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Časopis izlazi u elektroničkom izdanju dva puta godišnje, krajem lipnja i prosinca, a predviđena su i dva specijalna izdanja tijekom godine iz biotehničkog područja.
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SADRŽAJ:

Dodaci prehrani, polifarmacija i interakcije lijekova i dodataka prehrani u starijoj odrasloj populaciji korisnika ljekarničkih usluga s područja kontinentalne Hrvatske

Supplements, polypharmacy and drug-supplement interactions in older pharmacy users from continental Croatia

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Sažetak

Cilj ovog rada bio je ispitati učestalost konzumacije dodataka prehrani odraslih osoba s područja kontinentalne Hrvatske. Ovo opažajno, jednokratno istraživanje uključilo je 231 ad hoc korisnika ljekarničkih usluga, 69,3 % žena i 30,3 % muškaraca, s udjelom osoba ≥ 65 godina 27,7 %. Dodatke prehrani koristi 51,1 % ispitanika, najčešće vitamine i minerale (37,6 %), probiotike (17,3 %) i omega-3 masne kiseline (15,6 %), a kao glavni razlog navodi se opće poboljšanje zdravstvenog stanja (62,5 %). Dvije trećine ispitanika (71,0 %) ima minimalno jednu bolest, najčešće hipertenziju (43,3 %). Tri i više lijekova koristi 42,0 % ispitanika, no moguće je da je polifarmacija i više izražena s obzirom na udio osoba starije životne dobi. Interakcije lijek – dodatak prehrani identificirane su kod 27,3 % ispitanika. Rezultati jasno pokazuju visoku učestalost potrošnje različitih dodataka prehrani koji zbog primjene većeg broja lijekova, posebice među osobama u dobi 65+ godina povećavaju rizik od neželjenih interakcija.

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Ključne riječi: osobe starije životne dobi; dodaci prehrani; polifarmacija; interakcije lijek-dodatak prehrani.

Abstract

The aim of this work was to assess the frequency of dietary supplement consumption among adults from continental Croatia. This observational study on 231 ad hoc pharmacy users, 69.3% women and 30.3% men, with 27.7% of study participants being 65+ years old. Dietary supplements are used by 51.1% of participants, most often vitamins and minerals (37.6%), probiotics (17.3%) and omega-3 fatty acids (15.6%). General health improvement was the main reason for their use (62.5%). Two-thirds (71.0%) have at least one health condition, most often hypertension (43.3%). Three or more medications are used by 42.0% of participants, but it is possible that polypharmacy is even more pronounced given the proportion of elderly population. Interactions drug-dietary supplement are identified among 27.3% of participants. The results clearly show a high frequency of consumption of various dietary supplements, which, due to the use of a larger number of medications, increases the risk of adverse interactions, especially among people aged 65+.

Key words: elderly population; dietary supplements; polypharmacy; interactions drug-dietary supplement.

Uvod

Dodaci prehrani su široko upotrebljavana grupa proizvoda čija popularnost i potražnja iz godine u godinu raste (Papatesta et al., 2023; Skeie et al., 2009) bez obzira na moguće prepreke, nejasnoće, i ograničenja njihove primjene. Analiza istraživanja o korištenju dodataka prehrani koja je obuhvatila 53 europske zemlje pokazala je kako najveću potrošnju imaju Finska i Danska gdje više od polovice populacije koristi dodatke prehrani, zatim slijedi Švicarska s 47 % i Nizozemska s 42 % dok je u Mađarskoj to 25 % populacije, a u Njemačkoj 24,3 %. Treba napomenuti kako rezultati za potrošnju dodataka nisu bili dostupni za 26 zemalja, među kojima je i Hrvatska (Papatesta et al., 2023).

Kvaliteta dodataka prehrani, odnosno njihovi aktivni sastojci utječu na ukupnu zdravstvenu ispravnost jer su upravo sastav i namjena svrha stavljanja takvog proizvoda na tržište (Brykman et al., 2022). Zakonska regulativa dodatke prehrani svrstava u skupinu hrane, a ne lijekova pa stoga i podliježu znatno slabijim zahtjevima kvalitete, učinkovitosti i sigurnosti, što je posebno problematično u okviru današnje ovisnosti o društvenim mrežama (Klein i Schweikart, 2022).

Vjerovanje da su dodaci prehrani sigurni postoji, no veliki je broj rezultata koji govore suprotno. Učinkovitost postaje upitna zbog nedosljednosti istraživačkih metoda, malog broja ispitanika, nepostojanja kontrolne skupine, uključivanja zdravih dobrovoljaca ili skupine bolesnika niskog rizika bez prisutnosti komorbiditeta (za koje se taj pripravak ispituje), nedostatak standardiziranosti dodataka

koji se ispituju i nedostatak podataka o interakcijama dodataka prehrani i lijekova (Kummer et al., 2015). Osim interakcija dodataka prehrani i lijekova, važno je naglasiti da dodaci prehrani mogu ulaziti u brojne interakcije, kako s hranom tako i s drugim dodacima prehrani (Tsai et al., 2012). Veliki dio javnosti je mišljenja kako su dodaci prehrani ne samo potpuno sigurni, već i učinkovitiji od standardne medicinske terapije (Van der Bijl, 2014). Ipak, broj dokaza o neželjenim učincima je u porastu (Tucker et al., 2018). U Sjedinjenim Američkim Državama godišnje se 23 000 hitnih prijema pripisuje neželjenim nuspojavama dodataka prehrani (Geller et al., 2015).

Posebnu grupu dodataka prehrani predstavljaju biljni pripravci kod kojih se bilježe brojne varijacije u sadržaju aktivnih komponenti kao i znatna odstupanja od deklariranog sadržaja. Ujedno, veliki problem predstavlja i moguća kontaminiranost sirovina, kao i samih konačnih proizvoda (Mornar et al., 2013). Upravo su dodaci prehrani na biljnoj bazi, uz multivitaminske preparate najpopularniji među osobama starije životne dobi (Agbabiaka et al., 2017) i najveći dio starijih osoba ih smatra potpuno sigurnim za korištenje (González-Stuart, 2011). S druge strane, kod osoba starije životne dobi se zbog većeg broja kroničnih bolesti prepisuje veći broj lijekova, pa postoji opravdana bojazan od klinički značajnih interakcija između lijekova i dodataka prehrani (Masnoon et al., 2017; Agbabiaka et al., 2018).

Cilj ovog istraživanja bio je ispitati učestalost i vrstu dodataka prehrani koju koriste starije odrasle osobe, s posebnim naglaskom na njihovo zdravstveno stanje i analizu mogućih interakcija s lijekovima.

Materijali i metode

Provedeno je opažajno istraživanje na odrasloj populaciji, starosti ≥ 40 godina, oba spola u ljekarnama na području kontinentalne Hrvatske u periodu od srpnja do prosinca 2017. godine. Ispitanici su bili korisnici ljekarničkih usluga, bilo da je riječ o savjetovanju, izdavanju receptnih lijekova ili prodaji bezreceptnih lijekova, dodataka prehrani ili kozmetičkih proizvoda, dakle radilo se o ad hoc uzorku. Regrutacija je provedena u dvije ljekarne koje su dio istog ljekarničkog lanca, jedna na području grada Zagreba i jedna na području grada Osijeka. Ljekarna u kojoj se provodila regrutacija je dala suglasnost za provedbu istraživanja a istraživanje je odobrilo Etičko povjerenstvo za istraživanja na ljudima Prehrambeno-tehnološkog fakulteta Osijek (odluka od 15. lipnja 2017. godine).

U istraživanju je sudjelovao 231 ispitanik, 161 žena (69,7 %) i 70 muškaraca (30,3 %).

Za potrebe istraživanja kreiran je upitnik čije je ispunjavanje bilo jednokratno, anonimno i dobrovoljno. Opći i socioekonomski podaci su obuhvatili pitanja o dobi, spolu, tjelesnoj masi i visini, obrazovanju i radnom statusu ispitanika, djelatnosti i vrsti posla koju obavljaju, prihodima i pomoći države, bračnom stanju, ukupnom broju članova kućanstva, broju djece u kućanstvu, i mjesečnim izdvajanjima za hranu.

Drugim dijelom upitnika vezanim za potrošnju dodataka prehrani ispitana je vrsta dodataka prehrani koji se koriste, učestalost njihove konzumacije, mjesečno izdvajanje za njihovu kupovinu, razlozi

njihova uzimanja, mjesto kupovine te utjecaj cijene, preporuke i proizvođača na njihov odabir kao i pitanja o zdravstvenom stanju i primjeni lijekova.

Treći dio upitnika je obuhvatio pitanja o prehrambenim (briga o zdravlju, broj i vrsta obroka u danu, vlastiti status uhranjenosti) i životnim navikama (fizička aktivnost, pušenje, konzumacija alkohola, boravak pred televizorom i računalom.

Analiza interakcija između lijekova i dodataka prehrani napravljena je ručnom provjerom za svakog ispitanika zasebno i to za sve lijekove i sve dodatke prehrane koje su naveli da koriste. Analiza interakcija napravljena je samo za one ispitanike (njih 99) koji su naveli nazive lijekova i dodatke prehrani koje troše. Za analizu interakcija korištena je aplikacija Mediately bazirana na podatcima medbase INXBASE koja uključuje farmakokinetičke interakcije.

Rezultati su obrađeni primjenom tabličnog alata MS Office Excel (inačica 2016) i statističkim programom Statistica (inačica 14.0.). Kategorički podatci su prikazani kao apsolutne frekvencije dok su numerički podatci prikazani medijanom i interkvartilnim rasponom jer nisu pratili normalnu raspodjelu (ispitano Kolmogorov-Smirnov testom).

Rezultati i diskusija

Ispitanici su bili u dobi od 40 do 97 godina, medijan starosne dobi iznosi 56 godina (interkvartilni raspon; 48 – 67). Osnovne i sociodemografske karakteristike ispitanika prikazane su u tablici 1. Broj ispitanih osoba ≥ 65 godina iznosi 27,7 %. Najviše ispitanika ima srednju stručnu spremu (54,5 %) i visoku stručnu spremu (30,3 %), pri čemu je 58,0 % ispitanika zaposleno, a 33,3 % su umirovljenici i 8,7 % je nezaposleno. Od ukupnog broja ispitanika najveći udio je vjenčanih (69,7 %) i najviše je kućanstava u kojima stalno boravi dvije odrasle osobe dobi ≥ 18 godina (38,1 %), tri osobe 28,1 %, dok je samaca 20,3 %. U 26,0 % kućanstava borave djeca dobi do 18 godina.

Tablica 1. Osnovni i sociodemografski podaci ispitanika (N=231)
Table 1. *Basic and sociodemographic characteristics of the study participants (N=231)*

Karakteristike	Kategorija	Udio (%)
Spol	Ženski	69,7
	Muški	30,3
Dob	40 – 64	72,3
	65 – 96	27,7
Školska sprema	Bez OŠ	1,7
	NKV	10,8
	SSS	54,5
	VSS/VŠS	30,3

Karakteristike	Kategorija	Udio (%)
	Magisterij/doktorat	2,6
Radni status	Zaposlen	58,0
	Nezaposlen	8,7
	Umirovljen/a	33,3
Bračno stanje	Nevjenčan	10,8
	Vjenčan	69,7
	Razveden/a	6,9
	Udovac/ica	12,6
Broj članova kućanstva ≥ 18 godina	1	20,3
	2	38,1
	3	28,1
	4	10,4
	5	3,0
Broj kućanstava s djecom	< 18 godina	26,0
	< 3 godine	3,5

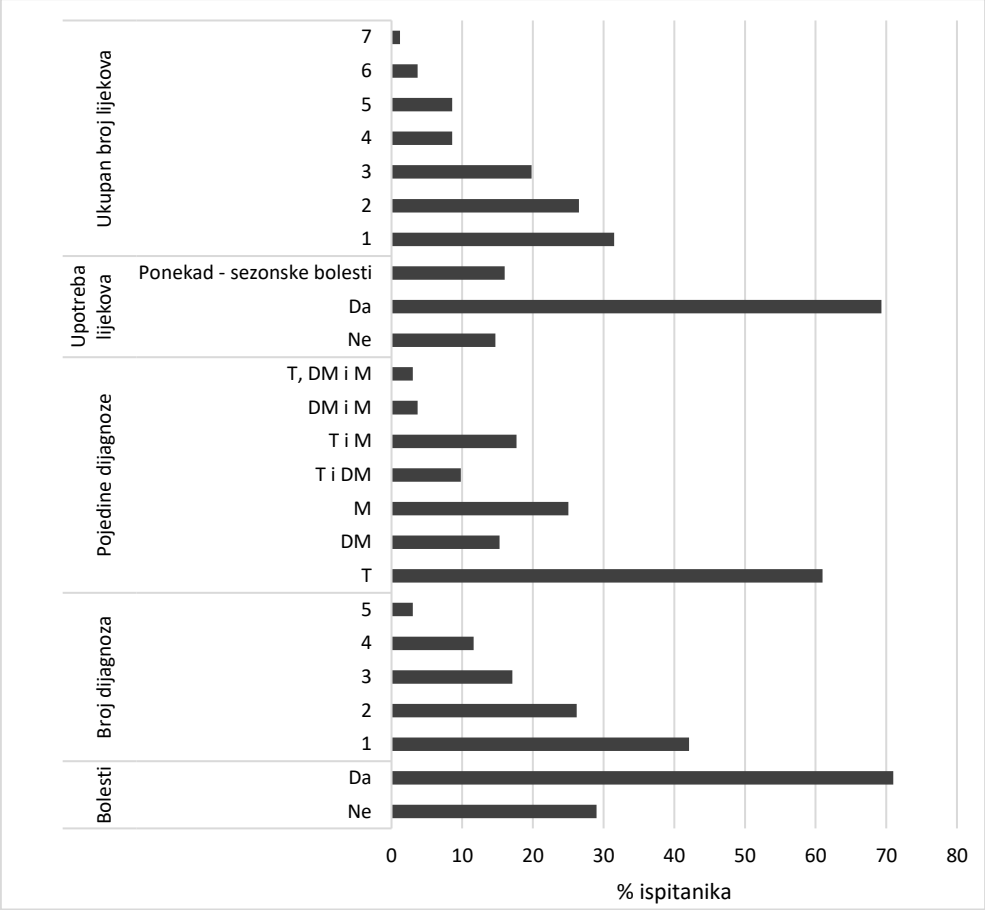
OŠ – osnovna škola; NKV – nekvalificirani; SSS – srednja stručna sprema;
VSS/VŠS – visoka stručna sprema/Visoka školska sprema

Od ukupno 231 ispitanika, njih 71,0 % ima barem jednu dijagnozu, dok 29,0 % ne boluje niti od jedne bolesti. Kako su najučestalije bolesti današnjice hipertenzija, dijabetes tip 2 i hiperlipidemija, posebno su promatrane te dijagnoze. Hipertenziju ima najviše ispitanika (61,1 % ispitanika s dijagnozama, odnosno 43,3 % ukupnog broja ispitanika), dijabetes 15,2 % (a u ukupnom broju ispitanih udio je 10,8 %) dok hiperlipidemiju ima njih 25,0 % (odnosno 17,7 % u ukupnom uzorku) (Slika 1). Ove bolesti nerijetko dolaze zajedno pa tako od ukupnog broja ispitanika s dijagnozama (n=164), hipertenziju i hiperlipidemiju ima 17,7 % ispitanika, hipertenziju i dijabetes njih 9,8 %, hiperlipidemiju i dijabetes njih 3,7 %, a sve tri dijagnoze ima 3,0 % ispitanika.

Redovnu terapiju troši njih 69,3 %, dok ih 14,7 % uopće ne uzima lijekove, a njih 16,0 % lijekove uzima samo ponekad, posebno u vrijeme sezonskih bolesti (najčešće u vrijeme gripa i prehlada) (Slika 1). Dobiveni rezultati o prisutnim bolestima (71,0 %) i uzimanju terapije (69,3 %) govore u prilog redovitom uzimanju terapije čime pokazuju postojanje svijesti o važnosti brige za svoje zdravlje i samokontrolu bolesti. Rezultati su također pokazali da najveći dio ispitanika za liječenje bolesti koristi jedan lijek (31,5 %), dva lijeka koristi njih 26,5 %, tri 19,8 %, dok četiri i pet lijekova uzima 8,6 % ispitanika. Šest lijekova uzima 3,7 %, a čak sedam lijekova 1,2 % ispitanih (Slika 1).

Podaci jednog američkog istraživanja iz 2008. godine govore da više od 20 % starijih osoba uzima pet ili više receptinih lijekova (Qato et al., 2008). Kada je riječ o liječenju većeg broja kroničnih bolesti, uzimanje više lijekova je neophodno, opravdano i korisno no rizik polifarmacije i štetnih učinaka iste

ne treba zanemariti (Masnoon et al., 2017). Prema jednom istraživanju provedenom u Hrvatskoj utvrđeno je da se osobama starijim od 70 godina u prosjeku propiše sedam lijekova te se smatra da će se uz očekivano produljenje života povećavati i broj korištenja lijekova među starijom populacijom (Vlahović-Palčevski i Bergman, 2004). Istraživanjem koje je obuhvatilo populaciju stariju od 60 godina utvrđeno je da 72,9 % ispitanih boluje od jedne kronične bolesti, od dvije njih 21,2 %, dok tri bolesti ima 4,3 %, četiri 1,3 % i pet 0,4 % ispitanika (Ambrosi-Randić et al., 2017). Rezultati ovog istraživanja se značajno razlikuju od spomenutog, izuzev udjela ispitanika s dvije kronične bolesti, a razlog bi bio niža prosječna dob ispitanika te su uzeti u obzir svi lijekovi, a ne samo lijekovi za liječenje kroničnih bolesti.



Slika 1. Prisutnost bolesti, broj dijagnoza, udio hipertenzije (T), dijabetesa (DM) i masnoća u krvi (M) te primjena lijekova među ispitanicima

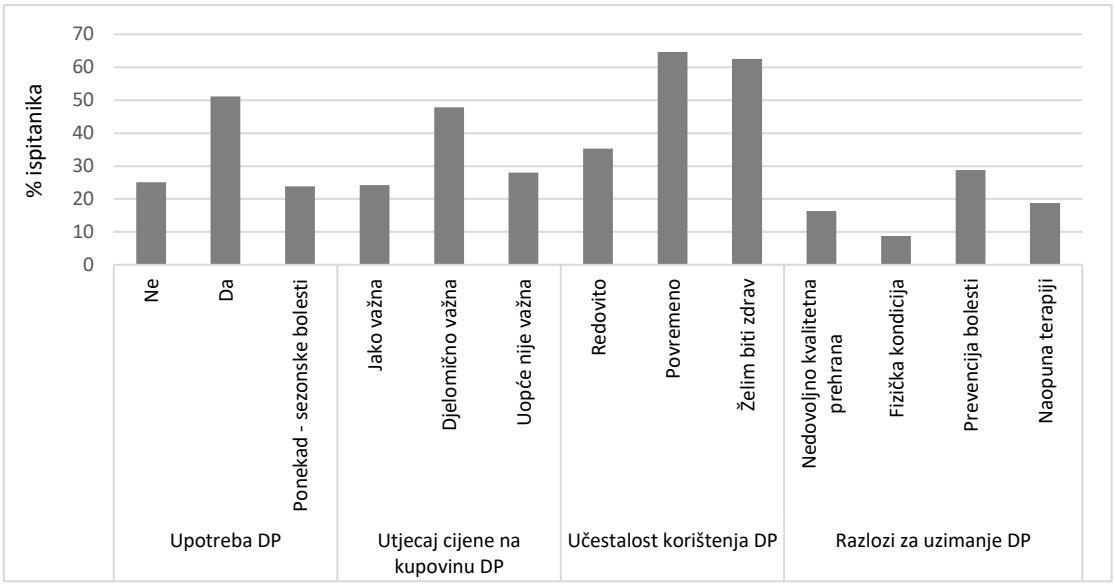
Figure 1. *Health condition, number of diagnoses, share of hypertension (T), diabetes (DM) and hyperlipidemia (M) and use of medication among the study participants*

Među anketiranim ispitanicima, dodatke prehrani uzima 51,1 % ispitanika, njih 25,1 % ih ne uzima, a 23,8 % ih uzima najčešće u vrijeme gripa i prehlada (Slika 2). Kako je već spomenuto, potrošnja dodataka prehrani značajno varira, a trendovi u pogledu korištenja dodataka prehrani s obzirom na dob su također različiti pa tako u Finskoj, Nizozemskoj i Njemačkoj starije osobe koriste dodatke prehrani

u većoj mjeri, dok je u Poljskoj većina konzumenata mlađe dobi a u Mađarskoj, Portugalu i Španjolskoj podjednako mlađe i starije osobe koriste dodatke prehrani (Papatesta et al., 2023). Prema istom istraživanju, neovisno o zemlji, žene u većoj mjeri koriste dodatke prehrani u odnosu na muškarce (Papatesta et al., 2023). Jedno ranije istraživanje provedeno u Sjedinjenim Američkim Državama pokazalo je da 49,0 % starijih osoba uzima barem jedan dodatak prehrani (Qato et al., 2008) što bi gotovo bilo jednako rezultatima ovog istraživanja. U zemljama obuhvaćenim istraživanjem Papatesta et al. (2023) je utvrđeno kako većina ispitanika koristi jedan dodatak prehrani, a oko 10 % ispitanika koristi tri i više dodataka prehrani i najviše korišteni dodaci prehrani u svim zemljama su multivitaminski i multimineralni pripravci uz vitamin D (Belgija i Danska) i riblje ulje odnosno omega masne kiseline (Švedska i Finska).

Cijena dodataka prehrani ne igra nikakvu ulogu za 28,0 % ispitanika, djelomično je važna za 47,8 % ispitanika, a jako važna 24,2 % ispitanika (Slika 2). Cijena dodataka prehrani važna je karakteristika na osnovu koje ljudi donose odluku o kupovini (Teoh et al., 2019). Prema istraživanju provedenom na osobama u dobi ≥ 65 godina koje su praćene pet godina potvrđeno je kako su se u tom periodu izdvajanja za dodatke prehrani povećala te da su ti troškovi bili visoki (Baird et al., 2025). Ovim istraživanjem nije ispitivan utjecaj prihoda na kupovinu proizvoda, no s obzirom na sociodemografske karakteristike osoba koje su sudjelovale u ovom istraživanju jasno je da bi cijena značajno utjecala na odabir dodatka prehrani.

Razlozi uzimanja dodataka prehrani su mnogobrojni pa je tako najveći dio ispitanika, njih 62,5 %, navelo da koristi dodatke prehrani zbog općeg zdravstvenog stanja i da žele biti zdravi. Da se ne hrani dovoljno kvalitetno te dodacima prehrani nadomještaju te nedostatke, smatra njih 16,3 %, dok je fizička kondicija i sposobnost razlog u 8,8 % slučajeva. Kako bi spriječili pojavu bolesti, 28,8 % ispitanika uzima dodatke prehrani, a kao nadopunu svojoj terapiji i rješavanju tegoba koje imaju njih 18,8 % (Slika 2). Razlozi uzimanja dodataka prehrani koje su naveli ispitanici u ovom istraživanju u skladu su s drugim istraživanjima. Gahche et al. (2017) su utvrdili kako je među odraslim osobama u dobi od ≥60 godina glavni razlog uzimanja dodataka prehrani upravo poboljšanje općeg zdravlja (za njih 41,2 %), zatim za zdravlje kostiju (36,8 %), za opći zdravstveni status (36,0 %), kao nadomjestak za lošu prehranu (22,0 %), zdravlje srca (22,0 %) i drugi razlozi. Prema rezultatima NHANES studije za period od 2011. do 2018. godine (Liu et al., 2024) glavni razlog uzimanja dodataka prehrani bilo je općenito poboljšanje zdravstvenog stanja (37,2 %), očuvanje zdravlja (34,7 %), zdravlje kostiju (21,4 %) i nadopuna prehrani (20,3 %) i dodatke prehrani su u većoj mjeri koristile starije osobe, više razine obrazovanja i viših prihoda.



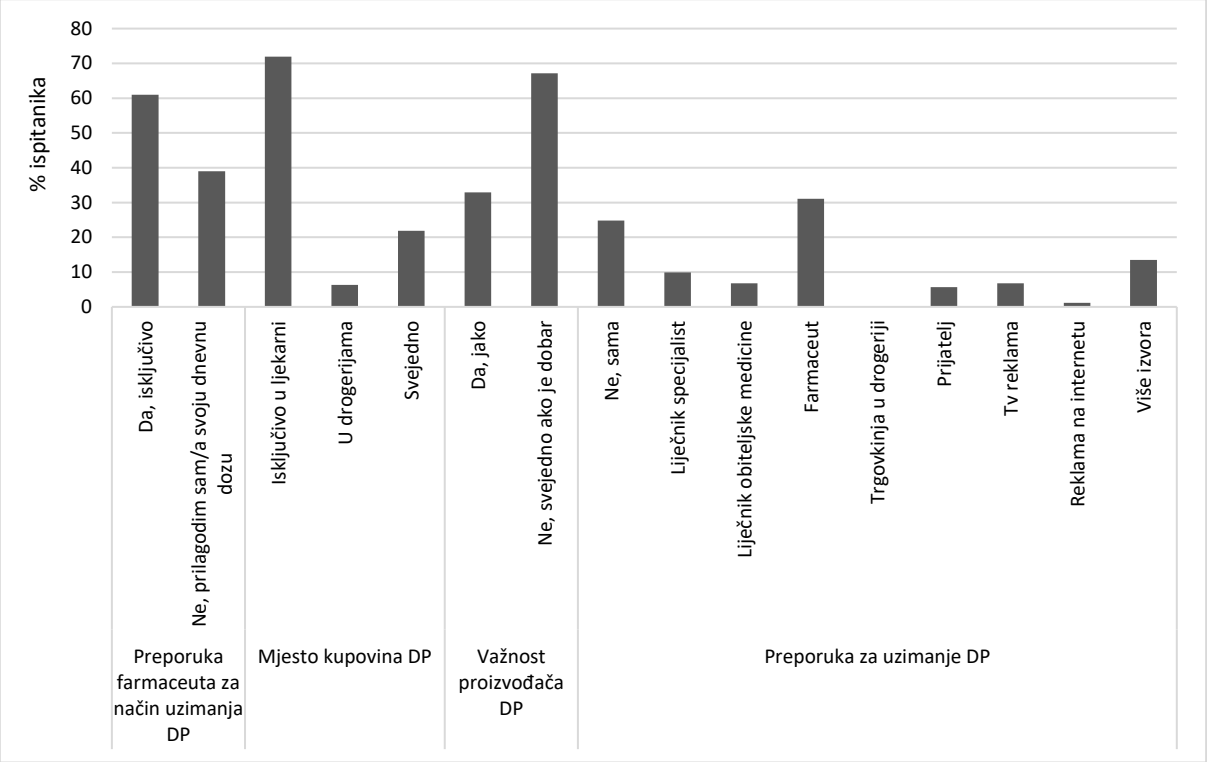
Slika 2. Karakteristike ispitanika vezane za uporabu dodataka prehrani (DP), utjecaj cijene na odabir i kupovinu, učestalost korištenja i razloge za uzimanje

Figure 2. *Participant's characteristics regarding the use of dietary supplements (DP), influence of product's price on purchase and use, the frequency of use and reasons for use (N=231)*

U 71,9 % slučajeva dodatak prehrani se kupuje isključivo u ljekarni, u drogerijama svega 6,3 %, a za njih 21,9 % je svejedno gdje će dodatak prehrani kupiti. Odabir dodatka prehrani ovisit će ponajviše o preporuci farmaceuta (31,1 %), 24,8 % ispitanika izabire ga samoinicijativno, dok po preporuci liječnika specijaliste 9,9 %, liječnika obiteljske medicine 6,8 % i prijatelja 5,7 %. Način uzimanja dodatka prehrani kod 61,0 % ispitanika ovisit će isključivo o preporuci farmaceuta i/ili proizvođača, dok 39,0 % ispitanika sami sebi prilagođavaju dozu. Utjecaj medija (reklama na TV-u ili Internetu) iznosi 8,0 %, a 13,4 % odabire dodatke prehrani pod utjecajem više izvora. Za 32,9 % ispitanika je važno tko je proizvođač dodatka prehrani, a za njih 67,1 % je važno da je dodatak prehrani dobar bez obzira na proizvođača (Slika 3) Ovi su rezultati ohrabrujući jer su odabir dodataka prehrani i način njegova uzimanja najvećim dijelom po preporuci zdravstvenih djelatnika, a mjesto kupovine ljekarna čime si korisnici dodataka prehrani osiguravaju provjerene i zdravstveno ispravne proizvode.

Kako bi se dobio uvid koje dodatke prehrani ispitanici koriste, dodaci prehrani grupirani su u 14 skupina (Tablica 2). Ispitanici su također mogli navesti dodatke prehrani koje koriste, a ne pripadaju niti u jednu od navedenih skupina (vitamini, minerali, čajevi, ulja i sl.). Najveći dio ispitanika, njih 37,6 % uzima vitamine, minerale ili njihove kombinacije. Probiotici su kao i omega masne kiseline prilično zastupljena grupa proizvoda sa 17,3 % i 15,6 %. Pripravke za tegobe probavnog trakta uzima 10,4 % ispitanika, a za kosu, kožu i nokte 8,1 %. Podjednaka je upotreba pripravaka za jetru i žuč (4,6 %), za oči (5,2 %), zglobove (5,2 %), za tegobe prostate (5,8 %), cirkulaciju (6,4 %) i za opuštanje (6,9 %). Nešto rjeđa upotreba je beta glukana (2,9 %), pripravaka za klimakterijske tegobe (1,2 %) i pripravke za regulaciju kolesterola u krvi (1,2 %). Pripravke za regulaciju šećera u krvi ne koristi niti jedan ispitanik (Tablica

2). Dodaci prehrani se uglavnom uzimaju povremeno (64,7 %), a redovito 35,3 % (op.a. rezultati nisu prikazani).



Slika 3. Karakteristike povezane s odabirom, mjestu kupovine, važnosti proizvođača dodatka prehrani (DP) i preporuci za uzimanje

Figure 3*. Characteristics related to selecton, place of purchase, importance of a producer and recommendation for use*

Tablica 2. Skupine dodataka prehrani i učestalost njihovog korištenja među ispitanicima

Table 2. *Groups of dietary supplements and the share of their use among the study participants*

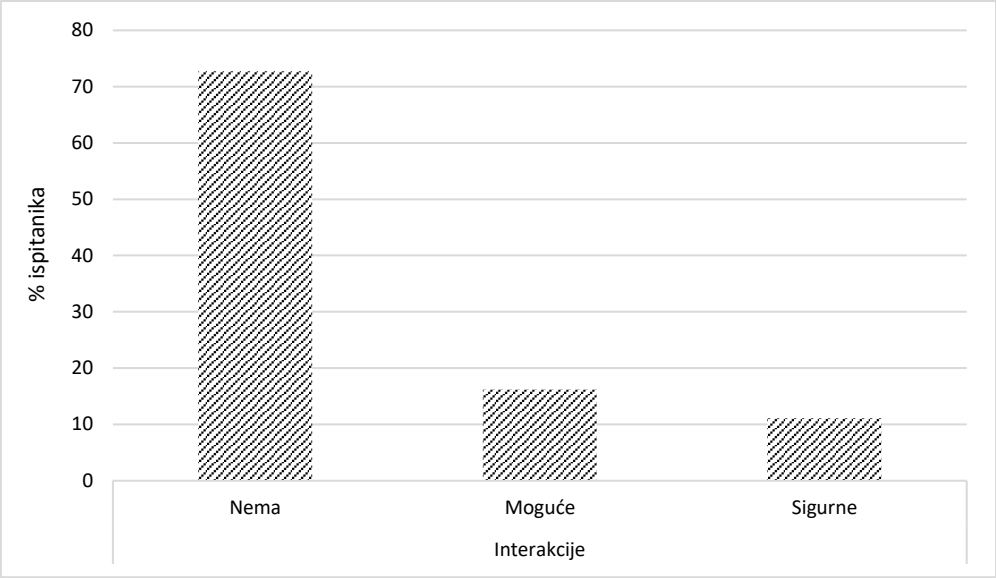
Skupina proizvoda	**Udio (%)**
Probiotici	17,3
Beta glukani	2,9
Omega masne kiseline	15,6
Pripravci za kosu kožu i nokte	8,1
Pripravci za oči	5,2
Pripravci za klimakterijske tegobe	1,2
Pripravci za tegobe prostate	5,8
Pripravci za zglobove	5,2
Pripravci za regulaciju cirkulacije	6,4
Pripravci za opuštanje	6,9
Pripravci za regulaciju šećera u krvi	0
Pripravci za regulaciju kolesterola	1,2

Skupina proizvoda	Udio (%)
Pripravci za tegobe probavnog trakta	10,4
Pripravci za tegobe jetara i žuči	4,6
Vitamini, minerali i kombinacije	37,6

Gahche et al. (2017) su među 3469 odraslih osoba u dobi od ≥ 60 godina koji su dio kohorte Nacionalnog istraživanja o zdravstvenom i prehrambenom statusu (NHANES; engl. *National Health and Nutrition Examination Survey*) za period 2011-2014 utvrdili su da se najviše koriste jedan ili dva proizvoda, najčešće multivitamini ili minerali (39 %), vitamin D (26 %) i omega-3 masne kiseline (22 %). Ispitivanje koje je obuhvatilo 6045 ispitanika s područja Sjedinjenih Američkih Država prosječne dobi 67,7 godina (59,3 % žena) zabilježila je redovitu primjenu dodataka prehrani kod 84,6 % ispitanika koji su prosječno uzimali čak 3,2±0,1 različitih proizvoda a 41,9 % ih je uzimalo četiri i više proizvoda (Tan et al., 2022). Multivitamini su bili najčešće korišteni, a drugi često korišteni dodaci prehrani su vitamin D, riblje ulje, kalcij, vitamin C i vitamin B12. Starija dob (75+ godina), ženski spol, viša razina obrazovanja, dnevna konzumacija alkohola, intenzivna fizička aktivnost, redovita primjena medikamentne terapije i artritis bili su povezani s višom vjerojatnošću za korištenjem dodataka prehrani u ispitivanoj populaciji (Tan et al., 2022).

Starija populacija je izrazito osjetljiva na moguće interakcije i neželjene reakcije kao posljedica polifarmacije i interakcija lijekova s komponentama dodataka prehrani (Loya et al., 2009; Qato et al., 2016; Agbabiaka et al., 2018; Qato et al., 2008; Sood et al., 2008). Analizirajući rezultate ovog istraživanja, a uzimajući u obzir samo ispitanike koji su naveli koje lijekove troše (N=99), pokazalo se da 11,1 % ispitanika ima prisutnost sigurnih interakcija lijek – dodatak prehrani, kod 16,2 % su one moguće, a kod 72,7 % navedenih interakcija nema (Slika 4).

Uz polifarmaciju, koja podrazumijeva primjenu više lijekova, uglavnom od pet i više različitih lijekova (Masnoon et al., 2017), treba uzeti u obzir i neodgovarajuću terapiju (Masnoon et al., 2017) kao i nesuradljivost osobe kada je u pitanju uzimanje kronične terapije (Lee et al., 2018). Rizik za neželjene interakcije se procjenjuje na 13 % za primjenu dva lijeka, 58 % kod primjene pet lijekova i čak 82 % kod primjene sedam ili više lijekova. S druge strane, danas se procjenjuje kako između 11,5 % i 62,5 % starijih osoba nema adekvatnu terapiju ili dobivaju više lijekova nego je klinički potrebno (Gujjarlamudi, 2016). Qato et al. (2016) su analizirajući trendove u pogledu interakcija među osobama u dobi od 62 do 82 godine utvrdili kako je broj mogućih interakcija u periodu od 2005. do 2006. godine s 8,4 % porastao na 15,1 % u periodu od 2010. do 2011. godine. Utvrđeno je kako je jedna od 25 osoba u potencijalnom riziku od značajnih interakcija lijek – dodatak prehrani (Qato et al., 2008).



Slika 4. Prikaz interakcija lijek – dodatak prehrani među ispitanicima (N=99)

Figure 4. *Interactions dietary supplement-medication among the study participants (N=99)*

Istraživanje koje je provedeno na osobama ≥ 65 godina u ordinacijama obiteljske medicine u dvije regije u Velikoj Britaniji koje uzimaju minimalno jedan receptni lijek je pokazalo kako je 32,6 % ispitanika bilo u riziku od neželjenih interakcija lijekova i dodataka prehrani. Ispitanici su koristili između jednog i čak osam različitih dodataka prehrani, a najčešće su to bili: riblje ulje, glukozamin, multivitamini i vitamin D (Agbabiaka et al., 2018). Jedno američko istraživanje provedeno na odrasloj populaciji prosječne dobi 71,4 godine gdje je 38,5 % njih uzimalo istodobno pet i više lijekova, uz istodobnu primjenu jednog ili više dodatka prehrani u riziku od interakcija bilo je njih 31,5 % (Loya et al., 2009). U šest različitih specijalističkih klinika Mayo u periodu od rujna 2002. do srpnja 2003. godine provedeno je istraživanje na uzorku od 1818 ispitanika koji su istovremeno uzimali lijekove i dodatke prehrani (Sood et al., 2008). Rezultati su pokazali da dodaci prehrani s valerijanom, ginkom, gospinom travom, češnjakom, glukozaminom, kavom, đumbirom i ginsengom imaju najviši potencijal stupanja u interakcije s lijekovima. S druge strane, najviše interakcija se može očekivati kod primjene slijedećih lijekova: sedativi, antidepresivi, antitrombotici i antidijabetici. Među 236 ispitanikom utvrđeno je 369 potencijalnih interakcija, dok ih je 107 imalo klinički značaj, no unatoč tome, niti jedan ispitanik nije imao ozbiljne posljedice (Sood et al., 2008).

Svakako treba uzeti u obzir činjenicu kako je ovo istraživanje provedeno na ad hoc populaciji korisnika ljekarničkih usluga te se rezultati ne mogu primijeniti na opću populaciju iste dobi. Razlozi leže u činjenici kako korisnici ljekarničkih usluga imaju zdravstvene probleme, najčešće kronične prirode koji zahtijevaju redovitu terapiju, a i češće koriste dodatke prehrani pa je njihov rizik za interakcije između lijekova i dodataka prehrani viši nego u općoj populaciji.

Zaključak

Dodatke prehrani uzima više od polovice ispitanih (51,1 %) pretežito s ciljem poboljšanja općeg zdravstvenog statusa, najčešće su to proizvodi iz skupine vitamina i minerala, probiotici i omega masne kiseline. Najveći dio ima razvijenu svijest o važnosti kvalitete i zdravstvene ispravnosti dodataka prehrani (njih 71,9 % kupuje dodatke prehrani u ljekarni), iako o načinu uzimanja dodatka prehrani njih 39,0 % odlučuje ipak samostalno. Dvije trećine ispitanih ima barem jednu bolest, najčešće hipertenziju i redovito troše lijekove što govori u prilog brige o vlastitom zdravlju i samokontroli bolesti. Ispitanici najčešće koriste jedan (31,5 %), zatim dva (26,5 %) a tri i više lijekova koristi njih 42,0 %. Polifarmacija je vjerojatno i više izražena jer među ispitanicima jedna trećina je u dobi od ≥ 65 godina (27,7 %) koji se svih svojih lijekova često ne mogu sjetiti. Moguće interakcije lijek – dodatak prehrani ima 27,3 % ispitanika. Dobiveni rezultati jasno ukazuju na potrebu intenziviranja aktivnosti u pogledu polifarmacije i evidentiranja svih dodataka prehrani kako bi se izbjegle interakcije s lijekovima koji su neophodni za održanje zdravstvenog stanja.

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The offer and quality of extra virgin olive oils in stores in the area of the Herzegovina-Neretva canton

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Abstract

This paper explores the significance of olives and extra virgin olive oil in nutrition, focusing on oil quality. The study aimed to analyse the quality of extra virgin olive oil available in the market of the Herzegovina-Neretva Canton (HNK) by analyzing three key chemical characteristics: free fatty acid (FFA) content, peroxide value and total polyphenol content. Six samples of extra virgin olive oil were analyzed. The results showed that sample no. 1 had the lowest free fatty acid (FFA) content (0.5%), indicating better quality than the other samples according to this parameter. In contrast, sample no. 3 (0.89%) and no. 5 (0.9%) had elevated FFA values, which reduced both the quality and shelf life of the oil. According to Regulation on Market Standards for Olive Oil (Official Gazette of BiH 81/12), samples no. 3 and no. 5 do not meet the criteria for extra virgin olive oil due to their higher free fatty acid content. The lowest peroxide value was observed in sample no. 1 (2.83 mmol O_2/kg), while the highest was in sample no. 2 (5.26 mmol O_2/kg). The acceptable limit for the peroxide value in extra virgin olive oils, according to the Regulation on Market Standards for Olive Oil (Official Gazette 81/12) and harmonised with EU Implementing Regulation (EU) 2022/2105, is ≤ 10 mmol O_2/kg. Regarding total polyphenols, sample no. 1 had the highest value (411.229 mg GAE/kg), while sample no. 5 had the lowest (159.278 mg GAE/kg). Polyphenols are crucial for the quality of olive oil, both organoleptically, and in terms of its nutritional and chemical properties. Statistical analysis (ANOVA test) revealed significant differences among the samples based on sensory evaluation, confirming that the quality of olive oil varies depending on the analyzed parameters. These findings highlight the need for stricter quality control of extra virgin olive oil in the HNK market, particularly concerning free fatty acid content and polyphenol levels.

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Key words: extra virgin olive oil, free fatty acids, polyphenols, peroxide value.

Introduction

Olive (*Olea europaea* L.) is one of the most significant plants in the Mediterranean region and is often regarded as the oldest cultivated plant species. The fruit of the olive tree is primarily used for the production of olive oil, which has become widely recognized as a symbol of a healthy diet and modern lifestyle. Numerous studies have demonstrated that olive oil positively influences human metabolism, and the health of the digestive system, blood vessels, arteries, liver, and bile ducts, while also contributing to increased life expectancy, particularly among the elderly population. Furthermore, it has been shown to support the growth and development of children (Žanetić et al., 2014). In addition to its health benefits, olive oil plays a significant role in the cosmetic industry, where it is used for maintaining skin health and beauty. Olive oil is obtained from the fruit of the olive tree, where natural biosynthetic processes within the olive contribute to the formation of oil droplets that accumulate during ripening. Extra virgin olive oil, in particular, is highly valued in the market today, making it one of the most sought-after and expensive food products. To justify its high price and demand, this oil must meet strict quality standards. Ensuring the high quality of extra virgin olive oil requires meticulous monitoring throughout all stages of production, including fruit ripening, harvesting, processing olives into oil , and proper oil storaging. Each of these stages significantly influences the development of both desirable and undesirable organoleptic properties of the oil, such as taste and aroma (Koprivnjak, 2006).
Due to its nutritionally balanced composition and distinctive aroma, olives and olive oil are considered fundamental components of the Mediterranean diet, the efficacy of which has been proven in the prevention of various diseases, maintenance of health, and promotion of longevity.

The Importance of Olive Oil for Human Health

Olive oil is a one of the most valuable source of fat in the human diet. Its nutritional significance is primarily attributed to its high content of monounsaturated fatty acids, particularly oleic acid, which exert significant biological and nutritional effects. Additionally, olive oil is rich in phenolic compounds, which act as potent antioxidants, enhancing its health benefits. Tocopherols, or vitamin E, present in the oil, also contribute to its stability and enhance its antioxidant properties. Numerous studies have confirmed the positive effects of extra virgin olive oil on cardiovascular health, particularly its ability to reduce blood pressure (Estruch et al., 2013; Schwingshackl et al., 2019; Sarapis et al., 2020). Research on animal models, particularly rats, has shown that phenolic compounds in extra virgin olive oil, such as tyrosol and hydroxytyrosol, significantly promote bone mass formation. The authors of these studies suggest that the consumption of olive oil may help prevent bone mass loss; however, further research is

needed to confirm these findings (Pejović et al., 2014). Moreover, olive oil has been shown to reduce the risk of certain types of cancer, particularly breast cancer

Garcia-Segovia et al. (2006) performed a study which was designed to assess the role of differential fatty acid intakes and olive oil consumption on breast cancer risk among women in the in the Canary Islands. The results of the study suggest that higher consumption of olive oil is associated with the lower risk of breast cancer

The anti-inflammatory properties of olive oil are attributed to oleic acid, which inhibits the synthesis of inflammatory mediators and other antioxidants such as oleocanthal. Notably, oleocanthal not only has anti-inflammatory effects but also exhibits analgesic properties. According to some studies, consuming 50 g of olive oil daily is equivalent to one-tenth of the recommended dose of analgesics for adults (Šarenić, 2018).

Free Fatty Acid Content

The content of free fatty acids (FFA) in olive oil, commonly called acidity, is a crucial indicator of oil quality. This parameter reflects various stages in the olive oil production process, including flowering, harvesting, processing, and storaging. It directly influences both the market value and the suitability of the oil for consumption. Oils derived from healthy olive fruits typically exhibit low free fatty acid content. In contrast, oils produced from damaged fruits-such as those affected by the olive fruit fly (*Bactrocera oleae*)-or fruits that have not been properly handled and stored for extended periods before processing, often show elevated FFA levels. The total fatty acid content in the oil is usually expressed as a percentage of oleic acid (Soldo, 2016).

Peroxide Value

The peroxide value is an indicator of the primary oxidation of olive oil, a process that leads to the formation of peroxides and hydroperoxides of fatty acids. Although these compounds do not have a distinct taste or odor, they can significantly affect the overall quality of the oil. The peroxide value is expressed as the amount of substance in the oil sample that oxidizes potassium iodide and is measured in millimoles of active oxygen per kilogram of oil (mmol O_2/kg) or in milliequivalents of active oxygen per kilogram of oil (mEq O_2/kg) (Mandić et al., 2020). The peroxide value provides valuable insight into oxidation processes, which can be either enzymatic or chemical. Since olive oil primarily contains unsaturated fatty acids with double bonds, the peroxide value is more likely to increase during processing, especially under high temperatures or improper storage conditions, such as exposure to air, light, and high temperatures. An increase in the peroxide value is often associated with a sensory defect commonly referred to as "rancidity" in olive oil (Dobra, 2017).

Total Polyphenol Content

Polyphenols are natural antioxidants that effectively protect olive oil from autoxidation, thereby contributing to its stability, preservation of quality, and extended shelf life. These phenolic compounds protect the unsaturated fatty acids within the triglycerides of olive oil from oxidation (Šindrak et al., 2007). In addition to their strong antioxidant properties, polyphenols also influence the organoleptic characteristics of the oil, such as its bitternes and pungency and play a significant role in the sensory evaluation of olive oil (Gorzynik-Debicka et al., 2018). Natural polyphenols are essential for human metabolism. Studies have shown that polyphenols reduce the incidence and/or slow the progression of cardiovascular diseases, neurodegenerative disorders and certain types of cancer. Their mechanism of action is primarily based on their antioxidant activity, which helps reduce the levels of reactive oxygen species in the body (Gorzynik-Debicka et al., 2018). Furthermore, polyphenols exhibit anti-atherogenic effects by binding to LDL particles and preventing their oxidation (Perona et al., 2006). Additionally, polyphenols possess anti-inflammatory, anti-allergic and anti-mutagenic properties. They are also capable of preventing DNA damage, potentially offering anticancer effects and inhibiting the expression of adhesion molecules (Gorzynik-Debicka et al., 2018).

Sensory Evaluation of Olive Oils

The organoleptic properties of olive oil, such as taste and aroma, are primarily influenced by the olive variety and its genetic predispositions. The effect of the variety (genotype) on these properties is most evident in enzymatic activity, which contributes to the formation of desirable volatile compounds, as well as in the content of phenolic compounds. These factors directly influence the taste and aroma characteristics of the oil, in addition to its resistance to oxidation (Klepo and Benčić, 2014). Sensory analysis is a crucial analytical procedure used to evaluate the taste and aroma properties of virgin olive oil and plays a key role in its market classification. This analysis is conducted by trained and experienced evaluators called panelists (Gauta, 2018).

Materials and Methods

The objective of this research is to analyze the supply and quality of olive oils available in stores within the Herzegovina-Neretva Canton (HNC). The study begins with a review of relevant literature to describe the biological characteristics of the olive tree and to analyze the nutritional and medicinal potential of olives and their products in the context of human health. Additionally, the peroxide value, free fatty acid content, and polyphenol content were determined for six samples of extra virgin olive oil available in stores in the HNC. The results were compared with the "Regulation on the Methods of Olive Oil Analysis" (Official Gazette of BiH 68/13) and the "Regulation on Market Standards for Olive Oil"

(Official Gazette 81/12). Sensory analysis of the six olive oil samples were conducted in order to evaluate their organoleptic properties. Finally, the results were compared with findings from similar studies conducted in Bosnia and Herzegovina and internationally.

The olive oil samples analyzed in this study were obtained from the local market. According to the lables, olive oils originated from the folowing countries: Spain, Croatia, Italy and France.The samples were collected in their original packaging, in 1-liter bottles, with identical expiration dates but from different producers and various regions of the European Union. Following the chemical analyses, a panel of trained evaluators, including individuals with no prior training, was formed to conduct the sensory analysis of the olive oils. This analysis took place in the laboratory of the Agromediterranean Faculty. The following samples were analyzed:

Sample 1: Zvijezda (Country of origin: Croatia);
Sample 2: Filippo Berio (Country of origin: France);
Sample 3: Blanqueta (Country of origin: Spain);
Sample 4: Trenton (Country of origin: Croatia);
Sample 5: Olitalia (Country of origin: Italy);
Sample 6: Basso (Country of origin: Italy);

Determination of Total Polyphenols

The total polyphenol content in the extracts of the olive oil samples was determined using a spectrophotometric method, based on the color reaction between phenolic compounds and the Folin-Ciocalteu reagent. The intensity of the resulting color was measured at a wavelength of 765 nm. The total polyphenol content was determined by comparing the absorbance of the sample with the calibration curve of the standard, and the results were expressed as milligrams of gallic acid per kilogram of sample (mg GAE/kg). The determination was performed in triplicate to ensure accuracy.

A methanol extract of each olive oil sample was prepared by mixing 1 g of olive oil with 10 mL of methanol, followed by vortexing for 2 minutes. The mixture was centrifuged at 4000 rpm for 10 minutes and the supernatant was used for further analysis

Preparation of Calibration Curve:

To prepare the calibration curve, 0.5 g of gallic acid was weighed, dissolved in 10 mL of 80 % methanol, and then diluted with distilled water to a total volume of 100 mL. Gallic acid solutions were prepared in concentrations of 50, 100, 150, 250, and 500 mg/L. Each solution was subjected to spectrophotometric measurement to generate the calibration curve.

Determination of Peroxide Value

The peroxide value is a measure of the amount of substances in the sample that oxidize potassium iodide, and it is expressed in millimoles of active oxygen per kilogram of oil (mmol O_2/kg) or milliequivalents of active oxygen per kilogram of oil (mEq O_2/kg). The peroxide value is determined according to the methods described in Regulation 68/13 and the Regulation on Market Standards for Olive Oil (Official Gazette 81/12). The acceptable limit for the peroxide value in extra virgin olive oils is ≤ 10 mmol O_2/kg.

Procedure:

A 250 mL Erlenmeyer flask with a ground-glass stopper was prepared. Approximately 5.00 g of the oil sample (m) was weighed into the flask (or the sample was weighed in a glass capsule and transferred quantitatively). A solvent mixture of chloroform and glacial acetic acid (2:3, v/v) was added (e.g., 10 mL chloroform + 15 mL acetic acid) and the sample was completely dissolved by swirling.
Then 1.0 mL of saturated potassium iodide (KI) solution was added. The flask was immediately stoppered, shaken vigorously for ~30 seconds, and kept in the dark for 5 minutes to allow iodine liberation.
After incubation, 75 mL of distilled water was added and the released iodine was titrated with standard sodium thiosulfate solution (e.g., 0.01 mol/L $Na_2S_2O_3$) with continuous shaking until the yellow color became pale.
At this point, 1–2 mL of freshly prepared starch solution (≈1%, w/v) was added as an indicator, producing a blue coloration. Titration was continued dropwise with sodium thiosulfate until the blue color disappeared and the solution became colorless. A blank determination was performed under the same conditions using all reagents but without the sample.

Calculation of Peroxide Value:

The peroxide value was calculated from equation 1,

$$PV = \frac{V \, x \, T \, x \, 1000}{2 \, x \, m} \qquad (1)$$

Where:

- V = volume of sodium thiosulfate (mL),
- T = molarity of the sodium thiosulfate solution,
- m = mass of the sample (g).

Determination of Free Fatty Acid Content

The content of free fatty acids in olive oil, also referred to as its acidity, is determined according to the methods outlined in Regulation 68/13 and the Regulation on Market Standards for Olive Oil, where the free fatty acid content in extra virgin olive oils should be ≤ 0.8%.

Titration Procedure:

For the titration procedure, 10 g of the olive oil sample was dissolved in 50 mL of a neutralized mixture of diethyl ether and ethanol in a 1:1 (V:V) ratio. The resulting solution was then titrated with sodium hydroxide (0.1 mol/L) using phenolphthalein as an indicator. The titration was performed until the first permanent color change of the indicator occurred, which must remain stable for at least 15 seconds.

Calculation of Free Fatty Acid Content:

The free fatty acid content (acidity) is expressed according from equation 2,

$$FFA = \frac{V \; x \; c \; x \; M}{10 \; x \; m} \qquad (2)$$

Where:
V = volume of sodium hydroxide used for titration (mL),
c = concentration of the standardized sodium hydroxide solution (mol/L),
M = molar mass of oleic acid (282 g/mol),
m = mass of the sample (g).

Sensory Analysis of Olive Oil

The sensory analysis of olive oils was carried out by a panel of 10 trained assessors, in accordance with the Regulation on Methods for Olive Oil Analysis (Official Gazette of BiH 68/13). The evaluation was performed under standardized tasting conditions, including controlled lighting and temperature, and using standardized blue tasting glasses in order to avoid visual bias during assessment.
A total of six olive oil samples were analyzed. The samples were coded and presented to the panelists in a randomized order. Sensory evaluation was conducted using the official evaluation sheet for the sensory assessment of virgin olive oils, which includes the assessment of olfactory–gustatory–tactile properties, gustatory–retronasal properties, and final olfactory–gustatory–tactile properties.

Olfactory–gustatory–tactile properties were evaluated with a maximum of 35 points, including fruity notes of olive (0–7), green notes (olive or grass; 0–2), fruitiness of other fruits (0–3), other positive attributes (0–3), and harmony, which increases when the attributes are well balanced (0–20).
Gustatory–retronasal properties were evaluated with a maximum of 45 points and included fruity notes of olive (0–10), green notes (0–2), sweetness (0–4), bitterness (0–3), pungency (0–3), other positive attributes (0–3), and harmony (0–20).
Final olfactory–gustatory–tactile properties were evaluated with a maximum of 20 points, including complexity (0–10), which increases with the intensity of aromas and flavors, and persistence (0–10).
Between samples, panelists rinsed their mouths with water to minimize carry-over effects and prevent sensory fatigue. The total sensory score for each sample was obtained by summing the scores of the individual groups of attributes, while the final values were expressed as the median of the panelists' scores, in accordance with the principles of sensory data processing.

Olfactory-taste-tactile properties – maximum score: 35 points
Taste-retro-nasal properties – maximum score: 45 points
Final taste-olfactory-tactile properties – maximum score: 20 points
Total score – maximum score: 100 points

Based on the sensory profile, fruitiness category classification of the olive oil samples (green or ripe) was also performed.

Statistical Analysis

Statistical analysis of the sensory evaluation data was performed using analysis of variance (ANOVA) to determine statistically significant differences between the olive oil samples and between the sensory attributes (aroma, taste and aftertaste harmony). A two-way ANOVA was applied at a 5% significance level. When a statistically significant effect was detected, the Tukey-Kramer post-hoc test was used to identify differences among the individual samples and sensory attributes. The results of the ANOVA test showed statistically significant differences both among the samples and among the sensory properties.

Results and discussion

This study analyzed the quality parameters of olive oils, including the content of free fatty acids (FFA), peroxide value, and total polyphenols. In this section, we will discuss the significance of the obtained results and their correlation with established quality standards.

Results of Free Fatty Acids (FFA) Content

The content of free fatty acids (FFA) is a crucial indicator of olive oil quality, as it reflects the degradation processes of the olive fruit, which are influenced by various factors. The most common causes of elevated FFA levels include mechanical damage and improper handling of the fruit.. An increase in FFA concentration is typically inversely related to the presence of other key components in olive oil, such as aromatic compounds, vitamins, and polyphenols. Consequently, higher FFA content can significantly reduce the nutritional and health benefits of olive oil (Klepo & Benčić, 2014). Table 1 presents the results of the FFA content in the analyzed olive oil samples, along with the values specified in Regulation 68/13. These results allow for a direct comparison between the obtained values and the regulatory standards, providing a basis for assessing the compliance of the analyzed olive oil samples with market standards for extra virgin olive oils.

Table 1. *Free Fatty Acid Content of Analyzed Oils and Values from Regulation 68/13*

Sample	Free Fatty Acids (FFA) Content (%) (as Oleic Acid)	Regulation 68/13
1	0.50	
2	0.68	
3	0.89	
4	0.71	≤0.8
5	0.90	
6	0.66	

The hydrolytic degradation of virgin olive oils is determined by the mass percentage of free fatty acids (FFA). This parameter serves as a standard market indicator for assessing the extent of hydrolytic deterioration (Koprivnjak, 2006). The classification criteria for free fatty acid content were compared with the standards defined in the Regulation on Market Standards for Olive Oil (Official Gazette 81/12) and the Implementing Regulation (EU) 2022/2105. In a study performed by Gauta (2018), nine olive oil samples from Croatia were analyzed and the FFA content ranged from 0.17% to 0.66%. Additionally, Dobra (2017) reported the average FFA values in the analyzed olive oil samples ranged from 0.21% to 0.55%. Mena et al. (2018) cited a range of FFA content from 0.18% to 0.8% in the analyzed olive oils. Research conducted by Carolina et al. (2020) on Spanish virgin olive oils, which focused on determining the total polyphenol content and metal concentrations, revealed that the FFA values were either lower or very close to 0.2 g oleic acid per 100 g of oil. This indicated that all analyzed samples met the criteria for extra virgin olive oil, except for one sample, which exceeded the maximum value of 0.8 g oleic acid per 100 g of oil despite being labeled as extra virgin. These findings align with the results of the present

study, where two of the samples exceeded the recommended FFA limits. In a study on the aromatization of virgin olive oil using seeds of *Pimpinella anisum* (Youssef et al., 2021), the FFA content in the control samples ranged from 0,03% to 1,46%. In the current study, the FFA content, expressed as a percentage of oleic acid, in the analyzed samples ranged from 0.5% to 0.9%. Sample 1 exhibited the lowest FFA value (0.5%), while Sample 5 had the highest (0.9%). Elevated levels of free fatty acids have a detrimental effect on the quality and shelf life of olive oil. According to Regulation on Market Standards for Olive Oil 81/12, Samples 3 and 5 should be classified as virgin olive oils due to their elevated FFA content.

Peroxide Value Results

The peroxide value is a critical indicator of oxidative deterioration in olive oil, expressed as the amount of active oxygen bound to one kilogram of oil (mmol O_2/kg). The maximum permissible peroxide value for virgin olive oil intended for human consumption, without any refining process, is set at 10 mmol O_2/kg (Klepo & Benčić, 2014). For high-quality, freshly produced oils, the peroxide value typically ranges from 1 to 3 mmol O_2/kg, indicating minimal oxidation and preserving the oil's quality (Koprivnjak, 2006).

Table 2. *Peroxide Value Results of Analyzed Olive Oils and Values from Regulation 68/13*

Sample	Peroxide Value (PV) in mmol O_2/kg	Regulation 68/13
1	2.83	
2	5.26	
3	4.75	
4	4.21	≤10
5	4.81	
6	3.85	

The peroxide value is a crucial indicator of oxidative degradation in olive oil, quantifying the amount of active oxygen bound to one kilogram of oil, expressed in millimoles (mmol O_2/kg). According to the guidelines, the maximum permissible peroxide value for virgin olive oil, without any refining, is 10 mmol O_2/kg (Klepo & Benčić, 2014). For freshly produced, high-quality oils, the peroxide value typically ranges from 1 to 3 mmol O_2/kg, reflecting minimal oxidative degradation (Koprivnjak, 2006). Gauta's study (2018) reported that, of the nine analyzed olive oil samples, the peroxide values were within the acceptable limits for extra virgin olive oil. Among these, five samples had a peroxide value below 3 mmol O_2/kg, while the highest recorded value was 5.7 mmol O_2/kg for sample 5. In contrast, Dobra (2017) analyzed five olive oil samples and found a broader range of peroxide values, ranging

from 4.9 mmol O_2/kg to 8.2 mmol O_2/kg, indicating a higher degree of oxidation in some of the samples. The study perofrmed by Youssef et al. (2021), which focused on the aromatization of virgin olive oil with *Pimpinella anisum* seeds, reported that the peroxide values in the control samples ranged from 0.51 mmol O_2/kg to 7 mmol O_2/kg, suggesting varying effects of the aromatization process on the oil's oxidative status. Similarly, Mena et al. (2018) observed a peroxide value range from 1.79 mmol O_2/kg to 4.69 mmol O_2/kg in their study, with results consistent with the findings of the current study. Shiling et al. (2022) conducted a comprehensive analysis of the chemical composition and health effects of edible vegetable oils using chemometric methods. In their study, the peroxide values of olive oils ranged from 0.06 mmol O_2/kg to 1,11 mmol O_2/kg, indicating high-quality oil compared to other samples evaluated. In the present study, the lowest peroxide value was observed in sample 1 (2.83 mmol O_2/kg), while the highest peroxide value was found in sample 2 (5.26 mmol O_2/kg). All samples analyzed in this study comply with the standards set by the Regulation on Methods of Analysis of Olive Oil (Official Gazette BiH 68/13) and the Regulation on Market Standards for Olive Oil (Official Gazette 81/12).

Results of Total Polyphenol Content

While the determination of polyphenol content is not classified as a primary quality indicator for olive oil, polyphenols are among the most significant groups of compounds that influence the overall quality of the oil. These compounds affect the organoleptic, chemical, and nutritional properties of olive oil. The unique combination of polyphenols in olive oil distinguishes it from other vegetable oils, contributing to both its distinctive flavor and its health benefits. The concentration of polyphenols in olive oil is influenced by several factors, including the degree of fruit maturity, olive variety, altitude, water supply, oil extraction methods, storage conditionsand any refining processes. Refined olive oils generally contain the lowest concentrations of polyphenols, as a significant portion of these compounds is removed during the refining process. In contrast, extra virgin and virgin olive oils typically retain the highest levels of polyphenols, which enhances their health-promoting properties and overall quality (Šindrak et al., 2007).

Table 3. *Total Polyphenol Content of Analyzed Olive Oils and Literature Value*

Sample	Total Polyphenols (mg/kg)	Literature Values (mg/kg)
1	411.229	150-300 (Orva J.H. et al., 2014.)
2	201.287	73-265 (Pellegrini et al., 2001.)
3	214.670	85.59 – 382.99 (Žanetić et al., 2014)
4	220.165	50- 500 (Espejo, 2005; Del Carlo et al., 2006)
5	159.278	178 – 591.8 (Ciafardini, et al., 2013; de la Torre-
6	178.519	Robles et al., 2014)

The total polyphenol content in olive oils, as reported in a study on the chemical composition and health effects of edible vegetable oils using chemometric analysis (Shiling et al., 2022), ranged from 7.40 to 62.96 mg/kg. Perona-Arquillué et al. (2003) found a higher polyphenol content of 631.3 mg/kg in olive oil, while Baccouri et al. (2008) reported that the polyphenol content in oils from wild olive varieties ranged from 182 to 430 mg/kg. Numerous studies have reported a wide range of total polyphenol content in extra virgin olive oils, typically from about 50 up to over 1000 mg/kg, depending on cultivar, ripening stage and processing conditions (Albdady, 2023; Arafat et al., 2016; López-Bascón et al., 2024; De Santis et al., 2022; Manai-Djebali et al., 2023). The polyphenol content in olive oil is influenced by several factors, with the olive variety being one of the most significant. However, the fruit ripeness is considered the most crucial factor affecting polyphenol levels (Škevin et al., 2003). Olive oils contain various phenolic compounds, which can exist either in their free form or bound with other compounds in complex structures. These compounds may degrade and break down into other components during the aging process of the oil. Similarly, Carolina et al. (2020) reported that the total polyphenol content in their analyzed samples ranged from 93 to 375 mg/kg, which aligns with previous findings. Based on the total polyphenol content observed in this study, it can be concluded that the results are consistent with the literature data, as shown in Table 3. Generally, the high-quality olive oils contain between 100 and 250 mg/kg of polyphenols (Saima et al., 2021).

Results of Sensory Analysis of Olive Oils

Virgin olive oils, after undergoing physico-chemical analysis, were subjected to sensory analysis. It is important to note that oils classified as extra virgin, following physicochemical analyses, must not exhibit any organoleptic defects (Median of defects=0) while their fruitiness must be higher than zero (Median of fruity >0).. In contrast, virgin olive oils may have minor organoleptic defects (Median of defects ≤3,5). . Additionally, the fruitiness of these oils must also remain above zero (Median of fruity >0). (Jiménez Herrera and Carpio Dueñas, 2008). The sensory analysis was conducted by 10 panelists, who assessed the olive oil samples across different properties, After completing the sensory analysis, the results were processed using statistical significance analysis (ANOVA). To determine statistical significance and correlations between the measured variables, the Tukey-Kramer test was conducted. The analysis revealed significant differences in the sensory properties between the evaluated olive oil samples.

Table 4 presents the scores from the sensory analysis of the olive oil samples. All assessors were provided with brief guidelines for evaluation before proceeding with the assessment. The results showed that Sample 1 received the highest score for all evaluated properties (smell, taste, and overall harmony), achieving the highest total score compared to the other samples. In contrast, Sample 4 received the lowest score across sensory properties. Additionally, the results indicate significant variation in the ratings of the oils across the different properties (smell, taste, overall harmony), suggesting notable

differences in the sensory properties of the analyzed samples. This variability reflects the unique characteristics of each olive oil, which may be influenced by several factors such as the olive variety, origin and production process.

***Table 4**. Results of Sensory Analysis Scores*

Samples	Aroma	Taste	Aftertaste harmony	Total score
1	245	306	159	710
2	169	240	114	523
3	237	287	130	654
4	134	143	79	356
5	225	279	132	636
6	215	257	126	598

Statistical Analysis of Sensory Analysis Results

A two-way analysis of variance (ANOVA) was conducted to assess the statistical significance of the differences in sensory properties and between the olive oil samples. The F-value obtained for the differences between the samples was 22.88, which was greater than the critical F-value (2.27), indicating a statistically significant difference between the samples. Similarly, the F-value for the differences in sensory attributes (such as smell, taste, and overall harmony) was 109.90, which exceeded the critical F-value (3.05). These results indicate a highly statistically significant difference in both the sensory properties and between the olive oil samples, as also confirmed in Table 5.

***Table 5.** Results of Statistical ANOVA Analysis at 5% Significance Level for Sensory Evaluation*

ANOVA 5%						
Source of Variation	**SS**	**df**	**MS**	**F**	**P-value**	**F crit**
Samples	2641.983	5	528.3966667	22.88348705	2.45E-17	2.26996
Senses	5075.433	2	2537.716667	109.9019168	6.94E-31	3.051819
Interaction	340.8333	10	34.08333333	1.47606063	0.152589	1.889561
Within	3740.7	162	23.09074074			
Total	11798.95	179				

The Tukey-Kramer test was applied based on the data obtained from the sensory analysis to confirm the statistical significance in the measurements of olive oil samples and different sensory attributes. By

comparing all individual samples and sensory attributes (odor, taste, and overall harmony), a highly significant statistical difference was found between all analyzed parameters. The Tukey-Kramer test showed statistically significant differences only for the taste and aroma of sample 2 compared with samples 1 and 3, and for the odor of sample 4 compared with sample 5. No other significant differences were observed among the remaining samples. In 2010, during the Olive Oil Fair in Imola (Emilia-Romagna, Italy), Predieri et al. (2013) asked 133 consumers to evaluate four olive oil samples selected based on their sensory attributes related to quality. These samples were also evaluated by a trained panel, and the results were compared. Most consumers highlighted fruitiness, bitterness, and pungency as attributes of high-quality oils, which was in line with the evaluations of the trained panel. Additionally, 66% of consumers assigned higher ratings to samples with more bitterness and pungency, considering them of higher quality (Predieri, 2013). A similar study was conducted in Finland, where Recchia et al. (2012) asked 74 consumers to taste four different olive oils previously evaluated by a trained panel. The panel classified two of the oils as high-quality, with intense green fruitiness, bitterness, and pungency. Consumers were divided into three groups based on their knowledge of olive oil, and the authors expected a good correlation between the panel and the most dedicated group. However, all groups disagreed with the panel's classification, preferring less intense oils. The authors attributed these differences to the lack of sensory experience among the consumers. A high level of involvement with olive oil does not necessarily mean that the consumer has sufficient sensory experience to accurately assess its quality (Recchia et al., 2012). These studies indicate a similar trend in our research, where a low level of knowledge regarding the evaluation of extra virgin olive oil was also observed, possibly due to the lack of tradition in consuming olive oil in daily diets in our country. The sample of evaluators was small (10 evaluators), which limits the ability to generalize, but it was sufficient to conduct a comparative analysis of the sensory evaluations of the analyzed olive oil samples. Delgado et al. (2017) compared evaluations between a group of 23 olive oil experts and 110 American consumers on 22 olive oil samples. They found no correlation between the assessments of experts and American consumers. Experts classified sharper and more bitter samples as higher-quality oils, while American consumers preferred less intense samples. In some cases, consumers even preferred samples with sensory defects, such as rancidity, mustiness, cloudiness and winey acidity. Only in a few instances were the results correlated (Delgado et al., 2017). Similar patterns were observed in our research, where some evaluators gave higher scores to samples that were on the verge of a rancidity rather than to those with higher quality. However, ample 1 exhibited the best properties in the sensory analysis and received the highest overall score, as clearly seen in Table 4.

Conclusion

Extra virgin olive oil is highly valued for its balanced nutritional composition and characteristic aroma, making it an essential component of the Mediterranean diet and contributing to its recognized health benefits. This study assessed the availability and quality of extra virgin olive oils sold in the Herzegovina-Neretva Canton (HNK), leading to several key findings.

Sample 1 demonstrated the best overall quality, with the lowest free fatty acid content, the lowest peroxide value and the highest concentration of total polyphenols. Samples 3 and 5 exceeded the allowable limits for free fatty acids and should therefore be classified as virgin olive oils. All samples complied with regulatory requirements regarding peroxide value. Differences in polyphenol content among the oils were consistent with ranges reported in the literature.

Statistical analysis (ANOVA and Tukey-Kramer tests) confirmed significant differences among the samples in sensory attributes, with sample 1 receiving the highest sensory scores.

Overall, the results highlight noticeable variability in the quality of olive oils available on the local market. Increasing consumer awareness and sensory education may help prevent the mislabelling and misuse of the "extra virgin" designation and promote higher standards in olive oil quality.

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The impact of location and planting time on the morphological characteristics of the domestic ecotype of garlic (*Allium sativum* L.)

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Abstract

Garlic is one of the oldest cultivated species, with a characteristic smell and taste. This paper aimed to prove the impact of the production location and planting time on morphological traits of the bulbs of the domestic ecotype of garlic from Berkovići. Before setting up the experiment, the morphological characteristics of the bulb planting material originating from Berkovići were determined. That planting material was planted at two locations (Bijelo Polje and Hodbina) in two planting terms: autumn and spring planting terms. According to the results of this research, we can conclude that the traits of the bulbs of the domestic ecotype of garlic were influenced by cultivating location and planting term. Average values for all tested parameters were higher at the Bijelo Polje location and in the spring planting time, but these differences were not all statistically significant

Key words: garlic, ecotype, location, planting time, morphological characteristics.

Introduction

Garlic (*Allium sativum* L.) is a traditional species inour country and its surrounding area with a large amount of local populations, produced in almost every garden, and is one of the most popular species from the *Allium* genus. It is produced on 16.8 million hectares in the world with an average yield of 17 t/ha (FAOSTAT, 2023). It is used in nutrition, as a condiment, and as raw material for phytoformation. Despite the economic and culinary value of garlic, its cultivation is accompanied by certain problems, primarily the selection of planting material. Due to the inability to flower and reproduce by seed, garlic

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is propagated exclusively vegetatively. Most cultivars in our country and around the world were obtained through clonal selection of local ecotypes. Ecotypes have relatively poor adaptability (Lešić et al., 2004). Progress in garlic cultivation requires the evaluation and selection of superior clones adapted to different agroecological conditions (Azimi et al., 2025).

The most cultivated populations in our area are domestic spring and winter kinds of garlic. Garlic is very responsive to the changes in ecological conditions. It belongs to species with moderate requirements to agroecological environmental conditions. It is sensitive to drought, and maximizing garlic bulb yield depends largely on water availability (Habuš Jerčić et al., 2023).

Planting time is one of the most important agronomic measures in garlic production technology. Planting date affects morphological characteristics such as plant height, leaf length, number of leaves per plant, and yield attributes such as bulb diameter, number of cloves per bulb, and bulb yield (Sultana et all., 2022). The same authors point out that growth, yield attributes and yield of garlic decreased gradually with delayed planting. Planting date is a critical factor determining the yield and quality parameters of garlic bulbs (Kacjan Maršić et all., 2020). It is very important to plant garlic on time in spring. Delays in planting spring garlic can have several negative consequences. With rising temperatures spring garlic forms a weak root system (optimal temperature is 5-10 °C) which cannot nurture the above-ground part of the plant (Gvozdenović-Varga et al., 2009). Delayed planting not only reduces bulb size but also decreases the mass and number of cloves, negatively affecting the quality of the planting material (Gvozdenović-Varga et al., 2009). Gvozdanović-Varga, (2005) states that there is a significant impact of weather conditions during vegetation on yields' basic components such as the cloves' mass, size, and compactness of the bulb. Tomić (2007) states that morphological features of bulbs are characteristic of each genotype, but they also depend on planting term.

This research aimed to determine in which way the population of domestic ecotype of garlic from the area of Berkovići would behave in other locations, and what would be the quality of bulbs in the new locations, as well as which planting term would give better results.

Materials and methods

In this research domestic ecotype of garlic from Berkovići was used. It belongs to the spring type of garlic. The experiment was set at two locations: Bijelo Polje (north of Mostar, about 200 m altitude, coordinates 43°27′N17°53′E), and Hodbina (south of Mostar, about 47 m altitude, coordinates 43°14′N17°51′E). Planting material was planted at both of these locations in two terms: autumn planting term (last decade of October 2016.) and spring planting term (first decade of March 2017). The experiment was set to the block schedule in three replications. The size of the main parcel was 1 m^2. Before setting the experiment, bulb mass was determined, as well as its width and height, the number of cloves, and cloves width and height of planting material. Before planting, basic soil preparation was

performed by plowing to a depth of 25 cm, followed by pre-planting soil preparation through tilling and leveling the surface layer of the soil. The soil of the experimental plot in Bijelo Polje belongs to the soil type of redeposited (allochthonous) red soil, with an alkaline pH reaction (pH in water 7.56). The soil in Hodbina belongs to the type of brown colluvial soil with a slightly heavier texture, neutral pH reaction (pH in water 6.92). Planting was done in rows, with a spacing of 30 cm between rows and 10 cm within rows. During the vegetation period, the usual crop maintenance measures were carried out destroying ragweed and hoeing. During the experiment, the onset of emergence, growth dynamics, and the beginning of ripening were monitored. After ripening and harvesting the bulbs, the following measurements were taken: bulb mass, bulb width and height, number of cloves, clove mass, clove width, and clove height. The obtained results were processed using analysis of variance, and the differences between individual average values were tested using the LSD test, using Excel software.

Results and discussion

The *bulb mass* varied from 22.45 to 36.93 g (table 1). According to the variance analysis results it can be seen that research factors did not have a statistically significant impact on this feature, while the interaction of researched factors showed statistical significance. The bulb mass was larger at the location of Bijelo Polje (30.65 g) compared to the other location, and that the bulb mass was larger in the spring planting term compared to the autumn period (29.69 g). However, the LSD test has shown that these differences are not statistically significant.

Table 1. *The impact of the location and planting term on the bulb mass (g)*

Location		Planting term		Average
		Spring	Autumn	
Bijelo Polje		36.93	24.37	**30.65^{A}**
Hodbina		22.45	34.47	**28.46^{A}**
Average		**29.69^{A}**	**29.42^{A}**	
LSD	0.05		Term	Location
	0.01		4.41	4.41
			5.95	5.95

Bulb width and height - variance analysis results show that location and planting term had a significant impact on the height of the bulb, while their interaction did not have a statistically significant impact (table 2). Regarding the location, bulb height was greater at the location of Bijelo Polje (3.80 cm), which is statistically significant according to the LSD test. Regarding the planting term and according to the LSD test, the garlic from the spring planting term had statistically bigger bulb height (3.69 cm).

Table 2. *The impact of location and planting term on bulb height (cm)*

Location		Planting term		Average
		Spring	Autumn	
Bijelo Polje		4.03	3.58	**3.80^{A}**
Hodbina		3.37	2.75	**3.06^{B}**
Average		**3.69^{A}**	**3.16^{B}**	
LSD	0.05		Term	Location
	0.01		0.27	0.27
			0.36	0.36

The factors research, as well as their interaction, had a statistically significant effect on the width of the garlic bulb (table 3). The width of the garlic bulb, depending on the location of cultivation and the planting term, ranged from 3.16 to 4.62 cm. The LSD test showed that the value of this parameter was statistically significantly higher at the location of Bijelo Polje. Regarding planting terms, a higher value of this parameter was recorded in the spring planting term, but this difference was not statistically significant.

Table 3. *The impact of location and planting term on bulb width (cm)*

Location		Panting term		Average
		Spring	Autumn	
Bijelo Polje		4.62	4.16	**4.16^{A}**
Hodbina		3.34	3.16	**3.25^{B}**
Average		**3.97^{A}**	**3.66^{A}**	
LSD	0.05		Term	Location
	0.01		0.41	0.41
			0.55	0.55

The *number of cloves* per bulb varied from 9.90 to 12.60. Variance analysis showed that research factors did not have a statistically significant impact on the number of cloves in a garlic bulb, while their interaction had that effect. Although the LSD test indicated that differences in the number of cloves between location and planting terms were not statistically significant, the results in Table 4 show that number of cloves was higher at the location of Bijelo Polje (11.85) and in the spring planting term (11.80).

Table 4. *The impact of location on cloves number in a bulb*

Location		Planting term		Average
		Spring	Autumn	
Bijelo Polje		11.10	12.60	**11.85^{A}**
Hodbina		12.50	9.90	**11.20^{A}**
Average		**11.80^{A}**	**11.25^{A}**	
LSD	0.05		Term	Location
	0.01		1.97	1.97
			2.66	2.66

Mass of cloves - although variance analysis indicated that research factors had a statistically significant impact on this feature, the LSD test showed that the values of clove mass did not differ significantly between locations and planting terms, which is seen in the results presented in Table 5.

Table 5. *The impact of location on garlic clove mass (g)*

Location		Planting term		Average
		Spring	Autumn	
Bijelo Polje		4.69	2.82	**3.75^{A}**
Hodbina		2.85	4.61	**3.72^{A}**
Average		**3.76^{A}**	**3.71^{A}**	
LSD	0.05		Term	Location
	0.01		0.84	0.84
			1.13	1.13

Clove width and height - research factors, as well as their interaction, had a statistically highly significant impact on the height of garlic cloves. When we look at the results in Table 6, we can see that the cloves' height was bigger at the location of Bijelo Polje (2.94 cm) compared to the location of Hodbine, as well as in the spring planting period (3.04 cm) compared to the autumn planting period, but these differences were not statistically significant according to the LSD test.

As in the case of clove height, the research factors, as well as their interaction, had a statistically highly significant impact on the width of garlic cloves. LSD test showed that the clove width differed statistically significantly between locations and planting terms. From the results shown in Table 7 we can see that the clove width at the location of Bijelo Polje (1.77 cm) was statistically highly bigger in

comparison to the location of Hodbine, as well as in the spring planting term (1.75 cm) compared to the winter planting term.

Table 6. *The impact of location and planting term on clove height (cm)*

Location	Planting term		Average
	Spring	Autumn	
Bijelo Polje	3.19	2.71	**2.94^{A}**
Hodbina	2.90	2.41	**2.65^{A}**
Average	**3.04^{A}**	**2.55^{A}**	
LSD	0.05	Term	Location
	0.01	0.57	0.55
		0.77	0.77

Table 7. *The impact of location and planting term on clove width*

Location	Planting term		Average
	Spring	Autumn	
Bijelo Polje	1.93	1.63	**1.77^{A}**
Hodbina	1.57	0.98	**1.27^{B}**
Average	**1.75^{A}**	**1.31^{B}**	
LSD	0.05	Term	Location
	0.01	0.19	0.19
		0.25	0.25

Characteristics of garlic planting material

Table 8 presents the results of morphometric measurements of garlic planting material produced in Berkovići.

Table 8. *Values of Examined Morphometric Parameters of Garlic Planting Material*

Parameters examined	Bulb mass (g)	Bulb height (cm)	Bulb width (cm)	Number of cloves	Clove mass (g)	Clove height (cm)	Clove width (cm)
The Value	44.59	3.53	4.25	11.9	4.42	2.01	0.96

Based on the measured parameters of the planting material produced in Berkovići, and comparing them with the values of the parameters of garlic produced in the experiment, it can be stated that the values of most of the examined parameters of the planting material produced in Berkovići were significantly higher compared to the garlic produced in the experiment (table 8).

The planting material, compared to the garlic produced in the experiment, had significantly higher values for the following parameters: bulb mass, bulb width, and clove weight. The number of cloves per bulb was also higher in the planting material in comparison to the obtained garlic, but this difference was negligible. The bulb height of the planting material (3.53 cm) was bigger than the garlic produced in the experiment at the location of Hodbine and in the autumn planting term, while it was lower than the bulb height of the garlic from the experiment at the location of Bijelo Polje and in the spring planting term.

Only the height and width of the cloves were greater in the produced garlic compared to the planting material.

Discussion

Research factors location and time of planting influenced the following characteristics of the garlic bulb: bulb height, bulb width, cloves height and cloves width, while bulb weight, number of cloves in the bulb and cloves weight were not influenced. The interaction of the research factors showed a significant influence in all tested parameters except for the bulb height parameter.

When analyzing the average values of the tested parameters according to the treatments of the experiment, we can state that all the average values of all the tested parameters were higher at the Bijelo Polje location and in the spring planting time. However, not all of these differences were statistically significant.

Thus, we can distinguish that the height of the bulb, the width of the bulb and the width of the cloves were statistically significantly higher in the Bijelo Polje location compared to the Hodbina location, and the height of the bulb and the width of the cloves were statistically significantly higher in the spring planting time compared to the autumn planting time.

These differences between localities could be related to different growing conditions, given that localities have different altitudes and different types of soil. Differences in altitude cause differences in the average air temperature, which affected the growth and development of plants during critical phases.

This could have resulted in a location with higher altitude having more moderate air temperatures, which potentially mitigated heat stress that could negatively affect vegetative growth and root system formation, especially in spring planting time.

Proper planting time, first of all, ensures favorable temperatures for individual growth phases. Mensah and Valenti 2025. state that early autumn planting produces large bulbs, and Plodma et al., 2005. point out that autumn planting outperforms spring planting.

Light, alluvial and well-structured soils are more suitable for growing garlic. When we compare the types of soil in the localities of cultivation, we can say that allochthonous pre-deposited red soils have an advantage for growing garlic, compared to brown colluvial soil.

The difference in average bulb weight values between treatments is not statistically significant. However, when analyzing the interaction effect, it can be seen that the highest bulb mass was recorded in the combination Bijelo Polje/spring planting date (36.93 g), and the next highest value was recorded in the combination Hodbina/winter planting date (34.47 g). The significant interaction effect of planting date and location on bulb mass and width (diameter) indicates that both planting time and location-specific environmental conditions play a key role in determining these traits (Mensah i Valenti, 2025).

The obtained values of the examined parameters in the experiment are similar to the results of other authors. According to Gvozdenović – Varga et.al. (1994), the bulb mass of different clones of spring garlic ranged from 16.47 to 21.81 g. The number of cloves is a varietal characteristic, and in this study, it ranged from 9.8 to 16.8. The higher the number of cloves in the head, the lower their weight is. The values of certain bulb features of domestic and introduced garlic ecotypes in the study by Dumičić et al., (2013), ranged as follows: bulb mass ranged from 39.6 to 58.0 g, number of cloves from 10.5 to 11.9, bulb height from 2.2 to 3.9 cm, bulb width from 4.1 to 5.0 cm, and clove mass from 3.2 to 5.2 g.

Many authors have established a significant influence of the time of planting on plant growth and development, as well as yield and yield (Bhuiya et. al., 2003; Sultana et al., 2022; Shuvra et al., 2017).

From the previously presented results related to the comparison of planting material and experimental results, we can state that the average experimental results for most parameters were lower. We can single out that the height and width of the cloves in cultivated garlic were higher compared to the planting material, as well as the height of the bulb in the Bijelo Polje location and in the spring planting time. However, when we single out the result of the best treatment combination Bijelo Polje/spring planting date (4.62 cm) for the bulb width property, we can see that the obtained value significantly exceeds the planting material. This shows that the most effective combination of treatments was able to produce larger bulbs than the original material.

Dumičić et al., 2013, investigated the influence of domestic ecotypes (Ljubitovački šarac and Ljubitovački garlic) and introduced cultivars (Domestic winter red onion and Domestic winter garlic) of garlic on yield components under traditional cultivation conditions in the karst field area of Ljubitovica. Both ecotypes from Ljubitovica achieved a significantly higher percentage of dry matter

and higher morphological parameters of the bulbs compared to the two introduced cultivars. Azimi et al. 2025. investigated the adaptability of selected garlic clones in comparison with local populations in three localities. All selected clones outperformed their parental populations, and two clones showed superior performance at all three breeding locations, which suggests the high adaptability of these two clones and they are recommended for mass production at all three studied locations (regions).

Conclusion

The examined features of the bulb of domestic ecotype of garlic were influenced by the following research factors – location of cultivation and planting terms. The values of all examined parameters of the bulb were higher at the location of Bijelo Polje and in the spring planting term. The average values of most of the investigated parameters of the produced garlic in the experiment are significantly lower compared to the values of the parameters of the planting material originating from the area of Berković. Although the average values of most experimental results are lower than the starting material, it should be noted that the bulb diameter obtained at the Bijelo Polje location and in the spring planting time is significantly larger than the bulb diameter of the planting material, which means that the most effective combination of treatments managed to produce larger bulbs than the original material.

This experiment should be repeated and expanded to determine whether a longer period of adaptation is needed.

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Ekološki aspekti algi i viših biljaka Jadranskog mora

Ecological Aspects of Algae and Higher Plants of the Adriatic Sea

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Sažetak

Ovaj rad analizira raznolikost, rasprostranjenost, ugroženost i gospodarski potencijal morskih algi i cvjetnica Jadranskog mora. Na temelju analize dostupne znanstvene i stručne literature obrađeni su aspekti bioraznolikosti, prisutnosti endemskih i invazivnih vrsta te utjecaja antropogenih pritisaka, klimatskih promjena i onečišćenja na ekosustave. Posebna pozornost posvećena je značaju *Posidonia oceanica*, *Laminaria rodriguezii* i invazivnih algi poput *Caulerpa cylindracea* i *C. taxifolia*, koje predstavljaju najveću prijetnju lokalnoj biološkoj raznolikosti. U radu su također prikazane zaštićene vrste i metode praćenja stanja ekosustava, uključujući autonomna plovila (BRIGANTINE) i digitalne platforme (BIOPRESS ADRIA), te primjeri gospodarskog korištenja algi kroz kulinarske projekte i istraživanja tržišnog potencijala. Zaključeno je da alge i morske cvjetnice imaju ključnu ulogu u očuvanju ekološke stabilnosti Jadranskog mora i predstavljaju vrijedan resurs za prehranu, biotehnologiju i ekološke tehnologije. Njihova zaštita zahtijeva unaprijeđeni monitoring, edukaciju i jasne smjernice za održivo upravljanje.

Ključne riječi: Jadransko more, alge, morske cvjetnice, invazivne vrste, bioraznolikost, gospodarska primjena.

Abstract

This study analyzes the diversity, distribution, threats, and economic potential of marine algae and seagrasses in the Adriatic Sea. Based on the review of available scientific and professional literature, the work addresses biodiversity, the presence of endemic and invasive species, and the impact of anthropogenic pressures, climate change, and pollution on marine ecosystems. Particular attention is

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given to the significance of *Posidonia oceanica*, *Laminaria rodriguezii*, and invasive algae such as *Caulerpa cylindracea* and *C. taxifolia*, which pose major threats to local biodiversity. The study also presents protected species and ecosystem monitoring methods, including autonomous vessels (BRIGANTINE) and digital platforms (BIOPRESS ADRIA), as well as examples of the economic use of algae through culinary projects and market potential research. The study concludes that algae and seagrasses play a key role in maintaining the ecological stability of the Adriatic Sea and represent a valuable resource for food, biotechnology, and ecological technologies. Their conservation requires improved monitoring, education, and clear guidelines for sustainable management.

Key words: Adriatic Sea, algae, seagrasses, invasive species, biodiversity, economic use.

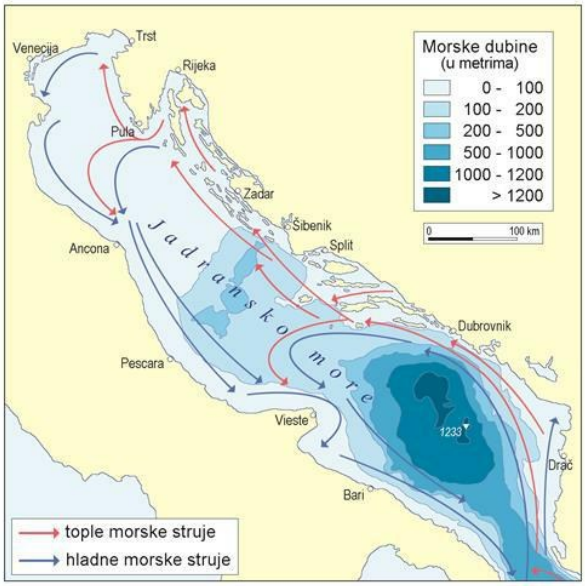
Uvod

Jadransko more smatra se jednim od biološki najraznolikijih dijelova Sredozemlja, s bogatim zajednicama makroalgi i morskih cvjetnica te velikim brojem endemskih svojti. U ranijim istraživanjima značajna se pozornost posvećivala bentoskim i planktonskim algama, njihovoj ekološkoj ulozi, vrijednosti kao pokazateljima kakvoće morskog okoliša te utjecaju klimatskih promjena i antropogenih pritisaka. U novije vrijeme raste interes za održivu primjenu algi u prehrambenoj industriji, biotehnologiji, energetici i ekološkim rješenjima, čime se dodatno naglašava važnost njihove ekologije i biogeografske raznolikosti.

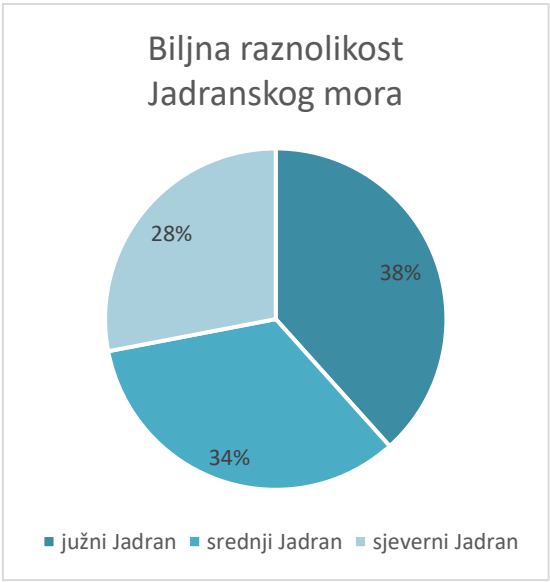
Jadransko more je najsjeverniji izdanak Sredozemnog mora i zauzima oko 4,6 % njegove ukupne površine. Proteže se u smjeru jugoistok–sjeverozapad te obuhvaća oko 138 000 km². Prema batimetrijskim obilježjima (slika 1) dijeli se na vrlo plitki Sjeverni Jadran, srednji Jadran i najdublji južni dio (Viličić, 2014). Najveća zabilježena dubina, 1 233 m, nalazi se u Južnojadranskoj kotlini (Jardas et al., 2008). More je visokog saliniteta, koji u površinskom sloju prosječno iznosi 38,30 ‰, a smanjuje se od juga prema sjeveru. Temperatura ne pada ispod 10–12 °C ni u najdubljim slojevima. Najznačajniji vjetrovi koji utječu na hidrodinamiku Jadrana su bura i jugo (Krželj, 2010). Istočna obala pretežno je kamenita i vrlo razvedena, dok je zapadna obala plitka, slabije razvedena i prekrivena širokim pojasom pjeskovitih sedimenata (Antonić et al., 2005).

Biljna raznolikost Jadranskog mora (slika 2) povećava se od sjevera prema jugu (Dulčić, 2019). Procjenjuje se da u Jadranu obitava između 7 000 i 8 000 vrsta, dok novija istraživanja ukazuju da bi ukupan broj mogao biti veći od 12 000, pa čak i doseći 15 000 svojti (Riedl, 1983). Jadran se izdvaja kao posebna biogeografska cjelina zbog velikog broja endemskih vrsta, koje čine oko 12 % njegove ukupne flore (Kružić, 2023). U Sredozemnom moru poznato je oko 650 vrsta bentoskih algi, od kojih je duž istočne jadranske obale zabilježeno oko 350 svojti, odnosno 55 % ukupnog broja do sada poznatih 638 svojti, dok je u hrvatskom dijelu Jadrana utvrđeno oko 340 svojti (Antolić et al., 2001, 2009, 2010, 2011).

Unatoč visokoj raznolikosti, ekosustav Jadrana suočava se s brojnim ugrozama, uključujući utjecaj klimatskih promjena, eutrofikaciju, onečišćenje komunalnim i industrijskim otpadnim vodama, masovni turizam te neracionalno iskorištavanje morskih resursa. Ovi pritisci dovode do promjena u strukturi i funkciji algalnih zajednica te zajednica cvjetnica, što naglašava potrebu za njihovim sustavnim praćenjem i zaštitom.



Slika 1. Batimetrijska karta Jadranskog mora (https://proleksis.lzmk.hr/28692/)
Figure 1. *Bathymetric map of the Adriatic Sea (https://proleksis.lzmk.hr/28692/)*



Slika 2. Biljna raznolikost Jadrana (Dulčić, 2019)
Figure 2. *Plant diversity of the Adriatic (Dulčić, 2019)*

Materijali i metode

U ovom radu provedena je sveobuhvatna analiza dostupne znanstvene i stručne literature (ukupno 66 referenci) vezane uz raznolikost morskih algi i cvjetnica Jadrana. Prikupljeni su i sistematizirani podaci o biljnoj raznolikosti, uključujući endemične, invazivne i ekološki značajne vrste, kao i informacije o promjenama staništa pod utjecajem prirodnih i antropogenih čimbenika. U razmatranje su uključeni i postojeći modeli praćenja stanja morskih ekosustava, s posebnim naglaskom na autonomne sustave, sustave daljinskog nadzora te nove digitalne platforme za prikupljanje i obradu podataka.

Cilj istraživanja bio je prikupiti, sintetizirati i kritički analizirati relevantne podatke o vrstama morskih algi i cvjetnica Jadrana, njihovoj prostornoj i ekološkoj rasprostranjenosti, stupnju ugroženosti te potencijalnoj primjeni u prehrambenoj, biotehnološkoj i ekološkoj praksi. Metodološki okvir rada temelji se na kvalitativnoj i komparativnoj analizi recentne literature iz područja marinog botaničkog znanja, ekologije mora te zaštite i održivog upravljanja morskim resursima. Ovakav pristup omogućio je integrirano sagledavanje trenutnog stanja i izazova vezanih uz biološku raznolikost morskih algi i cvjetnica Jadranskog mora.

Rezultati i diskusija

Alge u Jadranu

Alge predstavljaju veliku i raznoliku skupinu autotrofnih organizama koji nastanjuju vodena i vlažna staništa. Njihova se veličina kreće od mikroskopskih oblika promjera 0,2–2 mm do velikih višestaničnih organizama koji mogu doseći duljinu i do 60 m (Barsanti i Gaultieri, 2022). U ekološkom i morfološkom smislu dijele se u dvije osnovne skupine: makroalge (morske alge), koje pretežno obitavaju u litoralnoj zoni (slika 4.), te mikroalge, prisutne u bentoskim i litoralnim staništima, ali i u otvorenim oceanskim vodama kao sastavni dio fitoplanktona.

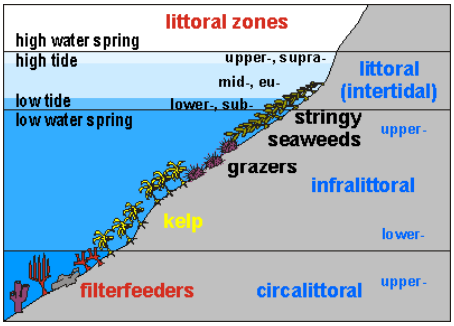
Bentoske alge naseljavaju područje obale i morskog dna u rasponu od zone prskanja valova do najveće dubine na koju može doprijeti dovoljna količina svjetlosti za nesmetanu fotosintezu (slika 5.). Njihov razvoj, struktura zajednica i prostorna rasprostranjenost ovise o složenoj interakciji biotskih čimbenika – među kojima su odnosi s drugim algama i organizmima – te abiotskih fizikalno-kemijskih značajki morskog okoliša (Ministarstvo poljoprivrede, 2023).

Prema pigmentacijskim obilježjima alge se razvrstavaju u tri glavne skupine: zelene (Chlorophyta), smeđe (Phaeophyta) i crvene alge (Rhodophyta) (Ministarstvo poljoprivrede, 2023). Klasifikacijski pregled i osnovne značajke svake skupine prikazani su u tablici 1.

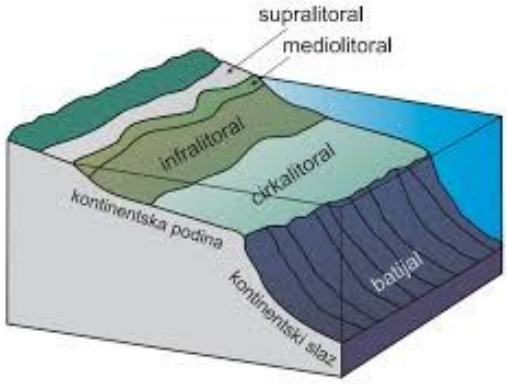
Promjene u sastavu i dinamici zajednica bentoskih i planktonskih algi važni su indikatori ekoloških promjena i razine onečišćenja u morskim ekosustavima (Prvan et al., 2016). Osim svoje ekološke uloge,

alge imaju značajan gospodarski potencijal. Koriste se u prehrani ljudi, u proizvodnji agara, kozmetičkih i farmaceutskih proizvoda, a sve više i kao održivi izvor za razvoj gnojiva i bioplastike (Ministarstvo poljoprivrede, 2023).

Stipković (1983) detaljno opisuje prehrambenu i medicinsku vrijednost morskih algi. Za ljudsku prehranu osobito su zanimljive zbog visokog sadržaja mineralnih soli i vitamina, kao što je slučaj kod vrsta *Chondrus crispus* Stackhouse, *Ulva lactuca* L., *Porphyra* spp., *Laminaria* spp. i drugih. Njihova medicinska vrijednost temelji se prvenstveno na antivirusnim svojstvima, što dodatno potvrđuje njihovu važnost u biomedicinskim i biotehnološkim primjenama.



Slika 4. Litoralne zone
Figure 4. *Littoral zones*



Slika 5. Podjela bentoskih stepenica u Jadranskom moru (Bakran-Petricioli, 2007)
Figure 5*. Division of benthic stages in the Adriatic Sea (Bakran-Petricioli, 2007)*

Tablica 1. Klasifikacija i osnovne značajke algi (prilagođeno prema Antolić et al., 2011; Kim, 2012)

Table 1. *Classification and basic characteristics of algae (adapted to Antolić et al., 2011; Kim, 2012)*

	zelene alge (*Chlorophyta*)	**smeđe alge (*Phaeophyta*)**	**crvene alge (*Rhodophyta*)**
Rasprostranjenost s obzirom na dubinu	u zoni plime i oseke	pliće vode	dubokomorske (otok Jabuka - dubina 250 m)
Staništa	češće slatkovodna staništa	obično morska staništa	obično morska staništa
Morsko stanište	stjenovite obale – stvaraju vrlo gusta naselja, potpuno prekrivaju taj dio morskoga dna	stjenovita podloga do 20-30 m dubine	stjenovito dno, nalazimo ih i na pjeskovitom, pjeskovito-muljevitom i muljevitom dnu
Primjena	u prehrambenoj industriji, za izolaciju pigmenata	bogate jodom i alginatima – do 1930. godine glavni izvor za dobivanje joda	izvor agara, najvažnijih proizvoda akvakulture
Zanimljivosti	u Sredozemnom moru pronađeno je otprilike 214 vrsta, u hrvatskom dijelu Jadrana zabilježeno je 118 vrsta	ekonomski značajne – uzgajaju se u količinama većim od 2 milijuna tona godišnje; u Jadranskom moru poznato 170 vrsta iz 11 taksonomskih redova	uspijevaju u uvjetima različitog stupnja onečišćenja mora

Primjena algi u svijetu i u Hrvatskoj

Uzgoj algi predstavlja područje s iznimno velikim potencijalom za različite industrijske sektore, osobito u kontekstu rastućih globalnih ekoloških i gospodarskih izazova. Alge se sve češće ističu kao održiva i ekološki prihvatljiva alternativa tradicionalnim resursima, nudeći rješenja u području prehrane, energetike, biotehnologije i zdravstvene industrije (Ministarstvo poljoprivrede, 2023). U Europskoj uniji bilježi se kontinuirani porast potražnje za biljnim, održivim izvorima hrane, biogorivima te prirodnim zdravstvenim proizvodima, što dodatno potiče razvoj komercijalne proizvodnje algi (slika 6.). U tom kontekstu, tablica 2. prikazuje usporedni pregled primjene algi u svijetu i u Hrvatskoj.

Makroalge, zahvaljujući velikoj morfološkoj i ekološkoj raznolikosti, značajnoj biomasi, širokoj rasprostranjenosti te važnoj ulozi u strukturi morskih ekosustava, smatraju se vrlo osjetljivim i pouzdanim indikatorima ekoloških promjena (Levine, 1984). Brojna su istraživanja potvrdila da urbano i industrijsko onečišćenje negativno utječu na zajednice makroalgi, uzrokujući promjene u njihovoj strukturi, smanjenje brojnosti i nestanak osjetljivih svojti (Munda, 1974, 1980; Littler i Murray, 1975;

Belsher, 1977; Levine, 1984; Gorostiaga i Díez, 1996; Díez et al., 1999; Terlizzi et al., 2002; Arévalo et al., 2007; Wells et al., 2007; Guinda et al., 2008).

Slika 6. Očekivani porast potražnje 2030. za proizvodima na bazi algi (https://ribarstvo.mps.hr/UserDocsImages/Alge%20-priru%C4%8Dnik%20finalna%20verzija.pdf)

Figure 6. *Expected increase in demand for algae-based products in 2030 (https://ribarstvo.mps.hr/UserDocsImages/Alge%20-priru%C4%8Dnik%20finalna%20verzija.pdf)*

Tablica 2. Primjena algi u svijetu i u Hrvatskoj (prema Samaraweera et al., 2012; Ministarstvo poljoprivrede, 2023; Cofrades et al., 2017; Agatonović-Kustrin i Morton, 2013; Menon, 2011)

Table 2. *Application of algae in the world and in Croatia (according to Samaraweera et al., 2012; Ministarstvo poljoprivrede, 2023; Cofrades et al., 2017; Agatonović-Kustrin and Morton, 2013; Menon, 2011)*

Primjena algi u svijetu	**Primjena algi u Hrvatskoj**
Široka primjena: prehrana, biogoriva, kozmetika	Veliki potencijal za uzgoj (obala, sunce, voda)
Alge „superhrana“, stabilizatori, emulgatori	Tržište još u začetku, sektor nerazvijen
Gnojiva, pesticidi, bioindikatori	Raste interes za prehranu i održive proizvode
Uzgoj uz napredne tehnologije, velika potražnja	Postoje prirodni resursi i EU podrška
Aktivno korištenje u industriji i agronomiji	Potrebna ulaganja i strateški razvoj

Pod utjecajem stresnih čimbenika, bilo prirodnih ili antropogenih, zajednice makroalgi pokazuju smanjenje bioraznolikosti, gubitak ključnih vrsta te promjene u ukupnoj biomasi. Posebice u uvjetima povećane eutrofikacije i antropogenog onečišćenja dolazi do značajnog narušavanja strukture bentoskih zajednica (Golubić, 1970; Díez et al., 1999; Orfanidis et al., 2001, 2003).

U Jadranskom moru, za potrebe procjene stanja morskog ekosustava unutar različitih znanstvenih istraživanja i nacionalnih monitoring programa, primjenjuje se niz pokazatelja koji se temelje na

zajednicama makroalgi. Najčešće korišteni parametri obuhvaćaju brojnost, raznolikost, biomasu te kvalitativnu i kvantitativnu dominaciju pojedinih skupina (Iveša et al., 2009; Slišković et al., 2011). Ovakav pristup omogućuje dugoročno praćenje promjena u obalnim ekosustavima te predstavlja temelj za učinkovitije upravljanje i zaštitu morskih resursa.

Više bilje Jadranskog mora

Livade morskih cvjetnica predstavljaju ključni segment infralitorala, dijela morskog dna koji je kontinuirano pod morem. Ove zajednice oblikuju guste livade koje mogu prekrivati vrlo velike površine, od plićih zona do dubina od približno 50 m, te spadaju među najvrjednija i najbogatija staništa Jadranskog mora (Antolić et al., 2011). Njihova struktura i prostorna rasprostranjenost izravno doprinose biološkoj raznolikosti, stabilnosti morskog dna i ekološkim procesima poput proizvodnje kisika i taloženja sedimenta.

Iako su nekoć bile široko rasprostranjene, tijekom posljednjih dvadesetak godina zabilježeno je značajno smanjenje površina livada morskih cvjetnica. Danas se one uglavnom zadržavaju u izoliranim i zaštićenim uvalama, što upućuje na snažan pritisak okolišnih promjena i antropogenih aktivnosti (Odak i Treer, 2000).

U Jadranskom moru prisutne su četiri autohtone vrste morskih cvjetnica: posidonija ili oceanski porost (*Posidonia oceanica*), morska svilina (*Zostera marina* L.), patuljasta svilina (*Zostera noltii* Hornemann) te čvorasta morska resa (*Cymodocea nodosa* (U.) Ascherson) (HAOP, 2017). Svaka od ovih vrsta ima važnu ulogu u očuvanju ekološke ravnoteže, osiguravanju staništa mnogim morskim organizmima i održavanju ekosustavne stabilnosti obalnih područja Jadrana.

Posidonia oceanica (L.) *Delile*

Posidonija endem je Sredozemnog mora i najrasprostranjenija vrsta morskih cvjetnica u Jadranu (slika 7.). Stvara prostrane morske livade na muljevito-pjeskovitom dnu, a s površine mora uočljiva je kao tamne mrlje (HAOP, 2017). Budući da za fotosintezu zahtijeva obilje sunčeve svjetlosti, prozirnost mora glavni je čimbenik njezina dubinskog raspona. Cvjeta u kasnu jesen i početkom zime, i to ne svake godine. Zbog izrazito sporog rasta, pojedini primjerci mogu biti stariji od 1000 godina, što je čini jednim od najdugovječnijih organizama Sredozemlja (HAOP, 2017).

Slika 7. Rasprostranjenost *P. oceanica* u Jadranskom moru

Figure 7. *Distribution of P. oceanica in the Adriatic Sea*

Livade posidonije (slika 8.) važna su „tvornica“ kisika i žarišta velike biološke raznolikosti. U njima obitava više od 20% poznatih sredozemnih vrsta. Na svakom listu može se naći više od 30 vrsta algi, a livade služe kao obitavališta, mrijestilišta i hranilišta za više od 100 vrsta riba, od kojih je većina gospodarski značajna. Gusta mreža položenih stabljika i uspravnih izdanaka smanjuje odnošenje sedimenta morskim strujama te ima važnu ulogu u kruženju hranjivih soli (HAOP, 2017).

Posidonija svake godine odbacuje staro i obnavlja novo lišće. Naplavljeno lišće krajem ljeta i početkom jeseni nakuplja se na obali. U prošlosti se, diljem Sredozemlja, suho lišće koristilo za termoizolaciju štala, ishranu stoke, punjenje madraca i jastuka te za zaštitu venecijanskog stakla tijekom transporta. Egipćani su svježem lišću pripisivali ljekovita svojstva kod bolnog grla i kožnih tegoba. Iako se danas više ne koristi za te svrhe, naplavljene naslage imaju važnu ulogu u ublažavanju obalne erozije, posebno tijekom jakih valova, dok se brojni organizmi hrane detritusom nastalim razgradnjom lišća (HAOP, 2017).

Slika 8. *Posidonia oceanica* (L.) Delile (https://www.haop.hr/hr/morske-cvjetnice)

Figure 8. *Posidonia oceanica (L.) Delile (https://www.haop.hr/hr/morske-cvjetnice)*

Livade posidonije smatraju se najvažnijim priobalnim ekosustavom Sredozemnog mora, ali se razvijaju upravo u područjima pod snažnim pritiskom ljudskih aktivnosti. Sidrenje plovila oštećuje mrežu položenih stabljika, čineći je osjetljivom na razaranje valova. Ugrožavaju je i invazivne vrste, onečišćenje otpadnim vodama, gradnja i nasipavanje, uzgajališta riba i školjkaša, marine i lučice te pojedini ribolovni alati. Zbog svoje ekološke važnosti, osjetljivosti i ugroženosti, posidonija je u Hrvatskoj strogo zaštićena Zakonom o zaštiti prirode (NN 80/13, 15/18, 14/19, 127/19), a na razini Europske unije štiti je Direktiva o očuvanju prirodnih staništa te divlje faune i flore (HAOP, 2017).

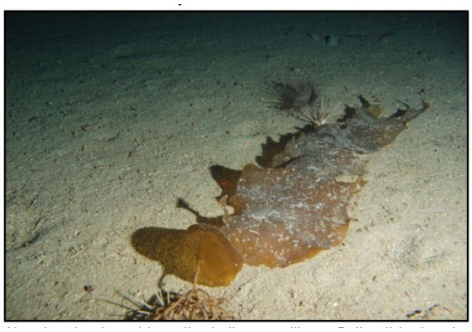
Laminaria rodriguezii B.

Laminaria rodriguezii endemska je dubokomorska sredozemna makroalga, građena od razgranatog korijena, stručka i nepodijeljene ploške veličine do 150 × 30 cm (Beck, 1896). Rasprostranjena je u zapadnom Sredozemlju i Jadranskom moru (Žuljević et al., 2016), pri čemu se glavne populacije nalaze oko Balearskih otoka (Joher et al., 2012) te u Tirenskom moru (Giaccone, 1967; Bo et al., 2011). U Jadranu je potvrđena isključivo u središnjem dijelu, uključujući područja Jabuke, Biševa i Palagruže, uglavnom na dubinama većim od 70 m, iako se može pojaviti i pliće, ovisno o okolišnim uvjetima (Žuljević et al., 2016). Najveća zabilježena dubina iznosi 260 m (Ercegović, 1960). Vrsta raste na strmim podmorskim strukturama u čistim vodama otvorenog mora, a zbog preklapanja njezina staništa s područjima koćarenja postoji opravdana zabrinutost za njezin opstanak (Žuljević et al., 2016).

Biologija vrste još uvijek nije dovoljno istražena, ponajprije zbog otežanog prikupljanja živih primjeraka. Genetska istraživanja talusa iz Jadrana i zapadnog Sredozemlja pokazuju njezinu blisku filogenetsku povezanost s atlantskim vrstama roda *Laminaria* (Žuljević et al., 2016). Usporedba povijesnih i suvremenih podataka o rasprostranjenosti otkrila je drastičan pad—prema kriterijima IUCN-a, rasprostranjenost vrste u Jadranu smanjila se za više od 85%, ponajviše zbog izravnih i neizravnih učinaka koćarenja (Žuljević et al., 2016).

Sukladno IUCN kriterijima predloženo je da se vrsta klasificira kao ugrožena te da se izradi plan upravljanja za njezino očuvanje, osobito na području otoka Palagruže, koji predstavlja posljednje poznato utočište *L. rodriguezii* u Jadranu i istočnom Sredozemlju (Žuljević et al., 2016).

U proljeće 2010. godine provedeno je istraživanje dubokomorskih naselja ove alge brodom BIOS DVA, tijekom kojeg su pretražene lokacije od Jabuke do Palagruže, na kojima je ranije bila zabilježena. Alga je pronađena (slika 9.) jedino u blizini Palagruže (IZOR, 2010).



Slika 9. *Laminaria rodriguezii* snimljena kraj otoka Palagruža (IZOR, 2010)

Figure 9. *Laminaria rodriguezii photographed near the island of Palagruža (IZOR, 2010)*

Invazivne vrste algi

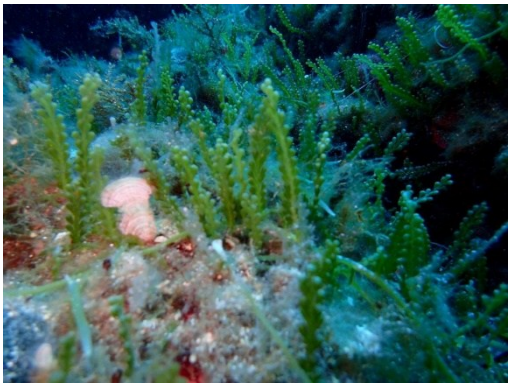
Tijekom posljednjih dvadesetak godina u Jadranskom moru zabilježen je značajan porast stranih toplofilnih vrsta algi, beskralježnjaka i riba, od kojih mnoge pokazuju invazivne karakteristike. Riječ je o južno-sredozemnim vrstama koje prirodnim širenjem ulaze u Jadran, migrantima iz Crvenog mora koji prelaze kroz Sueski kanal te vrstama koje su, vjerojatno, unesene balastnim vodama (AZO, 2014; Grbec, 2000; Despalatović et al., 2008). Već 2006. godine najmanje 30 od 100 najgorih invazivnih vrsta Sredozemlja bilo je prisutno u Jadranu, a od 19 najinvazivnijih algi čak 11 živi u njegovim vodama (Despalatović et al., 2008; Cheung et al., 2009; Streftaris i Zenetos, 2006).

Najveću prijetnju biološkoj i ekološkoj raznolikosti Jadranskog mora predstavljaju tropske zelene alge *Caulerpa taxifolia* (M. Vahl) C. Agardh i *C. cylindracea* S. (sin. *C. racemosa* var. cylindracea). Ove vrste su izrazito invazivne, učinkovito koloniziraju naseljena i nenaseljena staništa (Streftaris i Zenetos, 2006), potiskuju pridnene životinje, osobito spužve i koralje, kao i druge alge te morske cvjetnice (Žuljević, 2005). Širenjem mogu potpuno prekriti morsko dno te izmijeniti prirodna staništa i biocenoze (Žuljević et al., 2011). Njihova invazivnost proizlazi iz brze prilagodljivosti, otpornosti na širok raspon ekoloških uvjeta te izostanka prirodnih neprijatelja (Žuljević, 2005a). Budući da ne sudjeluju u prehrambenim lancima, njihov je ekološki utjecaj dodatno naglašen. Najintenzivnije širenje i povećanje biomase ovih algi bilježi se od svibnja do rujna. U Jadranu su prisutne tri vrste zelenih algi iz roda *Caulerpa*: *C. taxifolia*, *C. racemosa* (sin. *C. cylindracea*) i autohtona *C. prolifera* (https://www.akvarij.net/zanimljivosti/ekologija/more-ekologija/196-caulerpa-taxifolia-i-caulerpa-racemosa).

Caulerpa cylindracea Sonder

Caulerpa cylindracea u Jadranu je prvi put zabilježena 2000. godine u blizini Paklinskih otoka, odakle se proširila velikim dijelom južnog i srednjeg Jadrana (Bratoš Cetinić et al., 2013). Riječ je o invazivnoj zelenoj algi podrijetlom iz Crvenog mora (slika 10.), koja se zbog iznimno brzog širenja i agresivnog

rasta smatra ozbiljnom prijetnjom sredozemnim ekosustavima (Milovan, 2024). Prema IUCN-ovom popisu svrstana je među 100 najgorih invazivnih vrsta, a na područjima na kojima se nastani potiskuje autohtone vrste algi, čime značajno smanjuje bioraznolikost.



Slika 10. *Caulerpa cylindracea* (Sonder) (https://www.zastita-prirode-dnz.hr/invazivna-vrsta-alge-grozdasta-kaulerpa/)

Figure 10. *Caulerpa cylindracea (Sonder) (https://www.zastita-prirode-dnz.hr/invazivna-vrsta-alge-grozdasta-kaulerpa/)*

Caulerpa taxifolia (M.Vahl) C. Agardh

Caulerpa taxifolia unesena je u Sredozemno more 1984. godine iz akvarija kod Monaka, odakle se brzo proširila čitavim Sredozemljem i Jadranom. Najveće naselje zabilježeno je u Starogradskom zaljevu na otoku Hvaru (Turk et al., 2011). Poznata i kao „alga ubojica“ (slika 11.), pokazuje stalno širenje i visoku otpornost, a prema dosadašnjim spoznajama nije moguće potpuno ukloniti ni kemijskim ni fizičkim metodama. Djelotvorna se mjera pokazalo pokrivanje rubnih dijelova tamnom folijom oko tri mjeseca, dok se obećavaju rezultati bioloških studija, uključujući primjenu morskih puževa koji se isključivo hrane kaulerpom (Odak i Treer, 2000). Rasprostranjenju alge pridonose sidra brodova i ribolovne mreže koje je prenose na velike udaljenosti.

U Jadranu je širenje *C. taxifolia* posebno ugrožavajuće za posidoniju (*Posidonia oceanica*), pri čemu je u nekim područjima zabilježeno smanjenje populacija i do 45 % (Streftaris i Zenetos, 2006). Nakon 2009. godine primijećen je značajan pad brojnosti livada *C. taxifolia* u većini napadnutih područja, što se povezuje s velikim godišnjim promjenama temperature Sredozemnog mora, budući da alga pokazuje osjetljivost na hladnije uvjete (Tejada i Sureda, 2013; Montefalcone et al., 2015). Oko 2007. i 2008. godine, *C. taxifolia* je masovno opala u cijelom Sredozemlju (Meinesz et al., 2010), a u Jadranu je preostalo jedino nalazište u Starogradskom zaljevu, gdje je kolonija s površinom od 70 ha smanjena za više od 90 %. Glavni uzrok masovnog izumiranja tada se povezuje s biljnom bolesti (Žuljević et al., 2019).

Slika 11. *Caulerpa taxifolia* (M.Vahl) C. Agardh (https://www.biologiamarina.org/caulerpa-taxifolia/)

Figure 11*. Caulerpa taxifolia (M.Vahl) C. Agardh (https://www.biologiamarina.org/caulerpa-taxifolia/)*

Zaštićene vrste

Jadransko more dom je mnogim vrstama biljaka, od kojih su neke zaštićene zbog ekološkog značaja i ugroženosti. Prema dostupnim podacima, do sada je u Jadranu zabilježeno 2.597 vrsta algi, od čega 152 endema. Srednji Jadran ističe se najvećim brojem endemskih vrsta, s 535 identificiranih vrsta zelene, smeđe i crvene alge (HAOP, 2017a; Prvan et al., 2016).

Među najvažnijim zaštićenim vrstama morske flore, koje imaju ključnu ulogu u održavanju ravnoteže ekosustava, nalaze se morske cvjetnice i alge. To uključuje posidoniju (*Posidonia oceanica*), čvorastu morsku resu (*Cymodocea nodosa*), morsku svilinu (*Zostera marina*), patuljastu svilinu (*Zostera noltii*) te smeđu algu *Fucus virsoides* J. Agardh, poznatu kao jadranski bračić.

Jadranski bračić (*Fucus virsoides*, slika 12.) je strogo zaštićena smeđa alga Jadranskog mora, čije su populacije osobito ugrožene degradacijom staništa i onečišćenjem obalnog pojasa. Ova endemska alga naseljava sjeverne dijelove Jadrana, a njezino prisustvo smatra se pouzdanim pokazateljem čistoće mora i očuvanosti ekosustava (https://zastita-prirode.hr/zasticena-priroda/vrste-i-stanista/jadranski-bracic-smeda-alga-jadrana/).

Slika 12. *Fucus virsoides* J.Agardh (https://zastita-prirode.hr/zasticena-priroda/vrste-i-stanista/jadranski-bracic-smeda-alga-jadrana/)

Figure 12. *Fucus virsoides J.Agardh (https://zastita-prirode.hr/zasticena-priroda/vrste-i-stanista/jadranski-bracic-smeda-alga-jadrana/)*

Glavni uzroci ugroženosti morskih alga i cvjetnica

Ugroženost morskih alga i cvjetnica posljedica je direktnih i indirektnih čimbenika. Direktni utjecaji uključuju gradnju i nasipanje obale, dok indirektni obuhvaćaju prelov riba, što može uzrokovati prekomjerni razvoj ježinaca, te onečišćenja komunalnim i industrijskim otpadnim vodama (Prvan et al., 2016).

Posebnu prijetnju predstavljaju bakreni spojevi, poput modre galice, koji se unose ispiranjem s vinograda ili lokalnom primjenom u turističkim naseljima radi ubijanja ježinaca. Takve aktivnosti rezultirale su drastičnim ugibanjem algi i *Posidonia oceanica*, dok populacije ježinaca ostaju nepromijenjene (Prvan et al., 2016).

Fizička oštećenja nastaju i zbog pojačanog sidrenja plovila i povlačenja mreža po morskom dnu, osobito u livadama *P. oceanica* (slika 13.). Povijesno, dinamit se također koristio za ribolov, što je dovelo do dugotrajnih oštećenja livada čija regeneracija zahtijeva više od stotinu godina (Prvan et al., 2016). Klimatske promjene zasad nisu izravno povezane s nestankom vrsta, no primjerice endemska alga *Fucus virsoides* bila je sedamdesetih godina prošlog stoljeća široko rasprostranjena oko Splita, dok u posljednjih deset godina nije zabilježena (Prvan et al., 2016).

Odabir vrsta za Crveni popis morskih algi i cvjetnica Republike Hrvatske temelji se na znanstvenim i stručnim radovima, internim podacima Instituta za oceanografiju i ribarstvo te procjeni stručnjaka. Međutim, nepostojanje sustavnog kartiranja morske flore otežava preciznu procjenu ugroženosti. Primjena IUCN kriterija na alge dodatno je ograničena zbog teškoće određivanja bioloških karakteristika poput broja jedinki ili generacijskog vremena, što je posljedica njihove filogenetske raznolikosti (Prvan et al., 2016).

Slika 13. Uništavanje morskih cvjetnica sidrenjem u livadama (https://sunce-st.org/wp-content/uploads/2021/01/Prirucnik_za_zastitu_mora_Final_screen.compressed.pdf)

Figure 13. *Destruction of seagrasses by anchoring in meadows (https://sunce-st.org/wp-content/uploads/2021/01/Prirucnik_za_zastitu_mora_Final_screen.compressed.pdf)*

Gospodarske mogućnosti algi

U okviru promicanja održivog korištenja morskih resursa i očuvanja bioraznolikosti Jadranskog mora, tijekom posljednjeg desetljeća pokrenut je niz projekata usmjerenih na istraživanje i razvoj potencijala algi i morskih cvjetnica. Ovi projekti obuhvaćaju različite sektore, uključujući prehrambenu industriju, biotehnologiju, farmaceutsku proizvodnju te primjenu u ekološkim i energetskim rješenjima. Pregled odabranih projekata prikazan je u tablici 3.

Tablica 3. Prikaz projekata koji istražuju potencijal algi i morskih cvjetnica (prema: IRB, 2024; JU More i krš, 2024; https://native.24sata.hr/proveli-smo-dan-s-davidom-skokom-evo-stonam-je-otkrio/; Tomić Maksan et al., 2025)

Table 3. *Overview of projects exploring the potential of algae and seagrasses (according to: IRB, 2024; JU More i krš, 2024; https://native.24sata.hr/proveli-smo-dan-s-davidom-skokom-evo-stonam-je-otkrio/; Tomić Maksan et al., 2025)*

Jestive alge u Jadranu: kulinarski projekt Davida Skoke za popularizaciju konzumacije algi	**Makroalge kao hrana 21. stoljeća: istraživanje potrošača i tržišnog potencijala algi u Hrvatskoj**	**BRIGANTINE: autonomna plovila za praćenje stanje livada i očuvanje bioraznolikosti**	**BIOPRESS ADRIA: digitalna rješenja za sprječavanje štete od sidrenja i turizma**
Alge predstavljaju vrijedan, ali nedovoljno iskorišten resurs Jadrana. Kroz projekt kuhar David Skoko nastojao je približiti alge široj	U okviru znanstveno-stručnog skupa istraženo je tržišno prihvaćanje algi u Hrvatskoj. Pokazalo se da postoji interes za njihovu konzumaciju,	U okviru istraživanja, znanstvenici koriste autonomna plovila opremljena kamerama i senzorima za mapiranje podmorja, praćenje stanja algi i	Projekt BIOPRESS ADRIA usmjeren je na zaštitu morskih cvjetnica u Jadranu, s ciljem smanjenja negativnog utjecaja turizma i sidrenja

Jestive alge u Jadranu: kulinarski projekt Davida Skoke za popularizaciju konzumacije algi	**Makroalge kao hrana 21. stoljeća: istraživanje potrošača i tržišnog potencijala algi u Hrvatskoj**	**BRIGANTINE: autonomna plovila za praćenje stanje livada i očuvanje bioraznolikosti**	**BIOPRESS ADRIA: digitalna rješenja za sprječavanje štete od sidrenja i turizma**
javnosti i potrošačima, promovirajući njihovu konzumaciju u svakodnevnoj prehrani. Projekt je postigao značajan edukativni uspjeh, no komercijalna primjena zaustavljena je zbog nejasne zakonske regulative. Unatoč tome, neke vrste jadranskih algi odlikuju se posebnim nutritivnim svojstvima i specifičnim okusom, različitim od poznatih azijskih vrsta.	osobito među zdravstveno osviještenim potrošačima. Ključni čimbenici koji potiču konzumaciju uključuju podršku obitelji i liječnika, dostupnost algi u restoranima te brigu za osobno zdravlje. S druge strane, glavne prepreke širem prihvaćanju algi su visoka cijena proizvoda i zabrinutost zbog mogućeg prisustva toksina.	morskih cvjetnica te prikupljanje kemijskih podataka o kvaliteti morske vode. Dobiveni podaci omogućuju bolje razumijevanje ugroženih područja te razvoj učinkovitih mjera za zaštitu i očuvanje bioraznolikosti Jadranskog mora.	plovila. Kroz primjenu digitalnih rješenja i sustava praćenja stanja staništa, projekt omogućuje kontinuirano prikupljanje podataka o ekološkoj kvaliteti livada. Posebna pozornost posvećena je uključivanju lokalne zajednice u očuvanje i održivo upravljanje morskim resursima. Projekt se provodi u Hrvatskoj i Italiji, kombinirajući tehnologiju i edukaciju za zaštitu osjetljivih ekosustava.

Zaključak

Istraživanje je potvrdilo da su alge i morske cvjetnice ključni čimbenici ekološke stabilnosti Jadranskog mora te važni bioindikatori stanja okoliša. Unatoč visokoj bioraznolikosti, mnoge vrste suočene su s ugroženošću uzrokovanom antropogenim pritiscima, onečišćenjem, sidrenjem i širenjem invazivnih algi. Istovremeno, njihov potencijal u prehrani, biotehnologiji i ekološkim tehnologijama ostaje značajan, ali nedovoljno iskorišten. Za učinkovito očuvanje i održivo upravljanje ovim resursima nužno je unaprijediti monitoring, pojačati edukaciju i razviti jasne smjernice za gospodarsku primjenu algi i morskih cvjetnica.

Napomena

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Edukativno-prirodoslovni projekti udruge Futura u 2025

Educational-natural science projects of the Futura Association in 2025

Boris Dorbić[1]*

društvene vijesti i obavijesti (social news and announcements)

Projekt udruge Futura: „Poticanje šibenskih osnovnoškolaca za držanjem i uzgojem ukrasnih autohtonih i alohtonih ptica“, bio je fokusiran na predavanja za učenike 6 i 7 razreda osnovne škole (Osnovna škola Vrpolje i Osnovna škola Petar Krešimir IV). Za osnovnoškolce su održana dva predavanja iz predmetne problematike, u travnju i lipnju 2025. godine. Osim navedenog učenici su različitim likovnim tehnikama crtali njima najljepšu vrstu ptice te su ispunjavali anketne upitnike znanja i interesa o ukrasnim pticama. Na zadnjem satu je održana zakuska, nagradna lutrija za učenike i proglašenje najboljih crteža. Tijekom trajanja predavanja održana su tri fakultativna termina konzultacija za učenike i njihove nastavnike. Za učenike je organizirana mogućnost fakultativne posjete jednom od šibenskih uzgajivača ptica. Javnost je informirana o projektu. Projekt je financirao Grad Šibenik.

U sklopu projekta udruge Futura: „Baštinjenje ornitofilske i ornitokulturne tradicije Šibensko-kninske županije“, informirani su i intervjuirani stanovnici županije (ornitofili) o držanju i uzgoju ptica pjevica na području Šibensko-kninske županije te je analizirana stručna literatura. Izvršena je stručna posjeta međunarodnoj ornitološkoj izložbi SOR u Italiji (Modena, 22.11-23.11.2025.) te je javnost informirana o projektu. Projekt je financirala Šibensko-kninska županija.

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Upute autorima

Stručno znanstveni časopis Futura objavljuje znanstvene i stručne radove iz biotehničkih znanosti (poljoprivrede, šumarstva, drvne tehnologije, prehrambene tehnologije, nutricionizma, biotehnologije i interdisciplinarne biotehničke znanosti) kao i društvene vijesti, bibliografije, zatim prikaze knjiga i radova, popularne znanstvene radove, polemike i dr. Objavljuju se samo radovi koji nisu drugdje predani za objavljivanje, niti objavljeni. Znanstveni radovi se kategoriziraju: – izvorni znanstveni rad (original scientific paper) – pregledni znanstveni rad (scientific review) – prethodno priopćenje (preliminary communication) – konferencijsko priopćenje (conference paper) – rad prethodno prezentiran na konferenciji. Radove recenziraju dva ili više znanstvenika iz odgovarajućeg područja. Rad ne smije imati više od 17 tipkanih stranica, veličina slova 11, font Times New Roman, prored 1,5, margine 2,5. Izuzetno, uz odobrenje uredništva, neki interdisciplinarni ili uredništvu interesantni radovi mogu sadržavati do 25 ili više tipkanih stranica. Rukopisi se predaju u elektroničkom obliku na hrvatskom ili engleskom jeziku (e-mail: urednistvo@gazette-future.eu).

Izvorni znanstveni rad treba sadržavati: puna imena i prezimena autora s nazivima institucija, adresom i e-poštom u bilješkama – font 10, naslov, sažetak, abstract, uvod, materijale i metode, rezultate istraživanja, diskusiju, zaključak i literaturu – font 12 podebljano za naslove. Radovi napisani na engleskom jeziku se predaju bez naslova na hrvatskom jeziku i hrvatskog sažetka.

Naslov rada treba biti što kraći, na hrvatskom i engleskom jeziku. Kategoriju rada predlažu autori, a potvrđuju recenzenti i glavni urednik.

Sažetak treba sadržati opći prikaz, metodologiju, rezultate istraživanja i zaključak. Rad je potrebno pisati u trećem licu s min. 3 do 5 ključnih riječi. Obim sažetka ne bi smio biti veći od 250 riječi. Abstract je prijevod sažetka s ključnim riječima.

Uvod treba sadržavati što je do sada istraživano i što se željelo postići danim istraživanjem. Materijale i metode istraživanja treba ukratko izložiti. U rezultatima i diskusiji (raspravi) potrebno je voditi računa da se ne ponavlja iznijeto. U zaključcima je potrebno izložiti samo ono što pruža kratku i jasnu predstavu istraživanja. Literaturu treba poredati prema abecednom redu autora i to: prezime i početno slovo imena autora ili Anonymous (nepoznat autor), godina izdanja u zagradama, naslov knjige ili članka, naziv časopisa te broj ili godište, kao i mjesto izdavanja i oznaku stranica od–do. Više od deset autora se u literaturi navodi kao npr. Prezime et al. (2018). Fusnote u radu treba izbjegavati ili eventualno koristiti za neka pojašnjenja. Autori se u tekstu citiraju sukladno APA standardu npr. (Prezime, 2018); (Prezime1 i Prezime2, 2016); (Prezime et al., 2018) (više od dva autora). Citate prate navodnici („n“) i stranica preuzimanja citiranog teksta (Prezime, 2018, str. 44).

Tablice se numeriraju i navode iznad na hrvatskom i u kurzivu na engleskom jeziku.

Slike se numeriraju i navode ispod na hrvatskom i u kurzivu na engleskom jeziku.

Rezolucija slika (grafikon, fotografija, crtež, ilustracija, karta) treba iznositi najmanje 300 dpi.

Fotografija: prodaja voća i povrća, 2025.

Autor: Boris Dorbić.