements. Learner-centred, active, problem-based, project-based, collaborative, differentiated, and technology-enhanced approaches represent significant methodological directions in contemporary education. Their effective implementation requires teachers to possess methodological competence, understand the principles underlying different methods, and make evidence-informed decisions concerning their selection and combination. Thus, the development of modern teaching methodology should be associated not with the complete rejection of traditional methods but with their purposeful integration with contemporary approaches in accordance with the objectives and conditions of the educational process.

CONCLUSION

Modern teaching methodology is an essential component of an effective educational process and plays a significant role in determining the quality of teaching and learning outcomes. The analysis demonstrates that contemporary teaching methods have gradually moved beyond the traditional transmission of knowledge towards approaches that emphasise active participation, learner autonomy, collaboration, critical thinking, problem-solving, and the practical application of knowledge.

The study shows that active learning, learner-centred education, problem-based learning, project-based learning, collaborative learning, differentiated instruction, and technology-enhanced learning provide diverse methodological opportunities for addressing the changing needs of contemporary learners. However, the effectiveness of these methods depends not only on their theoretical advantages but also on their appropriate selection and purposeful implementation within a particular educational context.

An important finding is that there is no universally applicable teaching method. The methodological choice should be determined by the objectives and content of instruction, learners' characteristics, available educational resources, classroom conditions, and expected learning outcomes. Therefore, effective teaching requires methodological flexibility and the ability to combine different approaches in accordance with specific pedagogical requirements.

The analysis also confirms the importance of the teacher's methodological competence. Teachers need to understand the theoretical foundations of different instructional approaches and possess the ability to adapt and integrate them according to learners' needs

and educational objectives. In this respect, the teacher's role increasingly extends beyond knowledge transmission to include the organisation, facilitation, monitoring, and evaluation of the learning process.

Consequently, modern teaching methodology should be viewed as a dynamic and continuously developing system. Its further improvement requires the integration of evidence-based pedagogical practices, appropriate use of digital technologies, attention to individual learner differences, and systematic evaluation of teaching effectiveness. A balanced combination of established and innovative teaching methods can contribute to creating a more interactive, inclusive, flexible, and outcome-oriented educational environment. Top of Form

References

1. Barrows, H.S. Problem-Based Learning in Medicine and Beyond: A Brief Overview / H.S. Barrows. – New Directions for Teaching and Learning. – 1996. – No. 68. – P. 3–12.
2. Biggs, J., Tang, C. Teaching for Quality Learning at University / J. Biggs, C. Tang. – 4th ed. – Maidenhead: Open University Press, – 2011. – 389 p.
3. Bonwell, C.C., Eison, J.A. Active Learning: Creating Excitement in the Classroom / C.C. Bonwell, J.A. Eison. – Washington, DC: George Washington University, – 1991. – 121 p.
4. Johnson, D.W., Johnson, R.T., Smith, K.A. Active Learning: Cooperation in the College Classroom / D.W. Johnson, R.T. Johnson, K.A. Smith. – 3rd ed. – Edina, MN: Interaction Book Company, – 2014. – 128 p.
5. Richards, J.C., Rodgers, T.S. Approaches and Methods in Language Teaching / J.C. Richards, T.S. Rodgers. – 3rd ed. – Cambridge: Cambridge University Press, – 2014. – 410 p.
6. Thomas, J.W. A Review of Research on Project-Based Learning / J.W. Thomas. – San Rafael, CA: Autodesk Foundation, – 2000. – 49 p.
7. Tomlinson, C.A. The Differentiated Classroom: Responding to the Needs of All Learners / C.A. Tomlinson. – 2nd ed. – Alexandria, VA: ASCD, – 2014. – 197 p.
8. Weimer, M. Learner-Centered Teaching: Five Key Changes to Practice / M. Weimer. – 2nd ed. – San Francisco: Jossey-Bass, – 2013. – 288 p.

Nishanova Tursunoy Abdivohidovna,
Associate Professor, Namangan State University

DEVELOPING COMMUNICATIVE COMPETENCE IN GERMAN THROUGH THE STEAM APPROACH

Abstract:

This article examines the methodological potential of the STEAM approach for developing communicative competence in German. The interdisciplinary nature of STEAM makes it possible to integrate German language learning with science, technology, engineering, arts, and mathematics, thereby creating meaningful opportunities for practical communication, collaboration, problem-solving, and creative thinking. Particular attention is paid to project-based learning, problem-solving tasks, collaborative activities, and presentations as mechanisms for developing communicative competence. The study argues that STEAM-based German language instruction can transform German from an isolated object of linguistic study into a practical means of inquiry, information exchange, collaborative decision-making, and project presentation. The analysis demonstrates that this approach can contribute to the development of learners' linguistic, sociolinguistic, strategic, collaborative, and creative abilities.

Keywords: STEAM approach, German language, communicative competence, interdisciplinary integration, project-based learning, problem-based learning, communicative language teaching, collaboration.

INTRODUCTION

The rapid development of science, technology, digital communication, and international cooperation has significantly changed the requirements placed on modern foreign language education. In contemporary educational contexts, the ability to memorize vocabulary and reproduce grammatical structures is no longer sufficient to ensure effective language use. Learners are increasingly expected to communicate independently, exchange information, cooperate with others, solve problems, interpret information, express and justify opinions, and use the target language appropriately in different social and professional contexts. Consequently, foreign language education needs approaches that connect linguistic knowledge with meaningful intellectual and practical activities[1].

German as a foreign language is taught in an increasingly complex educational environment in which learners may be expected to use the language not only for everyday communication but also for academic study, professional interaction, international mobility, and interdisciplinary collaboration. This situation requires a shift from purely form-oriented instruction towards learning environments in which language functions as a means of communication and action. In this regard, the integration of innovative interdisciplinary approaches into German language teaching has become increasingly relevant[2].

One of the approaches that can provide such opportunities is STEAM education. The term STEAM refers to Science, Technology, Engineering, Arts, and Mathematics. The approach developed from STEM education but expanded its scope by emphasizing creativity, design, communication, and the human dimensions of problem-solving. Yakman conceptualized STEAM as an integrative educational framework in which different areas of knowledge are connected rather than taught in isolation. Yakman and Lee further emphasized the potential of STEAM as a practical framework for interdisciplinary education [3].

Although STEAM is frequently associated with science and technology education, its principles can be

extended to foreign language learning. Language is the primary means through which learners access information, discuss problems, exchange ideas, negotiate solutions, and present the outcomes of their activities. Therefore, when STEAM principles are incorporated into German language instruction, German can become an authentic medium for interdisciplinary communication.

The concept of communicative competence is central to this process. Hymes (1972) challenged the idea that language competence could be reduced to grammatical knowledge and emphasized the importance of knowing how to use language appropriately in social contexts. Canale and Swain (1980) subsequently developed a broader model of communicative competence that included grammatical, sociolinguistic, discourse, and strategic dimensions. Contemporary language education continues to emphasize the importance of meaningful language use. The Common European Framework of Reference for Languages views learners as social agents who use language to perform communicative activities in specific contexts [4].

This perspective is particularly relevant to STEAM-based German instruction because interdisciplinary projects naturally require learners to perform communicative actions. For example, when learners design a sustainable city, they need to discuss environmental problems, analyze data, compare possible solutions, negotiate decisions, create a visual representation, and present the final project. Each of these activities creates a reason to use German.

The main purpose of this article is to examine the methodological potential of the STEAM approach for developing communicative competence in German and to demonstrate how interdisciplinary project-based activities can create meaningful contexts for language use. Particular attention is paid to the relationship between STEAM principles and communicative language teaching, the role of project-based activities, and the development of linguistic, sociolinguistic, strategic, collaborative, and creative skills [5].

LITERATURE REVIEW

The theoretical foundations of STEAM education are connected with interdisciplinary learning, inquiry, creativity, problem-solving, and the practical application of knowledge. Yakman (2008) describes STEAM as an educational framework that integrates several areas of knowledge in order to provide learners with a more holistic understanding of complex phenomena. Rather than treating disciplines as separate domains, STEAM encourages learners to identify relationships between them [6].

Yakman and Lee emphasize that STEAM can serve as a practical educational framework because it encourages learners to connect knowledge with real-world situations. The significance of this principle for language learning lies in the fact that communication itself is usually connected with real-world purposes. People use language to obtain information, solve problems, make decisions, cooperate, and communicate ideas. Therefore, the use of German within STEAM projects can provide learners with a more authentic communicative environment.

The problem-solving orientation of STEAM is also consistent with contemporary views of effective learning. Bybee emphasizes the importance of applying knowledge to authentic problems and developing learners' ability to investigate and solve problems. When these principles are applied to German language education, learners can use the target language as a tool for analyzing interdisciplinary problems rather than simply as a collection of linguistic structures [7].

The development of communicative competence provides another important theoretical foundation. Hymes argued that linguistic competence involves knowledge of appropriate language use in particular social situations. Canale and Swain further conceptualized communicative competence as a multidimensional construct that includes grammatical and sociolinguistic knowledge as well as strategic abilities. These perspectives demonstrate that successful language learning requires opportunities for meaningful interaction [8].

The CEFR Companion Volume also emphasizes the role of interaction, mediation, reception, and production in language use. From this perspective, learners need to be able to understand information, communicate with others, produce spoken and written texts, and mediate information between participants. STEAM projects can incorporate all of these activities within a single learning experience [9].

Project-based learning provides a particularly strong connection between STEAM and foreign language education. Ellis emphasizes the importance of meaningful tasks in language learning, arguing that learners can develop language through activities that require them to use language for specific purposes. A STEAM project can therefore provide an extended task environment in which communication is necessary for successful completion [10].

Content and Language Integrated Learning also offers a relevant theoretical perspective. Coyle, Hood, and Marsh demonstrate that language and subject content can be taught together in ways that create meaningful learning contexts. Although STEAM-based German

instruction is not identical to CLIL, both approaches recognize the pedagogical value of integrating language with meaningful content.

The literature therefore suggests a strong conceptual relationship between STEAM, communicative language teaching, task-based learning, and interdisciplinary education. However, the specific application of STEAM principles to German language learning remains an area in which further methodological development is needed. The present article addresses this issue by proposing a practical framework for integrating STEAM activities into German language instruction [11].

MATERIALS AND METHODS

The present research is theoretical and methodological in nature. Its primary purpose is to identify the potential of STEAM-based instruction for developing communicative competence in German and to formulate methodological principles for its classroom implementation.

The study employed analysis of scientific and methodological literature, comparative analysis, pedagogical observation, methodological modelling, and analysis of potential classroom activities. The theoretical framework was constructed around four complementary approaches: communicative language teaching, interdisciplinary education, project-based learning, and collaborative learning.

The proposed instructional process begins with a meaningful interdisciplinary problem. Instead of introducing language structures independently, the teacher establishes a situation that requires learners to communicate. The problem may concern environmental protection, sustainable transport, technological innovation, urban planning, renewable energy, digital technologies, or another topic appropriate to the learners' linguistic and cognitive level.

After the problem has been introduced, learners investigate relevant information. At this stage, German can be used for reading, listening, searching for information, interpreting visual materials, and discussing findings. The teacher provides linguistic support through vocabulary, sentence patterns, discourse markers, and communicative expressions.

The next stage involves collaborative discussion. Learners exchange information, compare perspectives, and negotiate possible solutions. This stage is particularly important for communicative competence because learners must respond to one another rather than simply produce isolated sentences.

The following stage involves the development of a product or solution. Depending on the topic, learners may create a poster, infographic, model, digital presentation, diagram, video script, or project proposal. The product itself is less important than the communicative and interdisciplinary process through which it is developed.

The final stage is presentation and reflection. Learners present the results of their work in German and respond to questions from classmates. They then reflect on the content they learned, the language they used, the difficulties they encountered, and the effectiveness of their collaboration.

This methodological sequence can be represented as a continuous process of problem identification, inquiry, communication, solution development, product creation, presentation, and reflection. The essential principle is that German should remain a functional medium throughout the process rather than being limited to a separate language exercise.

RESULTS

The analysis demonstrates that STEAM-based German language instruction can support the development of several dimensions of communicative competence simultaneously. The interdisciplinary structure of STEAM creates situations in which learners must use language for specific purposes, while the collaborative nature of the activities increases opportunities for interaction.

One of the most important outcomes is the development of linguistic competence. Learners encounter vocabulary and grammatical structures within meaningful contexts. For example, a project on sustainable transportation may require learners to use vocabulary related to traffic, pollution, energy, public transport, cycling, and urban planning. Instead of memorizing these words in isolation, learners use them to explain problems and propose solutions.

Grammar can also be integrated into communicative tasks. Modal verbs may be used to make recommendations, comparative structures can be used to evaluate alternatives, causal clauses can be used to explain reasons, and conditional structures can be used to discuss hypothetical solutions. In this way, grammar becomes a resource for expressing meaning.

Another important result concerns sociolinguistic competence. Group discussions and presentations expose learners to different communicative purposes and levels of formality. During informal group work, learners may ask classmates for opinions or clarification. During a formal presentation, they may need to introduce a topic, explain a process, present evidence, and answer questions. Such variation helps learners understand that effective communication involves not only grammatical accuracy but also appropriateness.

Strategic competence can also be developed through STEAM activities. Open-ended tasks frequently create communication problems because learners may not know a particular word or expression. Instead of stopping communication, learners can use paraphrasing, clarification, repetition, gestures, synonyms, or requests for assistance. These strategies are essential for maintaining communication in real-life situations [12].

The collaborative nature of STEAM provides further benefits. Learners must distribute responsibilities, listen to each other, express agreement or disagreement, and reach collective decisions. This type of interaction is particularly valuable because communication becomes necessary for task completion. Learners therefore experience a stronger communicative purpose than in exercises that require them merely to repeat predetermined language. The relationship between STEAM components and communicative development can be summarized in the following table.

Table 1.

STEAM Components and communicative competence development

STEAM component	Application in German language learning	Communicative competence developed
Science	Discussing scientific phenomena, environmental issues, and evidence	Explaining, describing, expressing opinions
Technology	Using digital resources and presenting technological solutions	Information exchange and digital communication
Engineering	Designing solutions to practical problems	Negotiation, cooperation, problem-solving
Arts	Creating posters, videos, visual designs, and presentations	Creative expression and presentation skills
Mathematics	Interpreting statistics, percentages, measurements, and diagrams	Comparing, interpreting, explaining, drawing conclusions

The table demonstrates that each STEAM component can contribute to communicative development when it is integrated with an explicit language objective. Science can provide content for explanation and discussion, technology can create opportunities for information exchange, engineering can require negotiation, arts can support creative expression, and mathematics can encourage learners to interpret and communicate quantitative information.

An example of such integration can be found in the topic “Meine nachhaltige Stadt”. Learners can be asked to design a sustainable city for a particular population. They need to decide how people will travel, how

energy will be produced, where green spaces will be located, and how waste will be managed. In order to complete the task, they communicate in German, use relevant vocabulary, interpret data, negotiate solutions, and finally present their city.

During this activity, learners may use expressions such as “Meiner Meinung nach...”, “Wir könnten...”, “Ich stimme dir zu...”, “Ich bin nicht ganz einverstanden...”, “Unser Vorschlag ist...”, and “Die Daten zeigen, dass...”. These expressions correspond to important communicative functions such as expressing opinions, making suggestions, agreeing, disagreeing, presenting evidence, and drawing conclusions.

Another possible project is related to renewable energy. Learners can investigate different energy sources and develop a model of an energy-efficient house. Science provides the content, technology provides the digital resources, engineering contributes to the design process, mathematics can be used to interpret energy consumption data, and arts can contribute to the visual presentation. German functions as the common language through which the project is discussed and presented.

DISCUSSION

The results indicate that the main pedagogical value of STEAM in German language teaching lies in its ability to create meaningful reasons for communication. In conventional language lessons, learners may sometimes speak simply because the teacher has assigned a speaking exercise. In STEAM-based learning, communication is connected with a concrete intellectual or practical goal.

This distinction is important because meaningful communication involves a need to exchange information. If learners already know everything that their partner knows, communication may become predictable. STEAM projects, however, can distribute information among group members and require learners to exchange their findings. Each learner may therefore possess information that is necessary for the completion of the task.

The approach is consistent with the principles of task-based language learning. Ellis (2003) emphasizes that meaningful tasks can create opportunities for learners to use language in order to achieve a non-linguistic outcome. In a STEAM project, the final outcome may be a design, model, presentation, or solution. German becomes the means through which learners achieve that outcome. The approach is also compatible with the CEFR perspective on language learners as social agents. Learners are not passive recipients of linguistic information; they use language to participate in activities. STEAM projects provide precisely this kind of participation.

Another important aspect is the development of higher-order thinking. Language learning is sometimes separated from intellectual development, particularly when lessons focus heavily on memorization and controlled practice. STEAM challenges this separation by requiring learners to analyze, compare, evaluate, design, and create while using German. The Arts component is particularly significant because it broadens the concept of communication. Communication does not occur only through spoken sentences. Visual design, digital storytelling, posters, diagrams, and presentations can all support meaning-making. Learners can therefore combine linguistic and visual resources when communicating their ideas.

Nevertheless, the implementation of STEAM in German language teaching requires careful planning. One potential difficulty is the cognitive and linguistic complexity of interdisciplinary tasks. If learners have insufficient German proficiency, they may revert to their first language during group work. Teachers should therefore provide appropriate scaffolding, including

vocabulary banks, sentence frames, functional expressions, visual support, and model texts.

Another issue concerns the balance between content and language. The purpose of the lesson is not simply to teach science or technology in German. The interdisciplinary content should serve as a context for language development. Therefore, each project should have explicit linguistic objectives alongside its content objectives. Assessment also requires careful consideration. Traditional language assessment often focuses on grammar, vocabulary, reading, and writing. STEAM-based instruction requires a broader assessment framework that also considers interaction, fluency, collaboration, problem-solving, creativity, and presentation. For example, a teacher may evaluate whether learners can explain their ideas clearly, respond appropriately to questions, use topic-specific vocabulary, cooperate with group members, and justify their proposed solution. Such assessment provides a more comprehensive picture of communicative competence.

STEAM-based German instruction can therefore be understood as an integrated learning environment in which language, content, cognition, creativity, and collaboration interact. The effectiveness of the approach depends on the quality of task design and the teacher's ability to maintain a clear connection between interdisciplinary content and language objectives.

CONCLUSION

The integration of the STEAM approach into German language teaching provides substantial methodological opportunities for developing communicative competence. By combining Science, Technology, Engineering, Arts, and Mathematics with language learning, teachers can create meaningful educational situations in which German functions as a practical tool for inquiry, interaction, collaboration, problem-solving, and presentation.

The analysis shows that STEAM activities can contribute to the development of linguistic, sociolinguistic, strategic, collaborative, creative, and critical-thinking abilities. Project-based activities provide learners with opportunities to use vocabulary and grammar in context, while group work creates authentic reasons for interaction. Problem-solving activities encourage learners to negotiate meaning, express opinions, justify decisions, and respond to alternative perspectives.

The integration of STEAM should not be understood as simply adding interdisciplinary topics to an existing language lesson. Its methodological value emerges when the interdisciplinary problem and the language objectives are deliberately integrated. Learners should have a genuine communicative reason to use German while working with scientific, technological, engineering, artistic, or mathematical content. For effective implementation, teachers should select problems that correspond to learners' linguistic proficiency, provide appropriate language scaffolding, organize collaborative interaction, and assess both language performance and project participation. When these conditions are fulfilled, STEAM can contribute to a more active, meaningful, and communicative German language learning environment.

Thus, STEAM-based German language instruction can be regarded as a promising interdisciplinary model for developing communicative competence. It connects language learning with real-world problems and transforms the target language from a purely academic subject into a functional instrument of communication, inquiry, creativity, and collaborative action.

References

1. Bybee, R. W. (2013). *The Case for STEM Education: Challenges and Opportunities*. Arlington, VA: NSTA Press.
2. Canale, M., & Swain, M. (1980). Theoretical bases of communicative approaches to second language teaching and testing. *Applied Linguistics*, 1(1), 1–47.
3. Council of Europe. (2020). *Common European Framework of Reference for Languages: Learning, Teaching, Assessment – Companion Volume*. Strasbourg: Council of Europe.
4. Coyle, D., Hood, P., & Marsh, D. (2010). *CLIL: Content and Language Integrated Learning*. Cambridge: Cambridge University Press.
5. Ellis, R. (2003). *Task-Based Language Learning and Teaching*. Oxford: Oxford University Press.
6. Hymes, D. (1972). On communicative competence. In J. B. Pride & J. Holmes (Eds.), *Sociolinguistics* (pp. 269–293). Harmondsworth: Penguin.
7. Yakman, G. (2008). *STEAM Education: An Overview of Creating a Model of Integrative Education*. Proceedings of the Pupils' Attitudes Towards Technology Conference.
8. Yakman, G., & Lee, H. (2012). Exploring the exemplary STEAM education in the U.S. as a practical educational framework for Korea. *Journal of the Korean Association for Science Education*, 32(6), 1072–1086.
9. Nargiza, D., & Palina, B. (2019). Features of the english translation of Russian-Speaking realities in the texts of fiction novels. *Academicia: An International Multidisciplinary Research Journal*, 9(4), 117–121.
10. Khakimjonovna, B. P. (2020). Development of coherent speech of students of technical universities in english language education process. *European Journal of Research and Reflection in Educational Sciences* Vol, 8(11).
11. Нишанова, Т. А. (2017). Учёт психологических особенностей учащихся в обучении иностранному языку. *NovaInfo. Ru*, 5(58), 349–352.
12. Нишанова, Т. 15. Роль и использование игровых технологий на уроках иностранного языка. In *Conference Paper "Modern Approaches and Methods of Teacher Training" for German language teachers* (p. 62).

TECHNICAL SCIENCES

UDC 664.8.037.1:635.649

Kalaida K.,

PhD in Agricultural Sciences, Associate Professor

Haidai I.,

PhD in Technical Sciences, Associate Professor

Uman National University, Uman, Ukraine

<https://doi.org/10.5281/zenodo.22996457>

NUTRITIONAL AND ENERGY POTENTIAL OF SWEET PEPPER CULTIVARS AS HIGH-QUALITY PLANT-BASED RAW MATERIALS FOR THE FOODSERVICE INDUSTRY

Abstract

This article substantiates the selection and evaluation of sweet pepper (*Capsicum annuum* L.) cultivars and hybrids at the biological stage of ripeness as high-quality plant-based raw materials for the restaurant and foodservice industry (HoReCa). The study presents an analysis of 65 cultivars and hybrids of red sweet pepper based on dry matter content, primary nutrients (proteins, fats, digestible carbohydrates), energy potential, and thermodynamic state (entropy). The dry matter content was found to vary significantly across ripeness groups, ranging from 4.7% to 11.0%. Out of the studied assortment, only 11 cultivars and hybrids (including Prytavit F1, Skrivia, Centuri F1, Liubov F1, Favilla, etc.) demonstrated high energy value combined with superior commodity characteristics such as pericarp wall thickness, fruit weight, and marketability. The findings emphasize the need to optimize the cultivated assortment of sweet pepper to establish a reliable, high-value plant raw material base for culinary technologies and the restaurant sector.

Keywords: plant-based raw material, restaurant industry, foodservice, sweet pepper, nutritional value, energy potential, commodity evaluation, cultivars and hybrids.

Introduction

The biological principles governing the functioning of living organisms are rooted in the fundamental laws of physics and chemistry; however, their manifestation in open biological systems is characterized by specific features [1,2]. In particular, the fundamental thermodynamic concept of entropy acquires a distinct meaning in living organisms, where metabolic processes involving the transformation of matter and energy constitute a complex self-regulating system. The bioenergetic and thermal balance of an organism is governed by the first law of thermodynamics: the intake of nutrients (proteins, fats, and carbohydrates) is equivalent to the amount of energy released, confirming that living organisms do not generate primary “new” energy and are therefore absolutely dependent on external sources of dietary nutrients.

In this context, sweet pepper (*Capsicum annuum* L.) is of particular value as a high-quality plant-based raw material for food technologies and the hospitality and foodservice sector (HoReCa) [3,4]. Sweet pepper fruits are a valuable source of dry matter, digestible carbohydrates, vitamins, and antioxidant compounds, which play a crucial role in maintaining human energy metabolism and biochemical homeostasis [5,6].

Recent international studies have demonstrated that the contents of dry matter, total sugars, and bioactive compounds vary considerably depending on genotype, cultivar, and fruit maturity stage [7,8]. In particular, the accumulation of sugars and total soluble solids (TSS) represents an important quality parameter for the assessment of raw materials, determining not only their energy potential but also their sensory and technological suitability for culinary processing and foodservice applications [9]. The attainment of biological maturity

is accompanied by increased accumulation of dry matter and vitamin compounds, providing a rationale for the careful selection and evaluation of sweet pepper cultivars as a high-quality raw-material base for the foodservice industry.

The aim of this study was to determine the entropy of sweet pepper cultivars included in the State Register of Plant Varieties of Ukraine and to classify cultivars of different maturity groups according to their thermal state.

Based on the above considerations, the study was not intended to investigate the forms in which energy is stored, transported, and utilized in living organisms through so-called “macroergic bonds” in ATP and other macroergic compounds. Rather, the objective was to investigate the energy potential of sweet pepper cultivars at the stage of biological maturity as a genetic factor determining their consumer value. This issue is relevant both for the assessment of fruit as a food product and for evaluating its quality throughout the supply chain from field to consumer.

In determining the energy value of sweet pepper fruits, the energy contributions of proteins, fats, and digestible carbohydrates were taken into account, although a certain amount of energy may also be derived from other compounds. In addition, the energy value depends on the digestibility and utilization of nutrients by the human body. Under conditions of a mixed diet in adults, the average digestibility of proteins is 84.5%, carbohydrates 95.6%, and fats 94%.

To evaluate sweet pepper fruits as a standardized plant-based raw material for the foodservice and restaurant industry (HoReCa), both theoretical and metabolizable energy values were determined. Energy conversion factors upon nutrient oxidation in the human body

were defined as 16.7 kJ/g (4.00 kcal/g) for proteins, 37.7 kJ/g (9.00 kcal/g) for fats, and 15.7 kJ/g (3.75 kcal/g) for digestible carbohydrates.

Theoretical energy value ($E_{\text{theoretical}}$) per 100 g of biological maturity edible portion (containing 1.3% protein, 0.5% fat, and 5.0% carbohydrates) was calculated without accounting for digestibility: $E_{\text{theoretical}} = 1.3 \cdot 16.7 + 0.5 \cdot 37.7 + 5.0 \cdot 15.7 = 119.06 \text{ kJ}$ (28.40 kcal).

Actual metabolizable energy value ($E_{\text{metabolizable}}$) was derived by incorporating nutrient digestibility coefficients for mixed diets (proteins: 84.5%, fats: 94.0%, carbohydrates: 95.6%): $E_{\text{metabolizable}} = (1.3 \cdot 16.7 \cdot 0.845) + (0.5 \cdot 37.7 \cdot 0.940) + (5.0 \cdot 15.7 \cdot 0.956) = 111.00 \text{ kJ}$ (26.54 kcal).

This approach provides a quantitative tool for calculating the exact nutritional and caloric specifications required in culinary processing and standardized menu design.

The study evaluated 65 red-fruited sweet pepper (*Capsicum annuum* L.) cultivars and hybrids at the biological stage of ripeness to determine their competitive potential, dry matter content, energy value, and thermodynamic state (entropy). The thermodynamic state was utilized as an indicator of physiological and biochemical activity, natural disease resistance, and postharvest storage potential, which are paramount for fresh supply chain management in the foodservice sector.

Based on proportional nutrient distribution, the dry matter of sweet pepper fruits at biological maturity comprises 14.44% proteins, 3.33% fats, and 63.33% total carbohydrates.

Among the 19 early-maturing cultivars and hybrids, the mean dry matter content was 7.54% (ranging from 4.9% to 9.6%). Consequently, the metabolizable energy density varied considerably (Table 1):

- High-energy raw material group (26.99–31.22 kcal/100g / 112.96–130.65 kJ/100g): Exhibited by genotypes with superior dry matter accumulation, including hybrids *Prytavit F1* (9.6%), *Slavi F1* (9.0%), *Rafaella F1* (8.3%), *Salamander* (8.3%), and cultivar *Skrivia* (9.1%).

- Standard raw material group (15.90–25.69 kcal/100g / 66.69–107.52 kJ/100g): Encompassing the remaining 14 early-maturing genotypes with dry matter levels between 4.9% and 7.9%.

From a culinary processing perspective, high dry matter in cultivars such as *Prytavit F1* and *Skrivia* reduces moisture loss during thermal treatment and yields denser, flavor-rich culinary preparations. Conversely, although *Salamander* yielded high energy values, its commodity limitations (thin pericarp wall of 2 mm, low marketability score, competitiveness coefficient of 0.52) reduce its commercial suitability for restaurant preparation compared to premium cultivars like *Skrivia* and *Prytavit F1*.

Among the 19 early-maturing cultivars and hybrids evaluated, only five demonstrated high energy values suitable for premium food applications. Notably, the high-yielding cultivar *Salamander* (5 points for

yield) was constrained by low marketability (2 points), moderate fruit weight (3 points), and a thin pericarp wall (2 points; 2 mm). Consequently, its overall competitiveness coefficient reached only 0.52, ranking it ninth among early-maturing genotypes. Only *Skrivia* and *Prytavit F1* achieved top-tier competitive standing by combining high energy density with thick pericarp walls and high marketability.

Within the mid-early maturity group (Table 2), *Centuri F1* (32.2 kcal / 134.7 kJ), *Myroliubivskyi F1* (29.3 kcal / 122.5 kJ), *Chervonyi Dyvosvit* (28.0 kcal), and *Samotsvit* (27.0 kcal) presented high energy values. However, *Myroliubivskyi F1* exhibited a wall thickness of only 2 mm, reducing its culinary processing suitability and competitive score relative to *Centuri F1*.

The mid-season group was the largest, comprising 25 genotypes (Table 3). Despite this diversity, the top five competitive ranks were secured by *Liubov F1* (35.8 kcal / 149.7 kJ; 11.0% dry matter), *Favilla* (32.2 kcal / 134.7 kJ), *Feia* (28.9 kcal), *Mercedes* (27.3 kcal), and *Antei* (26.0 kcal). These genotypes successfully combine high energy yield with thick pericarp walls and superior commercial marketability.

Mid-late and late-maturing cultivars exhibited moderate energy values ranging between 22.1 and 24.7 kcal (92.5–103.4 kJ) per 100 g.

Conclusions

Out of the 65 sweet pepper (*Capsicum annuum* L.) cultivars and hybrids evaluated at the biological stage of ripeness, only 11 demonstrated high energy density. When critical commodity and culinary processing traits (such as pericarp wall thickness, fruit mass, and marketability) were integrated into the comprehensive evaluation, the number of top-tier candidates suitable for the foodservice and restaurant industry (HoReCa) was narrowed down further.

The current selection and registration framework for plant varieties in Ukraine often underrepresents key quality indicators, including biochemical composition, technological yield, and disease resistance. Aligning registration criteria with actual nutritional and processing characteristics is crucial for building a high-value plant-based raw material base and strengthening national export potential.

It is strongly recommended to streamline the sweet pepper variety list by excluding low-yielding, non-competitive genotypes. Reallocating agricultural resources toward superior, highly competitive cultivars and hybrids (e.g., *Prytavit F1*, *Skrivia*, *Centuri F1*, *Liubov F1*, *Favilla*) will optimize supply chains for both domestic culinary applications and international markets.

The evaluation of newly bred cultivars should be conducted by specialized agricultural research institutions to ensure unbiased assessment of their consumer, culinary, and agronomic value prior to commercial release. Future research should focus on monitoring thermodynamic state (entropy changes) during fruit ripening to establish precise harvesting schedules and optimal postharvest cold storage parameters for premium plant raw materials.

Table 1

Energy Value of Early-Maturing Sweet Pepper Fruits

No.	Cultivar	Dry matter, %	Content, %			Energy value, kcal			Energy value, kJ			Total energy value	
			Proteins	Fats	Carbohydrates	Proteins	Fats	Carbohydrates	Proteins	Fats	Carbohydrates	kcal	kJ
1	Aden	7.8	1.13	0.26	4.94	4.51	2.34	18.52	18.81	9.79	77.55	25.37	106.16
2	Amulet	7.2	1.04	0.24	4.56	4.16	2.16	17.10	17.36	9.04	71.59	23.42	97.99
3	Atlant	6.0	0.87	0.20	3.80	3.47	1.80	14.25	14.47	7.53	59.66	19.51	81.66
4	Barbi F1	6.3	0.91	0.21	3.99	3.64	1.89	14.96	15.19	7.91	62.64	20.49	85.74
5	Danai	7.2	1.04	0.24	4.56	4.16	2.16	17.10	17.36	9.04	71.59	23.42	97.99
6	Denis F1	6.3	0.91	0.21	3.99	3.64	1.89	14.96	15.19	7.91	62.64	20.49	85.74
7	Gypsy F1	7.1	1.03	0.24	4.50	4.10	2.13	16.86	17.12	8.91	70.59	23.09	96.63
8	Dimentio F1	7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.72	103.43
9	Zlahoda F1	7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.72	103.43
10	Quadri F1	7.9	1.14	0.26	5.00	4.56	2.37	18.76	19.05	9.92	78.55	25.69	107.52
11	Krasnyi Rytsar F1	7.9	1.14	0.26	5.00	4.56	2.37	18.76	19.05	9.92	78.55	25.69	107.52
12	Lumhi F1	7.5	1.08	0.25	4.75	4.33	2.25	17.81	18.09	9.42	74.57	24.39	102.07
13	Monanta	4.9	0.71	0.16	3.10	2.83	1.47	11.64	11.82	6.15	48.72	15.94	66.69
14	Prytavit F1	9.6	1.39	0.32	6.08	5.54	2.88	22.80	23.15	12.05	95.45	31.22	130.65
15	Rafaela F1	8.3	1.20	0.28	5.26	4.79	2.49	19.71	20.02	10.42	82.53	26.99	112.96
16	Salamander	8.3	1.20	0.28	5.26	4.79	2.49	19.71	20.02	10.42	82.53	26.99	112.96
17	Skrivia	9.1	1.31	0.30	5.76	5.26	2.73	21.61	21.94	11.42	90.48	29.59	123.85
18	Slavi F1	9.0	1.30	0.30	5.70	5.20	2.70	21.37	21.70	11.30	89.49	29.27	122.49
19	Telestar F1	7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.72	103.43
	Mean	7.54	1.09	0.25	4.77	4.35	2.26	17.90	18.17	9.46	74.94	24.51	102.57
	Max	9.6	1.39	0.32	6.08	5.54	2.88	22.80	23.15	12.05	95.45	31.22	130.65
	Min	4.9	0.71	0.16	3.10	2.83	1.47	11.64	11.82	6.15	48.72	15.90	66.69

Table 2

Energy Value of Mid-Early Sweet Pepper Fruits

No.	Cultivar	Dry Matter %, DM	Content, %			Energy value, kcal			Energy value, kJ			Total energy value	
			Proteins	Fats	Carbohydrates	Proteins	Fats	Carbohydrates	Proteins	Fats	Carbohydrates	kcal	kJ
1	Baktyanets	6.0	0.87	0.20	3.80	3.47	1.80	14.25	14.47	7.53	59.66	19.5	81.7
2	Boneta	7.0	1.01	0.23	4.43	4.04	2.10	16.62	16.88	8.79	69.60	22.8	95.3
3	Valiusha	7.4	1.07	0.25	4.69	4.27	2.22	17.57	17.84	9.29	73.58	24.1	100.7
4	Hercules F1	5.6	0.81	0.19	3.55	3.23	1.68	13.30	13.50	7.03	55.68	18.2	76.2
5	Holubok	7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.7	103.4
6	Zlata	8.1	1.17	0.27	5.13	4.68	2.43	19.24	19.53	10.17	80.54	26.3	110.2
7	Lada	6.7	0.97	0.22	4.24	3.87	2.01	15.91	16.16	8.41	66.62	21.8	91.2
8	Madonna F1	7.9	1.14	0.26	5.00	4.56	2.37	18.76	19.05	9.92	78.55	25.7	107.5
9	Myrolubivskiy F1	9.0	1.30	0.30	5.70	5.20	2.70	21.37	21.70	11.30	89.49	29.3	122.5
10	Mintos F1	5.0	0.72	0.17	3.17	2.89	1.50	11.87	12.06	6.28	49.71	16.3	68.0
11	Obrii	7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.7	103.4
12	Poltavskiy	7.2	1.04	0.24	4.56	4.16	2.16	17.10	17.36	9.04	71.59	23.4	98.0
13	Samotsvit	8.3	1.20	0.28	5.26	4.79	2.49	19.71	20.02	10.42	82.53	27.0	113.0
14	Snihur	7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.7	103.4
15	Siaivo	8.1	1.17	0.27	5.13	4.68	2.43	19.24	19.53	10.17	80.54	26.3	110.2
16	Flamingo F1	7.2	1.04	0.24	4.56	4.16	2.16	17.10	17.36	9.04	71.59	23.4	98.0
17	Centuri F1	9.9	1.43	0.33	6.27	5.72	2.97	23.51	23.87	12.43	98.43	32.2	134.7
18	Cynthia F1	7.0	1.01	0.23	4.43	4.04	2.10	16.62	16.88	8.79	69.60	22.8	95.3
19	Chervonyi Dyvosvit	8.6	1.24	0.29	5.45	4.97	2.58	20.42	20.74	10.80	85.51	28.0	117.0
Mean		7.5	1.08	0.25	4.73	4.31	2.24	17.72	18.00	9.37	74.20	24.27	101.57
Max		9.9	1.43	0.33	6.27	5.72	2.97	23.51	23.87	12.43	98.43	32.20	134.70
Min		5.0	0.72	0.17	3.17	2.89	1.50	11.87	12.06	6.28	49.71	16.30	68.00

Table 3

Energy Value of Mid-Season, Mid-Late, and Late-Maturing Sweet Pepper Fruits

No.	Cultivar	Dry matter, %	Content, %			Energy value, kcal			Energy value, kJ			Total energy value	
			Proteins	Fats	Carbohydrates	Proteins	Fats	Carbohydrates	Proteins	Fats	Carbohydrates	kcal	kJ
1	Ivanhoe	7.1	1.03	0.24	4.50	4.10	2.13	16.86	17.12	8.91	70.59	23.1	96.6
2	Acteon	6	0.87	0.20	3.80	3.47	1.80	14.25	14.47	7.53	59.66	19.5	81.7
3	Ami	6.8	0.98	0.23	4.31	3.93	2.04	16.15	16.40	8.54	67.61	22.1	92.5
4	Antei	8	1.16	0.27	5.07	4.62	2.40	19.00	19.29	10.04	79.54	26.0	108.9
5	Aristotel Kh3R F1	6.2	0.90	0.21	3.93	3.58	1.86	14.72	14.95	7.78	61.65	20.2	84.4
6	Bahrianyi Vulkan	7.2	1.04	0.24	4.56	4.16	2.16	17.10	17.36	9.04	71.59	23.4	98.0
7	Beatrix	6.7	0.97	0.22	4.24	3.87	2.01	15.91	16.16	8.41	66.62	21.8	91.2
8	Beia	5	0.72	0.17	3.17	2.89	1.50	11.87	12.06	6.28	49.71	16.3	68.0
9	Bila Zirka	6.5	0.94	0.22	4.12	3.75	1.95	15.44	15.67	8.16	64.63	21.1	88.5
10	Boyard F1	6.3	0.91	0.21	3.99	3.64	1.89	14.96	15.19	7.91	62.64	20.5	85.7
11	Demetra	5.1	0.74	0.17	3.23	2.95	1.53	12.11	12.30	6.40	50.71	16.6	69.4
12	Druzhok	6.1	0.88	0.20	3.86	3.52	1.83	14.49	14.71	7.66	60.65	19.8	83.0
13	Canyon	7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.7	103.4
14	Kapro	7.25	1.05	0.24	4.59	4.19	2.17	17.22	17.48	9.10	72.09	23.6	98.7
15	Liubov F1	11	1.59	0.37	6.97	6.35	3.30	26.12	26.53	13.81	109.37	35.8	149.7
16	Mazurka F1	7.8	1.13	0.26	4.94	4.51	2.34	18.52	18.81	9.79	77.55	25.4	106.2
17	Mercedes	8.4	1.21	0.28	5.32	4.85	2.52	19.95	20.26	10.55	83.52	27.3	114.3
18	Nadiia	7.2	1.04	0.24	4.56	4.16	2.16	17.10	17.36	9.04	71.59	23.4	98.0
19	Priscilla	4.8	0.69	0.16	3.04	2.77	1.44	11.40	11.58	6.03	47.73	15.6	65.3
20	Svitozar	6.3	0.91	0.21	3.99	3.64	1.89	14.96	15.19	7.91	62.64	20.5	85.7
21	Solomon	5	0.72	0.17	3.17	2.89	1.50	11.87	12.06	6.28	49.71	16.3	68.0
22	Favilla	9.9	1.43	0.33	6.27	5.72	2.97	23.51	23.87	12.43	98.43	32.2	134.7
23	Feia	8.9	1.29	0.30	5.64	5.14	2.67	21.14	21.46	11.17	88.49	28.9	121.1
24	Flexum F1	6.3	0.91	0.21	3.99	3.64	1.89	14.96	15.19	7.91	62.64	20.5	85.7
25	Tsitrina	4.7	0.68	0.16	2.98	2.71	1.41	11.16	11.33	5.90	46.73	15.3	64.0
Mean		6.9	0.99	0.23	4.36	3.98	2.06	16.35	16.61	8.64	68.47	22.39	93.72
Max		11.0	1.59	0.37	6.97	6.35	3.30	26.12	26.53	13.81	109.37	35.80	149.70
Min		5.0	0.68	0.16	2.98	2.71	1.41	11.16	11.33	5.90	46.73	15.30	64.00
Mid-late and late-maturing cultivars													
1	Sondela F1	7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.7	103.4
2	Sandra	6.8	0.98	0.23	4.31	3.93	2.04	16.15	16.40	8.54	67.61	22.1	92.5
Mean		7.2	1.04	0.24	4.56	4.16	2.16	17.10	17.36	9.04	71.59	23.42	97.99
Max		7.6	1.10	0.25	4.81	4.39	2.28	18.05	18.33	9.54	75.57	24.72	103.43
Min		6.8	0.98	0.23	4.31	3.93	2.04	16.15	16.40	8.54	67.61	22.11	92.55

References

1. Pasynskyi, A. G. (1968). Biophysical chemistry (2nd ed.). Vysshaja shkola.
2. Pevzner, L. (1977). Bases of bioengineering. Mir.
3. Plant-based: A perspective on nutritional and technological issues. Are we ready for «precision processing»? (2022). *Foods*, 11(9), Article 9094677. <https://pmc.ncbi.nlm.nih.gov/articles/PMC9094677/>
4. Sweet bell pepper: A focus on its nutritional qualities and illness-alleviated properties. (2024). *Journal of Functional Foods*, 114, Article 11436515. <https://pmc.ncbi.nlm.nih.gov/articles/PMC11436515/>
5. Kalaida, K. V., Koltunov, V. A., & Volkova, T. V. (2017). The resource potential of assortment of sweet pepper and its competitiveness. *Proceedings of the International Scientific Conference «Topical Problems of Modern Science»*, 4, 28–33.
6. Soare, R., Dinu, M., Băbeanu, C., Popescu, M., & Popescu, A. (2017). Nutritional value and antioxidant activities in fruit of some cultivars of pepper (*Capsicum annuum* L.). *Journal of Agroalimentary Processes and Technologies*, 23(4), 217–222.
7. Bharti, H., Hemalatha, N., Malita, R., Sharma, V. K., Bharadwaj, R., & Babu, P. (2026). Phytochemical characterization and correlation analysis of nutritional value in sweet pepper (*Capsicum annuum* L.) genotypes at various growth stages. *Frontiers in Plant Science*, 16, Article 1719537. <https://doi.org/10.3389/fpls.2025.1719537>
8. Stoleru, V., Mangalagiu, I., Amăriucăi-Mantu, D., Teliban, G.-C., Cojocaru, A., Rusu, O.-R., Burducea, M., Mihalache, G., Rosca, M., Caruso, G., Sekara, A., & Jităreanu, G. (2023). Enhancing the nutritional value of sweet pepper through sustainable fertilization management. *Frontiers in Nutrition*, 10, Article 1264999. <https://doi.org/10.3389/fnut.2023.1264999>
9. Vardanian, I., Sargsyan, G., Martirosyan, G., Shirvanyan, A., Tadevosyan, L., Avagyan, A., Pahlavanyan, A., Martirosyan, H., Sukhudyan, D., Solomonyan, A., Zakharyan, M., Danielyan, M., & Harutyunyan, Z. (2025). Comprehensive agrobiological and biochemical study of sweet pepper (*Capsicum annuum* L.) varieties. *Functional Food Science*, 5(6), Article 1640. <https://doi.org/10.31989/ffs.v5i6.1640>

*Demianov Oleksyi, Oliniichuk Anjela, Verysotska Olena,**Yuliihin Viktor, Vorobiov Valerii, Pervushyn Maksym, Demianova Natalya**E.O. Paton Electric Welding Institute, National Academy of Sciences of Ukraine of Ukraine / 11 Kazymyr**Malevych St., 03150 Kyiv, Ukraine*<https://doi.org/10.5281/zenodo.22996465>

EFFECT OF ELECTRIC-ARC SPRAYING CONFIGURATION ON THE STRUCTURE AND PROPERTIES OF COATINGS PRODUCED FROM Fe–Cr–C–Al FLUX-CORED WIRE

Abstract.

The work is devoted to establishing the influence of different electric arc spraying schemes—conventional subsonic, modified with an additional air flow, and supersonic—on the structure, phase composition, microhardness, bond strength, and wear resistance of Fe–Cr–C–Al powder-wire coatings. The results obtained demonstrate that a successive increase in the intensity of gas-dynamic interaction with the molten metal—from conventional air atomization through additional compression of the metal–gas flow to supersonic acceleration of the particles—provides a consistent improvement in the structure and a set of practically important properties of electric arc coatings. The most pronounced effect is achieved with the supersonic scheme, which produces a dense, fine-lamellar structure with minimum porosity and a reduced degree of oxidation, while simultaneously increasing the microhardness, bond strength, and wear resistance of the coating.

Keywords: electric arc spraying, structure, phase composition, microhardness, bond strength, coating wear resistance.

INTRODUCTION

Enhancing the durability and reliability of machine parts and equipment operating under conditions of intensive wear, contact and dynamic loads remains a relevant task for transport engineering and other industrial sectors. One of the effective methods for restoring and strengthening working surfaces is the application of thermal-spray coatings. Practical experience with the use of such technologies for restoring safety-critical railway transport components confirms the possibility of substantially extending their service life [1–5].

Among thermal-spray methods, electric-arc spraying is of considerable practical interest owing to its high productivity, relatively low energy consumption, the possibility of processing large-sized components, and the use of a wide range of wire materials. The use of flux-cored wires further expands the possibilities for controlling the chemical and phase composition of the sprayed material and for producing wear-resistant coatings with a specified set of service properties [6, 11].

One of the determining factors in the formation of an electric-arc coating is the gas-dynamic conditions of molten-metal atomization and transport. The velocity and configuration of the atomizing gas flow directly affect particle size and velocity, the duration of their interaction with the surrounding atmosphere, the degree of oxidation, the temperature at the moment of impact with the substrate, and the nature of deformation during lamella formation. As a result, changes in the gas-flow configuration can significantly affect the porosity, lamellar structure, phase composition, and service properties of the formed coating.

Conventional electric-arc spraying with subsonic air atomization is characterized by relatively low particle velocities and their intense interaction with the surrounding atmosphere, which promotes oxidation of the atomized metal, the formation of oxide interlayers, pores, and structural heterogeneity of the coating. One approach to improving the process is the formation of a directed auxiliary air flow that compresses the metal–

gas jet and increases particle velocity. A further increase in the intensity of atomization and acceleration of the molten metal can be achieved through the use of supersonic gas flows [7–9].

The use of a supersonic flow in electric-arc spraying fundamentally changes the conditions governing the formation of the two-phase metal–gas jet. An increase in the velocity and a reduction in the size of atomized particles shorten the duration of their interaction with the surrounding atmosphere, while increased kinetic energy upon impact with the surface promotes more intensive particle deformation and the formation of a dense fine-lamellar structure. To implement this approach, specialized supersonic electric-arc spray guns have been developed, in which melting of the wire material by an electric arc is combined with its atomization and acceleration by a high-velocity gas flow [10]. Previously conducted studies confirm the significant influence of such conditions on the structural-phase state of electric-arc coatings [12].

At the same time, to assess the effectiveness of different methods of organizing the gas flow, their direct comparison in spraying the same material is of interest. A comparison of the conventional configuration with subsonic air atomization, the modified configuration with an additional compressing air stream, and the supersonic configuration makes it possible to establish the relationship between particle transport conditions, the structural-phase state of the coating being formed, and its service-relevant characteristics.

The aim of this work was to establish the effect of different electric-arc spraying configurations—conventional subsonic, modified with an additional air flow, and supersonic—on the formation of the microstructure, phase composition, microhardness, adhesion strength, and wear resistance of coatings produced from Fe–Cr–C–Al system flux-cored wire.

RESULTS AND DISCUSSION

To achieve the aim of the work, three electric-arc spraying configurations shown in Fig. 1 were used in the study.

The supersonic metallizer (Fig. 1a) is based on a process in which the stabilized electric arc is blown by hot natural-gas combustion products at supersonic velocity [10]. That is, this technology is hybrid, combining electric-arc spraying with supersonic flame spraying to form a single supersonic high-temperature flow of gas and molten particles of the sprayed wire material. The electric arc is oriented along a high-temperature gas flow with a velocity of Mach 1.5 and burns between two consumable wires. Such a system ensures a high level of arc-burning stability due to its orientation along

the gas flow and, consequently, efficient heat transfer to the electrodes: intensive acceleration and fragmentation of molten-metal particles, their protection against oxidation in flight, and a reduction in the amount of evaporated material (owing to the formation of a two-phase flow by a high-velocity jet of combustion products).

The differences between the standard EM-14 metallizer (Fig. 1b) and the upgraded EM-14M (Fig. 1c) consist in the use in the latter of special nozzles for forming an air flow that provides compression of the spray jet, increases its velocity, and reduces material oxidation [12].

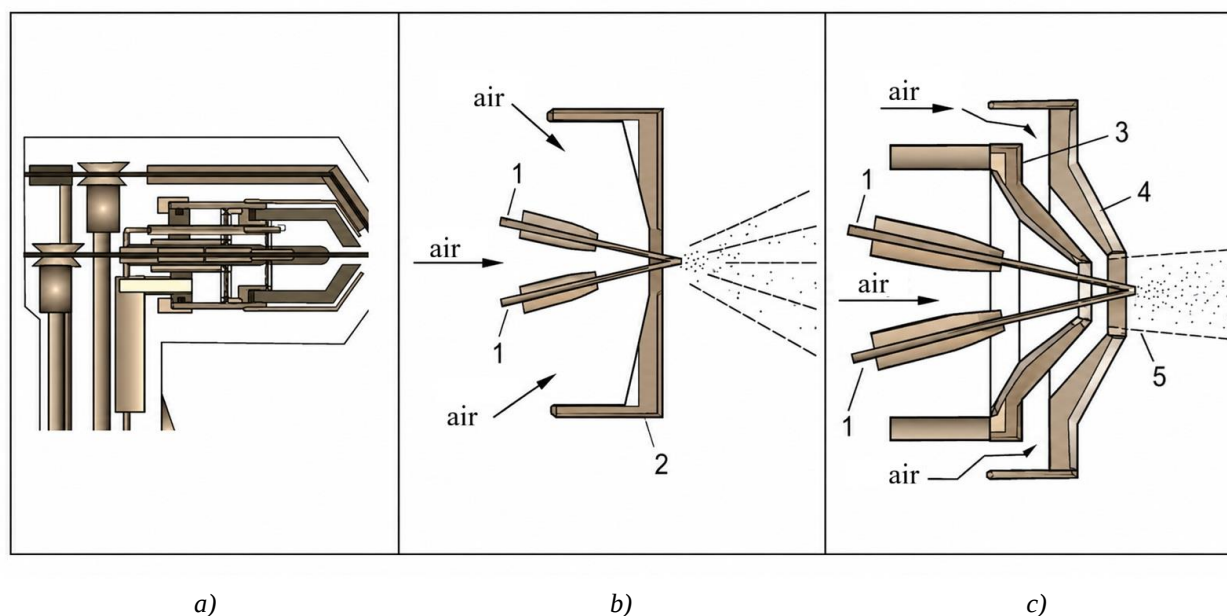


Fig. 1. Schematic diagrams of the supersonic PLAZER15-SA-E (a), standard EM-14 (b), and upgraded EM-14M-1 (c) electric-arc metallizers used for comparative studies of the spraying process and coating characteristics: 1 – flux-cored wire; 2 – standard nozzle; 3 – profiled ceramic nozzle; 4 – auxiliary nozzle for forming a co-flowing air stream; 5 – co-flowing air stream.

An economically alloyed Fe–Cr–C-based flux-cored wire, in which high-carbon ferrochrome was the main component of the powder core, was used as the spraying material. The composition of this flux-cored wire was selected based on the further development of approaches to alloying flux-cored wires for metallizing [6,11], which provide for the selection of powder filler components that ensure the formation of a sprayed coating with a composition close to that of chromium steels containing 1–2% C and 4–10% Cr, which are prone to hardening from the liquid state and, as a result, exhibit increased wear resistance. Since the coatings of friction assemblies in railway rolling-stock components operate under increased dynamic loads, they are subject to increased requirements for bond strength. Therefore, in developing the composition of flux-cored wires for applying coatings to the specified types of components, taking into account the features of supersonic electric-arc spraying technology, the following approaches were used to increase the bond strength of such coatings to the substrate:

- an increase in the temperature of the sprayed particles due to aluminothermic reactions, ensured by introducing additives of a hematite–aluminum mixture ($\text{Fe}_2\text{O}_3 + \text{Al} = \text{Al}_2\text{O}_3 + \text{Fe} + \text{Q}$). As a result of this reaction, the temperature of the deposited particles increases, and a strengthening aluminum oxide phase is formed in the coating;

- reduction of iron oxides formed during melting and dispersion of the sheath and powder filling of the flux-cored wire by introducing aluminum-containing additives and master alloys with mischmetal into the powder filling, with exothermic reactions occurring;

- an increase in arc temperature and a reduction in arc column size through the introduction of optimal amounts of alkali metal halide additives.

Increasing the temperature of the sprayed particles and their fineness is especially important when spraying at supersonic jet exit velocities, since in this case the residence time of the molten droplet at the wire tips in the high-temperature zone of the electric-arc region is substantially reduced compared with conventional spraying technologies using low-velocity (subsonic)

jets. This also achieves the formation of strong metallurgical bonds between the sprayed particles and the metal substrate by activating chemical interaction between them and the substrate and by producing hard and durable oxides.

Since different hardness values are required depending on the types of railway rolling-stock components, a range of flux-cored wire compositions PP-AN202-S has been developed to provide different hardness and tribotechnical characteristics. A mandatory requirement was that, as a result of supersonic electric-arc spraying of such flux-cored alloy wire, a coating be obtained with a composition close to that of chromium steels containing 1–2% C and 4–10% Cr and exhibiting a tendency to harden from the liquid state, containing metastable quenched structures based on supersaturated solid solutions.

The ratio of the concentrations of elements in the sprayed layer to the concentrations of components in the powder charge was calculated based on the solution of a system of equations [11]:

$$A_a = \frac{n_a}{100} (x_1 k_1^{(a)} + x_2 k_2^{(a)} + \dots + x_n k_n^{(a)}) k_3$$

$$A_i = \frac{n_i}{100} (x_1 k_1^{(i)} + x_2 k_2^{(i)} + \dots + x_n k_n^{(i)}) k_3$$

where $a, \dots, i$ – alloying elements, n_a, n_i – transfer coefficients of these elements, $x, \dots, x_n$ – the fractional proportions of materials (ferromanganese, ferrochrome, metallic aluminum, etc.), $k_1^{(a)} \dots k_n^{(a)}, k_1^{(i)} \dots k_n^{(i)}$ – the concentrations of elements in the respective materials introduced into the powder core charge, k_3 – the filling coefficient ($k_3 = 0.15, \dots, 0.45$).

The chemical composition and microstructure of the initial Fe–Cr–C flux-cored wire (FCW) and coatings produced by electric-arc spraying using subsonic and supersonic jets were investigated. Steel strip 08kp was used to manufacture the sheath of this flux-cored wire. The main components of the powder charge were high-carbon ferrochrome ΦX900 and iron powder with ferromanganese additions. Hematite ПЖР5.315.28 МРТУ 14-14p-84 and aluminum powder ПА-3 with a particle size of up to 150 μm were used as exothermic additives. The microstructure and composition of this flux-cored wire and the powder filler are shown in Fig. 2.

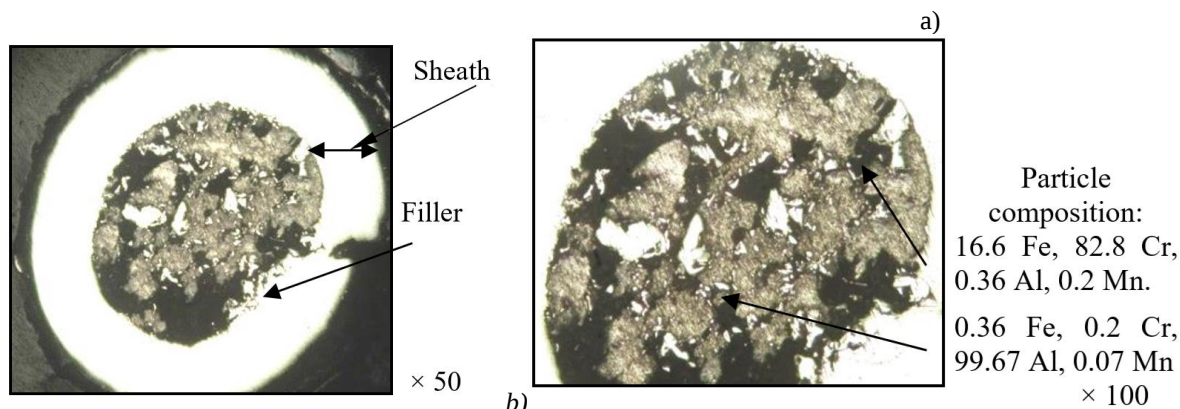


Fig. 2. Microstructure of the cross-section of PP-AN202-S wire.

Analysis of the metallographic examination results of the coatings showed that, at subsonic air exit velocities, the microstructure is heterogeneous and coarse-grained, with a large number of pores and oxide inclusions. The coating material is overheated and oxidized; the oxide interlayers contain 29.0–32.0% oxygen, and the oxygen mass fraction in the lamellae reaches 2.5%. Spherical particles are also observed which, owing to their low flight velocity, had time to cool before colliding with the sprayed surface (Fig. 3a). The coating produced using the modified base unit with an additional air flow and an adjustable particle-flow divergence angle is less oxidized. In the lamellae and oxide interlayers, the oxygen mass fraction is 1.6–1.8% and 29.0–30.0%, respectively. The thickness of the lamellae (δ_p) in these coatings is the same as under conventional subsonic conditions and is 10–30 μm (Fig.

3b); the porosity of the coatings is 2–3%. Upon transition to the supersonic air-gas electric-arc spraying method, an increase in air-jet velocity increases the particle flight velocity, and the microstructure of the resulting coating undergoes significant changes. The combination of the small size of the sprayed particles and their high velocities at the moment of impact on the substrate surface results in high cooling rates of their material. The particles are predominantly lamellar in shape and undergo substantial deformation. No inclusions of globular particles are observed. Thin oxide interlayers are noted. The coatings have a uniform fine-lamellar structure throughout their thickness, indicating process stability. In coatings deposited by supersonic air-gas spraying, the values δ are in the range of 5–10 μm (Fig. 3c). The porosity of the structure decreases to 0.4%.

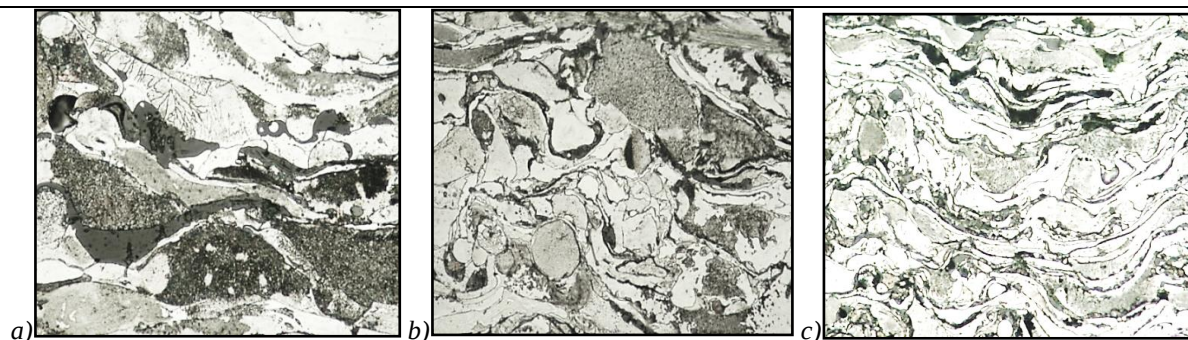


Fig. 3. Microstructure of coatings produced from Fe–Cr–C–Al system flux-cored wire by various electric-arc spraying methods: a—conventional spraying using the EM-14M electric-arc metallizer; b—modified spraying using EM-14M-1; c—supersonic spraying using PLAZER15-SA-EM. $\times 400$.

Analysis of the results of X-ray spectral microanalysis and diffraction patterns of the coatings showed that all the coatings studied, produced by conventional subsonic electric-arc metallization, modified electric-arc metallization, and supersonic electric-arc metallization, contain solid solutions of Al and Cr in alpha iron (body-centered cubic lattice with $a = 0.287$ nm), as well as solid solutions of Al and Cr in gamma iron with a face-centered cubic lattice and different contents of these elements. According to X-ray spectral microanalysis data, in coatings produced by conventional arc and modified metallization, a solid solution of chromium and aluminum in α -iron predominates, whereas in the case of supersonic electric-arc metallization, the main phase in the coating is the γ -phase. In supersonic electric-arc metallization and modified electric-arc metallization, the gamma-iron phase with altered parameters exists in two modifications, namely: $\gamma_1\text{Fe}(\text{Cr}, \text{Al})$ with $a = 0.3677$ nm and $\gamma_2\text{Fe}(\text{Cr}, \text{Al})$ with $a = 0.3633$ nm [12].

The difference in the values of the lattice parameters $\gamma_1\text{Fe}$ and $\gamma_2\text{Fe}$ indicates different contents of alloying elements. It was established that the maximum chromium concentration in the iron-based solid solution in the lamellae of coatings produced by conventional and modified spraying is 16.8–17.1 and 15.0–15.4 wt.%, respectively; under the same conditions, the aluminum content ranges approximately from 4% to 6.2%. In addition, during spraying, aluminum reacts with oxygen, forming Al_2O_3 -based inclusions containing 35.0–39.0 wt.% aluminum and 29.0–32.0 wt.% oxygen [12].

When supersonic jets are used, the turbulent jet-flow regime transitions to a laminar regime, thereby reducing air entrainment; at the same time, owing to the increased gas-jet velocity, the particle velocity increases. During supersonic spraying, the amounts of chromium and aluminum dissolved in iron increase, and the maximum chromium concentration in the lamellae reaches 20.0–20.5 wt.%. A solid solution of this concentration has greater resistance to oxidation by atmospheric oxygen. The degree of oxidation of the sprayed coating is significantly reduced. The lamellae contain approximately 1.0% oxygen. More detailed results of investigations of the structure of these types of coatings are presented in [12].

A comparison of the microhardness values of coatings from flux-cored wire sprayed by different methods shows that the microhardness of the coating produced by conventional electric-arc spraying ranges from 1930 to 4200 MPa, whereas the microhardness of the coating produced using the upgraded unit ranges from 2540 to 5100 MPa. The supersonic-sprayed coatings have the maximum microhardness, with values ranging from 3900–6100 MPa, which may be associated with an increase in the chromium content in the iron-based solid solution.

For comparative evaluation of the bond strength of coatings σ_{sc} to the substrate, the failure stress in the “coating–steel 45 substrate” assembly under normal tensile separation was determined using the “conical pin” method. The test results confirm the effectiveness of supersonic electric-arc spraying technology and an almost twofold increase in the bond strength of coatings to the substrate compared with conventional technology (Fig. 4).

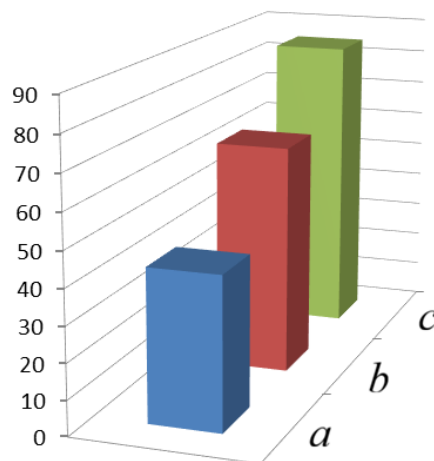


Fig. 4. Bond strength to a steel 45 substrate of coatings made from Fe–Cr–C–Al system PP-AN202-S flux-cored wire, produced by different electric-arc spraying methods: a — conventional spraying using an EM-14M electric-arc metallizer; b — modified spraying using EM-14M; c — supersonic spraying using PLAZER15-SA-EM.

Tribological tests of the coatings under consideration were conducted under limited lubrication using a coated disc–block configuration (counterbody: SCh-20 cast iron and 40Kh steel, $P = 10$ MPa, $V = 1$ m/s, HS20 oil, 30 drops/min). It has been established that the electric-arc spraying technology significantly affects the wear rate of coatings produced from Fe–Cr–C-based PP-AN202-S flux-cored wire. The wear-rate values of coatings deposited by supersonic electric-arc spraying using a PLAZER15-SA-EM electric-arc metallizer are $3.1 \mu\text{m}\cdot\text{km}/\text{km}$, whereas this value for coatings deposited using a modernized EM-14 electric-arc metallizer is $4.3 \mu\text{m}\cdot\text{km}/\text{km}$, and for a standard EM-14 metallizer it is $7.8 \mu\text{m}\cdot\text{km}/\text{km}$. That is, the application of supersonic electric-arc spraying technology makes it possible to increase the wear resistance of coatings by more than 2.5 times. At the same time, all the coatings studied surpass St 20 in wear resistance, with its wear values being about $10 \mu\text{m}/\text{km}$.

CONCLUSIONS.

1. It has been established that the formation pattern and parameters of the gas flow during electric-arc spraying are determining factors in coating structure formation. The transition from conventional subsonic atomization to a configuration with an additional constricting air jet, and subsequently to a supersonic air-gas flow, is accompanied by sequential changes in the conditions of dispersion, acceleration, and transport of molten particles, which are directly reflected in the structure and properties of the resulting coatings.

2. Conventional subsonic spraying produces a heterogeneous coarse-lamellar structure with an increased content of pores and oxide inclusions. The application of an additional air flow reduces material oxidation; however, the splat thickness remains at $10\text{--}30 \mu\text{m}$, and the porosity is $2\text{--}3\%$. Under supersonic spraying, a uniform fine-lamellar structure without globular particle inclusions is formed; the splat thickness decreases to $5\text{--}10 \mu\text{m}$, and the porosity to 0.4% .

3. Changes in the gas-dynamic spraying conditions have a significant effect on oxidation and the structural-phase state of the coating. With the transition to supersonic spraying, the oxygen content in the lamel-

lae decreases to approximately 1.0% , while the maximum chromium concentration increases to $20.0\text{--}20.5$ wt. %, and the principal phase constituent becomes a γ -phase based on iron alloyed with Cr and Al.

4. Improvement of the electric-arc spraying configuration is accompanied by a successive increase in coating microhardness. In conventional spraying, it is $1930\text{--}4200$ MPa; when using the modified configuration, $2540\text{--}5100$ MPa; and in supersonic spraying, it reaches $3900\text{--}6100$ MPa. At the same time, the use of a supersonic flow provides an almost twofold increase in the bond strength of the coating to the substrate compared with the conventional configuration.

5. A clear dependence of coating wear resistance on the electric-arc spraying configuration used was established. Wear intensity decreases successively from $7.8 \mu\text{m}/\text{km}$ for the conventional configuration to $4.3 \mu\text{m}/\text{km}$ for the modified configuration and to $3.1 \mu\text{m}/\text{km}$ for the supersonic configuration. Thus, the use of supersonic electric-arc spraying provides an increase in wear resistance by more than 2.5 times compared with conventional technology.

References.

1. Restoration of wheelset journals by metallization. V.P. Kuzmin et al. // *Railway Transport*, 2002, - 31, pp. 46–49.
2. Kuzmin V.P. Restoration of axle journals of railway wheelsets by electric-arc metallization. VNIIZhT Bulletin. No. 1, 2201, - p. 46.
3. Korzhyk V. N., Kryvtun I. V., Petrov S. V., Kharlamov M. Yu. A new “Plazer” technology for the refurbishment of railway components // *Repair, Restoration, Modernization*. – 2009, No. 1. – pp. 20–22.
4. Technology and equipment for plasma-arc spraying for the restoration of critical railway transport components / Korzhyk V. N., Kharlamov M. Yu., Petrov S. V., et al. // *Bulletin of the V. Dahl East Ukrainian National University*. 2001, No. 14, pp. 76–84.
5. V.I. Zelenin, P.V. Kavunenko, V.V. Tysenko et al. Extension of the service life of RU1 and RU1Sh axles of freight-car wheelsets restored by plasma-arc metallization of journal and wheel-seat sections. *Automatic Welding*, 2019, No. 9, pp. 39–43.

6. V.I. Pokhmurskyi, M.M. Student, V.M. Dovhunyk, I.I. Sydorak, Yu.M. Kuskov, I.A. Ryabtsev. Structure and tribotechnical characteristics of coatings produced by electric-arc metallization using flux-cored wires // Automatic Welding. – 2003. – No. 8. – pp. 13–17.
7. Borisov Yu.S., Petrov S.V. Use of supersonic jets in thermal spraying technology // Automatic Welding. 1995. No. 1. pp. 41–44.
8. Frolov V.A., Poklad V.A., Ryabenko B.V., Victorenkov D.V. Technological features of supersonic thermal spraying methods (review) // Welding Production. 2006. No. 11. pp. 38–47.
9. Petrov S.V., Karp I.N. Plasma gas-air spraying. Kyiv: Naukova Dumka, 1993. 495 p.
10. Petrov S.V., Korzhyk V.N. PLAZER15-SA electric-arc supersonic spraying system / Welder, 2011, No. 1, pp. 17–21.
11. Royanov V.A. Theoretical foundations for the development and industrial implementation of economically alloyed flux-cored wires for electric-arc spraying of wear-resistant coatings with improved service properties. Abstract of a dissertation submitted for the degree of Doctor of Technical Sciences. Minsk, BPI, 38 pp.
12. Korzhyk V.N., A. L. Borisova, G. N. Gordan, N. P. Lyutik, A. A. Chaika, T. V. Kaida. Structural features of coatings from Fe–Cr–Al flux-cored wire produced under supersonic electric-arc metallization conditions / “The Paton Welding Journal,” 2014, No. 2, pp. 33–38.

PHILOLOGICAL SCIENCES

Aliyeva Tanzila

PhD in Philology, Associate Professor
 Azerbaijan State Pedagogical University,
 Azerbaijan, AZ1000, Baku, Uzeyir Hajibeyli Street, 68
 Orcid id: 0000-0003-2055-7001
<https://doi.org/10.5281/zenodo.22996488>

ASPECTS OF LITERARY CRAFTSMANSHIP IN THE WORKS OF ƏNVƏR MƏMMƏDXANLI

Abstract:

Ənvər Məmmədxanlı, a People's Writer of Azerbaijan, is one of the prominent representatives of twentieth-century Azerbaijani literature. His distinguished literary career was illuminated by distinctive, original literary works, including novels, novellas, short stories and translations. The writer's works are wide-ranging in scope. In Ənvər Məmmədxanlı's oeuvre, human life and human destinies are portrayed truthfully, through convincing details. His works bring lifelike tableaux, the beauty of nature and a fascination with nature vividly to life through imagery and poetic expressions. Ənvər Məmmədxanlı's oeuvre is the finest example of poetic quality in prose. Throughout his literary career, the distinguished writer made extensive use of descriptive and expressive literary devices. With his profound knowledge of literary sources and folklore, he conveyed national colour and the subtleties of his native language with consummate skill in his works.

The present article examines aspects of literary craftsmanship in the writer's oeuvre.

Keywords: Ə. Məmmədxanlı, literary craftsmanship, oeuvre, poetic quality, prose, short story

Ənvər Məmmədxanlı, a People's Writer of Azerbaijan, is one of the prominent representatives of twentieth-century Azerbaijani literature. His distinguished literary career is rich in literary works, including novels, novellas, short stories and translations. Ənvər Məmmədxanlı was born in the city of Göyçay on 28 February 1913. Although he worked in various fields, he always gave priority to his literary activity.

The writer began his literary career in the 1930s. His work "The Morning of the East" (*Şərqi səhəri*) was loved by readers and received a prestigious award of the time, the USSR State Prize. During the war, his writing was distinguished by its original style. With "The Ice Statue" (*Buz heykəli*) alone, he erected an enduring monument to himself in the hearts of his readers. "Mothers Took to the Roads" (*Analar yollara çıxdılar*), "Armed Mountains" (*Silahlı dağlar*), "A Letter from the Western Front" (*Qərb cəbhəsindən məktub*), "The Bloody Seal" (*Qanlı möhür*), "Where Are You From, Soldier Brother?" (*Haralısan, əsgər qardaş*), "Amid the Flames" (*Od içində*) and others are among his finest works written during the war years.

"Ə. Məmmədxanlı's literary oeuvre is distinguished by its language and style. The depictions of nature in his works are so vivid in their craftsmanship and so artistically expressive that every reader seems to see what is described with their own eyes. These works portray the natural beauty of our homeland, the horrors of war and the bitter lives of our compatriots in the South" (Məmmədov, 1977).

The beauty of the language in the writer's literary style is captivating. His depictions of natural beauty are distinguished by their uniqueness. The scenes in the short story "Golden Buds" (*Qızıl qönçələr*) appear exceptionally vivid and natural. The harmony between the depictions of nature and the portraits of people further enhances the theme's emotional impact. The enduring

monument to maternal self-sacrifice in "The Ice Statue" has long moved readers' hearts.

The writer's relatively longer works bring more extensive natural landscapes before the reader's eyes. "The vivid, lifelike descriptions encountered in Ənvər Məmmədxanlı's oeuvre transport the reader to another world. The literary tableaux and the enchanting beauty of Azerbaijan's natural landscapes depicted in these works testify to the writer's love of his homeland. The reader cannot help being captivated by these sincere feelings. He has made his characters so vivid and lifelike that the reader feels immersed in the events, as though participating in them" (Rəsulova, 2026).

From the 1940s onwards, the writer also began to try his hand at drama. His play "The Morning of the East" addressed one of the principal themes of its time in twentieth-century literature. The work depicts the social and historical events unfolding in Baku in the early 1920s in realistic detail, brings portraits of various historical figures to life, and portrays world imperialism's interest, particularly that of the British, in "Baku" and "oil". The various judgements expressed by the characters reveal their conflicting positions and encourage the reader to draw the correct conclusions from the events. The comparison between the characters Tomson and Ağalarov demonstrates this.

The theme of the South holds a special place in the history of the writer's public and literary activity. The play "Amid the Flames" concerns the national liberation movement in South Azerbaijan in 1945–46 and its tragic conclusion. "The Beauty of Şirvan" (*Şirvan gözəli*) is distinguished by its lyricism. While offering aesthetic pleasure to readers and audiences, "The Beauty of Şirvan" directs their attention towards the problems of life and attracts them with its optimistic humour. The film "Babək", based on the great writer's screenplay, is also a work of art that millions of viewers wish to watch again and again. The screenplay for

“Leyli and Məcnun” (*Leyli və Məcnun*), the film “Bəxtiyar”, the screenplay for “Fətəli Khan” (*Fətəli xan*), on which he collaborated with M. Hüseyin, and other precious artistic gems constitute his enduring fame and a magnificent monument to him.

The short story “In the Moonlight” (*Ay işığında*) brings to life the figure of an elderly folk artist. The wise artist Aşıq Valeh, whose life stories and experiences exemplify reality, is portrayed in natural colours. The long-lived *aşıq*, a traditional poet-musician whose heart constantly beats with the desire to create, to live and to sustain life, sees his youth in his pupil Cəlal. Depicting a person’s material world together with their spiritual world, Ənvər Məmmədخانلی captivates the reader through Aşıq Valeh’s love of life, which challenges youth itself, and through his counsel. The elderly *aşıq*, who also commends a love of labour to his grandchildren and great-grandchildren, is as tireless in work as he is accomplished in his art. Keeping himself occupied with work and daily tasks, the *aşıq* carried within his breast an inexhaustible artistic ardour. “It was that ardour which, each time, had brought words and music into the world like two inseparable twin sisters, had sent every word springing from the heart soaring on the flight of his voice; then these songs, cleaving the darkness like a white bird, had gone forth, travelled through villages and communities, and left a luminous trace in people’s hearts” (Məmmədخانلی, 2005).

The work makes extensive use of vernacular expressions. Phrases such as *qoşa qovaq ağacları* (“a pair of poplar trees”), *tənha çinar* (“a solitary plane tree”), *həsir üstündə döşəkçə* (“a cushion on a reed mat”), *bardaş qurmaq* (“to sit cross-legged”) and *qənşər* (“in front of”) convey descriptions rooted in the vernacular. Expressions such as *quyruğunu ələ vermirdi* (“would not let himself be caught out”) and *əl-ayaq yığışandan sonra* (“after the bustle had died down”) are well-known folk idioms. The poetic quality and lyricism in prose evident in the writer’s oeuvre are also clearly apparent in this work: “The leaves of the twin poplars gleamed like fish scales” (Məmmədخانلی, 2005).

In “The Mother’s Death” (*Ananın ölümü*), written by Ənvər Məmmədخانلی in 1944, scenes of life are depicted through truthful, convincing details. In this short story, the mother, Murad, whom she has raised alone since he was two, the neighbouring women, and her nearest neighbour, the woman Məsmə, and Məsmə’s grandchild are realistic human characters. Each has a distinct role in conveying the work’s central idea. Images of objects such as a candle, triangular letters, a hand stone for pressing *abqora* (unripe grape juice), a reed mat and a kilim occupy an important place in the work’s content. The mother and her son have boundless aspirations. Yet the war, which prevents those aspirations from being realised, completely changes the course of events. Murad’s working life gives way to life at the front. The mother’s waiting, suffering and anxiety for her son remain the focus throughout the story. Certain images of objects associated with war also have considerable significance for the plot. For example, triangular letters and *qara kağız* (“black paper”, a death notice), papers conveying hopeful or terrifying news of the war, express the people’s state of mind even without

words. The series of synonyms used in the work enhances the beauty of its language and expression. The richness of its content is conveyed in beautiful literary language. The writer’s creative capacity, with its distinctive stylistic features, attracts attention. Vernacular expressions such as *ismarış* (“a message”), *öyrəli* (“a few days ago”), *artırma* (“a veranda”) and *bardaş qurmaq* (“to sit cross-legged”) testify to the work’s closeness to the spirit of the people.

Like his other works, “The Caravan Stopped” (*Karvan dayandı*) is exceptionally engaging and rich in its theme, language and style. The author describes the magic of a beautiful voice that captivates its listeners. This enchanting voice comes from deep within a dense forest. The image of the voice that makes a woodcutter’s son beloved by the people, his sublime love, and the people’s respect for that love are conveyed in beautiful literary language. The work juxtaposes the way of life of ordinary people with the lives of the pampered and domineering. The voice and music to which Çimnaz, the village beauty, listens like everyone else give voice to the woodcutter’s son’s sublime love. Çimnaz, too, is moved by this voice. Everything changes when Əlyar Khan hears it while returning from a hunt with his retinue. Bitter days replace the peaceful lives of the village, Çimnaz and the woodcutter’s son. The writer portrays the people’s lives and customs through natural scenes. Sensing Əlyar Khan’s intentions, Çimnaz rushes into the forest in alarm to warn the woodcutter’s son. Both the young man and Çimnaz become the khan’s captives. In Əlyar Khan, the author depicts the most pronounced manifestation of self-indulgence and arrogance. The young man, who captivated everyone with his voice in the freedom of nature, does not sing amid the splendour of the palace. They cannot force him to sing. Freed from bondage, he once again sings beautifully in freedom. This time, Çimnaz, now a woman in the khan’s harem, herself sends someone to fetch him. At first, the woodcutter’s son is delighted. Then, when he learns that Çimnaz is no longer the Çimnaz he once knew, his thoughts are thrown into turmoil. Wandering from land to land, the woodcutter’s son amazes the world with his songs. The image of nature in the work is created with love. In general, depictions of nature occupy an extensive place in Ənvər Məmmədخانلی’s oeuvre. As in all his works, descriptions of natural scenes and a love of nature are prominent here. The songs composed by the singing woodcutter’s son as he wanders from land to land pass from mouth to mouth. The story of the woodcutter’s son, whose voice stops a caravan, seems like a history demonstrating how folk songs came into being. The work employs vernacular expressions such as *bir hovur* (“a little while”), *artırma* (“a veranda”), *təkliyin qara quyusu* (“the dark well of solitude”), *qara əl* (“a black hand”), *gəncliyimin səsi* (“the voice of my youth”) and *şələ* (“a bundle carried on the back”). The sound of bells, the caravan, those weary from travelling, the caravan that does not stop, the returning caravan, music reaching the stars, unfulfilled love whose heart strikes against stone, and sublime love are all brought to life in beautiful literary language.

“Baku Nights” (*Bakı gecələri*) occupies a distinctive place in Ənvər Məmmədخانlı’s oeuvre: “My mother was filling my saddlebag with *ayın-oyun* [odds and ends]; my father was waiting for me in front of the *doqqaz* [gateway], beside the ox cart with the oxen harnessed” (Məmmədخانlı, 2005). These lines exemplify the introduction of dialect words into literary language. Drawing on his rich observations of life, the great writer depicts the realities he has witnessed through convincing details. Whatever or wherever the author describes, he takes the reader there. His world of dreams and imagination rests on reality. The concepts of time and space in the writer’s oeuvre are far removed from abstraction. Thus, it is through Ənvər Məmmədخانlı’s works that the reader sees and understands the true face of life. In the novella “Baku Nights”, time and space are depicted through appropriate details. A remote mountain village, a no. 7 lamp, a train, the farewell scene, the father’s instructions, a herd of gazelles, plains covered with wormwood and *sirkan* (a thorny plant): none of these descriptions tires the reader. On the contrary, they direct the reader’s interest towards the work. Descriptions of the horse-drawn carriage and the remote mountain village give way to depictions of Baku, including İçərişəhər, Ağşəhər, Qaraşəhər and Bayıl. The comparison between rural and urban life is drawn naturally, through appropriate details. Windy, crowded and sometimes frightening, ominous Baku and Abşeron are depicted in vivid colours. Yunis, who leaves village life to come to the city for an education, Aunt Tutu, the city girl Yaqut and her mother, and Aunt Tutu’s husband, the oil worker Uncle Əlimürsəl, are characters the writer has created with affection. The author’s comparison of the city-dwelling oil worker Uncle Əlimürsəl with Diyar, the village elder, is particularly interesting. Each of these working men is a wise man who knows the language of the earth. However extensive the depiction of events in the novella “Baku Nights”, its content is connected to “Sevil”, which holds an irreplaceable place in Cəfər Cabbarlı’s dramatic oeuvre: the *çadra* (an enveloping veil), the *kəlağayı* (a silk headscarf), old Baku and a woman pilot. All these demonstrate the resemblance between the development of Yaqut’s character in “Baku Nights” and that of Sevil.

“They Parted” (*Ayrıldılar*) portrays the love between İlyas and Adilə, their outlooks on the world and their conflicting views. Muxtar kişi, Xasayoğlu and Murad are also interesting characters in the work. Yet nature, too, is a distinctive character here, brought to life in all its beauty and grandeur. The horse Tərən is another engaging figure portrayed with affection. Muxtar kişi’s words, “The men of old mounted the noble steeds and rode to the other world”, convey a profound meaning. In the work, İlyas and Adilə’s separation leads Adilə to decide to come to the city. However, after learning of the death of İlyas, who had joined in helping the police, Adilə decides to return, as İlyas had wished, despite her parents’ objections. Adilə’s subsequent fate is, in effect, a continuation of İlyas’s unfulfilled aspirations. In general, the celebration of sublime feelings in Ənvər Məmmədخانlı’s oeuvre is unparalleled (Məmmədخانlı, 2005).

“Mountains of Legend” (*Əfsanəli dağlar*), whose very substance is kneaded from legends, also occupies an important place in Ənvər Məmmədخانlı’s oeuvre. Although Ovçu and Pəri are lifelike characters, motifs of legend predominate in their lives and behaviour. Ovçu’s realistic thoughts and outlook on life form a subtle contrast with Pəri’s world of imagination. The events, natural scenes and the characters’ feelings are conveyed in metaphorical language through similes, tropes and various descriptive and expressive literary devices. The imagery sustained throughout the work is conveyed through exceptionally engaging tableaux. The language of the story reflects all the subtleties of the native tongue: “Moving a little farther away, they pushed chest-first through the thicket blocking their path, then stopped, bent their neck and looked back again” (Məmmədخانlı, 2013).

The writer’s language and style vividly express all the shades of our living vernacular. The linguistic features of the work, the expressions in the language of the author and the characters, embody the subtleties of vernacular speech. Expressions such as “the red flame beginning to dance”, “the dawn light”, “armfuls of stars”, “the flame fluttered and beat its wings like a bird”, “eyes blazed like a torch in the darkness”, “fear nesting in the eyes”, “the forests surged and resembled a roaring sea”, “the wolves’ eyes shine like lamps at the bottom of the ravine”, “a lake languishing in a delicate mist” and “poplar leaves singing a song of night overhead” are among the finest examples of poetics in prose. In these lines, we see the poetry of prose. Figurative narration continues throughout the work. The writer’s descriptions express his figurative imagination and lyrical, poetic thought. This accompanies him throughout his literary career. “The evening sun, like a fiery bird, traced a semicircle along the horizon and descended behind Yasamal to the west” (Məmmədخانlı, 2013).

Overall, Ənvər Məmmədخانlı’s language is a rich literary language of great expressive power, reflecting all the subtleties of our literary tongue. His descriptions recall a consummate work of art painted with an artist’s brush: “The dawn light, resembling a graceful butterfly, would draw its cool, silken wings across Pəri’s eyes, and the girl would awaken to see a golden-winged mountain morning before her; then, as this delicate butterfly danced in the air, armfuls of stars would fall from its wings to the earth; towards evening, it would fold its weary wings and spread itself over Yasamal to the west, fluttering and blinking there in the yellow strings of the setting sun’s rays, before slowly melting away and disappearing” (Məmmədخانlı, 2013).

The beauty of the language in the writer’s works persists throughout his oeuvre. In “Mountains of Legend”, as in all his works, the beauty of expression is in harmony with the beauty of the content. The highly artistic expression of imagery keeps the writer’s oeuvre at the heights of literature and at the summit of poetic quality: “Pəri, meanwhile, was like a carefree child running and playing after this butterfly in the mornings. Now it seemed to her that the sun rose to awaken her, that the moon glided across the middle of the sky to smile at her, that the wind sweeping down from the

mountain spread its wings and came to caress her hair, and that evenings with pensive eyes descended upon the earth to sing her a lullaby" (Məmmədخانلی, 2013). The astonishing beauty of expression in the writer's language captivates the reader. Fascination with nature and admiration for the beauty of our language flow from the writer's pen into the reader's soul. "The bird of my heart was a *dövlət quşu* [bird of fortune] seeking its king, which at last came and beat its wings above your head..." (Məmmədخانلی, 2013).

Through series of synonyms, the expression of contrasting ideas, the harmony of coordinated sentence elements and the harmonious nuances of sounds, Ənvər Məmmədخانلی's oeuvre displays imagery at every level. His works, whose profound beauty of content prompts deep reflection, give readers pleasure through their artistic beauty. "Then it was as though a fine rain of silver dust had been scattered over the mountains and forests. Above, a cluster of white stars alighted on the line where the mountain ridge cut across the horizon. They set off, taking these stars as their bearings... the stars rose from the ridge like startled white doves, fixed themselves one by one upon the vault of heaven, and once again began to wink and shimmer in their native expanses" (Məmmədخانلی, 2013).

The wondrous, enchanting depiction of nature transforms every natural entity, with its subtle details, into a literary image. Through the power of art, nature in its thousand patterns comes into view. Poetic expressions and the harmony of delicate words are evident in

the author's language throughout the work. Expressing the inner world and subtle feelings of each character, the writer also conveys the language of nature to the reader. Under the author's pen, living nature, even a dried branch, acquires profound meaning. "A little farther below, a small mountain lake sheltered among green, wooded hills gleamed in the moonlight like a broken mirror. It was as though the stars had laid a veil of silver spangles over its face" (Məmmədخانلی, 2013).

Through the gems he created, Ənvər Məmmədخانلی erected a magnificent monument not only to his characters and works but also to himself. With its distinctive literary signature, Ənvər Məmmədخانلی's oeuvre is loved by a broad readership today, just as it was during his lifetime, and will continue to be loved. His works are examples of literary art that play an important role in the education and upbringing of the younger generation.

References

1. Məmmədخانلی, Ə. (2005). *Seçilmiş əsərləri* [Selected Works]. Baku: Avrasiya press. 416 pp.
2. Məmmədخانلی, Ə. (2013). *Seçilmiş əsərləri* [Selected Works]. Baku: Təhsil. 184 pp.
3. Məmmədov, D. (1977). *Ədəbi əsərlərdə sənətkarlıq xüsusiyyətləri* [Features of Literary Craftsmanship in Literary Works]. Baku: Maarif. 255 pp.
4. Rəsulova, Ə. (2026). Ə. Məmmədخانlının yaradıcılıq yolu [Ə. Məmmədخانlı's Literary Career]. Baku: *Ədəbiyyat jurnalı* [Literature Journal].

Colloquium-journal №23 (288), 2026

Część 1

(Warszawa, Polska)

ISSN 2520-6990

ISSN 2520-2480

Czasopismo jest zarejestrowany i wydany w Polsce. Czasopismo publikuje artykuły ze wszystkich dziedzin naukowych. Magazyn jest wydawany w języku angielskim, polskim i rosyjskim.

Częstotliwość: co tydzień

Wszystkie artykuły są recenzowane.

Bezpłatny dostęp do elektronicznej wersji magazynu. *нотатки*

Przesyłając artykuł do redakcji, autor potwierdza jego wyjątkowość i jest w pełni odpowiedzialny za wszelkie konsekwencje naruszenia praw autorskich.

Opinia redakcyjna może nie pokrywać się z opinią autorów materiałów.

Przed ponownym wydrukowaniem wymagany jest link do czasopisma.

Materiały są publikowane w oryginalnym wydaniu.

Czasopismo jest publikowane i indeksowane na portalu eLIBRARY.RU,

Umowa z RSCI nr 118-03 / 2017 z dnia 14.03.2017.

Redaktor naczelny - **Paweł Nowak, Ewa Kowalczyk**

«Colloquium-journal»

Wydawca «Interdruk» Poland, Warszawa

Annopol 4, 03-236

Format 60 × 90/8. Nakład 500 egzemplarzy.

E-mail: info@colloquium-journal.org

<http://www.colloquium-journal.org/>