SNAGE I SLABOSTI REPRODUKTIVNOG BIOEKONOMSKOG TRŽIŠTA: UVIDI IZ PREGLEDA LITERATURE

PREGLEDNI RAD

REVIEW ARTICLE

STRENGTHS AND WEAKNESSES OF THE REPRODUCTIVE BIOECONOMY MARKET: INSIGHTS FROM THE LITERATURE REVIEW

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SAŽETAK

Uvod: Ekonomija je oblast koja obuhvata proizvode, usluge i trgovinu, a reproduktivna bioekonomija se odnosi na oblast reprodukcije i načine proizvodnje, usluga, kupaca i trgovine sa reproduktivnim ćelijama i tkivima. Svrha ovog istraživanja je da se identifikuju ključni faktori na tržištu reproduktivne bioekonomije koji je oblikuju, kako bi se prepoznale mogućnosti za unapređenje, i uočili potencijalni izazovi. U skladu s tim, cilj rada podrazumeva sprovođenje analize za opisivanje snaga, slabosti, mogućnosti i pretnji (SWOT analize) na tržištu reproduktivne bioekonomije, što će omogućiti formulisanje strategijskih smernica za dalji razvoj.

Metode: Sproveden je pregled literature objavljene od 2017. do 2024. Sprovedena je pretraga akademskih i naučnih radova korišćenjem baze podataka PubMed, Springer i Elsevier, kao i alata Google Scholar za identifikaciju dodatnih relevantnih izvora. Korišćen je sledeći string za pretragu: (("donacija reproduktivnih ćelija" ILI "donacija gameta" ILI "donacija jajnih ćelija" ILI "donacija sperme") AND ("biomedicinski inženjering" ILI "biotehnologija proizvodnje gameta" ILI "kriobiologija gameta" ILI "banke gameta" ILI "gamete banks" ILI "gamete banks" OR "gamete banks" OR "gamete cross-border game") roditeljstvo" ILI „uticaj karijere na reprodukciju" ILI „pojedinačni donator donira više banaka" ILI „netradicionalna porodica" ILI „altruizam" ILI „reproduktivni rad" ILI „bioetika u doniranju reproduktivnih ćelija")). Faktori koji imaju najveći uticaj na razvoj reproduktivnog bioekonomskog tržišta su identifikovani korišćenjem PRISMA vodiča za izveštavanje (engl, Preferred Reporting Items for Systematic reviews and Meta-Analyses), i klasifikovani uz pomoć SWOT instrumenta za stratešku analizu u snage, slabosti, mogućnosti i pretnje.

Rezultati: Pregledom literature pokazano je da su najuticajnije (i) snage reproduktivne bioekonomije: postojanje i razvoj biomedicinskog inženjerstva, razvoj novih tehnologija u biotehnologiji – Kriobiologija, distribucija i biodostupnost proizvoda – kriobanke; (ii) tržišne mogućnosti: prekogranična reproduktivna zdravstvena zaštita (eng., Cross Border Reproductive Care), transnacionalni program donacije gameta (eng., Transnacional Gamete Donation) i raznolikost potrošača koji učestvuju na tržištu reproduktivne bioekonomije; ali i (iii) slabosti: odlaganje roditeljstva na starije životne dobi, regulisanje broja porodica po davaocu gde različiti standardi otežavaju praćenje, buduće formiranje složene, netradicionalne, moderne porodice; kao i (iv) potencijalne pretnje u vidu nepoznatog kvaliteta i budućih rezultata, bioetičke dileme i da komercijalizacija reproduktivnog rada predstavlja pretnju altruizmu.

Zaključak: Rezultati ovog istraživanja su pokazali značajan potencijal reproduktivne bioekonomije za lečenje neplodnosti i diversifikaciju porodice. Neophodno je da regulatorni okvir bude transparentan, u skladu sa etičkim i normativnim propisima, pre sprovođenja programa doniranja reproduktivnog materijala, i uvođenja nacionalnog registra za domaće i strane državljane, sve potencijalne korisnike programa donacije.

Ključne reči: bioekonomija, biotehnologija, SWOT analiza, reproduktivno tržište, donacija gameta, PRISMA

ABSTRACT

Introduction: The economy is a field that includes products, services, and trade, and reproductive bioeconomy refers to the field of reproduction and the ways of production, services, customers, and trade of reproductive cells and tissues. This research aimed to identify the key factors that shape the reproductive bioeconomy market and pinpoint opportunities for improvement as well as potential challenges. Accordingly, the study objective includes implementing an analysis to determine the Strengths, Weaknesses, Opportunities, and Threats in the reproductive bioeconomy market (SWOT analysis); this will enable the formulation of strategic guidelines for further development.

Methods: A review of the literature published from 2017 to 2024 was carried out. A search of academic and scientific papers was conducted using the PubMed, Springer, and Elsevier databases, as well as the Google Scholar tool, to identify additional relevant sources. The following search string was used:"("donating reproductive cells" OR „gamete donation" OR „oocyte donation " OR „sperm donation") AND („ biomedical engineering" OR „in vitro gamete production biotechnology" OR „gamete cryobiology" OR „gamete banks" OR „cross-border reproductive care " OR „Transnational gamete donation") AND („ parenthood delay" OR „career impact on reproduction" OR „one donor donates to several banks" OR „non-traditional family" OR „altruism" OR „reproductive work" OR „ bioethics in donating reproductive cells")". The factors that have the greatest impact on the development of the reproductive bioeconomy market have been identified using the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) guide, and classified with the help of the SWOT instrument for strategic analysis into strengths, weaknesses, opportunities, and threats.

Results: The review of the literature showed that the most influential forces of the reproductive bioeconomy are: (i) the strengths of the reproductive bioeconomy: the existence and development of biomedical engineering, the development of new technologies in biotechnology – Cryobiology, distribution and bioavailability of products – cryobanks; (ii) market opportunities: cross-border reproductive care (eng., Cross Border Reproductive Care), Transnational Gamete Donation Program (eng., Transnational Gamete Donation), and the diversity of consumers participating in the reproductive bioeconomy market; but also (iii) weaknesses: postponing parenthood to older ages, regulating the number of families per donor where different standards make monitoring difficult, the future formation of a complex, non-traditional, modern family; as well as (iv) potential threats in the form of unknown quality and future results, bioethical dilemmas, and that the commercialisation of reproductive work poses a threat to altruism.

Conclusion: This research demonstrates significant potential for the reproductive bioeconomy in treating infertility and promoting family diversification. Before implementing the reproductive material donation program and establishing a national registry for domestic and foreign citizens who are potential beneficiaries of the donation program, the regulatory framework must be transparent and aligned with ethical and normative regulations.

Keywords: bioeconomy, biotechnology, SWOT analysis, reproductive market, gamete donation, PRISMA

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UVOD

Prema izveštaju Organisation for Economic Co-operation and Development (OECD), na srpskom - Organizacija za ekonomsku saradnju i razvoj [1], reproduktivna bioekonomija postaje sve značajnija za unapređenje zdravlja populacije. Ona obuhvata primenu biotehnoloških inovacija u oblasti reproduktivnog zdravlja, što dovodi do poboljšanog kvaliteta zdravstvene zaštite i povećanja uspešnosti u reproduktivnoj medicini. Uz razvoj reproduktivne bioekonomije, neophodno je prilagoditi javne zdravstvene politike kako bi se obezbedila njena dostupnost i etička primena. Globalna demografska kretanja ukazuju na starenje populacije i pad nataliteta u pojedinim zemljama [2]. Za održivi razvoj društva potrebni su inovativni pristupi u ključnim oblastima, kao što je reproduktivna bioekonomija [1].

Bioekonomija kombinuje biotehnologiju i prirodne biološke nauke, a biološki materijali i proizvodi predstavljaju priliku za održivi ekonomski rast [3]. Definicija „bioekonomije" kaže da je to deo ekonomije koji koristi napredno biološko razumevanje u poslovne i industrijske svrhe za unapređenje ljudskog blagostanja [4]. Prema projektu Bioekonomija Organizacije za ekonomsku saradnju i razvoj, do 2030. godine biotehnologija kao deo bioekonomije se opisuje kao „svet u kome biotehnologija daje značajan doprinos ekonomskom outputu", sa fokusom na korišćenje biotehnologije za generisanje ekonomskog rasta [5]. Današnja bioekonomija se smatra „biokapitalizmom" [6]. Resursi bioekonomije se upravljaju tako da zamene proizvode dobijene iz neobnovljivih izvora (npr. fosilnih goriva) sa proizvodima dobijenim iz obnovljivih izvora, kao što su oni koji se uzgajaju (npr. biogorivo) [4]. Reproduktivna bioekonomija obuhvata način na koji reproduktivna tkiva, ćelije, usluge donacije, korisnici i radnici postaju deo globalnog biokapitalizma. Reproduktivni organi, jajne ćelije, spermatozoidi, embrioni i materice uključuju reproduktivni rad u komercijalizaciji jajnih ćelija, sperme, dobavljača tkiva i surogat majki, a tržišni akteri podstiču komercijalizaciju i nadoknadu za davaoce [7]. Strateški cilj reproduktivne bioekonomije je proširenje spektra proizvoda uzgajanih in vitro - od proizvodnje reproduktivnih ćelija [8] do novih tehnologija inženjeringa tkiva za proizvodnju materice iz matičnih ćelija [9]. Razvijaju se strategije za tehnološki napredak regenerativne medicine u oblasti biologije matičnih ćelija koje mogu generisati zdravlje i bogatstvo, primenjujući inženjersku tehnologiju i prirodne nauke. Ćelije se generišu de novo i imaju potencijal i sposobnost da regenerišu i zamene oštećena tkiva usled starosti, bolesti, traume ili urođenih mana [10].

Za medicinski tretman koji uključuje donaciju reproduktivnih ćelija, trenutni resursi reproduktivne bioekonomije su neobnovljivi i oslanjaju se na ograničenu

INTRODUCTION

According to the Organisation for Economic Co-operation and Development (OECD) report [1], the reproductive bioeconomy is becoming more significant in improving population health. It encompasses the application of biotechnological innovations in reproductive health, leading to improved quality of healthcare and increased success in reproductive medicine. Along with the development of the reproductive bioeconomy, public health policies must be adapted to ensure its availability and ethical implementation. Global demographics indicate an aging population and a decline in birth rates in some countries [2]. For the sustainable development of society, innovative approaches are necessary for key areas such as the reproductive bioeconomy [1].

The bioeconomy combines biotechnology and natural biological sciences, and biological materials and products offer an opportunity for sustainable economic growth [3]. The definition of "Bioeconomy" says that it is part of the economy that uses advanced biological understanding for business and industrial purposes to develop human well-being [4]. According to the Bioeconomy project of the Organization for Economic Co-operation and Development, until 2030, biotechnology as a bioeconomy is described as "a world where biotechnology supply with a significant contribution to the economic output," focusing attention on the use of biotechnology to generate economic growth [5]. Today's bioeconomy is considered "biocapitalism" [6]. The resources of the bioeconomy are managed to replace products obtained from non-renewable sources (e.g., fossil fuels) with products derived from renewable sources, such as those grown (e.g., biofuel) [4]. The reproductive bioeconomy encompasses how reproductive tissues, cells, donation services, customers, and workers become part of global biocapitalism. Reproductive organs, eggs, sperm, embryos, and wombs involve reproductive labour in the commercialisation of eggs, sperm, tissue suppliers, and surrogate mothers, and market supporters encourage commercialisation and compensation to suppliers [7]. The strategic goal of the reproductive bioeconomy is to expand the range of products grown in vitro from the production of reproductive cells [8] to new tissue engineering technologies for the production of the uterus from stem cells [9]. Strategies are being developed for the technological advancement of regenerative medicine in the area of stem cell biology that can generate health and wealth that applies engineering technology and natural sciences, cells are generated de novo and have the potential and ability to regenerate and replace damaged tissues damaged by age, disease or trauma, or birth defects [10].

For reproductive medical treatment involving reproductive cell donation, the current resources of the

ponudu donatora (donora reproduktivnih ćelija) kao dobavljača bioproizvoda [11]. Tretman uključuje specifične skupove (fenotipskih karakteristika) koji predstavljaju resurse reproduktivnih bioekonomija u zemljama poput Španije, Grčke, Češke i Danske, a način na koji funkcioniše uparivanje pacijenata i donora oblikuje pacijente kao potrošače izbora, dok uparivanje ima ključnu ulogu u marketingu, pa se bazeni reproduktivnih ćelija tretiraju kao konkurentski proizvodi u reproduktivnoj bioekonomiji, iako reproduktivni zakoni insistiraju da se nabavka reproduktivnih ćelija zasniva na altruističkoj donaciji sa malom finansijskom nadoknadom u vidu ekonomske kompenzacije do maksimalno 1000 evra, što je iznos dovoljan da se izbegne komercijalizacija transakcije [5]. Banke smrznutih reproduktivnih ćelija se globalno šire slanjem setova ćelija širom sveta u kriogenim kontejnerima, što je dovelo do širenja tržišta. Kao rezultat toga, banke povećavaju svoje zalihe donatora sa specifičnim fenotipovima kako bi zadovoljile potrebe transnacionalne industrije plodnosti [11]. Tržište plodnosti je vredna industrija koja se procenjuje na više milijardi dolara ili nekoliko miliona evra i uključuje donaciju gameta/embriona i surogat materinstvo [12]. Industrija plodnosti Danske generiše stotine miliona dolara [13]. Svaka zemlja ima zakonske regulative koje definišu postupak korišćenja resursa reproduktivne bioekonomije, ali ti zakoni ne diktiraju već oblikuju transnacionalnu industriju plodnosti [14].

Regulisanje bioetičkih dilema, reproduktivnih prava i roditeljstva, koje zavise od nacionalnih pravnih okvira i kulturnih specifičnosti, pruža uvid u etičke i normativne izazove u ovoj oblasti [15].

Propisi koji se odnose na nabavku i upotrebu reproduktivnih ćelija razlikuju se od zemlje do zemlje. Te razlike su dovele do ideje o proceni snaga i slabosti tržišta reproduktivne bioekonomije, posebno u vezi sa korišćenjem neobnovljivih donorskih reproduktivnih ćelija.

Cilj ove studije bio je da se sprovede sistematski pregled postojeće literature u vezi sa snagama, slabostima, mogućnostima i pretnjama trenutnog tržišta reproduktivne bioekonomije i da se izvrši SWOT analiza koja omogućava formulisanje strateških smernica za dalji razvoj.

METODE

Strategija pretrage

Istraživanje i pregled literature sprovedeni su u periodu od januara do aprila 2024. godine. Pretraga je obuhvatila recenzirane članke objavljene na engleskom jeziku u akademskim časopisima, na osnovu kojih je formirana konačna referentna lista. Pregled akademskih i naučnih radova vršen je putem Google Scholar platforme, sa ciljem identifikacije što većeg broja recenziranih publikacija objavljenih u stručnim časopisima. Dodatne baze

reproductive bioeconomy are non-renewable, relying on a limited supply of donors (reproductive cell donors) as suppliers of bioproducts [11]. The treatment involves specific sets (of phenotypic characteristics) that represent the resources of reproductive bioeconomies in countries like Spain, Greece, the Czech Republic and Denmark, and how patient-donor matching works shapes patients as consumers of choice and how matching plays a key role in marketing so pools of reproductive cells are given the role of competing products in the reproductive bioeconomy, although reproductive laws insist that the procurement of reproductive cells is based on an altruistic donation with a small financial compensation in the form of economic compensation of a maximum of 1000 euros, which is a sum sufficient to avoid the commercialization of the transaction [5]. Frozen reproductive cell cryobanks are expanding globally by shipping sets of reproductive cells around the world in cryogenic containers, which has led to an expanding market. As a result, banks are increasing their reserves of donors with specific phenotypes to meet the needs of the transnational fertility industry [11]. The fertility market is a valuable industry estimated to be worth billions of dollars or several million euros and includes gamete/embryo donation and gestational surrogacy [12]. Denmark's fertility industry generates hundreds of millions of dollars [13]. Every country has legal regulations that define the procedure for using the resources of the reproductive bioeconomy, and these laws do not dictate but instead shape the transnational fertility industry [14].

The regulation of bioethical dilemmas, reproductive rights, and parenthood, which depend on national legal frameworks and cultural specificities, provides insights into the ethical and normative challenges in this area [15].

Regulations regarding the procurement and use of reproductive cells vary from country to country. These differences have led to the idea of assessing the strengths and weaknesses of the reproductive bioeconomy market, particularly in relation to the use of non-renewable donor reproductive cells.

This study aimed to conduct a systematic review of the existing literature regarding the strengths, weaknesses, opportunities, and threats of the current reproductive bioeconomy market, and to undertake a SWOT analysis that enables the formulation of strategic guidelines for further development.

METHODS

Search strategy

The research and literature review were conducted from January to April 2024. The search included peer-reviewed articles published in English in academic journals, based on which the final reference list was generated. A review

podataka koje su korišćene uključuju PubMed, Springer i Elsevier. Korišćen je sledeći niz ključnih reči za pretragu: SWOT analiza ILI bioekonomsko tržište I donacija reproduktivnih ćelija ILI donacija gameta ILI donacija jajnih ćelija ILI donacija sperme I (biomedicinski inženjering ILI biotehnologija proizvodnje gameta in vitro ILI kriobiologija gameta ILI banke gameta ILI prekogranična reproduktivna zaštita (CBRC) ILI transnacionalna donacija gameta I odlaganje roditeljstva ILI uticaj karijere na reprodukciju ILI jedan donor donira u više banaka ILI netradicionalna porodica ILI altruizam ILI reproduktivni rad ILI bioetika u donaciji reproduktivnih ćelija.

Kriterijumi za selekciju

Kriterijumi za uključivanje bili su publikacije koje su u svom tekstu sadržale opis ključnih pojmova i njihova objašnjenja, koja bi mogla doprineti njihovom uključivanju u SWOT analizu (snage, slabosti, mogućnosti, pretnje). Kriterijumi za isključenje su bili sledeći: po datumu objavljivanja – publikacije starije od 2017. godine su isključene, kao i one koje nisu pružale jasniji uvid u navedene snage, slabosti, mogućnosti i pretnje.

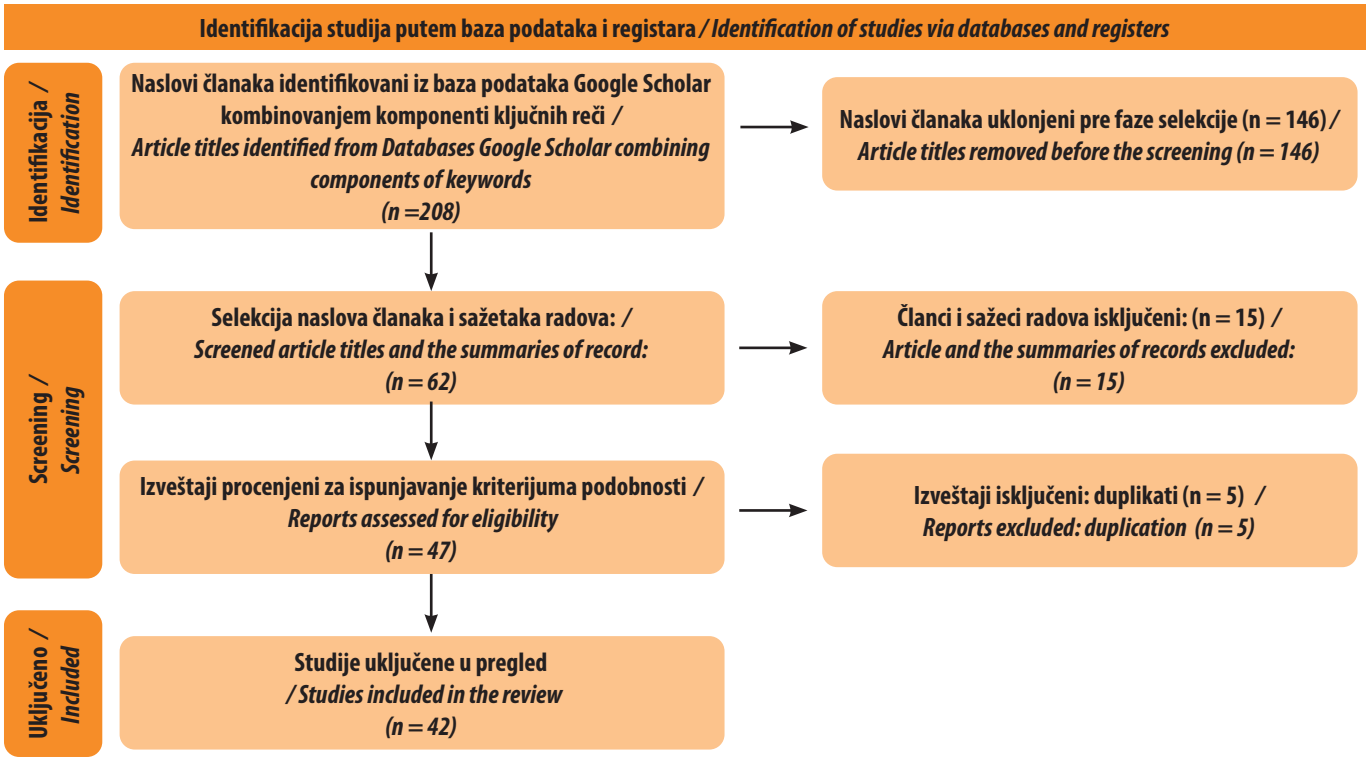
U skladu sa PRISMA smernicama [16] i pregledom PRISMA dijagrama toka (Slika 1), selekcija literature sprovedena je tako što su najpre analizirani naslovi. Za izvučene naslove izvršena je selekcija sažetaka svakog rada, nakon čega je procenjeno da li je sadržaj članka relevantan ili koristan za sistematski pregled. Ova pretraga je rezultirala analizom 208 naslova članaka, od

of academic and scientific works was conducted using Google Scholar to identify as many peer-reviewed publications as possible, published in academic journals. Additional database sources consulted included PubMed, Springer, and Elsevier. The following search string was used: SWOT analysis OR bioeconomic market AND donating reproductive cells OR gamete donation OR oocyte donation OR sperm donation AND (biomedical engineering OR in vitro gamete production biotechnology OR gamete cryobiology OR gamete banks OR cross-border reproductive care (CBRC) OR Transnational gamete donation AND parenthood delay OR career impact on reproduction OR one donor donates to several banks OR non-traditional family OR altruism OR reproductive work OR bioethics in donating reproductive cells.

Selection criteria

The criteria for inclusion were publications that contained in their text a description of keywords and their explanations that could help to include them in the SWOT analysis (strengths, weaknesses, opportunities, threats). The exclusion criteria were as follows: by publication date, publications older than 2017 were excluded, and those that could not give a clearer picture of the mentioned strengths, weaknesses, opportunities, and threats were excluded.

Following the PRISMA guide [16] and by reviewing the PRISMA flow diagram (Figure 1), we conducted the literature selection by initially analyzing the titles. For



Slika 1. Ilustrovani PRISMA dijagram toka izbora studija prema PRISMA vodiču [16]

Figure 1. Illustrated PRISMA flow diagram of study selection in accordance with the PRISMA guide [16]

kojih je 62 odabrano na osnovu naslova. Dodatnih 15 članaka je isključeno jer nisu sadržali podatke značajne za SWOT analizu i nisu nudili relevantne uvide u ključne aspekte programa donacije gameta i njihov uticaj na reproduktivnu medicinu. Takođe, uklonjeno je i pet duplikata. Na kraju, 42 članka su ispunila kriterijume selekcije i čine osnovu ovog rada.

Kvalitativna analiza

Ova studija sprovela je kvalitativnu analizu sadržaja literature kako bi identifikovala faktore koji potencijalno podstiču rast i predstavljaju izazove za razvoj reproduktivne bioekonomije. U istraživanju je korišćena SWOT analiza kao metodološki okvir za organizaciju i tumačenje kvalitativnih podataka. SWOT analiza pomaže u identifikaciji snaga, slabosti, mogućnosti i pretnji unutar reproduktivne bioekonomije, nudeći strukturiran pristup za razumevanje potencijala i izazova u ovoj oblasti. Ova metoda je korisna za sintezu podataka iz naučnih izvora, jer omogućava integraciju složenih informacija i njihovu primenu u strateškom planiranju i razvoju sektora.

Uspostavljena je kategorizacija na pokretače rasta i izazove. Faktori koji su klasifikovani kao pokretači rasta obuhvataju sve aspekte koji pozitivno doprinose razvoju reproduktivne bioekonomije, dok faktori klasifikovani kao izazovi obuhvataju prepreke i rizike.

Prvi autor je sproveo pregled naslova, analizu i sintezu članaka navedenih u referencama. Prvi autor je pročitao pune tekstove 42 članka i razvrstao ih po SWOT tabelama. Delovi teksta članaka koji su se bavili pitanjima snaga, slabosti, mogućnosti i pretnji analizirani su prema uputstvima o tome zašto pripadaju određenoj tabeli i obeleženi simbolom +. Drugi i treći autor su pregledali i proverili sve prikupljene radove. Okvir za pretragu informacija kreiran je na osnovu SWOT analiza, pri čemu su informacije iz svakog rada izvlačene i predstavljene u diskusiji od strane prvog autora, uz sugestije drugog i trećeg autora.

REZULTATI

Rezultati istraživanja prikazani su kroz četiri segmenta SWOT analize, korišćenjem relevantnih referenci iz literature:

1. Snage:
   - Razvoj novih biotehnologija i metoda krioprezervacije.
   - Povećana dostupnost bioekonomskih proizvoda putem biobanaka.
   - Odlaganje roditeljstva do kasnijeg životnog doba, sa medicinskim i društvenim posledicama.
2. Slabosti:
   - Visoki troškovi i tehnička ograničenja krioprezervacije.

the extracted titles, a screening of each record's summary was performed, after which it was determined whether the article's content would be relevant or helpful for a systematic review. This search resulted in an analysis of 208 article titles, from which 62 were selected based on their titles. An additional 15 articles were excluded because they did not contain data significant for the SWOT analysis and lacked relevant insights into the key aspects of donor gamete programs and their impact on reproductive medicine. Five duplicates were also removed. Consequently, 42 articles met the selection criteria, forming the basis of this paper.

Qualitative Analysis

This study conducted a qualitative content analysis of literature to identify factors that potentially promoted growth and posed challenges to the development of the reproductive bioeconomy. This research employed a SWOT analysis as a methodological framework for organizing and interpreting qualitative data. The SWOT analysis helps to identify strengths, weaknesses, opportunities, and threats within the reproductive bioeconomy, offering a structured approach to understanding the potential and challenges in this area. This method is beneficial for synthesising data from scientific references, as it allows for the integration of complex information and its application in strategic planning and development of the sector.

A categorization into growth drivers and challenges has been established. Factors classified as growth drivers include all aspects that positively contribute to the development of the reproductive bioeconomy, while factors classified as challenges involve obstacles and risks.

The first author did the title review, analysis, and synthesis of the articles listed in the references. The first author read the full texts of 42 articles and divided and grouped the titles into SWOT tables. The parts of the article text that addressed the questions on strengths, weaknesses, opportunities, and threats were examined based on the instructions on why they belonged in the given table and were assigned the symbol +. The second and third authors reviewed and cross-checked the texts of all retrieved papers. The information search framework was created based on SWOT analyses, requiring the extraction of information from each paper and its presentation in the discussion by the first author, with suggestions from the second and third authors.

RESULTS

The results of the research are presented through four segments of SWOT analysis, using relevant references from the literature:

3. Mogućnosti:
   - Implementacija transnacionalnih programa kao što su CBRC i TGD.
   - Aktivno učešće potrošača na tržištu reproduktivne bioekonomije.
4. Pretnje:
   - Etnička pitanja, komercijalizacija reproduktivnih usluga i nepoznati dugoročni efekti novih tehnologija.

Svaka od tabela u prilogu pokriva specifične aspekte reproduktivne bioekonomije. Snage (Tabela 1): Ova tabela pruža pregled referenci koje ističu snage repro-

1. Strengths:
   - Development of new biotechnologies and cryopreservation methods.
   - Increased availability of bioeconomic products through biobanks.
   - Delaying parenthood until later in life, with medical and social consequences.
2. Weaknesses:
   - High costs and technical limitations of cryopreservation.
3. Opportunities:
   - Implementation of transnational programs such as CBRC and TGD.

Tabela 1. Studije uključene u sistematski pregled (Snage)

Table 1. Studies included in the systematic review (Strengths)

	Naziv / *Name*	Godina / *Year*	Izvor / *Source*	Snage / *Strengths*	Razvoj biomedicinskog inženjeringa / *Development of biomedical engineering*	Razvoj novih tehnologija u biotehnologiji – Kriobiologija / *Development of new technologies in biotechnology – Cryobiology*	Bioiskoristivost proizvoda – Kriobanke / *Bioavailability of products – Cryobanks*	Odlaganje roditeljstva do poodmaklog životnog doba/ *Postponing parenthood to advanced age*
1	Razvoj biomedicinskih inženjerskih tehnologija za reproduktivnu medicinu [18] / *Developing biomedical engineering technologies for reproductive medicine [18]*	2022	Smart Med.	+	+			
2	Stvaranje veštačkih gameta i embriona iz matičnih ćelija u reproduktivnoj medicine [22] / *Generation of artificial gamete and embryo from stem cells in reproductive medicine [22]*	2020	Front Bioeng Biotechnol.	+	+			
3	Napredni bioinženjering matičnih ćelija muških zametnih ćelija za očuvanje plodnosti [23] / *Advanced bioengineering of male germ stem cells to preserve fertility [23]*	2021	J Tissue Eng.	+	+			
4	Kriopolitika reprodukcije na ledu: Nova skandinavska ledena epoha [13] / *The cryopolitics of reproduction on ice: A new Scandinavian ice age [13]*	2019	Emerald Publishing Limited;	+		+	+	
5	Pregled krioprezervacije ljudskih jajnih ćelija u programima asistirane reprodukcije: Trenutni izazovi i mogućnosti / *Review of human oocyte cryopreservation in ART programs: Current challenges and opportunities [24]*	2023	Cryobiology	+		+		
6	Jajkonomija: Vitrifikacija i bioekonomije donacije jajnih ćelija u Sjedinjenim Američkim Državama i Španiji / *Eggonomics: Vitrification and bioeconomies of egg donation in the United States and Spain [11]*	2023	Med Anthropol Q.	+		+		
7	Reprodukovanje beline i uspostavljanje srodstva u nordijskom kontekstu transnacionalne donacije jajnih ćelija: Usklađivanje donorki sa primaocima koji putuju preko granica u Finskoj[12] / *Reproducing whiteness and enacting kin in the Nordic context of transnational egg donation: Matching donors with cross-border traveller recipients in Finland [12]*	2018	Soc Sci Med.	+			+	
8	Prilagođavanje kriobioloških tehnika socijalno i ekonomski ugroženim populacijama - Deo 1: Strategije kriogene prezervacije [25] / *Translation of cryobiological techniques to socially economically deprived populations-Part 1: Cryogenic preservation strategies [25]*	2020	Journal of Medical Devices.	+			+	
9	Krioprezervacija jajnih ćelija i ovarijalnog tkiva u evropskim zemljama: zakonski okvir, praksa, skladištenje i upotreba [26] / *Oocyte and ovarian tissue cryopreservation in Europeancountries: statutory background, practice, storage and use [26]*	2017	Hum Reprod Open.	+			+	

duktivne bioekonomije, uključujući razvoj novih biotehnologija, napredak u biomedicinskom inženjeringu i inovacije u krioprezervaciji.

Mogućnosti (Tabela 2): Tabela prikazuje mogućnosti identifikovane u literaturi, kao što su širenje primene bioekonomskih rešenja, razvoj održivih biotehnologija i unapređenje međunarodne saradnje u ovoj oblasti.

- Active participation of consumers in the reproductive bioeconomy market.

4. Threats:
   - Ethical issues, commercialization of reproductive services, and the unknown long-term effects of new technologies.

Tabela 2. Studije uključene u sistematski pregled (Mogućnosti)

Table 2. Studies included in the systematic review (Opportunities)

	Naziv / *Name*	Godina / *Year*	Časopis / *Journal*	Mogućnosti / *Opportunities*	Prekogranična reproduktivna zaštita (CBRC) / *Cross-border reproductive care (CBRC)*	Transnacionalni program donacije gameta (TGD) / *Transnational Gamete Donation Program (TGD)*	Tip potrošača koji učestvuje na tržištu reproduktivne bioekonomije / *Participating consumer type in the reproductive bioeconomy market*
1	Prekogranična reproduktivna zaštita (CBRC): rastući globalni fenomen sa višedimenzionalnim implikacijama (sistematski i kritički pregled) / Cross border reproductive care (CBRC): a growing global phenomenon with multidimensional implications (a systematic and critical review) [27]	2018	J Assist Reprod Genet.	+	+		
2	Održivi pristupi medicinskom turizmu: Strategije za Centralnu Makedoniju / Grčku / Sustainable approaches to medical tourism: Strategies for Central Macedonia/Greece. Sustainability [28]	2023	Sustainability	+	+		
3	Globalizovane potrage za asistiranim začećem: Reproduktivna putovanja zbog neplodnosti i nevoljne bezdetnosti[29] / Globalised quests for assisted conception: Reproductive travel for infertility and involuntary childlessness [29]	2019	Glob Public Health.	+	+		
4	Španski pravni reproduktivni pejzaž: Stvaranje bio-industrije [30] / Spanish legal reproscape: The making of a bio-industry [30]	2021	Law, Tech. & Hum.	+	+		
5	Višestruke mobilnosti u industriji plodnosti u Meksiku [31] / Multiple mobilities in Mexico's fertility industry [31]	2019	Mobilities.	+	+		
6	Bioekonomije: Život, tehnologija i kapital u 21. Veku [5] / Bioeconomies: Life, Technology, and Capital in the 21st Century [5]	2017	Book	+	+	+	
7	Procvat biznisa sa bebama: Ekonomske geografije asistirane reprodukcije [32] / The baby business booms: Economic geographies of assisted reproduction [32]	2018	Geogr Compass.	+	+		
8	„Dve zemlje – dve laboratorije": Program transnacionalne donacije gameta (TGD) za podršku donaciji jajnih ćelija [33] / 'Two countries-two labs': the transnational gamete donation (TGD) programme to support egg donation	2020	Journal of Assisted Reproduction and Genetics	+		+	
9	Pregled krioprezervacije ljudskih jajnih ćelija u programima asistirane reprodukcije: Trenutni izazovi i mogućnosti [34] / Review of human oocyte cryopreservation in ART programs: Current challenges and opportunities [34]	2023	Cryobiology	+		+	
10	Transakcije jajnih ćelija preko granica u postsovjetskom prostoru [10] / Transacting oocytes across borders in the post-Soviet space [35]	2022	Cult Anthropol.	+		+	
11	Kriopolitika reprodukcije na ledu: Nova skandinavska ledena epoha [13] / The cryopolitics of reproduction on ice: A new Scandinavian ice age [13]	2019	Emerald Publishing Limite	+		+	
12	„Želela bih da joj platim": Izazivanje altruističke razmene jajnih ćelija u Kanadi kroz moralne mozaike [37] / "I would want to pay her": Challenging altruistic egg exchanges in Canada through moral patchworks [37]	2021	Soc Sci Med.	+			+
13	Karakteristike i namere heteroseksualnih parova koji uključuju transrodnog muškarca koji čeka donaciju sperme za začeće deteta [38] / Characteristics and intentions of heterosexual couples comprising a transgender man awaiting sperm donation to conceive a child [38]	2021	Andrology	+			+

Tabela 3. Studije uključene u sistematski pregled (slabosti)

Table 3. Studies included in the systematic review (Weaknesses)

	Naziv / *Name*	Godina / *Year*	Časopis / *Journal*	Slabosti / *Weaknesses*	Nedostatak regulative u vezi sa brojem porodica po donoru / *Lack of regulation regarding the number of families per donor*	Buduće formiranje složene, netradicionalne, moderne porodice / *The future formation of a complex, non-traditional, modern family*	Visoki troškovi i ograničenja krioprezervacije / *High costs and limitations of cryopreservation*
1	Vitrifikacija oocita za elektivno očuvanje plodnosti: SWOT analiza [39] / *Oocyte vitrification for elective fertility preservation: a SWOT analysis [39]*	2022	Reprod Biomed Online	+			
2	Odlaganje majčinstva: Razlozi, determinante, vreme potrebno za postizanje trudnoće i nivo anksioznosti kod majki [40] / *The delay of motherhood: Reasons, determinants, time used to achieve pregnancy, and maternal anxiety level [40]*	2019	PLoS One.	+			
3	Preporuke za dobru praksu u pružanju informacija onima koji su uključeni u reproduktivnu donaciju [41] / *Good practice recommendations for information provision for those involved in reproductive donation [41]*	2022	Human Reproduction Open	+	+		
4	Sperma na koju možete računati: Predlog saveznog regulatornog okvira za povećanje zaštite potrošača u industriji donacije sperme[42] / *Sperm you can bank on: A proposed federal regulatory scheme to increase consumer protection in the sperm donation industry [42]*	2021	Book	+	+		
5	„Mešati ili slagati?": Transnacionalna industrija plodnosti i poželjnost belaca [14] / *Mix or Match?": Transnational fertility industry and white desirability [14]*	2021	Med Anthropol.	+	+		
6	Pravni pejzaž reprodukcije u Španiji: Stvaranje bio-industrije [30] *Spanish legal reproscape: The making of a bio-industry [30]*	2021	Law, Tech. & Hum.	+	+		
7	Emocije, otelotvorenje i reproduktivni kolonijalizam u globalnoj trgovini ljudskim jajnim ćelijama [43] / *Emotion, embodiment, and reproductive colonialism in the global human egg trade [43]*	2021	Gend Work Organ.	+	+		
8	SWOT analiza neregulisane donacije sperme [44] / *A SWOT analysis of unregulated sperm donation [44]*	2023	Reprod Biomed Online	+	+		
9	Kreativno postajanje porodicom u klinici za plodnost? Uparivanje donora sa neheteroseksualnim i samostalnim primaocima u komercijalnoj zaštiti. U: Kreativne porodice: Rod i tehnologije svakodnevnog života [45] / *Creatively becoming a family in the fertility clinic? Matching donors with non-heterosexual and single recipients in commercial care. In: Creative Families: Gender and Technologies of Everyday Life [45]*	2021	Springer International Publishing;	+		+	
10	Roditeljstvo uz pomoć tehnologije i moderne porodice u 21. veku. U: *Moderne veze: Romansa, prijateljstvo i porodica u 21. veku* [46] / *Technology-Assisted Parenthood and Modern Families in the 21st Century. In: Modern Relationships: Romance, Friendship, and Family in the 21st Century [46]*	2024	Book	+		+	
11	U: Sloboda naučnog istraživanja [47] / *Reproductive technologies and the family in the twenty-first century. In: The freedom of scientific research [47]*	2020	Manchester University Press;	+		+	
12	„Dve zemlje – dve laboratorije": Transnacionalni program donacije gameta (TGD) za podršku donaciji jajnih ćelija [33] / *'Two countries-two labs': the transnational gamete donation (TGD) programme to support egg donation [33]*	2020	Journal of Assisted Reproduction and Genetics.	+			+
13	Krioprezervacija oocita – trenutna situacija i buduće perspektive: narativni pregled [48] / *Oocyte cryopreservation-current scenario and future perspectives: a narrative review [48]*	2021	J Hum Reprod Sci	+			+

Tabela 4. Studije uključene u sistematski pregled (pretnje)

Table 4. Studies included in the systematic review (Threats)

	Naziv / *Name*	Godina / *Year*	Časopis / *Journal*	Pretnje / *Threats*	Nepoznat kvalitet i budući rezultati / *Unknown quality and future results*	Reproduktivni rad kao pretnja altruizmu / *Reproductive work as a threat to altruism*	Bioetičke dileme / *Bioethical dilemmas*
1	„Dve zemlje – dve laboratorije": Transnacionalni program donacije gameta (TGD) za podršku donaciji jajnih ćelija [33] / *'Two countries-two labs': the transnational gamete donation (TGD) programme to support egg donation [33]*	2020	Journal of Assisted Reproduction and Genetics	+	+		
2	Pregled krioprezervacije ljudskih oocita u programima asistirane reprodukcije: Trenutni izazovi i mogućnosti [34] / *Review of human oocyte cryopreservation in ART programs: Current challenges and opportunities [34]*	2023	Cryobiology	+	+		
3	Upravljanje krioskadištenjem reproduktivnih ćelija i tkiva u asistiranoj reprodukciji: stanje, potrebe, mogućnosti i potencijalni novi izazovi [49] / *Cryostorage management of reproductive cells and tissues in ART: status, needs, opportunities, and potential new challenges [49]*	2023	Reproductive BioMedicine Online	+	+		
4	Krioprezervacija gameta i embriona i njihove molekularne promene [50] / *Cryopreservation of gametes and embryos and their molecular changes [50]*	2021	Int J Mol Sci.	+	+		
5	Kriopolitika reprodukcije na ledu: Nova skandinavska ledena doba [13] / *The cryopolitics of reproduction on ice: A new Scandinavian ice age [13]*	2019	Emerald Publishing Limited;	+		+	
6	Ekonomske geografije asistirane reprodukcije [32] / *Economic geographies of assisted reproduction [32]*	2018	Geogr Compass.	+		+	
7	Ekonomija donacije jajnih ćelija u Španiji kao globalna/intimna kontakt zona [51] / *The Spanish egg donation economy as a global/intimate contact zone [51]*	2022	Documents d'Anàlisi Geogràfica.	+		+	
8	O (globalnim) lancima nege u vremenima krize: donacija jajnih ćelija i kućni rad u Španiji [52] / *On (global) care chains in times of crisis: egg donation and domestic work in Spain [52]*	2020	Tapuya: Latin Am Sci Technol Soc.	+		+	
9	Da li banka gameta treba da verifikuje nemedicinske informacije koje pruža donor? [53] / *Should a gamete bank verify the non-medical information provided by a donor? [53]*	2024	Hum Reprod.	+		+	
10	Preporuke za dobru praksu u pružanju informacija onima koji su uključeni u reproduktivnu donaciju [41] / *Good practice recommendations for information provision for those involved in reproductive donation [41]*	2022	Human Reproduction Open	+			+
11	Razvijajuća etika donacije sperme[54] / *The evolving ethics of sperm donation [54]*	2022	Johns Hopkins University	+			+
12	Pravo deteta da zna naspram prava roditelja da ne kažu: Stavovi parova koji se podvrgavaju tretmanima plodnosti prema donaciji gameta sa otkrivanjem identiteta [55] / *The child's right to know versus the parents' right not to tell: The attitudes of couples undergoing fertility treatments towards identity-release gamete donation [55]*	2023	J Reprod Infertil.	+			+
13	Pravo na zaborav naspram prava na otkrivanje identiteta donora gameta: etički i pravni aspekti [56] / *The right to be forgotten versus the right to disclosure of gamete donors' ID: ethical and legal considerations [56]*	2021	Acta Bioethica.	+			+
14	Anonimna donacija gameta i član 8. Evropske konvencije o ljudskim pravima: Argument za nespojivost [57] / *Anonymous gamete donation and Article 8 of the European Convention on Human Rights: The case for incompatibility [57]*	2022	Med Law Int.	+			+
15	Etika banke oocita za asistiranu reprodukciju uz pomoć treće strane: sistematski pregled [58] / *Ethics of oocyte banking for third-party assisted reproduction: a systematic review [58]*	2018	Hum Reprod Update.	+			+

Slabosti (Tabela 3): Ova tabela navodi slabosti identifikovane kroz pregled literature, kao što su tehnički, finansijski i regulatorni izazovi. Ove prepreke ukazuju na potrebu za dodatnim istraživanjima kako bi se postojeće barijere prevazišle.

Pretnje (Tabela 4): Tabela prikazuje pretnje identifikovane analizom literature, uključujući rizike vezane za etička pitanja, regulatorna ograničenja i nedostatak finansijskih sredstava.

Faktori rasta korisni za razvoj tržišta uključuju inovacije, tehnološki napredak, povećanu potražnju i nove mogućnosti poput krioprezervacije, bioekonomskih proizvoda dostupnih putem biobanaka i odlaganje roditeljstva za kasnije životno doba. Ovi pokretači stvaraju nove tržišne mogućnosti, kao što su programi prekogranične reproduktivne zaštite (CRC) i transnacionalne donacije gameta (TGD). Aktivno učešće potrošača na tržištu reproduktivne bioekonomije omogućava bolji pristup savremenim rešenjima i doprinosi globalnoj povezanosti u ovoj oblasti.

S druge strane, izazovi na tržištu uključuju prepreke, regulatorna ograničenja, etičke dileme, visoke troškove i druge faktore koji mogu usporiti rast ili otežati održavanje tržišta, kao i regulisanje broja porodica po donoru, što zahteva stroge zakonske okvire (Slika 2). Takođe, visoki troškovi i tehnička ograničenja krioprezervacije, uz složenost formiranja savremenih porodica, predstavljaju značajne izazove koji ometaju širu primenu ovih tehnologija. Potencijalne pretnje uključuju nepoznate dugoročne posledice, bioetičke dileme, rizik da reproduktivne usluge postanu isključivo komercijalizovane i narušavanje altruističkih principa u ovoj oblasti.

Each of the tables in the appendix covers specific aspects of the reproductive bioeconomy. Strengths (Table 1): This table provides an overview of references that highlight the strengths of the reproductive bioeconomy, including the development of new biotechnologies, advancements in biomedical engineering, and innovations in cryopreservation.

Opportunities (Table 2): Table 3 focuses on opportunities identified in the literature, such as expanding the application of bioeconomic solutions, the development of sustainable biotechnologies, and the enhancement of international cooperation in this area.

Weaknesses (Table 3): This table lists the weaknesses identified through the literature review, such as technical, financial, and regulatory challenges. These obstacles indicate the need for further research to overcome existing barriers.

Threats (Table 4): Table 4 provides an overview of the literature, in which threats were identified through analysis, including risks associated with ethical issues, regulatory constraints, and inadequate financial resources.

Growth factors beneficial to market development include innovation, technological advances, increased demand, and new opportunities such as cryopreservation, bioeconomic products available through biobanks, and delaying parenthood to a later stage in life. These drivers create new market opportunities, such as cross-border reproductive care (CRC) and transnational gamete donation (TGD) programs. The active involvement of consumers in the reproductive bioeconomy market allows better access to modern solutions and contributes to global connectivity in this area.

FAKTORI RASTA	IZAZOVI TRŽIŠTA
Snage: ◆ Razvoj biomedicinskog inženjeringa. ◆ Odlaganje roditeljstva do kasnijeg životnog doba. ◆ Razvoj novih tehnologija u biotehnologiji – kriobiologija. ◆ Biodostupnost proizvoda - kriobanke.	**Slabosti:** ◆ Nedovoljna regulativa u vezi sa brojem porodica po donoru. ◆ Potencijalno formiranje složene, netradicionalne, savremene porodice. ◆ Visoki troškovi i ograničenja povezana sa krioprezervacijom.
Mogućnosti: ◆ Prekogranična reproduktivna zaštita (CBRC). Program transnacionalne donacije gameta (TGD). ◆ Načini učešća na tržištu reproduktivne bioekonomije.	**Pretnje:** ◆ Nepoznat kvalitet i budući rezultati ◆ Reproduktivni rad se posmatra kao pretnja altruizmu. ◆ Bioetičke dileme.

Slika 2. SWOT Analiza reproduktivne bioekonomije

GROWTH FACTORS	MARKET CHALLENGES
Strengths: ◆ Development of biomedical engineering. ◆ Postponing parenthood to advanced age. ◆ Development of new technologies in biotechnology – Cryobiology. ◆ Bioavailability of products – Cryobanks.	**Weaknesses**: ◆ Insufficient regulation concerning the number of families per donor. ◆ The prospective formation of a complex, non-traditional, modern family. ◆ High costs and limitations associated with cryopreservation.
Opportunities: ◆ Cross-border reproductive care (CBRC). Transnational Gamete Donation Program (TGD). ◆ Types of participation in the reproductive bioeconomy market.	**Threats**: ◆ Unknown quality and future results. ◆ Reproductive work is viewed as a threat to altruism. ◆ Bioethical dilemmas.

Figure 2. SWOT analysis of the reproductive bioeconomy

Ovi nalazi naglašavaju važnost uravnoteženja inovacija sa regulativama kako bi se obezbedio održiv i etički razvoj reproduktivne bioekonomije.

DISKUSIJA

Pregled literature i SWOT analiza su istakli ključne snage, mogućnosti, slabosti i pretnje unutar reproduktivne bioekonomije. Ovi rezultati podržavaju slične zaključke iz prethodnih radova, poput studije o bioekonomiji u Letoniji [17], koja je istakla regulatorne izazove i potrebu za podrškom inovacijama. Koherentnost rezultata ukazuje na univerzalne obrasce razvoja bioekonomije.

Rezultati istraživanja razmatraju se kroz četiri ključna segmenta SWOT analize, uz podršku referenci iz relevantnih naučnih časopisa. Sledeća diskusija kritički ispituje ova otkrića i njihova šira značenja za oblast.

SNAGE

Postojanje i kontinuirani razvoj biomedicinskog inženjeringa, zajedno sa napretkom u biotehnologiji, posebno u oblasti kriobiologije i proizvodnje veštačkih gameta, značajno su unapredili efikasnost donatorskih programa [19]. Primena ovih tehnologija u reproduktivnoj medicini dovela je do poboljšanja tehnika krioprezervacije, povećavajući održivost i dugovečnost čuvanih reproduktivnih ćelija. Ovo direktno doprinosi višim stopama uspeha tretmana asistirane reprodukcije i jača pouzdanost donatorskih programa. Dalje, integracija regenerativne biomedicine i personalizovanih terapijskih pristupa omogućava kreiranje individualizovanih strategija lečenja [20]. Time se omogućava precizniji odabir i optimizacija reproduktivnih ćelija, čime se poboljšavaju ishodi lečenja pacijenata. Klinike koje usvoje ove inovacije mogu poboljšati kvalitet svojih usluga, nudeći pacijentima šire mogućnosti za tretman neplodnosti. Odlaganje roditeljstva do kasnijih godina povećava zdravstvene rizike i izazove u demografskim trendovima. Iako tehnologije reproduktivne medicine omogućavaju produženje reproduktivnog potencijala, ograničenja ostaju izražena kod starijih pacijenata. Vitrifikacija jajnih ćelija omogućava efikasniju organizaciju donatorskih programa i smanjuje liste čekanja [21]. Prednosti se prepoznaju u visokom standardu usluge koji se postiže primenom novih tehnologija u dijagnostici, kliničkoj terapiji i regenerativnoj medicini, uključujući kulturu ćelija i tkiva, što potvrđuju brojni istraživači [18, 22, 23]. Istraživači takođe ukazuju da je formiranje kriobanki, zahvaljujući tehnikama vitrifikacije, smanjilo liste čekanja i eliminisalo potrebu za sinhronizacijom ciklusa donora i primaoca. Poštovanjem fenotipskog podudaranja između donora i pacijenata olakšava se ispunjavanje ključnog aspekta jačanja veze roditelj-dete [12, 13, 25, 26].

On the other hand, market challenges include obstacles, regulatory restrictions, ethical dilemmas, high costs, and other factors that can slow down growth or make it difficult to sustain a market, as well as regulating the number of families per donor, which requires strict legal frameworks (Figure 2). Moreover, the high costs and technical limitations of cryopreservation, along with the complexities of forming modern families, pose significant challenges that hinder the broader application of these technologies. Potential threats include unknown long-term outcomes, bioethical dilemmas, the risk of reproductive services becoming solely commercialized, and the erosion of altruistic principles in this field.

These findings emphasize the importance of balancing innovation with regulation to ensure the sustainability and ethical development of the reproductive bioeconomy.

DISCUSSION

The literature review and SWOT analysis highlighted key strengths, opportunities, weaknesses, and threats within the reproductive bioeconomy. These results support similar conclusions from previous works, such as the study on the bioeconomy in Latvia [17], which highlighted regulatory challenges and the need for support for innovation. The coherence of the results points to universal patterns of bioeconomy development.

The research results are discussed through four key segments of the SWOT analysis, supported by references from relevant scientific journals. The following discussion will critically examine these findings and their broader implications for the field.

Strengths

The existence and continuous development of biomedical engineering, along with advancements in biotechnology, particularly in cryobiology and artificial gamete production, have significantly improved the efficiency of donor programs [19]. Implementing these technologies in reproductive medicine has led to enhanced cryopreservation techniques, increasing the viability and longevity of stored reproductive cells. This directly contributes to higher success rates in assisted reproduction treatments and strengthens the reliability of donor programs. Furthermore, the integration of regenerative biomedicine and personalized therapy approaches within donor programs enables tailored treatment strategies [20]. This enables a more precise selection and optimization of reproductive cells, ultimately enhancing patient outcomes. By adopting these innovations, clinics can improve the quality of

Mogućnosti

Programi transnacionalne donacije gameta (TGD) i prekogranične reproduktivne zaštite (CBRC) omogućavaju prevazilaženje pravnih i društvenih ograničenja, čime se širi dostupnost usluga [27]. Španija, Češka, Grčka i Danska privlače korisnike zahvaljujući povoljnim zakonskim okvirima. Raznovrsnost tipova korisnika koji učestvuju na tržištu reproduktivne bioekonomije (heteroseksualni parovi, LGBT zajednice, transrodne osobe, samohrani roditelji) ukazuje na rastuće prihvatanje i prilagođavanje tržišta savremenim porodicama. Postoji značajan tržišni potencijal za međunarodnu ekspanziju usluga, što potvrđuju istraživanja o složenosti industrije prekogranične reproduktivne zaštite, posebno u zemljama gde postoji nedostatak donora ili gde postoje zakonska, etička ili verska ograničenja [27, 28, 29, 30]. Istraživanja pokazuju i da međunarodnu ekspanziju tržišta olakšava dobro organizovan transnacionalni trgovinski sistem [33, 34, 35].

Slabosti

Nedostatak jedinstvenih propisa u vezi sa brojem porodica po donoru predstavlja izazov, naročito u kontekstu globalizacije tržišta reproduktivnih ćelija. Razlike u nacionalnim standardima otežavaju praćenje donacija preko granica, čime se povećava rizik od slučajnih genetskih povezanosti među decom začetom donacijom. Takođe, neusaglašeni propisi stvaraju pravnu neizvesnost za reproduktivne banke i buduće roditelje, potencijalno ograničavajući efikasnost tržišta i pristup donorskim gametima u određenim regionima. Formiranje netradicionalnih porodica donosi izazove vezane za društveno prihvatanje i pravnu regulaciju [36], dok odsustvo genetske povezanosti može izazvati psihološke i socijalne prepreke.

Iako bi globalizacija donatorskih praksi mogla doprineti širenju reproduktivne bioekonomije, nedostatak jedinstvenih regulatornih standarda otežava praćenje ukupnog broja donacija i povezanih porodica, što stvara etičke i pravne prepreke daljem razvoju sektora [14, 43, 44]. Moderni oblici porodica, uključujući one zasnovane na donaciji gameta, često se suočavaju s pravnim ograničenjima jer tradicionalni zakonski okviri ne prate dinamične promene u tehnologijama i društvenim normama. Ta diskrepancija usporava razvoj tržišta i ograničava dostupnost usluga različitim grupama korisnika [45, 46, 47].

Pretnje

Nepoznat dugoročni kvalitet i ishodi krioprezervacije embriona, uključujući moguće epigenetske promene, predstavljaju ozbiljne izazove za zdravstvene ishode

their services, offering patients broader opportunities for infertility treatment. Postponing parenthood to later years increases health risks and challenges in demographic trends. Although reproductive medicine technologies allow for the extension of reproductive potential, limitations remain pronounced for older patients. Oocyte vitrification allows for a more efficient organization of donor programs and reduces waiting lists [21]. The advantages are recognized by the high standard of service achieved through new technologies in diagnostics, clinical therapy, and regenerative medicine, including cell and tissue culture, as confirmed by numerous researchers [18, 22, 23]. Researchers also indicate that the formation of cryobanks, thanks to vitrification techniques, has reduced the waiting list and eliminated the synchronisation of donor and recipient cycles, and by respecting the phenotypic match between donors and patients, it facilitates the fulfillment of an essential aspect of strengthening parent-child attachment, as researchers believe [12, 13, 25, 26].

Opportunities

Transnational gamete donation (TGD) and cross-border reproductive care (CBRC) programs allow for overcoming legal and social restrictions, thereby expanding the availability of services [27]. Spain, the Czech Republic, Greece, and Denmark attract users with favourable legal frameworks. The diversity of the type of consumers participating in the reproductive bioeconomy market (heterosexual couples, LGBT communities, transgender people, single parents] indicates a growing acceptance and adaptation of the market to the needs of modern families. There is significant market potential for expanding services internationally, as evidenced by research on the complexity of the cross-border reproductive care industry, particularly in countries where there is a shortage of donors or where there are restrictions, whether legal, ethical, or religious [27, 28, 29, 30]. Research also shows that international market expansion is facilitated by a well-organized transnational trade system [33, 34, 35].

Weaknesses

The lack of uniform regulations for the number of families per donor poses a challenge, particularly in the context of the globalisation of the reproductive cell market. Variations in national standards make it difficult to track donations across borders, increasing the risk of accidental genetic connections among donor-conceived individuals. Furthermore, inconsistent regulations create legal uncertainties for both reproductive banks and intended parents, potentially limiting market efficiency and access to donor gametes in certain

dece začete ovim tehnologijama, koji nisu dovoljno istraženi. Bioetičke dileme, poput anonimnosti donora i prava dece da znaju svoje genetsko poreklo, i dalje su nerešena pitanja u mnogim kontekstima. Komercijalizacija reproduktivnog rada ugrožava principe altruizma i potencijalno doprinosi eksploataciji ekonomski ranjivih osoba. Nepoznata bezbednost i kvalitet krioprezervisanih ćelija, uz moguće epigenetske promene koje mogu uticati na razvoj embriona [32, 33, 49, 50], predstavljaju značajnu pretnju rastu tržišta reproduktivne bioekonomije. Takođe, komercijalizacija donacije reproduktivnih organa i ekonomski motivisano učešće donora [51, 52, 53] izazivaju etičke izazove koji mogu dovesti do regulatornih ograničenja i smanjenja poverenja pacijenata. Bioetičke dileme, poput anonimnosti donora i psiholoških posledica po potomstvo [54], dodatno komplikuju percepciju javnosti i potencijalno ograničavaju razvoj tržišta.

Ova studija možda nije u potpunosti sveobuhvatna, jer je obuhvatila samo radove objavljene na engleskom jeziku. Kako je ovo oblast u razvoju, moguće je da članci objavljeni nakon perioda istraživanja nisu uključeni. Ipak, prateći PRISMA smernice, možemo izvući sledeće preporuke. Iako tehnološki napredak i rastuće tržišne mogućnosti ukazuju na značajan progres, ove koristi treba kritički sagledati u svetlu postojećih izazova. Na primer, iako krioprezervacija i regenerativna medicina unapređuju efikasnost donatorskih programa, dugoročne biološke i etičke implikacije ostaju neizvesne. Takođe, iako globalizacija reproduktivnih usluga povećava dostupnost, ona istovremeno otvara pitanja o regulatornim neusaglašenostima i etičkim dilemama. Zato je potreban uravnotežen pristup radi maksimizacije koristi uz minimizaciju rizika.

ZAKLJUČAK

Rezultati studije ukazuju na značajan potencijal reproduktivne bioekonomije u unapređenju lečenja neplodnosti i diverzifikacije porodica. Ipak, kreiranje nacionalnog registra predstavlja ključni regulatorni propust u nadzoru biomedicinski potpomognute oplodnje sa doniranim reproduktivnim ćelijama. Regulatorni okvir bi trebalo unaprediti u pravcu transparentnih i etičkih propisa koji bi obezbedili pristup, dostupnost i dobrobit svih učesnika (uključujući pravo dece začete donacijom da saznaju svoje genetsko poreklo). Kompromis se može postići ulaganjem u porodično orijentisane politike koje omogućavaju ženama koje odlažu roditeljstvo da se odluče na potomstvo ranije. Buduća istraživanja treba da se fokusiraju na dugoročne efekte tehnologija i standardizaciju međunarodnih praksi.

Sukob interesa: Nije prijavljen.

regions. The formation of non-traditional families presents challenges related to social acceptance and legal regulation [36], while the absence of a genetic connection can cause psychological and social obstacles.

Although the globalisation of donor practices could contribute to the expansion of the reproductive bioeconomic market, the lack of uniform regulatory standards makes it difficult to track the total number of donations and related families, which creates ethical and legal obstacles to the further development of this sector [14, 43, 44]. In addition, modern forms of families, including those based on gamete donation, often face legal constraints, as traditional legal frameworks do not keep pace with dynamic changes in reproductive technologies and social norms. This discrepancy between legal regulations and social needs slows market development and limits the availability of services for different groups of users [45, 46, 47]

Threats

The unknown long-term quality and outcomes of cryopreservation of embryos, including possible epigenetic changes, pose significant challenges to the health outcomes of children born through these technologies, which are not sufficiently researched, and the existence of which is unknown. Bioethical dilemmas, such as donor anonymity and the right of children to know their genetic origin, remain unresolved issues in many contexts. The commercialization of reproductive labour threatens the principles of altruism and potentially contributes to the exploitation of economically vulnerable individuals. The unknown safety and quality of cryopreserved cells, along with possible epigenetic changes that may impact embryo development [32, 33, 49, 50], pose a significant threat to the growth of the bioeconomic market. In addition, the commercialisation of reproductive organ donation and economically motivated donor participation [51, 52, 53] challenge the ethical principles of altruism, which may lead to regulatory constraints and reduce patient trust. Bioethical dilemmas, such as donor anonymity and psychological consequences for offspring [54], further complicate public perception and potentially limit market development.

This study may not be as comprehensive as it could be, as it only reviewed publications in the English language. Given that this is an evolving field of research, it is possible that articles published after our study were not included in this review. Nonetheless, following the PRISMA guide, our recommended insights include the following. While technological advancements and expanding market opportunities suggest significant progress, these benefits must be critically examined in light of ongoing challenges. For instance, although

cryopreservation techniques and regenerative medicine improve the efficiency of donor programs, the long-term biological and ethical implications remain uncertain. Additionally, while the globalisation of reproductive services increases accessibility, it also raises concerns about regulatory inconsistencies and ethical dilemmas. Therefore, a balanced approach is crucial to maximise benefits while mitigating potential risks.

CONCLUSION

The study results indicate the significant potential of the reproductive bioeconomy in improving infertility treatment and family diversification. However, the creation of a national registry is a key regulatory oversight for the control of biomedically assisted reproduction with donated reproductive cells. The regulatory framework should be changed in the direction of the need for transparent and ethical regulations to ensure transparency, accessibility, and the well-being of all participants (allowing access to children conceived from donation to choose to know about their genetic origin). A compromise can be achieved by investing in family-friendly policies, allowing women who delay childbearing to decide to have children earlier. Further research should focus on the long-term effects of technologies and the standardisation of international practices.

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