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NUTRITION

ASSESSMENT OF CAFFEINE INTAKE AMONG ADULTS IN THE SARAJEVO CANTON

Azra Hodžić[1*], Nihada Ahmetović[2], Sejad Mačkić[3], Amra Čolić[4], Mara Mustapić[5]

[1]Victoria International University, Faculty of Health Studies, Zalik bb, 88 000 Mostar, Bosnia and Herzegovina
[2]University of Tuzla, Faculty of Medicine, Univerzitetska 1, 75 000 Tuzla, Bosnia and Herzegovina
[3]American Northwest University of Health Science and Technology, Faculty of Health Sciences, Seada Sofovića Sofe, 73 000 Goražde, Bosnia and Herzegovina
[4]Healthcare Center Bugojno, Department of Hygiene and Epidemiology, Wagnerova 15, 70 230 Bugojno, Bosnia and Herzegovina
[5]State Inspectorate of the Republic of Croatia, Sanitary Inspection Sector, Makarska Branch, Trg Tina Ujevića 1, 21 300 Makarska, Croatia
[*]azrah_sa@yahoo.com

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ABSTRACT

Caffeine is the most widespread psychoactive substance in the world which is found in various foods and drinks, including coffee, tea, soft drinks, energy drinks, products containing cocoa or chocolate, as well as some medications and supplements. This paper aimed to assess dietary caffeine intake in relation to the dose considered by the EFSA as safe for adults in the general healthy population, and to identify the main sources to caffeine intake among adult population in the Sarajevo Canton.
The assessment of caffeine intake in the studied population (n=693, man 153 and woman 540 aged from 18 to 65 years) was carried out through a semi-quantitative questionnaire conducted in the Sarajevo Canton from September to December 2020. Average daily caffeine intake (mg/day and mg/kg of body weight) was calculated based on data on consumption of certain categories of foods and drinks and mean concentrations of caffeine for individual categories. Student's t-test was used to compare the means of daily caffeine intake between genders.
Average daily caffeine intake in the adults was 194.76 mg/day (2.75 mg/kg bw). Dietary sources contributing to total daily caffeine intake came from coffee (52 %), tea (8 %), chocolate (3 %), cocoa and chocolate drinks (14 %), soft drinks (6 %) and sports and energy drinks (17 %). Average daily intake of caffeine in men (232.05 mg/day) was statistically significantly higher than the average daily intake of caffeine in women (179.04 mg/day). Exposure to caffeine among adults was below caffeine intake recommendations by EFSA (400 mg/day) and did not pose a health risk.

Keywords: caffeine, adult population, health risk, safety dose

INTRODUCTION

Caffeine is the most widespread psychoactive substance found in various foods and drinks, including coffee, tea, soft drinks, energy drinks, products containing cocoa or chocolate, as well as some medications and supplements (Temple et al., 2017), and it is one of the most extensively studied dietary ingredient widely consumed in the world (Heckman et al., 2010). Consumption of caffeine is associated with both positive and negative effects on the human body, and its activity concerns a variety of systems including the central nervous system, immune system, digestive system, respiratory system, urinary tract, etc. (Rodak et al., 2021). Benefits attributed to caffeine include improving mood and alertness (Lorist and Tops, 2003), exercise performance (Doherty and Smith, 2004), awareness and attention (Cysneiros et al., 2007). Several studies have shown that the consumption of moderate amounts of caffeine has a protective effect against cancer (Arab, 2010), diabetes mellitus type 2 (Muley et al., 2012), inflammatory diseases (Paiva et al., 2019), Parkinson's and related neurodegenerative diseases (Ross et al., 2000), cardiovascular diseases (Bidel and Tuomilehto, 2013; Mineharu et al., 2011), and stroke (Kim et al., 2012; Larsson and Orsini, 2011). Also, it has been shown that moderate usual intake of caffeine, through coffee and tea, can have protective effect against development of dementia and Alzheimer's disease (Eskelinen and Kivipelto, 2010), and metabolic syndrome (Kim et al., 2016). Mild adverse effects of caffeine include anxiety, restlessness, fidgeting, insomnia, facial flushing, increased urination, irritability, muscle twitches or tremors, agitation, tachycardia or irregular heart rate, and gastrointestinal irritation. Severe adverse effects may include disorientation, hallucinations, psychosis, seizures, arrhythmias and ischemia (Evans et al., 2024). The European Food Safety Authority (EFSA) concluded that single doses of caffeine up to 200 mg (about 3 mg/kg bw for a 70-kg adult) do not give rise to safety concerns for the general healthy adult population (equivalent to approximately 2 ½ espressos or 4 cups of tea). Habitual caffeine intakes from all sources up to 400 mg per day (about 5.7 mg/kg bw per day for a 70-kg adult) consumed throughout the day do not give rise to safety concerns for healthy adults in the general population (EFSA, 2015). The aim of this study were 1) to assess caffeine intake in relation to the dose considered by the EFSA as safe for adults in the general healthy population, and 2) to identify the main sources to caffeine intake among adult population in the Sarajevo Canton.

MATERIALS AND METHODS

A dietary survey was conducted to assess caffeine intake from a wide range of foods and drinks containing caffeine among adults in the Sarajevo Canton from September to December 2020. The sample consisted of 693 respondents, of which 153 men and 540 women aged from 18 to 65 years. Participation in the survey was voluntary. Subjects were randomly selected through certain populations such as students and employees by face-to-face recruitment. Seeking participants for enrolment in research was conducted in public space. The participants are consecutively selected in order of appearance according to their convenient accessibility. An adapted semi-quantitative food frequency questionnaire (FFQ) was used in this survey. The FFQ included detailed questions about the consumed types of foods and drinks containing caffeine

(categories and subcategories), and questions about the amount and frequency of consumption during the last 12 months, as well as information about the respondent's body weight. The following categories and subcategories of foods and drinks containing caffeine were covered: coffee, regular coffee brewed, coffee instant (powder or granules), special coffee with additional ingredients (e.g. latte, mocha, cappuccino), special coffee espresso, ready to drink coffee (bottled or canned); tea, black tea, green tea, ice tea; chocolate, milk chocolate, dark chocolate, chocolate bar, chocolate snacks; cocoa and chocolate drinks, chocolate milk, cocoa drink based on cocoa powder, cocoa drink based on powder for preparing cocoa drinks; soft drinks with caffeine and sports and energy drinks with caffeine.

Data on the frequency and amount of consumption caffeine containing products were used to estimate the average daily caffeine intake, based on the mean caffeine concentrations and average body weight of respondents, as well as to estimate the share of different types of foods and drinks in the total daily caffeine intake. In order to calculate dietary intake of caffeine, data on caffeine concentrations in foods and drinks were used from a Scientific Opinion on the safety of caffeine reported by EFSA 2015. The intake of caffeine from certain categories of foods and drinks was calculated based on data on their consumption and mean concentrations of caffeine for individual types of foods and drinks according to EFSA, except for energy drinks for which the caffeine concentration of the corresponding brand was selected from the product declaration.

Average daily caffeine intake was shown as the amount of caffeine consumed per day (mg/day), which is the most common form for expressing daily intake, and also as the amount of caffeine per kilogram of body weight (mg/kg bw) using the self-reported body weight data collected during the survey. The share of individual categories of foods and drinks in the total daily intake of caffeine, expressed in %, was calculated from the data collected in the FFQ. Student's t-test was used to compare the means of daily caffeine intake between population groups of men and women.

The probability of an adverse health effects was estimated based on the relationship between the determined average daily intake and the recommended safety doses of caffeine intake defined by EFSA. Habitual daily intake of caffeine from all sources up to 400 mg per day (about 5.7 mg/kg bw per day for a 70-kg adult) and single dose of caffeine intake up to 200 mg (about 3 mg/kg bw for a 70-kg adult) do not give rise to safety concerns for the general healthy adult population.

RESULTS

Daily intake of caffeine

Total daily intake of caffeine in the general population of adults ranged from 0.08-951.4 mg/day, with an average of 194.76 mg/day. Daily intake of caffeine expressed per kg of body weight ranged from 0.001-15.86 mg/kg bw, average 2.75 mg/kg bw. The average body weight of the respondents used to calculate the daily intake of caffeine per kg of body weight was 71.73 kg. Table 1 shows daily intake of caffeine from different types of foods and drinks.

Table 1. Daily intake of caffeine in the adult population

Category	Daily intake (mg/day)			Daily intake (mg/kg bw)		
	Min.	Max.	Average	Min.	Max.	Average
Coffee	0.55	951.40	101.35	0.01	15.86	1.44
Tea	0.30	296.56	15.73	0.003	5.30	0.22
Chocolate	0.08	69.83	5.15	0.001	0.91	0.07
Cocoa and chocolate drinks	0.84	300.72	26.74	0.02	4.49	0.38
Soft drinks	0.54	80.0	12.35	0.01	1.33	0.17
Sports and energy drinks	1.34	320.0	33.44	0.02	4.71	0.47
Total			194.76			2.75

Dietary sources of caffeine

Dietary sources that participate in the total daily intake of caffeine in the population od adults come from the categories of coffee (101.35 mg/day), tea (15.73 mg/day), chocolate (5.15 mg/day), cocoa and chocolate drinks (26.74 mg/day), soft drinks (12.35 mg/day) and sports and energy drinks (33.44 mg/day). The share of certain types of foods and drinks in the total daily intake of caffeine is shown in Figure 1.

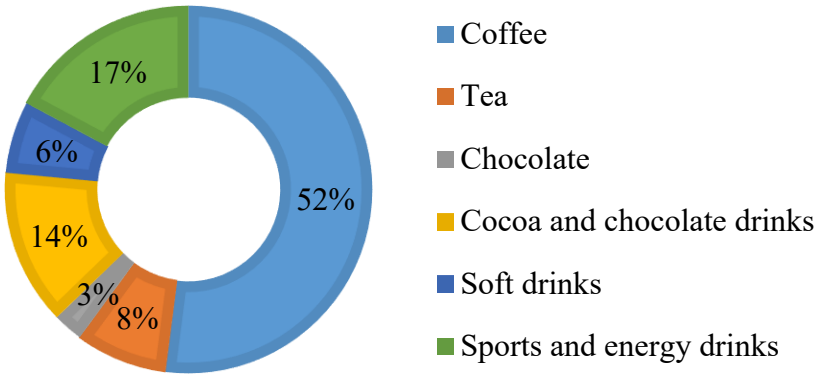

Figure 1. Dietary sources of caffeine in the adult population

Daily intake of caffeine (men and woman)

Total daily intake of caffeine in the male population ranged from 0.11-804.0 mg/day, with an average of 232.05 mg/day. Total daily intake of caffeine in the female population ranged from 0.08-951.4 mg/day, an average of 179.04 mg/day. Daily caffeine intake in men is statistically significantly higher than the daily caffeine intake in women ($t=4.03$; $p<0.0001$). Table 2 shows daily intake of caffeine mg/day from different types of foods and drinks in the population of men and woman.

Table 2. Daily caffeine intake mg/day in the population of men and women

Category	Daily intake - Men			Daily intake - Women		
	Min.	Max.	**Average**	**Min.**	**Max.**	**Average**
Coffee	2.27	804.0	122.5	0.55	951.4	95.38
Tea	0.76	151.0	17.46	0.30	296.56	15.42
Chocolate	0.11	52.5	6.58	0.08	69.83	4.80
Cocoa and chocolate drinks	0.84	179.76	25.74	0.84	300.72	27.01
Soft drinks	0.90	108.0	18.86	0.54	81.0	9.59
Sports and energy drinks	2.67	320.0	40.91	1.34	320.0	26.84
Total			232.05			179.04

Daily intake of caffeine expressed per kg of body weight in men ranged from 0.002-8.46 mg/kg bw, with an average of 2.67 mg/kg bw. Daily intake of caffeine expressed per kg of body weight in women ranged from 0.001-15.86 mg/kg bw, an average of 2.70 mg/kg bw. Table 3 shows daily intake of caffeine mg/kg bw from different types of foods and drinks in the population of men and women.

Table 3. Daily caffeine intake mg/kg bw in the population of men and women

Category	Daily intake - Men			Daily intake - Woman		
	Min.	**Max.**	**Average**	**Min.**	**Max.**	**Average**
Coffee	0.01	8.46	1.44	0.01	15.86	1.44
Tea	0.01	1.78	0.19	0.003	5.30	0.23
Chocolate	0.002	0.60	0.07	0.001	0.91	0.11
Cocoa and chocolate drinks	0.01	2.37	0.30	0.01	4.48	0.43
Soft drinks	0.009	0.90	0.21	0.007	1.32	0.14
Sports and energy drinks	0.03	3.76	0.46	0.017	4.70	0.35
Total			**2.67**			**2.70**

Dietary sources of caffeine (men and woman)

Dietary sources contributing to men's total daily caffeine intake come from the categories of coffee (122.5 mg/day), tea (17.46 mg/day), chocolate (6.58 mg/day), cocoa and chocolate drinks (25.74 mg/day), soft drinks (18.86 mg/day), and sports and energy drinks (40.91 mg/day). The contribution of individual types of foods and drinks to men's total daily caffeine intake is shown in Figure 2.

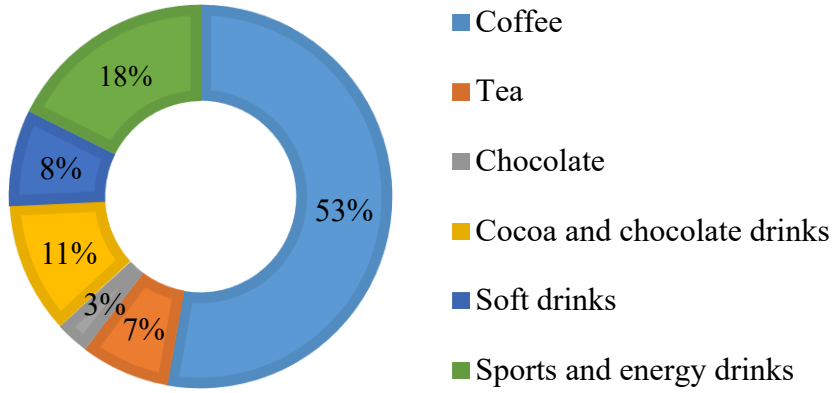

Figure 2. Dietary sources of caffeine in the male population

Dietary sources contributing to women's total daily caffeine intake come from the categories of coffee (95.38 mg/day), tea (15.42 mg/day), chocolate (4.80 mg/day), cocoa and chocolate drinks (27.01 mg/day), soft drinks (9.59 mg/day), and sports and energy drinks (26.84 mg/day). The contribution of individual types of foods and drinks to women's total daily caffeine intake is shown in Figure 3.

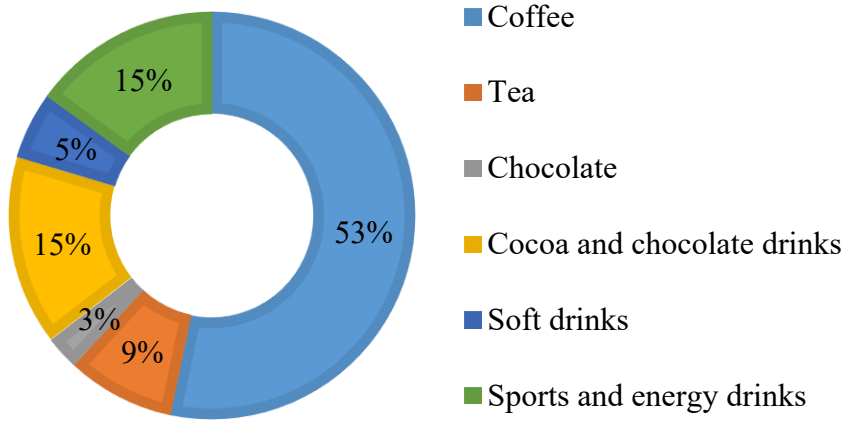

Figure 3. Dietary sources of caffeine in the female population

Single daily intake of caffeine

In the male population 5 (3.27 %) respondents of total 153 consumed a single daily dose of caffeine above 200 mg. High intake was recorded in the categories of coffee and sports and energy drinks, where high single intake of caffeine through these categories ranged from 201.0-320.0 mg/day. In the female population 14 (2.59 %) respondents of total 540 consumed a single daily dose of caffeine above 200 mg. High intake was recorded in the coffee category, where high single intake of caffeine through this category ranged from 201.0-335.0 mg/day (Table 4).

Table 4. Exceeding the recommended single daily intake of caffeine

Population group	Single daily intake of caffeine (mg/day)	Number of respondents
Men (18-65 years old)	201.0 – 320.0	5/153
Women (18-65 years old)	201.0 – 335.0	14/540

DISCUSSION

Daily intake of caffeine

Caffeine consumption varies worldwide. In the EU countries the minimum and maximum total daily caffeine intake ranged from 36.5 to 319.4 mg/day (0.5-4.3 mg/kg bw) for the adult population (EFSA, 2015). In this study, the average daily caffeine intake in the adult population in the Sarajevo Canton is in line with similar studies worldwide (Rochat et al., 2020., Frary et al., 2005, Finnegan, 2003). The average daily caffeine consumption per person in Switzerland was 191 mg/day. Differences in average caffeine consumption were observed in the age groups, 18-34 years 140 mg/day and 50-64 years 228 mg/day (Rochat et al., 2020). Caffeine consumption in the Republic of Ireland was 3.05 mg/kg bw/day, corresponding to 214 mg/day for a 70 kg person (Finnegan, 2003). The average caffeine consumption in adults in the UK is 138 mg/day. The Nordic countries are the highest consumers of caffeine. Caffeine intake in Denmark, Finland and Sweden is 320, 236 and 205 mg/day for adults (EFSA, 2015). The majority of New Zealanders consumed products containing caffeine where caffeine consumers vary from 73 to 96 % across age groups. The average intake was estimated to be 236 mg/day, or 3.5 mg/kg bw/day for adults aged 20-64 (Thomson and Schiess, 2010). In the USA according to Frary et al. the average caffeine intake of a representative sample of the American population is 193 mg of caffeine per day (Frary et al., 2005).

The results of this study showed that the average daily caffeine intake in men was higher than women, which have been reported by a number of authors (Lugasi et al., 2015, Fulgoni et al., 2015, Fitt et al., 2013, Rotstein et al., 2013). Dietary caffeine intake in the Hungarian population was estimated based on data from the National Nutritional Survey from 2009. Daily caffeine intake in adults aged 34 to 64 was 147 ± 6.2 mg in men and 138 ± 4.2 mg in women (Lugasi et al., 2015). Average caffeine intake in the UK study was higher in men than women and increased with age, men and women 19-64 years 130 mg/day and 122 mg/day. About 4.1 % of men and 3.8 % of women over 19 years had a caffeine intake of more than 300 mg/day (Fitt et al., 2013). The mean daily caffeine intake among adults in Saudi Arabia was 131 ± 1.4 mg/day (145 ± 2.3 mg/day for males, 120 ± 1.8 mg/day for females) (Almutairi et al., 2025). In Canada it was estimated that adult men and women have an average intake of 281 and 230 mg of caffeine per day. With a body weight of 80 and 65 kg, the intake is equal to a daily dose of 3.5 mg/kg bw and 3.1 mg/kg bw, respectively (Rotstein et al., 2013). About 89 % of US adults aged 19 years and older consumed caffeine from

2001 to 2010. The usual daily caffeine intake for consumers was 211 ± 3 mg/day, with 240 ± 4 mg/day in men and 183 ± 3 mg/day in women. Consumption was highest among men aged 31 to 50 (236 mg/day), and lowest among women aged 19 to 30 (152 mg/day) (Fulgoni et al., 2015). Similarly, the results of research by Mitchell et al. showed that 85 % of the American population consumed at least one caffeinated beverage per day. The average daily intake of caffeine from all beverages was 165 ± 1 mg for all age groups. Caffeine intake was highest among consumers aged 50 to 64 (226 ± 2 mg/day) (Mitchell et al., 2014). The National Health and Nutrition Examination Surveys (NHANES) in the USA were used to estimate caffeine intake. The NHANES reported data among all subjects showed total daily caffeine intake remained stable from 2001-2002 (142.1 mg/day) to 2003-2004 (150.8 mg), and 2005-2006 (149.8 mg/day) (Somogyi, 2010). Another NHANES survey from 2007-2012 found that caffeine consumption among adults in the USA averaged 169 mg/day. Middle-aged people (aged 50 to 54) consumed more caffeine (211 ± 6 mg/day) than younger people (107 ± 4 mg/day, aged 20 to 24) (Lieberman et al., 2019). NHANES reported in 2011-2012 the average population consumed 135 mg/day, with coffee accounting for the largest share (90 mg/day), tea (25 mg/day), and soft drinks (21 mg/day). Adults aged 51-70 years consumed the most caffeine (213 mg/day) (Drewnowski and Rehm, 2016).

The average daily intake of caffeine above 400 mg/day, which could pose a risk to human health, was not recorded in this study. Other studies around the world have reported exceeding the recommended daily intake (Derbyshire and Abdula, 2008, Yamada et al., 2010, Wierzejska, 2012, Malczyk et al., 2021, Wierzbicka and Momot, 2022). Average caffeine intake in Japan was 256 ± 2 mg/day for women and 268 ± 3 mg/day for men. The main contribution to the total daily intake was made by Japanese and Chinese teas and coffee (47 % each). Caffeine intake above 400 mg/day, which is assumed to have negative health effects, was observed in 11 % of women and 15 % of men (Yamada et al., 2010). According to research in Poland in the Warsaw region daily intake of caffeine in women was 251 mg, and about 15 % of the examined women consumed an excessive amount of caffeine (≥ 400 mg) (Wierzejska, 2012). Another study in Poland among females and males found approximately 20 % of respondents exceeded the threshold of daily caffeine intake considered safe (Malczyk et al., 2021). The average caffeine intake by women of reproductive age in the UK study was 173.95 mg per day. About 18 % of respondents exceeded the recommended doses of caffeine intake and consumed 300 mg or more of caffeine on average per day (Derbyshire and Abdula, 2008). According to the study by Hammami et al. on caffeine consumption among adults in the United Arab Emirates, the average daily caffeine intake was 316.7 mg, close to the recommended daily intake of 400 mg/day. More than 98.5 % of study participants were caffeine consumers, and 31 % reported being addicted to caffeine (Hammami et al., 2018).

A small rate of exceeding the single daily caffeine intake was observed in this study. Other studies by Mitchell et al., 2014 and Fulgoni et al., 2015 also reported single caffeine intake exceeding. The acute single intake of caffeine in USA was 380 mg/day for all age groups combined (Mitchell et al., 2014), and another similar study reported acute intakes ranged from 436 to 1066 mg/day (Fulgoni et al., 2015). Authors Wierzejska and Gielecińska evaluated the caffeine content in servings of popular

coffees in Poland and found that 4 % of coffee samples had over 200 mg of caffeine per serving. Authors concluded that recommendations on drinking coffee should indicate the "strength" of various types of coffee, in order to avoid the regular intake of high amounts of caffeine (Wierzejska and Gielecińska, 2024).

Dietary sources of caffeine

Obtained results regarding dietary sources of caffeine and the contribution of individual foods and drinks to total caffeine intake showed that coffee was the most important source of caffeine among adults. Other contributors to daily caffeine intake after coffee were cocoa drinks, energy drinks, tea and soft drinks. The main sources of caffeine in the Hungarian population aged 34-64 years were coffee and tea, which accounted for 58-59 % and 35-37 % of total dietary caffeine intake, respectively. A lower intake rate of cola drinks was found (5 % and 2 % for men and women), while sweets, chocolate, cocoa drinks and cakes had a very low caffeine intake rate, less than 1 % (Lugasi et al., 2015). In Switzerland the three main sources of caffeine intake were coffee (83 % of total caffeine intake), tea (9 %) and soft drinks (4 %) (Rochat et al., 2020). In Germany Lachenmeier et al. assesed caffeine intake and found that coffee and tea contributed the most to the total caffeine intake in adults (Lachenmeier et al., 2013). Results from a study in Poland of young women aged 18-30 showed that the average daily caffeine intake from all sources was 232 mg/day or 2.88 mg/kg bw/day. In about 19 % of women, the daily intake was high (≥ 400 mg), and in half of the women (about 51 %) it was moderate (200-400 mg). The main dietary sources of caffeine were coffee (39 %) and tea (34 %), and a smaller share included energy drinks and soft drinks (12 % and 9 %, respectively) (Wierzbicka and Momot, 2022). A study in UK assessed caffeine intake via tea and found that daily caffeine intake ranged between 92 and 146 mg/day via tea (Khokhar and Magnusdottir, 2002). National Diet Survey of New Zealand Adults 2008-2009 reported that coffee (47 %) and tea (32 %) contributed the most to daily caffeine intake. Soft drinks (7 %), chocolate (4 %), chocolate drinks (1 %) and energy drinks (3 %) contributed less to total daily caffeine intake (Verster and Koenig, 2018).
According to research in Argentina by Olmos et al. average caffeine intake in adults was 288 mg per day, with yerba mate tea contributing the most to that intake. Drinking yerba mate tea is deeply rooted among the Argentine population and this is the possible reason for their largest share in the total daily intake of caffeine (Olmos et al., 2009). Data from the Korea National Health and Nutrition Examination Survey (KNHNES) conducted in the period 2010-2012 were used to calculate daily caffeine intake. The main sources of caffeine intake were coffee (89 %), followed by tea and carbonated soft drinks (Lim et al., 2015). Frary et al. reported in the USA the main sources of caffeine were coffee (71 %), soft drinks (16 %) and tea (12 %) (Frary et al., 2005). An earlier study (Knight et al., 2004) revealed a daily caffeine intake from beverages ranging from 106 to 170 mg/day for adults and coffee was the primary source of caffeine intake in adults. Similarly, Mitchell et al. reported that coffee was the primary source of caffeine in the US population (64 %), followed by carbonated soft drinks (17 %) and tea (17 %). Energy drinks contributed less than 2 % to total caffeine intake (Mitchell et al., 2014). Beverages provided 98 % of the caffeine

consumed, and coffee (64 %), tea (16 %) and soft drinks (18 %) were predominant, while energy drinks accounted for less than 1 % of intake (Fulgoni et al., 2015). The NHANES study in the USA showed that coffee (55.8 %) was the main source of caffeine, followed by tea (16.9 %) and carbonated soft drinks (16.1 %) (Somogyi, 2010).

According to the EFSA Comprehensive European Food Consumption Database, which combines data from 39 surveys in 22 European countries with a total of 66,531 participants, it was found that there are large differences between countries in terms of the contribution of different dietary sources to total caffeine intake. In European adults, coffee is the most important source of caffeine, accounting for 40-94 % of daily caffeine intake. In Ireland (59 %) and UK (57 %) tea is the main source of caffeine intake. The contribution of coffee to the total caffeine intake in Denmark, Finland and Sweden is 88 %, 94 % and 85 %, respectively. Soft drinks and chocolate drinks are negligible sources of caffeine in adults. The contribution of energy drinks to total daily caffeine intake was negligible across the EU, with the highest values in the UK (11 %), the Netherlands (8.1 %) and Belgium (5.3 %) (EFSA, 2015).

CONCLUSION

The average caffeine intake in adults is below caffeine intake recommendations by EFSA (400 mg/day), suggesting no immediate health concerns. However, determined exceeding of single daily intake above 200 mg/day represents a safety concerns to the health of those consumers. Coffee, cocoa drinks and energy drinks are the key contributors to daily caffeine intake. Tea and soft drinks contribute little caffeine to total daily intake. Further research is needed to assess the total intake of caffeine that would include all population groups. Public health initiatives should focus on educating specific population groups about the safe limits of caffeine consumption and increasing social awareness of the effects of caffeine consumption. It is important to monitor information for consumers related to caffeine content in different products, in order to control high caffeine intake, especially among vulnerable population groups.

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PROCESSED FOOD INTAKE PATTERNS IN PATIENTS WITH CHRONIC OBSTRUCTIVE PULMONARY DISEASE ACROSS FOUR SEVERITY STAGES

Alda Ranogajec[1,2], Ana Ilić[2*], Antonija Karić[2], Snježana Benko Meštrović[3,4], Ivana Rumbak[2]

[1]Special Hospital for Pulmonary Diseases, Rockefellerova 3, 10 000 Zagreb, Croatia
[2]University of Zagreb, Faculty of Food Technology and Biotechnology, Department of Food Quality Control, Pierottijeva 6, 10 000 Zagreb, Croatia
[3]University of North, Physiotherapy Department, Jurja Križanića 31b, 42 000 Varaždin, Croatia
[4]Clinical Hospital "Sveti Duh", Sveti Duh 64, 10 000 Zagreb, Croatia
[*]ana.ilic@pbf.unizg.hr

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ABSTRACT

As the majority of patients with chronic obstructive pulmonary disease (COPD) have compromised nutritional status, recent studies have focused on observing possible dietary patterns that may reduce the risk of disease. The aim of this study is to observe the consumption of differently processed food according to the Siga classification in COPD patients at different stages of the disease and to determine whether consumption is related to the pulmonary function. Food consumption was observed in 71 patients (66.5 ± 8.4 years; 53.5% men) who were divided into four groups according to disease severity (GOLD stages). All foods consumed were classified according to the Siga classification from three 24-hour recalls collected during pulmonary rehabilitation (September 2023 to May 2024; Special Hospital for Pulmonary Diseases, Zagreb). The assessment of respiratory function was performed following standard protocols. Daily energy intake was similar across the GOLD stage groups, with a median value of 1484 (1265–1742) kcal for the total study population. The results show that patients with GOLD I and GOLD II had a higher proportion of daily energy intake from the un/minimally processed food and culinary ingredients (56.1% *vs.* 61.8% *vs.* 47.3% *vs.* 49.5%, p=0.022) Siga group compared to the GOLD III and GOLD IV patients. In contrast, the patients with GOLD I and GOLD II had a lower proportion of daily energy intake from the ultra-processed foods (14.5% *vs.* 11.4% *vs*. 25.8% *vs.* 18.2%, p=0.016) Siga group. There is a positive association between the consumption of unprocessed foods and FEV1 (r=0.271; p=0.022), nutritionally balanced processed foods and FVC (r=0.314; p=0.008), while a negative association was found between the FEV1/FVC ratio and the consumption of ultra-processed foods (r=-0.251; p=0.031). The results highlight the need to consider the degree of food processing when assessing dietary intake in COPD patients.

Keywords: COPD, FVC, FEV_1, processed food, SIGA classification

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a systemic non-communicable disease that encompasses a group of pulmonary dysfunctions, including chronic bronchitis, emphysema and airway obstruction (Celli et al., 2022; GOLD, 2025). It is considered one of the leading causes of death worldwide, with smoking being the main risk factor for its development, although environmental factors such as occupational exposures, respiratory infections and genetic predisposition also play an important role (Safiri et al., 2022; Wang et al., 2025). Diagnosis and monitoring are based on spirometry parameters according to the GOLD guidelines, which categorize patients according to the severity of symptoms and the risk of exacerbations (GOLD, 2025). As the disease progresses, numerous comorbidities often occur as cardiovascular diseases, metabolic disorders, malnutrition and musculoskeletal complications which further worsen the patient's quality of life (May et al., 2015; Anandan et al., 2023; Zhou et al., 2023).

Although COPD is an irreversible disease, lifestyle changes can influence the progression of the disease and reduce symptoms of the disease (Rochester et al., 2015). Diet is one of the lifestyle factors that can play a role in the quality of life in patients with COPD (Fekete et al., 2023). Therefore, increasing attention is being paid to the role of dietary patterns and the consumption of specific food groups in these patients (Scoditti et al., 2019). Dietary patterns such as the Mediterranean diet and the DASH diet or generally high-quality diets reflected by high Healthy Eating Index score have been associated with better pulmonary function (Root et al., 2014; Varraso et al., 2015; Ardestani et al., 2017). However, dietary patterns similar to a Western diet have been observed in patients with COPD, characterized by a low intake of fruits and vegetables and regular consumption of meat, processed foods and foods high in added sugar, fat and salt. According to the available literature, these dietary patterns correlate with a worsening disease symptom (Heefner et al., 2024; Sorli-Aguilar et al., 2016; Brigham et al., 2018). Of particular interest is the consumption of ultra-processed foods, the negative effects of which include an increased risk of developing diseases such as cardiovascular disease, obesity, metabolic diseases and other non-communicable chronic diseases, including respiratory diseases (Srour et al., 2019; Elizabeth et al., 2020; Costa de Miranda et al., 2021; Mekonnen et al., 2025). Furthermore, there are only a few studies that have investigated risk or mortality in patients with COPD related to the ultra-processed food consumption with inconsistent results (He et al., 2023; Mekonnen et al., 2024; Salehi et al., 2024). These differences may be due to the fact that different methods are used to collect data on food and beverage intake, but also to the classification of processed food intake, for which there is no defined consensus (Marino et al., 2021; Sadler et al., 2021). Of the several classification models, Siga is one of the most recent. It is based on the NOVA food classification, but further distinguishes between nutritionally balanced and unbalanced foods as well as foods with at-risk additives in the groups of processed foods (Davidou et al., 2020).

Therefore, the aim of this study is to observe the consumption of food according to the Siga classification in COPD patients at different stages of the disease and to determine whether consumption is related to the pulmonary function.

MATERIALS AND METHODS

Participants and settings

For the present cross-sectional study, participants were recruited during pulmonary rehabilitation from September 2023 to May 2024 at the Special Hospital for Pulmonary Diseases in the city of Zagreb. The inclusion criteria were diagnosed COPD, while exclusion criteria were the use of systemic corticosteroids (< six months), the presence of a pacemaker or other electrical devices, neuromuscular disorders or damage to the phrenic nerve, a history of stroke resulting in residual hemiparesis, lung surgery, and autoimmune, neurological or other systemic diseases that could affect respiratory function. After applying exclusion criteria and collecting the necessary data, 71 (66.9%) of 106 eligible patients were included in the present study. General information about the patients was collected through interviews or the Hospital Information System software (IN2 Ltd., Zagreb, Croatia).
The study was conducted in accordance with the principles of the Declaration of Helsinki, and all research protocols were approved by the Ethics Committee of the School of Medicine, University of Zagreb (reference number: 251-59-10106-23-111/203, class: 641-01/23-02/01). Before participating in the study, each patient was informed about the study procedure and they gave their written consent.

Spirometry and GOLD classification

Spirometry was performed on each patient using a Medisoft HypAir PFT system (Medisoft, Sorrines, Belgium) to assess pulmonary function. Spirometry was performed in a seated position, with expiratory flow measured by the patient inhaling as deeply as possible and exhaling forcefully and completely as quickly as possible into a device that recorded forced expiratory volume in the first second (FEV1) and forced vital capacity (FVC). The recorded value was the highest of the three repeated measurements (Moore, 2012).
According to the recommendations of the Global Initiative for Chronic Obstructive Lung Disease (GOLD, 2025), patients were categorized into one of four disease stages: GOLD 1 – mild (FEV1 ≥ 80% predicted); GOLD 2 – moderate (50% ≤ FEV1 < 80% predicted); GOLD 3 – severe (30% ≤ FEV1 < 50% predicted); GOLD 4 – very severe (FEV1 < 30% predicted) (GOLD, 2025).

Dietary assessment

All food and beverages consumed were recorded using 24-hour recalls on three non-consecutive days. The first recall was collected during pulmonary rehabilitation, the others by telephone interview using a 5-step multipass protocol. Portions were described using kitchen utensils and food packaging. In addition, the recipes of the mixed dishes and the name of the brand of packaged food were recorded. To estimate energy intake, all data were processed using Prehrana software (version 1.0; Infosistem Plc., Zagreb, Croatia), which is based on national composition tables (Kaić-Rak and Antonić, 1990) and supplemented with the nutritional information of the packaged foods.

Siga classification

To estimate the consumption of ultra-processed foods, all foods and beverages were classified according to the Siga classification (Davidou et al., 2020). The Siga classification is based on the NOVA classification of food groups (Monteiro et al., 2019) with subgroups differentiated by nutritional value and level of at-risk additives. The proposed limits for nutritionally balanced processed and ultra-processed foods per 100 g of solid food were 1.5 g of salt, 12.5 g of sugar and 17.5 g of fat, while per 100 g of beverages were 0.75 g of salt, 6.25 g of sugar and 8.75 g of fat. The foods and drinks consumed were therefore divided into three groups and eight subgroups: (1) Un/minimally processed foods, including unprocessed foods (A0), minimally processed foods (A1) and culinary ingredients (A2); (2) Processed foods, including nutritionally balanced processed foods (B1) and processed foods high in salt, sugar and/or fat (B2); (3) Ultra-processed foods, including nutritionally balanced ultra-processed foods (C0.1) and ultra-processed foods high in salt, sugar and/or fat (C0.2) and ultra-processed foods (C1) (Davidou et al, 2020). The consumption of processed foods was observed as the contribution of each group and subgroup to daily energy intake.

Statistical analysis

For the statistical analysis, patients were divided into four GOLD groups reflecting the severity of the disease. All categorical variables were presented as frequencies or percentages. Daily energy intake and the contribution of each group and subgroup to daily energy intake were expressed as median and interquartile range, as they were skewed according to the Shapiro-Wilk test. The differences between the GOLD groups were tested using the Kruskal-Wallis test with post hoc Dunnett's test. Spearman correlation was performed on the total study sample to observe the association between consumption of foods with different levels of processing and pulmonary function. All tests were performed using IBM SPSS software (IBM SPSS Statistics for Windows, version 23.0. Armonk, NY, USA: IBM Corp.) with a significance level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

This study presents observations on processed food consumption in COPD patients, which has been rarely researched in the literature to date (He et al., 2023; Mekonnen et al., 2024; Salehi et al., 2024), especially not in relation to disease severity.
The total sample consisted of 71 patients with COPD aged 66.5 ± 8.4 years, of whom 53.5% were men and 46.5% women. This pattern aligns with the current epidemiology of the disease, where COPD is more prevalent among men and middle-aged adults (GOLD, 2025). Since smoking is a risk factor for developing COPD (Safiri et al., 2022; Wang et al., 2025), it is not surprising that a large proportion of the present study sample consists of smokers (42.3%) and former smokers (56.3%).
For the analysis the patients were divided into four categories in accordance with the GOLD stages of disease (Figure 1). The majority of patients in the present study had GOLD stage 2 (42.3%), GOLD 1 and GOLD 3 (23.9% each) and GOLD 4 (9.9%).

This distribution by disease stage aligns with existing literature that includes patients from both the continental and Mediterranean regions of Croatia (Muršić et al., 2024).

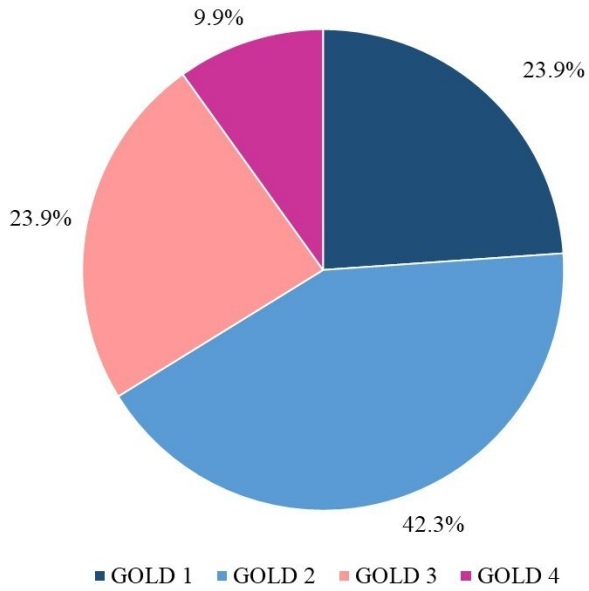
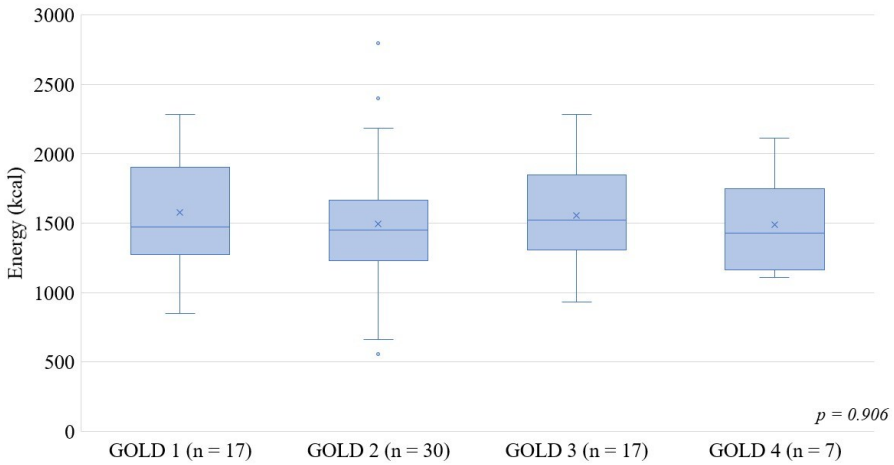


Figure 1. Distribution of the COPD patients across GOLD stages

On average, patients had a daily energy intake of 1484 (1265 – 1742) kcal, with no differences between the GOLD groups (Figure 2). In all four groups, energy intake was below the European Food Safety Authority recommendation for adults with a moderate activity level (EFSA, 2024). Lower energy intake than recommended may lead to malnutrition, especially in patients with COPD who have increased resting energy expenditure as assessed (Sergi et al., 2006; Kovarik et al., 2020).



Differences were tested using Kruskal-Wallis test with post hoc Dunnett's test ($p < 0.05$).
Figure 2. Daily energy intake Across GOLD Stages in Patients with COPD

The differences in the contribution to daily energy intake of the Siga classification groups and subgroups between the GOLD groups of COPD patients are shown in Table 1. In all four groups, the un/minimally processed food group contributed the most to the daily energy intake. Energy contribution of this food group was lower in patients with GOLD 3 and GOLD 4 compared to patients with GOLD 1 and GOLD 2 ($p = 0.022$). This difference was also observed in the subgroup of unprocessed foods consumption ($p = 0.010$). One possible explanation is the high frequency of meals prepared at home, where unprocessed or minimally processed foods and culinary ingredients were mostly used. Among the unprocessed or minimally processed foods, the most commonly consumed items were fruits (bananas, apples, tangerines, oranges), vegetables (celery, parsley, broccoli, onions, lettuce, tomatoes, carrots, cucumbers, potatoes), flour, rice, teas (chamomile, mint, pomegranate), legumes (beans, peas), meat (beef, veal, chicken, pork), eggs, coffee, milk, yogurt, salt, white sugar, honey, butter, vinegar, and oils (sunflower, olive, pumpkin). Less than 10% of the daily energy intake came from the processed food group, with no differences between patients with different disease stages. The most commonly consumed foods from the processed food group were canned vegetables (peas, beetroot, beans, pickles, corn, sauerkraut), cottage cheese, and sweetened juices (apple, orange, multivitamin). Whole meal breads and spreads such as cream cheese was consumed less frequently. Patients had one third or more daily energy intake from the ultra-processed food group. This result is similar to previous research reporting average ultra-processed food consumption in patients with chronic respiratory diseases, including COPD, were 37.7% kcal per day (Mekonnen et al., 2024). In contrast to the un/minimally processed food consumption, patients with GOLD 3 and GOLD 4 had a higher daily energy contribution from the total ultra-processed food group ($p = 0.035$) than patients with GOLD 1 and GOLD 2. This is reflected in the difference in the consumption of ultra-processed foods subgroup ($p = 0.016$), but not in the consumption of nutritionally balanced ultra-processed foods and ultra-processed foods high in salt, sugar and/or fat subgroups. The most frequently consumed foods from the ultra-processed food group were packaged industrially processed breads, sweetened beverages (Cedevita, Coca-Cola), probiotic yogurts, various bakery products (bureks, pastries, donuts, cheesecakes, puff pastry), chocolate, and snacks such as chips, sticks, biscuits, and cakes. In addition, patients most frequently mentioned processed meat products, including hot dogs, salami, sausages, and pâtés. The ultra-processed food group also included enteral preparations; however, only 5 patients (7.0%) consumed them.

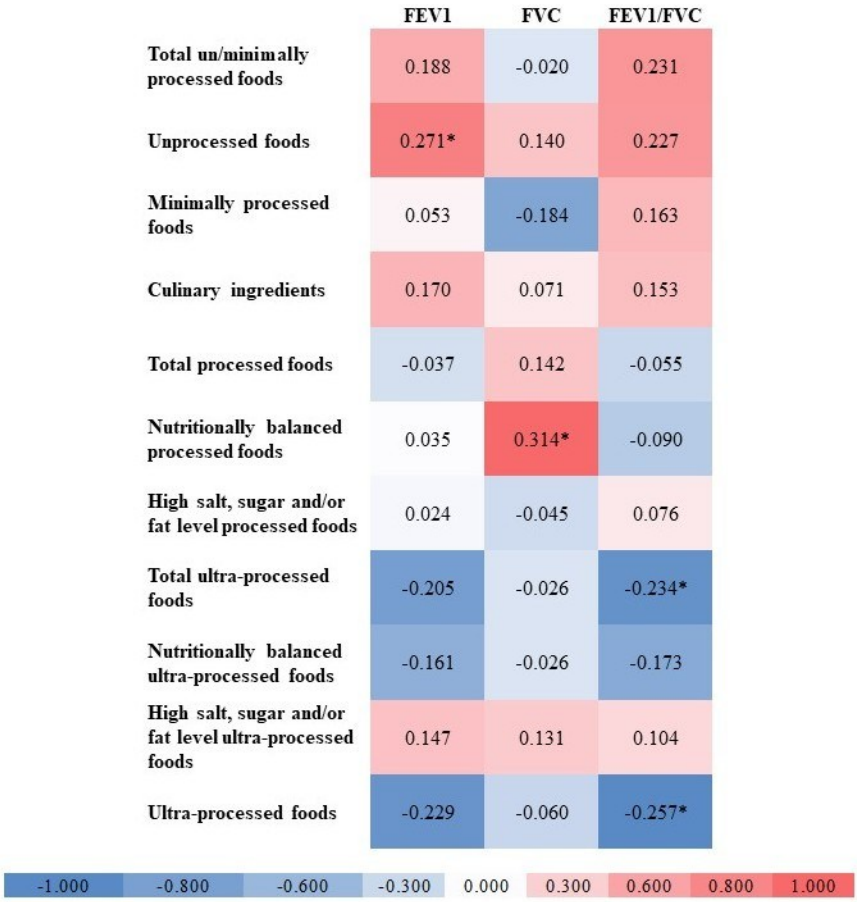
Table 1. Differences in contribution to the daily energy intake of Siga processed food groups and subgroups among COPD patients with different stage of disease

Siga processed food groups and subgroups	GOLD 1 (n = 17)	GOLD 2 (n = 30)	GOLD 3 (n = 17)	GOLD 4 (n = 7)	p-Values*
Total un/minimally processed foods (% kJ/day)	**56.1 [a] (46.5-58.0)**	**61.8 [a] (50.2-70.7)**	**47.3 [b] (40.2-59.1)**	**49.5 [b] (32.5 – 61.4)**	0.022
Unprocessed foods (% kJ/day)	33.1 [a] (22.7-36.9)	35.9 [a] (29.7-43.7)	31.8 [b] (25.9-35.2)	23.5 [b] (17.6-28.0)	0.010
Minimally processed foods (% kJ/day)	7.4 (5.0-8.2)	10.4 (7.5-15.4)	8.1 (5.1-11.4)	5.6 (3.6-9.1)	0.139
Culinary ingredients (% kJ/day)	13.4 (7.9-17.2)	13.0 (10.2-16.3)	8.5 (7.3-13.5)	9.9 (9.0-21.3)	0.155
Total processed foods (% kJ/day)	**7.9 (4.8-10.2)**	**5.3 (3.2-9.6)**	**7.1 (5.7-12.3)**	**4.5 (1.8-5.3)**	0.150
Nutritionally balanced processed foods (% kJ/day)	1.9 (0.1-3.5)	0.3 (0.0-3.5)	2.0 (0.0-7.0)	0.2 (0.0-0.5)	0.322
High salt, sugar and/or fat level processed foods (% kJ/day)	4.8 (0.0-8.8)	3.1 (1.2-6.9)	5.5 (1.6-7.1)	3.5 (1.7-4.3)	0.873
Total ultra-processed foods (% kJ/day)	**38.4 [a] (33.1-49.6)**	**31.4 [a] (23.6-42.1)**	**43.9 [b] (36.6-48.7)**	**45.8 [b] (34.6-55.9)**	0.035
Nutritionally balanced ultra-processed foods (% kJ/day)	9.2 (3.8-13.7)	9.1 (4.7-17.3)	6.9 (0.0-11.1)	19.0 (9.3-25.9)	0.141
High salt, sugar and/or fat level ultra-processed foods (% kJ/day)	10.9 (2.2-13.8)	3.9 (1.2-10.5)	6.2 (0.0-9.4)	5.4 (0.5-8.7)	0.201
Ultra-processed foods (% kJ/day)	14.5 [a] (10.2-24.2)	11.4 [a] (7.3-16.7)	25.8 [b] (16.2-33.1)	18.2 [b] (16.8-31.6)	0.016

*Data are presented as median (interquartile range); * Differences between groups were tested Kruskal-Wallis test with post hoc Dunnett's test [(a,b)] ($p < 0.05$).*

The last part of the study aimed to determine whether the consumption of foods with different levels of processing was related to the pulmonary function. The results of the analysis show (Figure 3) that a higher daily energy intake from the unprocessed food subgroup is associated with a higher FEV1 value ($r = 0.271$; $p = 0.022$). In addition, interestingly a higher intake of nutritionally balanced processed food subgroup is associated with a higher ($r = 0.314$, $p = 0.008$) FVC. The patients with a higher FEV1/FVC ratio had a lower daily energy intake from the total ultra-processed food group ($r = -0.234$, $p = 0.05$) and the ultra-processed food subgroup ($r = -0.257$, p

= 0.031). According to the available literature, an increased risk of COPD is observed in adults with higher intake of ultra-processed food (He et al., 2023), especially processed meat (Salari-Moghaddam et al., 2019). Moreover, dietary patterns characterized as Western are linked to greater odds of COPD and lower FEV1/FVC (Sorli-Aguilar et al., 2016; Zheng et al., 2016; Brigham et al., 2018; Kan, 2008).



*FEV1 - Forced Expiratory Volume in 1 second; FVC - Forced Vital Capacity; * Spearman correlation coefficient ($p < 0.05$)*

Figure 3. Correlation between spirometry parameters and contribution to the daily energy intake of Siga processed food groups and subgroups in patients with COPD (n = 71)

When interpreting the study results, several methodological limitations should be considered. The sample size of COPD subjects was relatively small, and participants had been diagnosed with COPD for between 6 and 30 years; there were no newly diagnosed COPD patients, unlike in previous studies. Dietary data were collected using a 24-hour recall method, which may introduce bias due to cognitive impairment, as the participants were older. To reduce variation in dietary intake data and changes in daily eating habits, recalls were collected on three non-consecutive days, and subjects were not informed in advance which day they would be interviewed. A

significant advantage of this study was the use of spirometry, considered the gold standard diagnostic protocol for COPD. An additional strength was the use of the Siga classification of food processing levels, which may distinguish nutritionally balanced processed foods. Since this is a cross-sectional study, no causal relationships can be established based on the results; therefore, further research on this topic is needed.

CONCLUSION

Patients with COPD consumed more than a third of their daily energy intake from the ultra-processed foods group, in which the intake of nutritionally unbalanced foods with the presence of at-risk additives dominated. In patients with milder stages of COPD, a higher consumption of un/minimally processed and nutritionally balanced foods was observed, which was positively associated with better pulmonary function reflected in higher FEV1 and FVC values. The results emphasize the need for targeted education of COPD patients on the importance of reducing the consumption of ultra-processed foods and replacing them with more nutritionally balanced and minimally processed foods. However, improved understanding of the impact of food processing on pulmonary function and disease progression requires studies with larger and more diverse samples using a longitudinal design.

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POVRTNI ČIPS S NAMAZOM – INOVATIVNA I NUTRITIVNO BOGATA GRICKALICA

VEGETABLE CHIPS WITH SAUCE – AN INNOVATIVE NUTRITIONALLY RICH SNACK

Katarina Vondrak*, Ema Herc, Paola Jambrović, Anita Rašić, Gabrijela Hron, Ivan Rengel, Svjetlana Škrabal

Sveučilište Josipa Jurja Strossmayera u Osijeku, Fakultet turzima i ruralnog razvoj u Požegi, Vukovarska 17, 34 000 Požega, Hrvatska
**kvondrak@ftrr.hr*

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SAŽETAK

Povrtni čips s namazom funkcionalna je i inovativna grickalica koju je razvio studentski tim *InovEativci* kao nutritivno bogatu alternativu uobičajenim grickalicama koje često sadrže puno soli, masti i aditiva. Namijenjen je, prije svega, djeci, ali je također pogodan za odrasle koji žele uravnoteženu prehranu. Proizvod se sastoji od čipsa napravljenog od dehidriranog povrća: batat, mrkva, peršin, cikla i koraba u kombinaciji s umakom na bazi indijskih oraščića obogaćenim nutritivnim kvascem, medom i kurkumom. Proces dehidriranja čuva nutritivne vrijednosti i osigurava visoku iskorištenost sirovina. Proizvod slijedi koncept zero-waste, koristeći dehidrirane povrtne oguljotine kao začin. Sadrži samo jedan alergen i pakiran je u recikliranu i višekratnu ambalažu, što doprinosi njegovom održivom profilu.
Senzorska analiza provedena među djecom osnovnoškolske dobi pokazala je visoku prihvaćenost u pogledu arome, izgleda i teksture. Čips od batata i mrkve bio je najčešće odabiran, dok su cikla i koraba bili manje omiljeni. Djeca su pokazala zanimanje za konzumaciju, uz male prijedloge za jače začinjavanje.
Taj proizvod predstavlja konkretan odgovor na rastuću tržišnu potražnju za održivim, privlačnim i nutritivno bogatim grickalicama, posebice među mlađom populacijom.

Ključne riječi: zdrava hrana, dehidrirano povrće, senzorska analiza, zero-waste

Keywords: healthy snacks, dehydrated vegetables, sensory analysis, zero-waste

UVOD

Prehrambene navike djece i mladih jedan su od ključnih čimbenika očuvanja zdravlja te prevencije kroničnih bolesti poput pretilosti, dijabetesa tipa 2 i kardiovaskularnih bolesti. Nažalost, statistike ukazuju na sve veći unos visokokaloričnih, nutritivno siromašnih i industrijski prerađenih grickalica među djecom, što dugoročno predstavlja ozbiljan javnozdravstveni izazov (Monteiro i sur., 2019; WHO, 2021). U kontekstu modernog načina života, grickalice su postale gotovo neizostavni dio svakodnevne prehrane, posebice u mlađoj populaciji. Razlog tomu nije samo okus i dostupnost nego i marketinški utjecaji i navike koje se formiraju od najranije dobi (Marrón-Ponce i sur., 2019). S obzirom na negativne prehrambene i zdravstvene posljedice učestalog konzumiranja konvencionalnih grickalica koje su bogate solju, zasićenim mastima i aditivima, sve više pažnje posvećuje se razvoju funkcionalnih snack-proizvoda. Takvi proizvodi trebaju zadovoljiti organoleptička očekivanja potrošača i pružiti dodatne koristi za zdravlje (Granato i sur., 2017). Funkcionalna hrana obuhvaća proizvode koji, osim osnovne prehrambene vrijednosti, imaju pozitivan utjecaj na jednu ili više ciljnih funkcija organizma, čime mogu doprinijeti boljem zdravlju ili smanjenju rizika od bolesti (Roberfroid, 2002). Povrće poput batata, mrkve, cikle, korabe i peršina bogato je prehrambenim vlaknima, vitaminima (posebno A i C), mineralima (kalij, željezo, magnezij) te bioaktivnim spojevima poput polifenola i antioksidansa, koji imaju dokazane koristi za zdravlje (Nicoli i sur., 1999; Slavin i Lloyd, 2012). Njihovom preradom u oblik čipsa putem procesa dehidracije omogućuje se očuvanje većine tih nutritivnih vrijednosti, uz istovremeno produljenje trajnosti i moguće smanjenje otpada. Dehidriranje povrća pri nižim temperaturama zadržava osjetljive bioaktivne komponente i poboljšava stabilnost proizvoda (Krokida i Maroulis, 2001). Dodatnu nutritivnu vrijednost moguće je postići uvođenjem biljnog namaza na bazi indijskih oraščića, koji su dobar izvor nezasićenih masnih kiselina, biljnih proteina i minerala poput cinka i magnezija. Obogaćivanjem namaza s funkcionalnim sastojcima poput nutritivnog kvasca (bogatog B vitaminima i beta-glukanima), kurkume (poznate po protuupalnim svojstvima) i meda (prirodni zaslađivač s antibakterijskim učinkom), moguće je stvoriti funkcionalnu grickalicu koja kombinira okus, teksturu i doprinosi očuvanju zdravlja (Wolfe i Liu, 2003; Jäger i sur., 2014). Osim nutritivnih vrijednosti, razvoj suvremenih prehrambenih proizvoda mora odgovoriti i na sve izraženije zahtjeve potrošača vezane uz ekološku održivost. Ekološka održivost uključuje ne samo korištenje prirodnih i lokalno dostupnih sirovina već i smanjenje otpada, upotrebu reciklirane i višekratne ambalaže te optimizaciju proizvodnih procesa da bi se smanjio ugljični otisak (Notarnicola i sur., 2017). U tom kontekstu, proizvodnja povrtnog čipsa s namazom, razvijenog od strane studentskog tima "InovEativci" primjenjuje zero-waste koncept, gdje se kore povrća, koje bi inače bile otpad, dehidriraju i koriste kao začin za dodatno obogaćivanje okusa. Prihvatljivost proizvoda među ciljnom skupinom ključna je za njegovu tržišnu održivost. Djeca su često selektivna u prehrambenim preferencijama, a okus, boja i tekstura igraju značajnu ulogu u odluci o konzumaciji. Senzorska evaluacija, provedena među učenicima osnovne škole, može pružiti uvid u potencijalnu prihvaćenost proizvoda, kao i smjernice za buduće dorade recepture (Lawless i Heymann, 2010). Usto, bilo bi poželjno provesti dodatne edukacija roditelja i djece i

usmjeriti ih prema boljem razumijevanju poželjnih prehrambenih navika. Također, tako se mogu dobiti informacije o učestalosti konzumacije grickalica te preferencijama pakiranja. Važnosti održivosti i percepcija zdravih proizvoda mogu poslužiti kao temelj za prilagodbu proizvoda tržištu. Prethodna istraživanja pokazuju ključnu ulogu roditelja u oblikovanju dječjih prehrambenih navika, ali i određeni nesrazmjer između onoga što djeca smatraju poželjnim i onoga što stvarno konzumiraju (Scaglioni i sur., 2008).
Cilj ovog rada jest prikazati razvoj inovativnog i funkcionalnog snack-proizvoda, povrtnog čipsa s namazom na bazi indijskih oraščića, koji objedinjuje nutritivnu vrijednost, održivost i prihvatljivost za djecu. Rad uključuje opis sastava i tehnološkog procesa, rezultate senzorske analize i ankete te razmatranje potencijala proizvoda u kontekstu tržišnih potreba i suvremenih prehrambenih trendova.

MATERIJAL I METODE

Izbor sirovina i priprema povrtnog čipsa

Za razvoj funkcionalne grickalice korišteno je povrće lokalnog podrijetla: batat (*Ipomoea batatas*), mrkva (*Daucus carota*), peršinov korijen (*Petroselinum crispum*), cikla (*Beta vulgaris*) i koraba (*Brassica oleracea* var. *gongylodes*). Povrće je temeljito oprano i oguljeno, pri čemu su kore pohranjene za daljnju uporabu. Korištenjem preporuka iz „Priručnika za skladištenje, preradu i doradu voća, povrća, ljekovitog i aromatičnog bilja“ (Žabur i Voća, 2023) određeni su parametri sušenja povrća i začina i uvjeti pakiranja. Nakon pripreme povrće je narezano na tanke ploške te podvrgnuto procesu dehidracije na temperaturi od 60 °C tijekom 12 sati u dehidratoru za hranu (proizvođač Gorenje). Dobiveni dehidrirani uzorci pakirani su u odgovarajuće vrećice te hermetički zatvoreni pomoću uređaja za vakuumiranje, s ciljem očuvanja nutritivnih i senzorskih svojstava te produljenja roka trajanja bez uporabe konzervansa.

Priprema začina

Nakon obrade osnovnih uzoraka ostaci povrća iskorišteni su za pripremu začinske mješavine. Kore povrća, koje bi inače bile odbačene, dehidrirane su zasebno te usitnjene i korištene kao prirodni začin. Na taj način implementiran je zero-waste princip, čime se dodatno povećava iskoristivost sirovina i smanjuje količina otpada. Otpadni biljni materijal nastao tijekom procesa guljenja i rezanja povrća iskorišten je za daljnju preradu u funkcionalni sastojak. Uzorci biljnog materijala kombinirani su s češnjakom (*Allium sativum*) i đumbirom (*Zingiber officinale*), nakon čega su ravnomjerno raspoređeni po katovima dehidratora da bi se omogućilo jednoliko strujanje zraka i optimalni uvjeti sušenja. Proces sušenja proveden je pod kontroliranim parametrima temperature i vremena (Žabur i Voća, 2023). Uzorci povrtnog materijala sušeni su na 65 °C tijekom 10 sati, dok su uzorci đumbira i češnjaka sušeni na 60 °C kroz šest sati. Na taj način osigurano je učinkovito uklanjanje vlage uz očuvanje karakterističnih aroma i bioaktivnih spojeva. Po završetku procesa svi uzorci samljeveni su pojedinačno i pohranjeni u zasebne posude. Dobiveni biljni

prahovi, zatim, međusobno su miješani u unaprijed određenim omjerima uz dodatak soli, češnjaka i đumbira, čime je formirana standardizirana „mješavina začina".

Priprema biljnog namaza kao funkcionalnog priloga

Kao funkcionalni prilog uz povrtni čips razvijen je biljni namaz na bazi indijskih oraščića (*Anacardium occidentale*). Oraščići su prethodno namočeni u vodi tijekom četiriju sati, a zatim dehidrirani na 50 °C kroz šest sati. Dehidrirani oraščići blendani su do postizanja homogene, srednje guste smjese bez krutih čestica. U postupak homogenizacije dodani su voda, suncokretovo ulje, maslac od indijskih oraščića, prehrambeni kvasac (*Saccharomyces cerevisiae*), med i kurkuma (*Curcuma longa*), uz neprestano miješanje do formiranja glatke i kompaktne teksture. Na kraju su dodani limunska kiselina, sol i preostale komponente radi postizanja optimalnog okusa, teksture namaza i stabilnosti.

Pakiranje proizvoda

Proizvod je pakiran u recikliranu kartonsku ambalažu obloženu iznutra aluminijskim prehrambenim papirom, koja je predviđena za višekratnu upotrebu (djeca je mogu koristiti za pohranu olovaka, sitnih igračaka i slično). Korišteni materijali pogodni su za kontakt s hranom, u skladu s važećim propisima (EU regulativa br. 10/2011). Proces pakiranja proveden je u kontroliranim uvjetima (temp. 18 °C, rel. vl. 65 %) da bi se očuvala kvaliteta i stabilnost proizvoda. Dehidrirani povrtni čips odmjeren je na točnu masu od 35 g (u jednakim omjerima svake pojedine vrste povrća) te smješten u donji dio ambalažnog spremnika. Nakon punjenja donji dio ambalaže hermetički je zatvoren radi sprječavanja prodora zraka i vlage. Biljni namaz, u količini od 40 g, doziran je u gornji dio ambalaže te zatvoren odgovarajućim poklopcem. Završnim korakom gornji i donji segment ambalaže spojeni su u cjelovitu jedinicu, čime je osigurana funkcionalna i estetski kompaktna ambalaža pogodna za tržišnu distribuciju.

Senzorska analiza

Senzorska analiza provedena je u dvjema osnovnim školama (N = 28 učenika, uzrast 8 – 11 godina), uz suglasnost roditelja i škole. Djeci su ponuđeni uzorci svih pet vrsta povrtnog čipsa s pripadajućim umakom te su zamoljena ocijeniti ponuđene uzorke i ispuniti anketni listić s pitanjima (Tablica 1).

Tablica 1. Pitanja za ocjenu uzoraka povrtnog čipsa
Table 1. *Questions for evaluating vegetable chips samples*

1. Sviđa li ti se ambalaža ?
a) Da
b) Ne
2. Sviđa li ti se izgled (oblik i boja) kušanog čipsa i namaza?
a) Sviđa mi se
b) Ne sviđa mi se
3. Sviđa li ti se tekstura / hrskavost čipsa?
a) Da
b) Ne
4. Koje od navedenog povrća ti se ne sviđa u obliku čipsa?
a) Cikla
b) Koraba
c) Peršin
d) Mrkva
e) Batat
5. Koje od navedenog povrća ti se sviđa u obliku čipsa?
a) Cikla
b) Koraba
c) Peršin
d) Mrkva
e) Batat
6. Zaokruži u odgovoru kako ti se sviđa začinjenost čipsa od povrća!
a) Dobro začinjeno (dobro je, ali može i bolje)
b) Loše začinjeno (začini se ne slažu uz čips)
c) Prejako je začinjeno
d) Taman je začinjeno (sviđa mi se kakav je spoj okusa začina i povrća)
7. Bi li si kupio (kupila) ovaj čips pod školskim odmorom (u školi), u trgovini…?
a) Bih
b) Ne bih

Nutritivna analiza

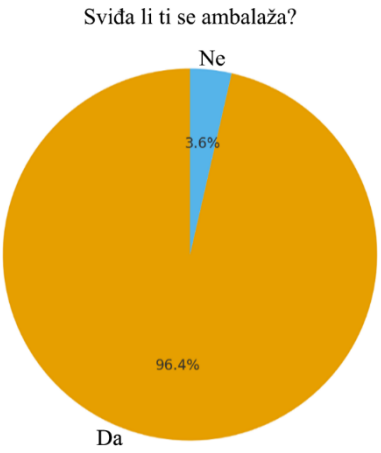
Nutritivna vrijednost povrtnog čipsa i namaza provedena je pomoću nutricionističke web-aplikacije „Program prehrane“. Svi sastojci povrtnog čipsa i namaza uneseni su u mrežnu nutricionističku aplikaciju „Program prehrane” koja omogućuje izračun energetske i nutritivne vrijednosti jela na temelju preciznih normativa. Unutar aplikacije odabrana je dobna skupina *djeca od 7 do 10 godina* da bi rezultati bili

relevantni. Aplikacija je generirala podatke o ukupnoj energetskoj vrijednosti te udjelu ugljikohidrata, masti, bjelančevina i vlakana. Dobiveni podaci, zatim, obrađeni su i uspoređeni s važećim nutricionističkim smjernicama. Sukladno Uredbi 1169/2011. tablično je prikazana energija (kJ/kcal), ukupne masti (g), zasićene masne kiseline (g), ukupni ugljikohidrati (g), šećeri (g), prehrambena vlakana (g), bjelančevine (g) i soli (g). Vrijednosti su izražene po 100 g proizvoda i po porciji od 75 g, a uspoređene su s preporučenim dnevnim unosom (RDA) za djecu starosti 7 – 10 godina. Dobiveni rezultati omogućili su procjenu nutritivnog profila proizvoda i njegovu prikladnost kao zdravog i uravnoteženog međuobroka. Podaci su prikazani kao apsolutne vrijednosti i postotak preporučenog dnevnog unosa (RDA). Za prikaz rezultata korišteni su opisni statistički pokazatelji.

REZULTATI I RASPRAVA

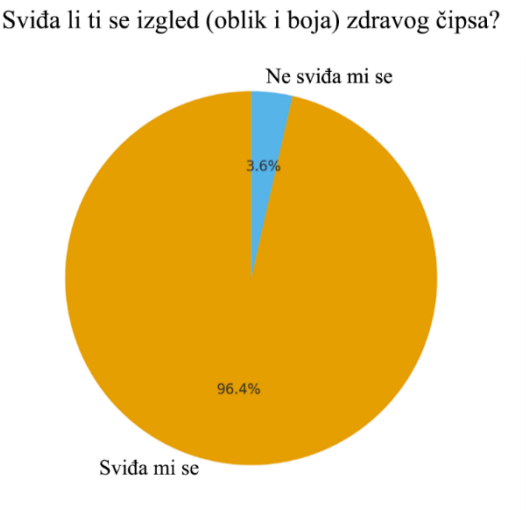
Anketa je pokazala da 96,4 % djece pozitivno reagira na ambalažu povrtnog čipsa (Slika 1), što naglašava važnost vizualnih čimbenika u prehrambenim preferencijama djece (Slika 2). Atraktivna ambalaža može potaknuti zanimanje za nutritivno vrijedne proizvode koji bi inače bili manje privlačni. Ovi rezultati upućuju na potrebu kombiniranja kvalitete sastava i dizajna proizvoda da bi se podržale zdrave prehrambene navike već od rane dobi.

Slika 1. Ambalaža i priređeni uzorci povrtnog čipsa s namazom
Figure 1. *Packaging and prepared samples of vegetable chips with spread*

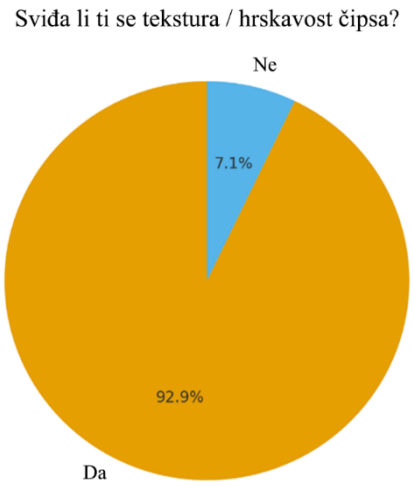


Slika 2. Prikaz rezultata o prihvatljivosti ambalaže
Figure 2. *Presentation of results on packaging acceptability*

Rezultati provedenog istraživanja ukazuju na visoku razinu prihvaćenosti zdravog povrtnog čipsa među ispitanicima, djecom u dobi od oko 10 godina. Većina sudionika (96 %) navela je da im se sviđa izgled proizvoda (Slika 3), što potvrđuje važnost vizualnog dojma u procesu donošenja odluke o konzumaciji hrane. Prema istraživanju Spencea (2015) vizualni elementi poput boje i oblika značajno utječu na percepciju okusa i ukupno zadovoljstvo hranom, što sugerira ključnu ulogu dizajna i vizualne prezentacije u privlačenju djece prema zdravim alternativama nasuprot tradicionalnim snack-proizvodima.

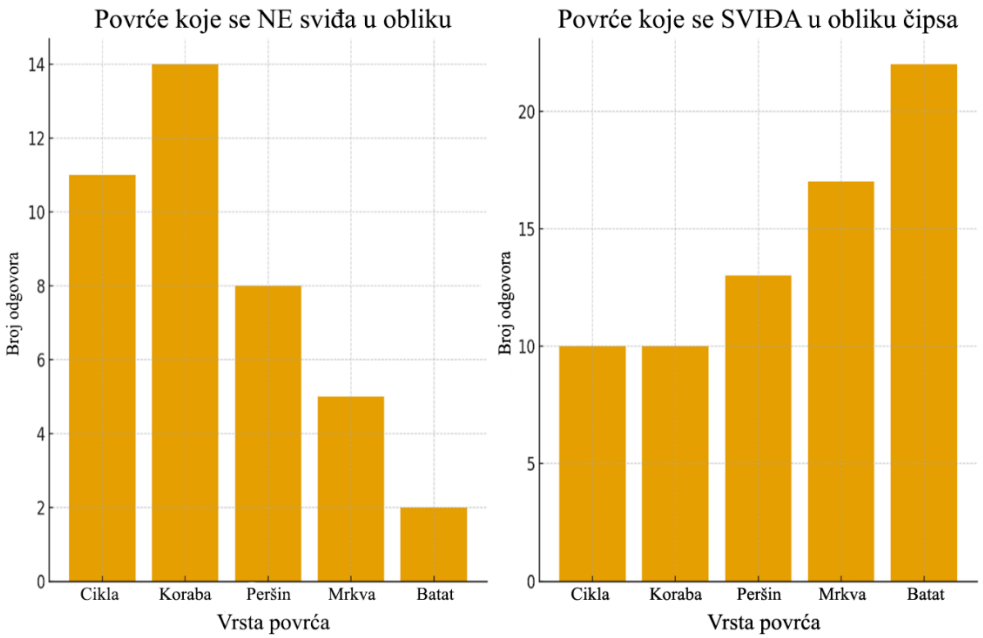


Slika 3. Prikaz rezultata o izgledu povrtnog čipsa
Figure 3. *Presentation of results on the appearance of vegetable chips*



Slika 4. Prikaz rezultata o hrskavosti čipsa
Figure 4. *Presentation of results on the crispiness of the chips*

Senzorne karakteristike proizvoda, posebice tekstura, također su prepoznate kao izrazito važne za percepciju kvalitete među djecom. Čak 93 % ispitanika izjavilo je da im se sviđa hrskavost čipsa (Slika 4). Laureati i sur. (2020) navode da na percepciju hrskavosti utječu prehrambene navike konzumacije tvrde i zrnaste hrane te da se u takvim slučajevima hrskavost često povezuje s pojmovima „svježe" i „ukusno", što dodatno povećava privlačnost proizvoda. Analizom preferencija prema vrstama povrća uočava se jasna razlika u prihvaćenosti okusa (Slika 5). Najmanje prihvaćen proizvod bio je čips od korabe (14 odgovora), dok je najprihvaćeniji bio čips od batata (22 odgovora). Takav rezultat može se objasniti većom poznatošću i prirodnom slatkoćom batata, koja odgovara očekivanjima djece naviknute na klasične oblike čipsa (Kuhar i sur., 2020). Suprotno tomu, koraba i cikla imaju izraženije zemljaste arome koje mogu biti percipirane kao neobične ili manje privlačne, što potvrđuje nalaze istraživanja o senzornim barijerama u prihvaćanju alternativnih povrtnih proizvoda (Hoppu i sur., 2021).



Slika 5. Prikaz odgovora o prihvaćanju / neprihvaćanju pojedinih vrsta čipsa od povrća

Figure 5. *Presentation of responses on acceptance/rejection of different types of vegetable chips*

U pogledu začinjenosti, većina djece ocijenila je čips kao „dobro začinjen" (68 %), dok je manji broj smatrao da je začinjenost „taman" (18 %) ili neodgovarajuća (14 %) (Slika 6). Ti rezultati sugeriraju relativno uspješan balans začina, iako postoji prostor za optimizaciju kombinacije začina i osnovnog sastojka. Prethodna istraživanja pokazala su povećavanu prihvaćenost zdravih grickalica kod djece umjerenom razinom začinjenosti i uporabom poznatih profila okusa (npr. sol, paprika, biljni začini) (Lähteenmäki, 2013).

Slika 6. Prikaz odgovora o začinjenosti čipsa
Figure 6. *Presentation of responses on the seasoning of the chips*

Važan podatak dobiven u ovom istraživanju odnosi se na namjeru kupnje proizvoda: čak 86 % djece izjavilo je da bi kupilo čips od povrća (Slika 7). Taj podatak ukazuje na značajan tržišni potencijal proizvoda, posebice u školskim ustanovama gdje postoji rastuća potreba za zdravijim međuobrocima. Kako navode Imtiyaz i sur. (2021), spremnost potrošača na prihvaćanje novih, nutritivno bogatijih proizvoda u velikoj mjeri ovisi o njihovom senzornom zadovoljstvu i percepciji zdravlja. Istraživanja pokazuju da transparentna komunikacija o zdravstvenim prednostima povećava prihvaćenost inovativnih proizvoda (Aschemann-Witzel i Grunert, 2015)

Slika 7. Prikaz rezultata o potencijalnoj kupnji povrtnog čipsa
Figure 7. *Presentation of results on the potential purchase of vegetable chips*

Tablica 2. Nutritivne vrijednosti povrtnog čipsa s namazom od indijskih oraščića
Table 2. *Nutritional values of vegetable chips with cashew spread*

	Na 100 g	**Na porciju (75 g)**	**% RDA (75 g)**
Energija	1894 kJ / 453 kcal	1453 kJ / 347 kcal	20,4 %
Masti	24	18,0	25
– od kojih zasićene masne kiseline	3,98	2,99	15
Ugljikohidrati	39	29,25	13
– od kojih šećeri	16	12	48
Vlakna	15,5	11,63	60
Bjelančevine	15	11,25	30
Sol	1	0,75	15

% RDA – postotak preporučenog dnevnog unosa za djecu (7 – 10 godina), temeljen na prosječnim nutritivnim potrebama.

Analiza nutritivnog sastava povrtnog čipsa s namazom pokazuje da proizvod predstavlja uravnoteženu i nutritivno vrijednu alternativu konvencionalnim grickalicama (Tablica 2). Čips od dehidriranog povrća u jednakim omjerima (47 %) s namazom od indijskih oraščića (53 %) čini proizvod posebno bogatim vlaknima i bjelančevinama. Porcija od 75 g sadrži 347 kcal (20,4 % RDA), 18 g masti (25 % RDA) s 2,99 g zasićenih masnih kiselina (15 % RDA), 29,25 g ugljikohidrata (13 % RDA), uključujući 12 g šećera (48 % RDA), 11,63 g vlakana (60 % RDA), 11,25 g bjelančevina (30 % RDA) i 0,75 g soli (15 % RDA). Visok udio vlakana i bjelančevina doprinosi sitosti i probavnom zdravlju, dok niski udio zasićenih masti i soli osigurava povoljan nutritivni profil. Proizvod sadrži samo jedan alergen i većinom prirodne šećere, što ga čini prikladnim za djecu te zdravom i održivom alternativom konvencionalnim grickalicama.

ZAKLJUČAK

Rezultati istraživanja pokazuju veliku prihvaćenost zdravog povrtnog čipsa među djecom u dobi od oko 10 godina, pri čemu vizualni dojam, tekstura i okus proizvoda igraju ključnu ulogu u percepciji kvalitete i ukupnom zadovoljstvu. Čips od batata bio je najbolje prihvaćen zbog poznatih i slatkih okusa, čips od korabe pokazao je nižu razinu prihvaćenosti, što ukazuje na važnost prilagodbe okusa ciljnoj skupini. Većina ispitanika ocijenila je začinjenost proizvoda kao odgovarajuću, a značajan udio djece izrazio je namjeru kupnje čipsa, što potvrđuje tržišni potencijal takvih zdravih grickalica. Rezultati naglašavaju da kombinacija vizualne privlačnosti, senzorne kvalitete i uravnoteženog okusa predstavlja ključni čimbenik u poticanju djece na konzumaciju nutritivno bogatih alternativa nasuprot tradicionalnim snack-proizvodima. Transparentna komunikacija o zdravstvenim prednostima dodatno može povećati prihvaćenost proizvoda i olakšati njihovu integraciju u prehranu djece.

Povrtni čips s namazom pokazuje povoljan nutritivni profil, umjerenu energetsku vrijednost, visok udio vlakana i biljnih bjelančevina, nizak udio zasićenih masti te ograničenu količinu soli. U kombinaciji s održivim načinom proizvodnje i konceptom zero-waste, proizvod zadovoljava suvremene prehrambene i ekološke zahtjeve potrošača.

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PREHRANA DOJENČADI OD ŠEST MJESECI DO PRVE GODINE STAROSTI

NUTRITION FOR INFANTS FROM SIX MONTHS TO ONE YEAR OF AGE

Mirjana Zukić*

Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno-tehnološki fakultet
Osijek, Franje Kuhača 18, 31 000 Osijek, Hrvatska
**mirjanazukic2@gmail.com*

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SAŽETAK

Ovaj rad usmjeren je na dojenčad do jedne godine života te razmatra uvođenje komplementarne prehrane u okviru cjelokupne prehrane tijekom druge polovice prve godine kod zdrave, terminski rođene djece. Poseban naglasak stavljen je na prijelaz s prehrane temeljene isključivo na mlijeku na raznoliku prehranu koja uključuje većinu skupina namirnica. Analizira se optimalno vrijeme uvođenja dohrane, načini hranjenja i kvaliteta prehrane u odnosu na rast i razvoj djeteta te dugoročne zdravstvene ishode. Komplementarna prehrana predstavlja važnu razvojnu i javnozdravstvenu prekretnicu jer obrasci hranjenja u tom razdoblju mogu utjecati na rizik od nezaraznih bolesti i alergija na hranu u kasnijem životu. Preporučuje se neuvođenje komplementarne hrane prije navršenog 17. niti odgađanje nakon 26. tjedna života dojenčeta. U radu se prikazuju najčešći pristupi hranjenju, uz naglasak na razvojno prilagođeno uvođenje hrane i postupno izlaganje potencijalnim alergenima.

Ključne riječi: komplementarna prehrana, vrijeme uvođenja dohrane, metode dohrane, alergije na hranu, suplementacija

Keywords: complementary feeding, timing of complementary feeding, complementary feeding methods, food allergy, supplementation

UVOD

Prvih tisuću dana života, posebice razdoblje od šestog do dvanaestog mjeseca, ključno je za oblikovanje zdravlja, rasta i razvoja djeteta. Uvođenje komplementarne prehrane, odnosno uključivanje hrane i tekućina uz majčino mlijeko ili adaptiranu formulu, označava prijelaz s isključivog dojenja na mješovitu prehranu i predstavlja važan korak u prehrambenom i senzornom razvoju dojenčeta. Pravilno vrijeme i način uvođenja hrane ključni su za sigurno prihvaćanje različitih tekstura i okusa te za poticanje motoričkih, senzorno-perceptivnih i prehrambenih vještina djeteta. Preporuke za uvođenje komplementarne hrane razlikuju se ovisno o smjernicama relevantnih organizacija, uključujući ESPGHAN (*European Society for Paediatric Gastroenterology, Hepatology and Nutrition*), EFSA-u (*European Food Safety Authority*)**,** WHO (*World Health Organization*), AAP (American Academy of Pediatrics), EACCI (*European Academy of Allergy and Clinical Immunology*) i Hrvatsko društvo za dječju gastroenterologiju, hepatologiju i prehranu. Pri uvođenju hrane važno je razumjeti da to nije prvi susret bebe s novim okusima.
Djetetovo izlaganje različitim okusima započinje već „*in utero*“ gutanjem amnionske tekućine te se nastavlja kroz dojenje, pri čemu majčino mlijeko mijenja okus ovisno o majčinoj prehrani (Fewtrell M. i sur., 2017). Prerano uvođenje komplementarne hrane, prije 17. tjedna života, može imati ozbiljne posljedice zbog nezrelosti probavnog, endokrinološkog, imunološkog i neuropsihomotornog sustava, uključujući povećan rizik od alergija i probavnih smetnji. S druge strane, odgađanje uvođenja hrane nakon 26. tjedna povećava rizik od kasnijih problema u hranjenju, odbijanja hrane, prehrambenih deficita i alergija te može usporiti mentalni i imunološki razvoj djeteta. Razumijevanje optimalnog vremena, načina i sastava komplementarne prehrane te poštivanje razvojnih sposobnosti dojenčeta omogućava roditeljima i zdravstvenim stručnjacima promicanje zdravog rasta, razvoja i dugoročnog zdravlja djece (Mennella i sur., 2001).

Vrijeme uvođenja komplementarne prehrane

Uvođenje komplementarne prehrane predstavlja važnu razvojnu prekretnicu za dojenče jer označava prijelaz s isključivo mliječne prehrane na raznovrsniji unos hrane. Taj proces uključuje senzorno upoznavanje novih okusa i tekstura te postupno prilagođavanje obiteljskoj prehrani (Niseteo, 2017). Preporučuje se neuvođenje komplementarne prehrane prije navršenog 17. tjedna niti odgađanje nakon 26. tjedna života dojenčeta (WHO, 2023). U tom razdoblju događaju se značajne razvojne promjene: dojenče postiže bolju kontrolu glave i trupa, pokazuje zanimanje za hranu iz okoline, razvija sposobnost aktivnog hvatanja predmeta, a probavni sustav sazrijeva uz povećanu aktivnost probavnih enzima i pojavu prvih zubiju. Do navršenih šest mjeseci dojenče u pravilu udvostruči porođajnu masu (Obradović, 2008). Istodobno, energetske i nutritivne potrebe djeteta počinju nadmašivati mogućnosti majčinog ili adaptiranog mlijeka, zbog čega je uvođenje komplementarne prehrane nužno za zadovoljenje potreba za energijom i hranjivim tvarima (Agostoni i sur., 2008). Komplementarna prehrana nadopunjuje unos mlijeka te osigurava veći udio energije, visokovrijednih bjelančevina, esencijalnih masnih kiselina i mikronutrijenata, posebice željeza i cinka, važnih za rast i razvoj. Istraživanja fiziološkog sazrijevanja

dojenčadi pokazuju da su bubrežne i gastrointestinalne funkcije oko četvrtog mjeseca dovoljno razvijene za metaboliziranje nemliječne hrane, čime se dodatno potiče sazrijevanje probavnog sustava (WHO, 2002; Ed i sur., 2001; Abate i sur., 2023). Nakon šestog mjeseca isključivo majčino mlijeko više ne može u potpunosti zadovoljiti rastuće metaboličke potrebe djeteta, zbog čega je komplementarna prehrana nužna za uredan somatski i neurorazvoj (Berti i sur., 2023; Campoy i sur., 2023). Prakse uvođenja komplementarne prehrane razlikuju se među populacijama. Studija provedena u Etiopiji pokazala je da je 65,1 % majki započelo dohranu u preporučenoj dobi, pri čemu su viša razina obrazovanja, savjetovanje i dobro znanje o dohrani bili značajno povezani s pravodobnim uvođenjem (Andualem i sur., 2020). Suprotno tomu, studije iz SAD-a i Irske pokazuju da oko 21 % majki uvodi komplementarnu prehranu prije četvrtog mjeseca, dok manji udio odgađa uvođenje do šestog mjeseca, bez jasne povezanosti s obrazovanjem (Fein i sur., 2008; Koletzko, 2005). Europski podaci upućuju na uvođenje komplementarne prehrane dojenčadi prije navršenih šest mjeseci (Caroli i sur., 2012), dok su u nekim azijskim zemljama zabilježene i prerane i prekasne prakse u odnosu na preporuke SZO-a (Sirkka i sur., 2022). Istraživanje u više europskih zemalja pokazalo je ranije uvođenje komplementarne prehrane kod dojenčadi hranjene adaptiranim mlijekom u usporedbi s dojenčadi hranjenom majčinim mlijekom (Schiess i sur., 2010). Vrijeme uvođenja krute hrane utječe i na razvoj crijevne mikrobiote, koja ima ključnu ulogu u imunološkom, metaboličkom i neurorazvoju dojenčeta (Tanaka i sur., 2017; Turroni i sur., 2020; Catassi i sur., 2024). S neurorazvojnog gledišta, dojenčad između četvrtog i šestog mjeseca stječe sposobnost uzimanja kašaste hrane sa žlice, dok je razdoblje između devetog i desetog mjeseca kritično za uvođenje hrane s grudicama. Odgađanje uvođenja takve hrane povezano je s povećanim rizikom od poteškoća hranjenja i smanjenom konzumacijom voća i povrća (Northstone i sur., 2001).
S obzirom na razvojne i prehrambene potrebe, važno je uvoditi komplementarnu prehranu u preporučenom vremenskom okviru te prilagoditi konzistenciju i način hranjenja dobi i razvojnim sposobnostima dojenčeta (Fewtrell i sur., 2017).

Sadržaj komplementarne prehrane i njezin utjecaj na zdravlje

Primjena znanstveno utemeljenih kriterija, koji se temelje na nutritivnoj vrijednosti pojedine namirnice, a ne na strogo definiranim obrascima prehrane, omogućuje siguran i razvojno primjeren prijelaz na krutu hranu. Društvo za preventivnu i socijalnu pedijatriju (SIPPS), Talijanska federacija pedijatara (FIMP), Talijansko društvo za razvoj *Origins of Health and Disease* (SIDOHaD) i Talijansko društvo za pedijatrijsku prehranu (SINUPE) objavili su preporuke o dobi te kvantitativnim i kvalitativnim obilježjima uvođenja komplementarne prehrane u dobi od šest do 24 mjeseca. Preporučeni unos makronutrijenata za zdravu terminsku dojenčad u dobi od šest do 12 mjeseci, izražen kao udio ukupnog dnevnog energetskog unosa, količina energije ili grama po danu (Caroli i sur., 2022), prikazan je u Tablica 1.

Tablica 1. Adekvatan unos makronutijenata (Capra i sur., 2024)
Table 1. *Adequate macronutrient intake (Capra et al., 2024)*

	MAKRONUTRIJENTI			
6 – 12 mjeseci	**proteini**	**ugljikohidrati**	**masti**	**vlakna**
	14 %	45 – 55 %	40 %	/kcal /dan

Smjernice za praktično uvođenje komplementarne prehrane prema tromjesečjima, koje se trebaju prilagoditi lokalnim prehrambenim navikama i dostupnosti namirnica (Caroli i sur., 2022), prikazane su u Tablica 2.

Tablica 2. Mjesečni raspored dohrane za dojenčad (6 – 12 mjeseci) (Capra i sur., 2024)
Table 2. *Monthly complementary feeding schedule for infants (6-12 months) (Capra et al., 2024)*

HRANA	**KOLIČINA HRANE**	
	6 – 9 mjeseci	**9 – 12 mjeseci**
Kreme od žitarica (riža, kukuruz, tapioka)	25 – 30 g	
Baby tjestenina i riža	/	25 – 30 g
Kruh	/	
Juha od povrća	/	30 – 40 g
Voće	40 g (svježeg voća) 40 g (voćne kaše)	50 g (svježeg voća) – 2 x dnevno 40 g (voćne kaše)
Povrće	20 g	
Riba	20 g (svježe ribe) 40 g (ribljeg pirea)	
Meso	10 g (svježeg mesa) 40 g (mesnog pirea)	
Jaja	¼ dobro kuhanog	
Mahunarke	25 g (svježeg graška) 10 g (osušenih mahunarki) 40 g (pirea od mahunarki)	
Ekstra djevičansko maslinovo ulje	10 g	

Svjetska zdravstvena organizacija (WHO, eng. World Health Organization) definira komplementarnu prehranu kao proces koji započinje kada majčino mlijeko ili dojenačka formula više nisu dovoljni za zadovoljenje prehrambenih potreba dojenčeta te je potrebno uvođenje druge hrane i tekućine uz mlijeko. Ona uključuje svu prikladnu hranu i napitke, domaće ili industrijski proizvedene, osim niskohranjivih napitaka poput čajeva, kave i zaslađenih sokova koji mogu smanjiti apsorpciju željeza (Daelmans i sur., 2009). Komplementarna prehrana obuhvaća kašastu, grudastu i finger food hranu, unesenu žlicom ili samostalno (Castenmiller i sur., 2019). Huss i sur. pokazali su da komercijalno pripremljeni pirei zadržavaju 88 % mikronutrijenata u odnosu na domaće pripravke, dok više od 90 % ugljikohidrata čine slobodni šećeri, uz nisko glikemijsko opterećenje, što ih čini nutritivno prikladnim za dojenčad (Huss i sur., 2022). Komercijalna hrana za dojenčad dodatno je podvrgnuta strogim kontrolama, ne sadrži dodane soli, šećere ni neke aditive te je često obogaćena vitaminima i mineralima (Dietz i sur., 1999; Nutrition, 2001). Nutritivne potrebe dojenčadi posebice zahtijevaju adekvatan unos željeza i cinka. Željezo je ključno za sintezu hemoglobina i razvoj djeteta, a njegova niska koncentracija u majčinom mlijeku (≈1 mg/L) zahtijeva nadopunu komplementarnom prehranom (Petry i sur., 2016; Daniels i sur., 2015). Nedostatak cinka može utjecati na kognitivni, motorički i imunološki razvoj, iako je bioraspoloživost iz majčinog mlijeka visoka (Daniels i sur., 2015). Preporučeni dnevni unos cinka za dojenčad 6 – 12 mjeseci iznosi 3 mg, a za djecu 1 – 3 godine 5 mg, što zahtijeva uključivanje mesa, ribe, peradi i jaja (WHO, 2005). Vitamin D i filokinon (K) nisu presudni za određivanje vremena uvođenja hrane, ali se rutinski nadopunjuju zbog niskog sadržaja u majčinom mlijeku (Braegger i sur., 2013; Munns i sur., 2016; Saggese i sur., 2018). Dugolančane n-3 masne kiseline, EPA (eikosapentaenska kiselina) i DHA (dokozaheksaenska kiselina) ključne su za neurološki i vizualni razvoj djeteta (Koletzko i sur., 2008; Valentine i sur., 2019; Di Maso i sur., 2021). Unatoč preporukama, u Europi i SAD-u i dalje se primjenjuje rano davanje kravljeg mlijeka, što povećava rizik od nedostatka željeza (Caroli i sur., 2012; Fein i sur., 2008). Neadekvatne prakse komplementarne prehrane, uključujući prerano uvođenje, neadekvatnu nutritivnu vrijednost i lošu higijenu, povezane su s proljevom, infekcijama, pothranjenošću, zastojem u rastu, lošim kognitivnim razvojem i povećanom smrtnosti djece globalno (Arikpo i sur., 2018).

Načini uvođenja komplementarne prehrane

Prvih 1000 dana djetetova života, uključujući razdoblje uvođenja komplementarne prehrane, smatra se ključnim za zdravlje i dugoročni razvoj djeteta (Mameli i sur., 2016). U ovom se radu razmatra razdoblje od 68. do 365. dana života, tijekom kojeg se aktiviraju brojni epigenetski mehanizmi s potencijalnim utjecajem na kasnije fizičko, kognitivno i socioemocionalno zdravlje (Agostoni i sur., 2008). U dobi od šest do 12 mjeseci dojenčad se u prosjeku hrani najmanje pet puta dnevno (Fein i sur., 2008). Tijekom tog razdoblja preporučuje se pridržavanje osnovnih načela uvođenja dohrane: uvođenje jedne nove namirnice u određenom vremenskom razmaku, davanje nove namirnice u kasnijim jutarnjim satima te razmak od triju do četiriju dana između dviju novih namirnica. Takav pristup omogućuje praćenje prihvaćanja hrane i eventualnih neželjenih reakcija. Važna je i emocionalna komponenta hranjenja –

dijete treba biti zdravo, odmorno i u ugodnom okruženju, što povećava vjerojatnost pozitivnog iskustva hranjenja (Niseteo, 2017). Pravilan pristup uvođenju komplementarne prehrane može povoljno utjecati na razvoj prehrambenih navika i smanjiti rizik od kroničnih bolesti poput prekomjerne tjelesne mase i pretilosti, alergijskih bolesti, celijakije i dijabetesa. Važno je naglasiti da dijete često treba višekratno izlaganje novom okusu (8 – 10 puta) prije nego ga prihvati, zbog čega se roditelje potiče na ustrajnost u nuđenju hrane, neovisno o početnim negativnim reakcijama djeteta (Remy i sur., 2013). Tradicionalni oblici uvođenja komplementarne prehrane, poznati kao standardno ili roditeljima predvođeno uvođenje dohrane (PLW), široko su prihvaćeni u znanstvenoj literaturi (Agostoni i sur., 2008). U posljednjih desetak godina sve je popularniji alternativni pristup poznat kao Baby-Led Weaning (BLW), odnosno uvođenje dohrane predvođeno djetetom. Prema definiciji Rapley i sur. BLW uključuje dijete u obiteljske obroke, uz ponudu hrane primjerene dobi, pri čemu dijete samostalno odlučuje što, koliko i kojim tempom jede (Rapley i sur., 2015; Brown i sur., 2017). Hrana se nudi u obliku finger fooda, prilagođenog veličini i sposobnostima dojenčeta. Modificirana verzija tog pristupa, Baby-Led Introduction to Solids (BLISS), razvijena je da bi se smanjili potencijalni rizici BLW-a. Roditelji se educiraju o prevenciji gušenja, osiguravanju adekvatnog unosa željeza i energije te pravilnoj pripremi hrane u izduženim oblicima, uz ponudu izvora željeza, energije i vlakana u svakom obroku (Taylor i sur., 2017). Neka istraživanja upućuju na to da BLW može biti povezan s povoljnijim prehrambenim ponašanjem, uključujući veće uživanje u hrani i manju izbirljivost. Studije koje su uspoređivale BLW i tradicionalno hranjenje žlicom nisu pokazale razlike u tjelesnoj masi, ukupnom energetskom unosu ni unosu makronutrijenata, ali su zabilježene razlike u unosu željeza, masti i natrija, pri čemu je BLW dojenčad imala niži unos željeza iz dojenačkih formula (Alpers i sur., 2019). Druga istraživanja pokazala su veću sklonost povrću i proteinskoj hrani u BLW skupini, bez razlika u izloženosti namirnicama bogatim željezom (Rowan i sur., 2019). Pretpostavlja se da pristupi predvođeni djetetom mogu poticati razvoj finih i grubih motoričkih vještina zbog aktivnog rukovanja hranom i bolje koordinacije pokreta usta i jezika (Carruth i sur., 2002). Međutim, BLW zahtijeva razvijene oralne vještine, a bez odgovarajućeg nadzora roditelja postoji povećan rizik od gušenja. Retrospektivna studija pokazala je znatno veću učestalost aspiracije stranog tijela kod dojenčadi hranjene BLW metodom u usporedbi s tradicionalnom dohranom (Özyüksel i sur., 2019). U Italiji se paralelno razvio pristup poznat kao komplementarna prehrana na zahtjev ili „samoodvikavanje“, koji se razlikuje od BLW-a po tome što dopušta uporabu žličice. Taj pristup temelji se na psihomotoričkoj zrelosti djeteta, pri čemu se prilagođavaju vrijeme, tekstura i količina hrane, a naglasak je na responzivnoj interakciji roditelja i djeteta (Alvisi i sur., 2021). WHO i AAP promiču koncept responzivne komplementarne prehrane (RCF), u kojoj roditelji nude hranu u skladu sa signalima gladi i sitosti djeteta. Suprotno tomu, neresponzivna komplementarna prehrana (NRCF) obilježena je prisilom, ignoriranjem djetetovih signala ili korištenjem hrane kao sredstva nagrađivanja, što može imati nepovoljne posljedice na prehrambeno ponašanje djeteta (Bergamini i sur., 2022). Ako obitelj odabere netradicionalni pristup komplementarnoj prehrani, uloga pedijatra iznimno je važna. Zdravstveni djelatnici trebaju osigurati nutritivno uravnoteženu prehranu, razvojno primjerenu i sigurnu, uz

poseban naglasak na prevenciju nedostatka mikronutrijenata i smanjenje rizika od gušenja.

Alergija na hranu

Razvoj alergije na hranu rezultat je složene interakcije genetskih predispozicija i okolišnih čimbenika, pri čemu okolišni čimbenici imaju značajnu ulogu u porastu prevalencije alergija na hranu. Oni mogu utjecati na razvoj oralne tolerancije izravno ili putem epigenetskih mehanizama (du Toit i sur., 2016). Suvremene smjernice preporučuju početak oralnog izlaganja potencijalnim alergenima od četvrtog mjeseca života, iako optimalni kritični trenutak za uvođenje komplementarne prehrane u svrhu prevencije alergija još uvijek nije jasno definiran (Prescott i sur., 2008). Neki dokazi upućuju na to da uvođenje komplementarne prehrane prije trećeg ili četvrtog mjeseca može povećati rizik od razvoja alergijskih bolesti u kasnijem dojenačkom i dječjem razdoblju (Forsyth i sur., 1993; Zutavern i sur., 2006). U toj dobi crijevna barijera pokazuje povećanu propusnost, a gastrointestinalna mikrobiota još nije u potpunosti uspostavljena, što može doprinijeti većem riziku od alergijskih reakcija. Zbog toga brojne međunarodne smjernice usmjerene na prevenciju alergija preporučuju uvođenje krute hrane, uključujući jaja i kikiriki, nakon navršenog četvrtog mjeseca života (West i sur., 2011; Zutavern i sur., 2008). Istraživanja također su pokazala da odgađanje izlaganja alergenoj hrani ne smanjuje rizik od alergije na hranu ni u djece s pozitivnom obiteljskom anamnezom atopije ni u djece bez takvog rizika (Zutavern i sur., 2008; du Toit i sur., 2008). Trenutačno ne postoje dovoljno snažni dokazi koji bi podupirali hipotezu da rano uvođenje svih potencijalno alergenih namirnica sprječava razvoj alergija na hranu. Iznimku predstavlja kikiriki, čije je rano uvođenje između 4. i 11. mjeseca života pokazalo zaštitni učinak kod dojenčadi s visokim rizikom od razvoja alergije na kikiriki. Kikiriki, jaja, kravlje mlijeko i riba najčešće su analizirane potencijalno alergene namirnice u kontekstu komplementarne prehrane. Više studija pokazalo je da je učinak ranog uvođenja kikirikija specifičan za taj alergen te ne utječe na razvoj drugih alergijskih stanja, poput astme ili atopijskog dermatitisa (du Toit i sur., 2018). Na temelju rezultata LEAP studije (Learning Early About Peanut Allergy) preporučuje se uvođenje kikirikija u prehranu dojenčadi s visokim rizikom između 4. i 11. mjeseca života (Fleischer i sur., 2015). Dodatne smjernice objavio je 2017. godine Nacionalni institut za alergije i zarazne bolesti SAD-a (National Institute of Allergy and Infectious Diseases) (Togias i sur., 2017). Za dojenčad s teškim atopijskim dermatitisom i/ili alergijom na jaja (EA, egg allergy), preporučuje se uvođenje kikirikija u dobi od četiri do šest mjeseci, uz prethodnu procjenu rizika pomoću kožnog ubodnog testa (SPT, skin prick test) ili mjerenja specifičnog imunoglobulina E (sIgE, specific immunoglobulin E). Ako je SPT ≤ 2 mm ili sIgE $< 0{,}35$ kUA/L, kikiriki se može uvesti u kućnim uvjetima. U slučaju SPT-a između 3 i 7 mm ili sIgE $\geq 0{,}35$ kUA/L preporučuje se nadzirani oralni izazov u medicinskom okruženju, dok dojenčad sa SPT ≥ 8 mm ima znatno povećan rizik od alergije na kikiriki i treba je pratiti pedijatrijski alergolog (Gupta i sur., 2020). U studiji HEAP (Hen's Egg Allergy Prevention) (Bellach i sur., 2017) 383 dojenčadi u dobi od četiri do šest mjeseci, bez prethodne senzibilizacije na jaja, nasumično je raspoređeno u skupinu koja je primala liofilizirani bjelanjak ili placebo tri puta tjedno

tijekom šest mjeseci. U dobi od jedne godine IgE-posredovana senzibilizacija na jaja zabilježena je kod 12 dojenčadi, pri čemu nije utvrđena značajna razlika između skupina. Zaključeno je da rana konzumacija jaja ne smanjuje rizik od razvoja alergije na jaja. Slični rezultati dobiveni su i u australskoj studiji STEP (Starting Time of Egg Protein) (Palmer i sur., 2017). Kada dojenje nije moguće ili je neadekvatno, proteini kravljeg mlijeka često se uvode rano putem dojenačkih formula, što je u skladu s preporukama detaljno razmotrenim u izvještaju komisija AAP-a (American Academy of Pediatricset (Institute of Medicine Committee Institute of Medicine Committee on the Evaluation of the Addition of Ingredients New to Infant, 2004). Ipak, AAP i ESPGHAN preporučuju izbjegavanje punomasnog kravljeg mlijeka kao glavnog izvora prehrane prije navršene 12. godine mjeseca života zbog niskog sadržaja željeza i rizika od crijevnih mikrohemoragija (Alvisi i sur., 2021). Brojne opservacijske studije ispitivale su povezanost vremena uvođenja ribe u prehranu dojenčadi s razvojem astme i alergija. U studiji EAT (Enquiring About Tolerance) (Perkin i sur., 2016) rano uvođenje šest alergenih namirnica (kravlje mlijeko, pšenica, sezam, bijela riba, kikiriki i jaja) između trećeg i šestog mjeseca života nije smanjilo rizik od razvoja alergija na hranu u usporedbi sa standardnim uvođenjem nakon šestog mjeseca.

ZAKLJUČAK

Uvođenje komplementarne prehrane ključno je za optimalni rast, razvoj i zdravlje dojenčadi, posebice u razdoblju od šestog do dvanaestog mjeseca života. Pravilno vrijeme uvođenja hrane, oko šestog mjeseca dojenačke dobi, omogućuje sigurno prihvaćanje različitih tekstura i okusa te podržava motorički i senzorno-perceptivni razvoj djeteta. Tijekom tog razdoblja dojenče razvija sposobnost samostalnog hranjenja, koordinaciju pokreta ruku i usta te zanimanje za obiteljske obroke.

Odgovarajući unos makronutrijenata i mikronutrijenata, uključujući proteine, željezo, cink, dugolančane polinezasićene masne kiseline (EPA i DHA) te vitamine D i K, presudan je za rast, razvoj mozga, imunološki sustav i prevenciju mikronutrijentskih deficita. Majčino mlijeko i adaptirana formula više ne zadovoljavaju sve energetske i nutritivne potrebe dojenčeta nakon šestog mjeseca, što čini komplementarnu prehranu nužnom za zadovoljavanje tih zahtjeva.

Metode uvođenja, uključujući standardnu dohranu, predvođenu roditeljem ili djetetom (BLW/BLISS), utječu na prehrambene navike, unos povrća i proteina te osjetljivost djeteta na hranu. BLW pristupi povezani su s većom autonomijom, uživanjem u hrani i boljim razvojem motoričkih sposobnosti, ali zahtijevaju pažljivu roditeljsku kontrolu da bi se smanjio rizik od gušenja. Pravovremeno izlaganje alergenskim namirnicama, poput jaja i kikirikija, može smanjiti rizik od alergija, dok odgađanje uvođenja alergena ne pruža zaštitu.

Neodgovarajuće prakse, uključujući prerano ili kasno uvođenje hrane, nisku nutritivnu vrijednost, lošu higijenu i neodgovarajuće teksture, povezane su s većim rizikom od pothranjenosti, infekcija, poremećaja rasta, mikronutrijentskih deficita, alergija i kroničnih bolesti. Edukacija roditelja, prilagodba hrane dobi i razvoju djeteta te odgovorna primjena preporučenih metoda uvođenja komplementarne prehrane ključne su za osiguravanje optimalnog rasta, razvoja i dugoročnog zdravlja djece.

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DIETETICS AND DIET THERAPY

THE IMPORTANCE OF PROPER NUTRITION IN TERMS OF CARDIOVASCULAR REHABILITATION OUTCOMES

Dorothea Bedeković*

Josip Juraj Strossmayer University of Osijek, Faculty of Dental Medicine and Health Osijek, Crkvena 21, 31 000 Osijek, Croatia
**dbedekovic@fdmz.hr*

review

ABSTRACT

Cardiovascular diseases (CVDs) represent one of the leading public health problems globally, with a significant burden of morbidity, mortality and reduced life's quality. Cardiac rehabilitation (CR) is a key strategy in the secondary prevention of Cardiovascular diseases and includes a multidisciplinary approach that includes physical activity, pharmacological therapy, psychosocial support and less, not least, nutritional interventions. Proper nutrition plays a crucial role in improving the outcome of Cardiac rehabilitation as it enables the optimization of cardiometabolic parameters such as blood pressure, lipid profile, glycemic regulation and body weight. A review of the literature suggests that dietary patterns such as the Mediterranean diet, Dietary Approaches to Stop Hypertension and the Whole Food Plant-Based diet are associated with lower rates of cardiovascular interventions, reduced inflammatory responses and improved endothelial function. Particularly relevant is the intake of essential fatty acids, fiber, antioxidants and reduced consumption of saturated fats, trans fats, refined carbohydrates and ultraprocessed foods. In addition to analyzing the impact of diet on rehabilitation outcomes, this review also considers key challenges in implementing nutritional interventions, including adherence to dietary guidelines, the role of educating patients and the integration of personalized nutritional counselling into clinical practice. To sum up, the available scientific evidence strongly supports the importance of proper nutrition as an integral part of Cardiac rehabilitation. The implementation of structured nutritional strategies in rehabilitation programs can significantly improve long-term cardiovascular interventions, which highlights the need for greater involvement of health proffesionals in this particular area.

Keywords: cardiovascular rehabilitation, DASH diet, Mediterranean diet, nutritional intervention, proper nutrition

INTRODUCTION

Cardiovascular disease (CVD) remains the leading cause of death globally, with ischemic heart disease and stroke being the most prominent forms within this disease group (World Health Organization, 2017). Unfortunately, it looks like that won't change in the near future. Considering the serious health and economic consequences of CVD, it is crucial to focus attention on effective prevention and rehabilitation measures. One of the fundamental aspects of successful rehabilitation of patients with CVD is proper nutrition, which can significantly reduce the risk of re-hospitalization and mortality (Lara-Breitinger et al., 2021).

Proper nutrition in the context of cardiovascular rehabilitation includes a balanced intake of macro- and micronutrients, with a special emphasis on reducing saturated fats, trans-fatty acids, cholesterol and salt, with an increased intake of fiber, antioxidants and unsaturated fatty acids. Such a nutritional approach contributes to improving the lipid profile, regulating blood pressure and reducing inflammatory processes, which are key factors in preventing the progression of CVD (Sacks et al., 2001). Although all this knowledge is very well known and in the general population, it is often not adhered to. Integrating proper nutrition with regular physical activity creates a synergistic effect that can optimize rehabilitation outcomes (Goldsborough et. al, 2022). Regular physical activity stimulates metabolism, increases calorie consumption, and promotes fat burning, while proper nutrition provides the necessary nutrients for muscle growth and recovery after exercise (Šarić et al., 2017).

National programs, such as the "Living Healthy Programme" in the Republic of Croatia, integrate interventions in the areas of proper nutrition and physical activity, synergistically affecting multiple risk factors associated with CVD. These programs emphasize the importance of education and promotion of healthy lifestyle habits in the population (Ministry of Health of the Republic of Croatia, 2024). Bearing in mind the importance of this topic, the aim of this paper is to analyze the scientific evidence on the impact of proper nutrition on the outcomes of cardiovascular rehabilitation and to consider nutritional strategies that contribute to reducing cardiovascular risk.

Psychological and motivational aspects of dietary changes

In addition to the physiological benefits, proper nutrition can also have a significant impact on the psychological state of patients with cardiovascular diseases. Nutritional interventions not only improve physical health, but can also significantly reduce symptoms of depression and anxiety that are often present in people with CVD. The psychological aspects of dietary changes are particularly important because mental health plays a key role in the recovery and rehabilitation of patients (Pepe et. al., 2022). Scientific studies show that patients who adhere to dietary recommendations within the framework of cardiovascular rehabilitation often report improved mood, reduced symptoms of depression and anxiety, and greater motivation to continue therapy (Rahelić et al., 2024). Proper nutrition can help maintain stable energy levels, which improves mental clarity and mood, making patients more positive about their recovery and rehabilitation.

Studies also suggest that dietary changes can have long-term benefits in reducing stress and improving quality of life (Berding et. al., 2023). A diet rich in fruits,

vegetables, whole grains, and healthy fats not only improves physical health, but also helps stabilize emotional states, which may be especially important for patients dealing with chronic health problems such as CVD (Lara-Breitinger et al., 2021). The motivational aspects of dietary changes should also not be overlooked. Setting realistic goals and providing support to patients in maintaining dietary habits can significantly increase the success of rehabilitation. Motivation for dietary changes can be crucial in reducing the risk of recurrent cardiovascular events and improving long-term prognosis (Popiolek-Kalisz et al., 2025).

METHODOLOGY

This review is based on the analysis of relevant scientific studies dealing with the impact of nutritional interventions on the outcomes of cardiovascular rehabilitation (CVR). In order to gather relevant information, a systematic literature search was conducted from the Google Scholar database, PubMed, and other relevant sources available in scientific journals. The search included works published in the last ten years (2013-2023) to ensure that the data is up-to-date. Keywords used in the search included: "cardiovascular rehabilitation", "nutritional interventions", "Mediterranean diet", "DASH diet", "heart health", "dietary patterns", "lipid profile", "blood pressure management", "metabolic effects", and "psychological effects of diet". The selected papers included research dealing with nutrition within the framework of KVR, as well as specific dietary patterns such as the Mediterranean diet and the DASH diet. After the relevant papers were identified, they all went through a selection process, whereby papers that were not based on scientific data or were not directly related to the topic of nutrition and KVR were excluded. Inclusion criteria were: randomized controlled trial studies, cohort studies, meta-analyses, as well as relevant systematic reviews. Each paper was evaluated according to its methodological quality and its relevance to the topic of this review.

Dietary patterns and their impact on cardiovascular health

Dietary habits are a major determinant of cardiovascular risk. Evidence consistently shows that dietary patterns rich in fruits, vegetables, whole grains, legumes, and nuts, combined with limited intake of saturated fats and processed foods, are associated with a lower incidence of cardiovascular disease (Skarupski et al., 2013; Santos, L., 2022.). The Mediterranean and DASH diets are the most extensively studied approaches, both emphasizing plant-based foods, healthy fats, and reduced consumption of red meat and processed products. The Mediterranean diet is linked to a reduced risk of cardiovascular disease through its favorable effects on lipid profiles, blood pressure, and inflammation, while the DASH diet primarily lowers blood pressure and consequently reduces the risk of myocardial infarction and stroke (Skarupski et al., 2013; Estruch et al., 2018). Additional dietary factors, including reduced salt intake and higher fiber consumption, contribute to lower blood pressure and LDL cholesterol levels (Hodson and Cooper, 2013; Brown et al., 1999). Long-term adherence to these dietary strategies has been shown to decrease the occurrence of major cardiovascular events, including myocardial infarction and stroke (Estruch et al., 2018). The effectiveness of nutritional interventions largely depends on

sustainability, patient education, and individualized recommendations, which improve adherence and enhance rehabilitation outcomes (Popiolek-Kalisz et al., 2025).

Mediterranean diet

The Mediterranean diet is based on traditional dietary practices of Mediterranean regions and is characterized by high consumption of plant-based foods and olive oil as the main fat source, moderate intake of fish and poultry, and limited consumption of red meat and dairy products (Estruch et al., 2018). Olive oil, rich in monounsaturated fatty acids and polyphenols, exerts anti-inflammatory and antioxidant effects, contributing to improved vascular function, lower LDL cholesterol, and reduced blood pressure (Simopoulos, 2016). This dietary pattern reduces oxidative stress and inflammation, which are key mechanisms in the development of atherosclerosis and other cardiovascular diseases (Ros, 2010; Kiani et. al., 2022). Large-scale and long-term studies demonstrate that adherence to the Mediterranean diet significantly lowers cardiovascular morbidity and mortality and reduces the incidence of myocardial infarction and stroke (Estruch et al., 2018; Sofi et al., 2010). In addition, its favorable effects on body weight regulation further contribute to cardiovascular risk reduction. Beyond prevention, the Mediterranean diet is also applied in cardiovascular rehabilitation, where it supports recovery, reduces rehospitalization, and improves quality of life (Estruch et al., 2018).

The DASH diet

The DASH diet (Dietary Approaches to Stop Hypertension) was specifically designed to reduce blood pressure and is characterized by high intake of fruits, vegetables, low-fat dairy products, whole grains, and lean protein sources, along with restricted consumption of salt, saturated fats, alcohol, and refined sugars (Sacks et al., 2001; Theodoridis et. al., 2023). Clinical studies show that this dietary pattern produces a significant reduction in systolic blood pressure, which translates into a lower long-term risk of cardiovascular and renal diseases (Sacks et al., 2001; Appel et al., 2011). In addition to its antihypertensive effects, the DASH diet improves lipid profiles, lowers LDL cholesterol levels, and enhances glucose tolerance, making it beneficial for individuals with hypertension and type 2 diabetes (Sacks et al., 2001). Increased intake of calcium, potassium, and magnesium further supports normal cardiovascular function (Appel et al., 2011). The DASH diet is therefore used not only for prevention but also in cardiovascular rehabilitation, where individualized dietary plans help reduce recurrence risk and improve patient outcomes.

The role of proper nutrition in cardiovascular rehabilitation

Nutritional interventions are a core component of cardiovascular rehabilitation, complementing physical activity, pharmacological therapy, and psychosocial support. The primary objectives include improvement of lipid profiles, regulation of blood pressure, weight management, reduction of inflammation, and enhancement of insulin sensitivity (Popiolek-Kalisz et al., 2025). Dietary approaches that limit saturated and

trans fats while increasing unsaturated fats effectively reduce LDL cholesterol levels (Estruch et al., 2018; Sacks et al., 2001). Blood pressure control is further supported by reduced sodium intake, which lowers both systolic and diastolic blood pressure and decreases the risk of myocardial infarction and stroke (Appel et al., 2011). Weight management through calorie control and increased fiber intake is essential, as excess body weight is strongly associated with hypertension, dyslipidemia, and type 2 diabetes (Lara-Breitinger et al., 2021). Individualized nutritional planning, tailored to patient-specific characteristics and comorbidities, improves adherence and leads to sustained health benefits (Popiolek-Kalisz et al., 2025). Proper nutrition also contributes to improved psychological well-being, which positively influences long-term rehabilitation success.

Metabolic effects of proper nutrition

Proper nutrition significantly modifies metabolic processes that influence cardiovascular health. Dietary interventions can reduce LDL cholesterol, enhance insulin sensitivity, and lower systemic inflammation, all of which are central to cardiovascular disease pathogenesis (Bazzano et al., 2008). High-fiber dietary patterns are particularly effective in lowering LDL cholesterol and slowing atherosclerotic progression (Estruch et al., 2018). Improved insulin sensitivity through increased consumption of whole grains, vegetables, and fiber is especially important in individuals with insulin resistance or type 2 diabetes, conditions that substantially elevate cardiovascular risk (Bazzano et al., 2008). Diets rich in antioxidants and omega-3 fatty acids reduce inflammatory markers and are associated with a lower risk of major cardiovascular events, including myocardial infarction and stroke (Estruch et al., 2018).

RESULTS AND DISCUSSION

The findings of this literature review indicate that nutritional interventions play a meaningful role in cardiovascular rehabilitation; however, a closer examination of the evidence reveals important methodological considerations that temper the strength of these conclusions. Although the Mediterranean and DASH diets are consistently identified as beneficial dietary strategies for patients with cardiovascular disease, the reported magnitude of their effects varies considerably across studies. This variability reflects differences in study design, participant characteristics, duration of intervention, and outcome assessment methods, all of which influence the interpretation and generalizability of results.

The Mediterranean diet is most frequently associated with reductions in recurrent cardiovascular events, including myocardial infarction and stroke, and is often presented as a benchmark dietary pattern for secondary prevention (Estruch et al., 2018; Sofi et al., 2010). Reported risk reductions of approximately 30% are clinically compelling; nevertheless, these estimates are largely derived from studies conducted under highly controlled conditions, characterized by intensive dietary counseling, frequent follow-up, and high participant engagement. Such conditions may overestimate the effectiveness of the intervention when compared with routine clinical practice, where adherence tends to decline over time (Lara-Breitinger et al., 2021).

Furthermore, the lack of a standardized definition of the Mediterranean diet across studies introduces substantial heterogeneity, complicating direct comparisons and limiting reproducibility.

From a mechanistic standpoint, improvements in lipid profiles, blood pressure regulation, and inflammatory status provide a biologically plausible explanation for the cardiovascular benefits associated with the Mediterranean diet (Estruch et al., 2018; Ros, 2010). However, not all studies demonstrate consistent improvements across these parameters. Some report only modest or statistically non-significant changes in LDL cholesterol or blood pressure, particularly among patients with advanced disease, polypharmacy, or multiple comorbidities (Banjari et al., 2013). These findings suggest that dietary interventions may exert their greatest benefit as part of a comprehensive rehabilitation strategy rather than as isolated therapeutic measures.

The psychological effects of dietary modification represent an important yet methodologically underdeveloped area of research. Several studies describe associations between healthier dietary patterns and reductions in symptoms of depression, anxiety, and psychological distress among patients undergoing cardiovascular rehabilitation (Skarupski et al., 2013; Popiolek-Kalisz et al., 2025). However, much of this evidence is derived from observational designs, limiting causal inference. In addition, psychological outcomes are often secondary endpoints and are assessed using heterogeneous or non-standardized instruments. Confounding factors such as increased social interaction, improved physical activity levels, and greater engagement with rehabilitation programs are rarely adequately controlled, making it difficult to isolate the independent contribution of nutrition to mental health outcomes.

Evidence supporting the DASH diet is strongest in the context of blood pressure reduction, with consistent and clinically meaningful decreases in systolic blood pressure reported across randomized controlled trials (Sacks et al., 2001; Appel et al., 2011). This consistency enhances confidence in its role as an effective dietary intervention for patients with hypertension. In contrast, evidence for its broader cardiovascular benefits, including effects on lipid metabolism, glycemic control, and long-term cardiovascular outcomes, is less robust and more variable. Many studies examining these outcomes are limited by short intervention periods, small sample sizes, or secondary analyses not powered to detect hard clinical endpoints.

A recurrent methodological limitation across the literature is the reliance on self-reported dietary intake, which is inherently susceptible to recall bias and social desirability bias. Objective measures of dietary adherence are rarely employed, and few studies incorporate biomarkers to validate reported intake. Additionally, adherence is often treated as a static variable, despite evidence that compliance with dietary recommendations fluctuates over time. This limitation is particularly relevant in cardiovascular rehabilitation, where sustained lifestyle modification is essential for long-term risk reduction.

Another important methodological concern relates to confounding and co-intervention effects. Many studies do not adequately adjust for concurrent pharmacological therapy, physical activity, smoking cessation, or psychosocial interventions, all of which independently influence cardiovascular outcomes. As a result, disentangling the specific contribution of nutritional interventions from other

components of rehabilitation remains challenging. This issue is further compounded by heterogeneity in baseline cardiovascular risk, medication regimens, and metabolic status among study participants.

Long-term outcomes represent a notable gap in the current evidence base. While short-term improvements in cardiometabolic markers are consistently reported, relatively few studies extend follow-up beyond one year. Consequently, evidence regarding the durability of dietary effects, their impact on rehospitalization rates, mortality, and sustained quality-of-life improvements remains limited (Lara-Breitinger et al., 2021). High attrition rates in longer studies further weaken confidence in long-term conclusions.

Implementation-related factors also merit critical attention. Despite strong evidence supporting nutritional interventions, their integration into routine cardiovascular rehabilitation remains inconsistent. Limited availability of specialized nutrition professionals, time constraints within rehabilitation programs, and insufficient emphasis on structured dietary education reduce the real-world effectiveness of dietary strategies (Popiolek-Kalisz et al., 2025). Moreover, many studies prioritize efficacy under controlled research conditions rather than effectiveness in everyday clinical settings, limiting translational applicability.

Finally, the generalizability of current findings is constrained by the underrepresentation of specific patient subgroups. Older adults, women, individuals from diverse ethnic backgrounds, and patients with complex multimorbidity are often inadequately represented. Given that nutritional needs, cultural dietary practices, and physiological responses may differ substantially across these groups, the lack of subgroup-specific analyses represents a significant gap in the literature.

The interpretation of findings in this review is limited by the heterogeneity of study designs, dietary definitions, and outcome measures across the included literature. Many studies rely on self-reported dietary data and short follow-up periods, limiting the assessment of long-term adherence and sustained clinical outcomes. In addition, insufficient control for confounding lifestyle and pharmacological factors restricts the ability to attribute observed benefits exclusively to nutritional interventions. The underrepresentation of diverse patient populations further limits the generalizability of findings and underscores the need for more inclusive and methodologically rigorous research.

CONCLUSION

Proper nutrition represents a fundamental pillar of cardiovascular rehabilitation and plays a decisive role in improving cardiometabolic health, supporting psychological well-being, and reducing the risk of recurrent cardiovascular events. The evidence reviewed in this paper confirms that structured dietary strategies, particularly those based on established dietary patterns, can meaningfully contribute to secondary prevention when integrated into comprehensive rehabilitation programs. However, despite the overall positive findings, current evidence is constrained by methodological heterogeneity, limited long-term follow-up, and insufficient attention to real-world implementation and individual patient differences. These limitations underscore the need for future research that prioritizes personalized nutritional

approaches, long-term adherence, and the interaction between dietary interventions and other components of cardiovascular rehabilitation. To enhance clinical impact, nutritional interventions must be supported by systematic patient education, multidisciplinary collaboration, and sustained follow-up. Strengthening the role of nutrition within rehabilitation programs and addressing barriers to adherence are essential for translating scientific evidence into lasting health benefits. Continued research and refinement of nutritional strategies will be crucial for developing more effective, individualized, and sustainable approaches to cardiovascular rehabilitation and for reducing the long-term burden of cardiovascular disease.

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CRIJEVNA MIKROBIOTA – NAŠ DRUGI OTISAK PRSTA: PRIKAZ SLUČAJA

GUT MICROBIOTA – OUR SECOND FINGERPRINT: CASE REPORT

Dražen Sitaš[1*], Katarina Fehir Šola[2,3]

[1]Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno-tehnološki fakultet Osijek, Franje Kuhača 18, 31 000 Osijek, Hrvatska
[2]ZU Ljekarna Bjelovar, Petra Preradovića 4, 43 000 Bjelovar, Hrvatska
[2]Sveučilište Josipa Jurja Strossmayera u Osijeku, Medicinski fakultet Osijek, Josipa Huttera 4, 31 000 Osijek, Hrvatska
[*]dsitas@ptfos.hr

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SAŽETAK

Ljudski gastrointestinalni trakt sadrži složenu i dinamičnu populaciju mikroorganizama zajednički poznatih pod nazivom crijevna mikrobiota. Crijevne bakterije igraju ključnu ulogu u održavanju imunološke i metaboličke homeostaze te zaštiti od patogena. Ovaj rad s prikazom slučaja usredotočuje se na profil crijevnog mikrobioma zdrave osobe dajući pregled mikrobnog sastava. Rad prikazuje interpretativne uvide u različite parametre, od raznovrsnosti do funkcionalnosti mikrobiote te sastava mikrobioma i preporuka za optimizaciju zdravlja crijevnog mikrobioma. Među višečimbeničnim odrednicama koje oblikuju sastav ljudske crijevne mikrobiote tijekom života prehrana se prepoznaje kao glavni modulator, kao i svakodnevna tjelesna aktivnost. Način uzorkovanja uzorka za analizu vrlo je jednostavan i neinvazivan. Kućni test dolazi na adresu ispitanika i, nakon što se uzme uzorak fecesa, vraća se dostavom u laboratorij na analizu. Metoda za analizu jest sekvenciranje 16s rRNA amplikona. Osim uzorka fecesa praćeno je još nekoliko parametra. Prikupljeni su uzorci venske krvi na početku i na kraju intervencije da bi se procijenila sistemska upala, metabolički status i razine mikronutrijenata, uključujući C-reaktivni protein (*CRP*), kompletnu krvnu sliku (*KKS*), serumski vitamin B_{12}, glukozu natašte i lipidni profil (ukupni kolesterol, LDL, HDL i trigliceridi).
Prvo testiranje napravljeno je u listopadu 2023.godine i pokazalo je umjeren rezultat zdravlja crijeva (60/100) te nisku bakterijsku raznolikost (46 %). Nakon tri mjeseca, i provedenih prehrambenih intervencija te svakodnevne tjelovježbe u trajanju od 30 minuta, analiza je pokazala značajno poboljšanje. Ukupni rezultat općeg stanja crijevne mikrobiote porastao je na (85/100), a raznolikost se povećala na (73 %). Međutim, proizvodnja vitamina B_{12} izostala je u obama slučajevima. Ti nalazi naglašavaju dinamičnu reakciju crijevne mikrobiote na čimbenike načina života i ističu važnost kontinuiranog praćenja da bi se uvodile personalizirane prehrambene intervencije i održavala fizička aktivnost usmjerena na obnavljanje i održavanje mikrobne homeostaze.

Ključne riječi: crijevna mikrobiota, analiza crijevne mikrobiote, mikroorganizmi, prehrana, fizička aktivnost

Keywords: gut microbiom, analysis gut microbiom, microorganisms, diets, physical activity

UVOD

Ljudski gastrointestinalni (GI) trakt predstavlja jednu od najvećih površina (250 – 400 m^2) između domaćina, čimbenika okoliša i antigena u ljudskom tijelu. Tijekom prosječnog životnog vijeka oko 60 tona hrane prođe kroz ljudski GI trakt, uz obilje mikroorganizama iz okoliša koji predstavljaju veliku prijetnju integritetu crijeva (Thursby i Juge, 2017). Ljudski crijevni mikrobiom velika je i složena mikrobna zajednica. Ukupno je identificirano preko 1000 bakterijskih vrsta od kojih mnoge ostaju nekultivirane, oko 160 vrsta nalazi se u crijevima bilo koje osobe. Procjenjuje se da je skup gena crijevnog mikrobiota (crijevnog mikrobioma) oko 3 milijuna gena – 150 puta veći od onog u ljudskom genomu (Rowland i sur., 2018). Crijevna mikrobiota zajednica je bakterija, arheja, virusa i eukariota koji koloniziraju probavni trakt (Palmas i sur., 2021). Crijevna mikrobiota sastoji se prije svega od šest glavnih koljena, uključujući *Firmicutes, Bacteroidetes, Actinobacteria, Proteobacteria, Fusobacteria i Verrucomicrobia* (Stojanov i sur, 2020). Promijenjeni sastav crijevnih bakterija (disbioza) povezan je s patogenezom mnogih upalnih bolesti i infekcija (Butel, 2014). Crijevna mikrobiota igra važnu ulogu u apsorpciji hranjivih tvari i minerala, sintezi enzima, vitamina i aminokiselina te proizvodnji kratkolančanih masnih kiselina. Nusprodukti fermentacije, acetat, propionat i butirat, važni su za zdravlje crijeva i osiguravaju energiju za epitelne stanice. Poboljšavaju integritet epitelne barijere te pružaju imunomodulaciju i zaštitu od patogena. Na sastav crijevne mikrobiote može utjecati nekoliko čimbenika, i to nutritivni, imunološki i kemijski gradijenti duž probavnog sustava (Ma, Lee, 2025). Osim toga, ostali čimbenici jesu način rođenja (vaginalni ili carski rez), genetika, prehrana, životni stil, starosna dob, lijekovi i geografska lokacija. Rezultat narušene eubioze povećani je rizik za upalne bolesti i narušavanje imunološkog sustava. Gubitak korisnih mikroorganizama i prerastanje štetnih bakterija može se povezati s razvojem upalnih bolesti crijeva, sindroma iritabilnog crijeva, dijabetesa, debljine, neurodegenerativnih bolesti, kardiovaskularnih i drugih bolesti (Butel, 2014). Posljednjih godina, brzim razvojem molekularne biologije, genomike i tehnologije bioinformatičke analize, istraživanje crijevne mikrobiote brzo je napredovalo (Chen i sur., 2021). U radu će biti riječi o funkcijama crijevne mikrobiote, utjecaju prehrane i tjelesne aktivnosti kao poznatih dobrobiti za mikrobiom te o analizi jednog crijevnog mikrobioma kroz prikaz slučaja.

RASPRAVA

Sastav crijevne mikrobiote

Razvoj crijevnog mikrobioma može započeti prije rođenja jer je fetus vjerojatno izložen mikrobnim metabolitima majke (Bradley i Haran, 2024). Nakon rođenja probavni trakt kolonizira se brzo, a životni događaji, poput bolesti, liječenja

antibioticima i promjena u prehrani, uzrokuju kaotične promjene u mikrobioti (Thursby i Juge, 2017). Na uspostavljanje mikrobiota novorođenčeta utječu mnogi čimbenici, uključujući zdravlje majke, način poroda (vaginalni ili carski rez) i navike hranjenja dojenčadi (dojenje u odnosu na hranjenje adaptiranim mlijekom) (Dalamaga i Tsigalou, 2024). Kada je riječ o distribuciji vrsta mikroorganizama u crijevnoj mikrobioti, u zreloj i stabilnoj mikrobioti u najvećoj mjeri zastupljene su anaerobne bakterije koje se nalaze u tankom crijevu, debelom crijevu i slijepom crijevu (Kumar i sur., 2025). U bakterijskoj taksonomiji najčešće korišteni rangovi u uzlaznom redoslijedu su vrsta, rod, porodica, red, klasa i koljeno.
U ranim fazama razvoja mikrobiota, općenito, niske je raznolikosti i dominiraju dva glavna koljena, *Actinobacteria* i *Proteobacteria* (Thursby, Juge, 2017). *Bacteroidetes i Firmicutes* čine 90 % crijevne mikrobiote koja je najzastupljenija u zdravom crijevu (Thursby, Juge, 2017). Rodovi *Bacteroidetes* uključuju *Prevotella* i *Bacteroides*. Koljeno *Firmicutes* sastoji se od > 200 rodova, uključujući *Bacillus*, *Lactobacillus*, *Ruminococcus*, *Enterococcus* i *Clostridium.* Manje brojni taksoni uključuju *Bifidobacterium*, *Akkermansia* i *Escherichia*. Otprilike 90 % svih filotipova crijevnih bakterija pripada ili gram-pozitivnima *Firmicutes* (64 %) ili gram-negativnima *Bacteroidetes* (23 %) (Cunningham i sur. 2021). Na sastav crijevne mikrobiote može utjecati nekoliko čimbenika: prehrana, stres, trening, geografska lokacija stanovanja, lijekovi, starenje (Cresci, 2015). Taj raznoliki i dinamični mikrobiom razvija se do rane odrasle dobi, a zatim postaje relativno stabilan kada počinje pokazivati pad raznolikosti nakon vrhunca koji dostiže kasno u životu (oko 65. godine) i postaje sve izraženiji kod osoba starijih od 80 godina (Bradlay i Haran, 2024). Mikrobna raznolikost povezana je s metaboličkom funkcijom crijevne mikrobiote, a nisko bakterijsko bogatstvo čimbenik je rizika za pretilost i blagu upalu (Cunningham i sur., 2021).

Funkcija crijevnog mikrobioma

Kada je riječ o funkcionalnosti, crijevni mikrobiom proizvodi mnoštvo bioaktivnih tvari koje imaju različite ulogu u organizmu (Tablica 1). Acetat, najzastupljenija kratkolančana masna kiselina, proizvodi crijevne bakterije iz rodova *Lactobacillus*, *Bifidobacterium*, *Akkermansia*, *Bacteroidea*, *Prevotella*, *Ruminococcus*, *Streptococcus* (Cunningham i sur., 2021). Kratkolančane masne kiseline (SCFA) igraju ključnu ulogu u zdravlju i bolestima jer reguliraju homeostazu crijeva. Njihov nedostatak uključen je u patogenezu nekoliko poremećaja, uključujući upalne bolesti crijeva, kolorektalni karcinom i kardiometaboličke poremećaje (Fusco i sur., 2023). Acetat se lako apsorbira, transportira u jetru gdje se koristi kao izvor energije, a koristi se i kao supstrat za sintezu kolesterola i dugolančanih masnih kiselina (Fouhy, 2019). Butirat ima posebnu važnost u homeostazi domaćina i može doprinijeti regulaciji tjelesne težine. Rodovi *Anaerostipes*, *Clostridium*, *Coprococcus*, *Dorea*, *Eubacterium*, *Faecalibacterium*, *Roseburia i Ruminococcus* proizvode butirat. Propionat uglavnom proizvode rodovi *Phascolarctobacterium*, *Bacteroides*, *Dialister*, *Megasphaera*, *Veillonella*, *Coprococcus*, *Roseburia*, *Ruminococcus i Salmonella* (Cunningham i sur., 2021). Vitamin K proizvodi crijevna mikrobiota, uglavnom u ileumu, i apsorbira se iz crijeva. Vitamin K, koji sintetizira crijevna

mikrobiota, veže se na R faktor u želucu, prenosi se na intrinzični faktor u tankom crijevu i apsorbira se u terminalnom ileumu (Ma, Lee, 2025).

Tablica 1. Ključne funkcije mikrobiote (Ma i Lee, 2025)
Table 1. *Key functions of the microbiota (Ma and Lee, 2025)*

Funkcije	Opis	Primjeri
Metaboličke funkcije	Razgradnja složenih ugljikohidrata i dijetalnih vlakana u kratko-lančane masne kiseline	Proizvodnja acetata, propionata i butirata za energiju i metaboličku regulaciju
Sinteza hranjivih tvari	Biosinteza esencijalnih hranjivih tvari	Sinteza vitamina K I B skupine (npr $B_{12)}$
Modulacija imunološkog sustava	Regulacija imunološkog odgovora i održavanje imunološke tolerancije	Interakcija s regulatornim T stanicama za smanjenje upale Potiče protuupalne putove
Obrana od patogena	Kompetitivno isključivanje patogena i proizvodnja antimikrobnih spojeva	Proizvodnja bakteriocina, inhibicija *Clostridiodes difficile*

Ako dođe do narušavanja homeostaze mikrobiote te prevladaju loše bakterije nad dobrim bakterijama, dolazi do disbioze. Crijevna propusnost definirana je kao neposredan prolaz kroz crijevni epitel hidrofilnih molekula srednje veličine koji se događa niz gradijent koncentracije (Aleman i sur., 2023). Neravnoteža crijevne mikrobiote znak je disbioze, omjer *Firmicutes/Bacteroidetes* predložen je kao njezin marker, posebice u kontekstu pretilosti (Karačić i sur., 2024). Studija Magnea i sur. (2020.) imala je za cilj raspraviti valjanost omjera *Firmicutes/Bacteroidetes* (omjer F/B) kao relevantnog markera crijevne disbioze kod pretilih pacijenata. Kontradiktorni rezultati i metodološke razlike u obradi uzoraka i sekvenciranju DNK-a, loša karakterizacija ispitanika i nedostatak razmatranja čimbenika te načina života ispitanika mogu biti razlog za odstupanje rezultata. Člankom se zaključilo teško povezivanje omjera F/B-a sa specifičnim zdravstvenim stanjem ili da se taj omjer može smatrati markerom pretilosti osporavajući ideju da je visoki omjer F/B-a univerzalni znak pretilosti (Magne i sur., 2020).

Utjecaj prehrane na crijevnu mikrobiotu

Prehrana je jedan od najopsežnije proučavanih čimbenika i smatra ju se odgovornom za > 20 % strukturnih varijacija mikroba, što ukazuje na potencijal prehrambenih intervencija u liječenju bolesti moduliranjem crijevne mikrobiote (Ma, Lee, 2025). Osim toga, navodi se da prehrambeni obrasci odgovaraju mikrobnom sastavu. Uobičajeni prehrambeni obrasci bogati mahunarkama, cjelovitim žitaricama, ribom i orašastim plodovima, voćem i povrćem povezani su sa smanjenom količinom oportunističkih bakterijskih nakupina (Ma, Lee, 2025). Prehrana koja uključuje konzumaciju životinjskih proteina i masti povezana je s enterotipom kojim dominiraju *Bacteroides*, dok je prehrana bogata ugljikohidratima povezana s enterotipom kojim dominira *Prevotella* (Merra i s98/ur., 2020). Mediteranska prehrana modulira i utječe na raznolikost i omjer pojednih bakterija. Mediteransku prehranu karakterizira velika

količina dijetalnih vlakana, a također i polifenola koji imaju prebiotičko djelovanje na određene sojeve (Merra i sur., 2020). Više od dva makronutrijenta može se pronaći u jednoj prehrani, što mijenja crijevnu mikrobiotu i istovremeno mijenja metabolički učinak. Pozitivne koristi dijetalnih vlakana na ljudski metabolizam istražene su i utvrđeno je da su značajne. Pokazalo se da dijetalna vlakna mijenjaju mikrobiotu i proizvode korisne metabolite poput butirata (Afzaal i sur., 2022).

Utjecaj tjelesne aktivnosti na crijevnu mikrobiotu

Promjene načina života i dalje su najčešće korištene i preporučene strategije za postizanje smanjenja težine kod pretilosti, posebice korištenjem različitih prehrambenih strategija i poticanjem tjelesne aktivnosti i vježbanja (Argon-Vela, 2021). Tjelesna aktivnost mogla bi biti probni tretman za postizanje različitih djelovanja na specifičnim razinama. Mijenjajući sastav mikrobiote i aktivirajući specifične proteine te potičući oslobađanje kratkolančanih masnih kiselina (Argon-Vela, 2021), WHO je tjelesnu neaktivnost rangirao kao četvrti glavni element rizika za globalnu smrtnost. Nasuprot tomu, redovita i adekvatna razina tjelesne aktivnosti smanjuje stopu smrtnosti uzrokovanu nekim kroničnim bolestima. Na primjer, tjelesna aktivnost koristi prevenciji nekoliko poremećaja povezanih s pretilošću, poput dislipidemije, inzulinske rezistencije i hipertenzije (Argon-Vela, 2021). Sve više je znanja o učincima vježbanja na mikrobiotu, ali potrebna su daljnja istraživanja mehanizama u vezi s fiziološkom komunikacijom između crijeva i mišića prije nego što se u potpunosti mogu razumjeti interakcije među njima. U tom području potrebne su studije intervencije vježbanjem da bi se procijenio terapijski potencijal vježbanja u kontekstu crijevne mikrobiote (Min i sur., 2024).

Crijevna mikrobiota: prikaz slučaja

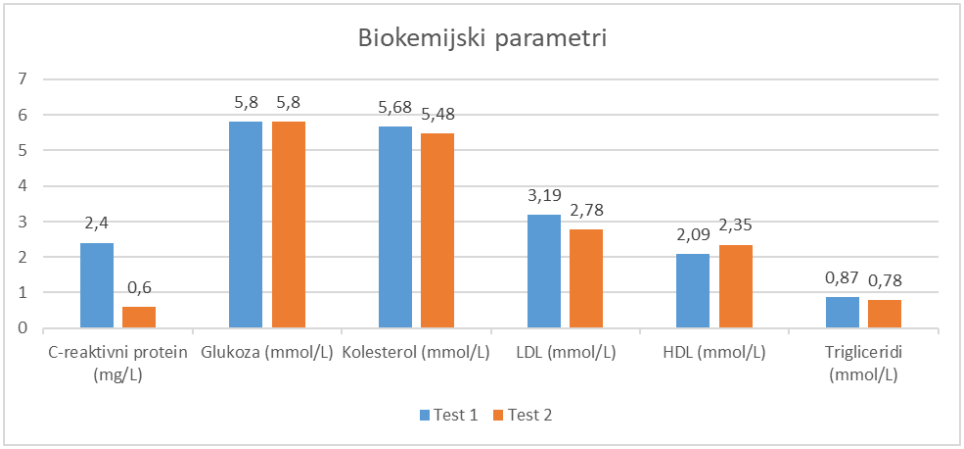
Različiti rezultati koji su prethodno objavljeni mogu se objasniti i razlikama u obradi uzoraka i analizi podataka, uključujući metodu ekstrakcije DNA, odabir amplificirane 16S rRNA regije (izbor primjera), metodu sekvenciranja i bioinformatičku analizu (korištena baza podataka taksonomije i algoritam za dodjeljivanje taksonomije) (Vaiserman i sur., 2021).
Za prikaz slučaja korišten je uzorak fecesa ženske osobe starosti 50 godina, bez komorbiditeta, nepušač. Rezultat analize crijevnog mikrobioma baziran je na algoritmu tvrtke BIOMES koji koristi najvažnije taksonomske i funkcionalne odrednice crijevnog mikrobioma. Prikupljanje uzoraka fecesa jednostavno je i neinvazivno. Kućni test dolazi na adresu ispitanika i nakon uzimanja uzorka fecesa, vraća se dostavom u laboratorij BIOMES NGS GmbH, Schwartzkopff str1.15745 Wildau, Njemačka. Metoda korištena za analizu jest sekvenciranje 16s rRNA amplikona, koja je specifična te identificira bakterije prema jedinstvenom njihovom otisku 16S rRNA gena.
Prvo testiranje provedeno je u listopadu 2023 godine, a nakon izvršene analize ispitanici je uručen sveobuhvatni nalaz koji je na hrvatskom i engleskom jeziku. Nalaz, osim sastava crijevnog mikrobioma, sadrži još nekoliko parametara koji daju detaljniji prikaz, kao i preporuke za optimizaciju mikrobioma. Nalaz je prikazao umjeren rezultat zdravlja crijeva (60/100), nisku bakterijsku raznolikost (46 %) i

nedostatne markere povezane s kratkolančanim masnim kiselinama. Na razini koljena vidljiva je minimalna dominacija koljena *Firmicutes* nad *Bacteroidetes*, što ukazuje na relativnu uravnoteženost crijevnog mikrobioma. Nakon testa 1 izdvojeno je deset rodova bakterija (Tablica 2.) koje najbolje prikazuju sveukupni sastav mikrobiote.

Tablica 2. Sastav crijevnog mikrobioma – test 1
Table 2. *Composition of the gut microbiome – test 1*

Akkermansia Ova vrsta se hrani namirnicama bogatim fenolima I sluzi domaćina, te ima protupalno djelovanje	–	*Roseburia* Ova vrsta hrani se uglavnom škrobom I šećerima. Djeluje preventivno zbog regulacije imunosnog sustava zbog proizvodnje butirata	+
Prevotella Ovaj rod bakterija se hrani kompleksnim ugljikohidratima	–	*Bifidobacterium* Ova vrsta se povezuje s mješovitom prehranom bogatom mliječnim namirnicama I unosom određenih vrsta vlakana	+
Bacteriodes Ovaj rod bakterija proizvodi kratko-lančane masne kiseline i povezan je s konzumacijom proteina (biljnih, životinjskih) i vlakana	–	*Ruminococcus* Ova vrsta sudjeluje u razgradnji kompleksnih polisaharida, a hrani se uglavnom ugljikohidratima. Biomarker je prehrane bogate žitaricama	+
Parabacteriodes Ovaj rod ima protupalno djelovanje. Povezuje se s ketogenom prehranom i unosom proteina te rezistentnog škroba	–	*Dorea* Ova vrsta povezuje se s prehranom bogatom životinjskim mastima I nezasićenim masnim kiselinama. Ima ključnu ulogu u regulaciji metabolizma	+
Lacctobacillus Unosi se fermentiranom hranom, posjeduje protuupalno djelovanje I ključan factor za zdravlje	–	*Escherichia* Potencijalno patogen rod, povezan s konzumacijom zapadnjačke procesuirane prehrane	+
*** - smanjena prisutnost**		***+ uvećana prisutnost**	

Na razini rodova vidljiva je dominacija saharolitičkih bakterija, dok su snižene razine protuupalnih bakterija iz roda *Akkermansia.* Također su snižene i razine bakterija povezanih s tjelesnom aktivnošću, a to upućuje na nedovoljnu fizičku aktivnost. Na razini proizvodnje bioaktivnih tvari jedino je povećana proizvodnja metana, koji nastaje uslijed stresa i konzumacije hrane bogate rafiniranim ugljikohidratima. Osim analize fecesa prikupljeni su uzorci venske krvi na početku i na kraju intervencije da bi se procijenila sistemska upala, metabolički status i razine mikronutrijenata, uključujući C-reaktivni protein, kompletnu krvnu sliku, serumski vitamin B_{12}, glukozu natašte i lipidni profil (ukupni kolesterol, LDL, HDL i trigliceridi) (Slika 1). Tu je također došlo do pozitivnih promjena biokemijskih parametara koji prikazuju utjecaj prehrambenih intervencija i tjelesne aktivnosti.



Slika 1. Biokemijski parametri
Figure 1. *Biochemical parameters*

Nakon temeljite analize rezultata testa 1, ispitanica je dobila jasne upute za promjenu prehrambenih navika i uvođenje redovite tjelesne aktivnosti. Što se tiče preporuke za prehranu, uvedena je visokoproteinska prehrana, 2 g/kg tjelesne mase dnevno, smanjiti unos ugljikohidrata na manje od 100 g dnevno. Izbjegavati nezasićene masti i rafinirane ugljikohidrate. Uvedena je svakodnevna tjelesna aktivnost u trajanju od minimalno 30 minuta. Cilj je podizanje pulsa i znojenje te poraditi na kvaliteti sna. Nakon tri mjeseca ponovljeno je testiranje. Rezultati su pokazali značajno poboljšanje: ukupni rezultat općeg stanja crijevnog mikrobioma porastao je na (85/100), raznolikost se povećala na 73 %, a markeri upale dosegli su optimalne razine (100 %), kao i kardiovaskularna kondicija koja je dosegnula razinu 100 %. Regulacija apetita i kolesterola također su se značajno poboljšali (s 57 % na 86 %), a funkcija mukozne barijere promijenila se (sa 71 % na 43 %) s obzirom na to da rezultati testa 1 i testa 2 prikazuju različite vrste bakterija. Dok je proizvodnja vitamina B_{12} izostala u obama testovima.

Na razini rodova vidljiva je je dominacija lipolitičkih bakterija, snižene su razine protuupalnih bakterija *Lactobacillus.* Rod *Prevotella* povećan je s 1 % na 2 %, *Bacteroides* sa 16 % na 28 %, a *Parabacteroides* s 2 % na 37 %. Povećana je razina bakterija povezanih s tjelesnom aktivnošću, što upućuje na dostatnu fizičku aktivnost. Proizvodnja metana ostala je i dalje povećana te bi se mogla primjenom probiotika određenog soja bakterija povećati zastupljenost dobrih bakterija s obzirom na visoke udjele metanogenih arheja. Za nastavak optimizacije crijevnog mikrobioma preporučene su detaljne upute da bi se zadržala postojeća eubioza.

ZAKLJUČAK

Mikrobiota, tjelovježba i prehrambene navike imaju složen odnos. Sukladno tomu, obavezno je procijeniti mogući utjecaj tjelovježbe, specifičnih dijeta, hrane i hranjivih tvari na mikrobnu raznolikost u crijevima. Ti nalazi naglašavaju dinamičnu reakciju crijevne mikrobiote na čimbenike načina života i ističu važnost sustavnog praćenja da bi se vodile personalizirane prehrambene i probiotičke intervencije usmjerene na

obnavljanje i održavanje mikrobne homeostaze. Osim toga, prehrambene intervencije (npr. prehrana s niskim udjelom ugljikohidrata i mediteranska prehrana) i redovita tjelovježba mogu dodatno poboljšati raznolikost i funkcionalnost crijevne mikrobiote, čime pomažu u vraćanju zdravije mikrobne ravnoteže. Te intervencije sinergijski djeluju na preoblikovanje crijevnog mikrobioma promičući metaboličko zdravlje i potencijalno smanjujući rizik od raznih bolesti. U kontekstu precizne medicine, moguće je koristiti personaliziranu, genetski modificiranu mikrobiotu za prevenciju i liječenje određenih bolesti u budućnosti.

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FUNCTIONAL FOOD AND FOOD SUPPLEMENTS

VALUABLE BY-PRODUCT: HARNESSING THE POTENTIAL OF GREEN WALNUT SHELLS

Vedrana Pleš[1], Marijana Blažić[1], Bojan Matijević[1], Ines Cindrić[1*], Almir Abdurramani[2], Elizabeta Zandona[1], Paula Kralj-Vrsalović[3]

[1]Karlovac University of Applied Sciences, Trg J. J. Strossmayera 9, 47 000 Karlovac, Croatia
[2]Shmat "Abdyl Frasheri" Prishtine, Kosovo
[3]Aspira University of Applied Sciences, Ulica Vjekoslava Heinzela 62, 10 000 Zagreb, Croatia
[*]*ines.cindric@vuka.hr*

review

ABSTRACT

The green walnut husk (*Juglans regia* L.) is a largely overlooked by-product of walnut processing, traditionally treated as agricultural waste. However, recent studies have revealed that this material is a rich source of bioactive compounds, particularly phenolic acids and juglone, with significant antioxidant and antimicrobial potential. This review provides an overview of the chemical composition of green walnut husk and highlights key findings from the literature regarding its biological activity and potential applications. In addition, various extraction methods are discussed, including conventional solvent-based techniques and more sustainable alternatives such as supercritical fluid extraction. The advantages of binary solvent systems are addressed through comparative analyses showing their superior performance in phenolic compound recovery. By compiling current knowledge, this paper emphasizes the potential of green walnut husk as a valuable raw material for use in the food, pharmaceutical, and cosmetic industries, supporting its transition from waste to resource within a sustainable bioeconomy framework.

Keywords: bioactive compounds, extraction, fruit and vegetable waste, green walnut husk sustainable processing

INTRODUCTION

Plant by-products are secondary materials that arise during the processing of plant-based raw materials in the food, pharmaceutical, and other industries. These by-products often remain underutilized, despite their potential to serve as sources of valuable compounds. One of the key challenges facing the global food system is the large-scale generation of food waste along the entire supply chain, from production and storage to processing and consumption. According to the Food and Agriculture Organization (FAO), approximately 14% of all food produced globally is lost between harvest and the retail stage, resulting in significant economic losses and contributing to environmental impacts such as greenhouse gas emissions and excessive resource use (Gustafsson et al., 2011).

Within this context, the valorization of agro-industrial by-products is gaining importance as part of a broader shift toward a sustainable and circular bioeconomy. The green walnut husk (*Juglans regia* L.), a major by-product generated during walnut processing, has traditionally been considered waste. However, recent studies have shown that it contains a range of bioactive compounds, particularly phenolic acids and juglone, with promising antioxidant, antimicrobial, and therapeutic properties (Solène and Verheggen, 2024). These findings open the possibility for its use as a natural raw material in high-value applications across the food, pharmaceutical, and cosmetic industries (Ramezani et al., 2020). The objective of this paper is to review current knowledge on the chemical composition, biological activity, and extraction methods of green walnut husk, emphasizing its potential for sustainable utilization and its transformation from waste into a valuable resource.

Walnut processing waste

Walnut (*Juglans regia* L.) is primarily cultivated for its wood, which is widely used in the furniture industry, as well as for its nut, which is rich in lipids and unsaturated fatty acids, polysaccharides, phospholipids and proteins (Vergano et al., 1993). A substantial proportion of biomass is generated during walnut processing, but many of these by-products have the potential to be turned into useful products. The processing of walnut fruits generates a substantial amount of waste (Figure 1), primarily consisting of the green outer husk and the hard inner shell. The fruit of the walnut tree is the most important part of the plant in terms of human consumption, primarily due to its nutritional composition. Regular consumption of walnuts and other nuts has been associated with a reduced risk of certain diseases, such as cardiovascular diseases and different types of cancers (Kornsteiner et al., 2006). However, the kernel represents only a small portion, approximately 30–40% of the total fruit weight, with the exact proportion depending on the cultivar. The walnut fruit consists of five distinct components: the kernel, skin, pellicle, shell, and green husk. Surrounding the kernel is the shell, a hard lignocellulosic structure that represents the middle layer of the walnut fruit. This shell, commonly referred to as the nut, must be mechanically cracked to access the edible kernel inside. The shell accounts for approximately 50–70% of the total fruit mass, depending on the cultivar, making it one of the most significant agro-industrial by-products generated during walnut processing. Due to its high lignocellulosic content, the shell is resistant to natural degradation, and its

disposal represents a financial and environmental challenge. Nevertheless, walnut shells can be repurposed as a valuable raw material in various applications, including as an additive in construction materials (AbdulWahid et al., 2024). The outermost layer of the walnut fruit is the green husk, a thick, fleshy pericarp that encloses the shell during the early stages of development. The green husk is removed during post-harvest processing. Historically considered waste, it was traditionally used in some cultures as a key ingredient in the production of walnut liqueurs (Stampar et al., 2006). Depending on the cultivar and harvest stage, the green husk can constitute 34.63–56.78% of the total fruit mass when the walnut is unripe, and 14.39–25.11% once the fruit reaches full maturity (Yilmaz et al., 2017). The green husk contains more moisture than the shell or kernel. As the walnut dries, the husk loses a significant amount of water, causing its weight (and thus percentage of total fruit mass) to drop more rapidly than the inshell walnut. These processing residues, particularly the green walnut husk, represent an underutilized yet promising source of valuable bioactive compounds, and their sustainable valorization could contribute to the development of high-value products within the framework of a circular bioeconomy.

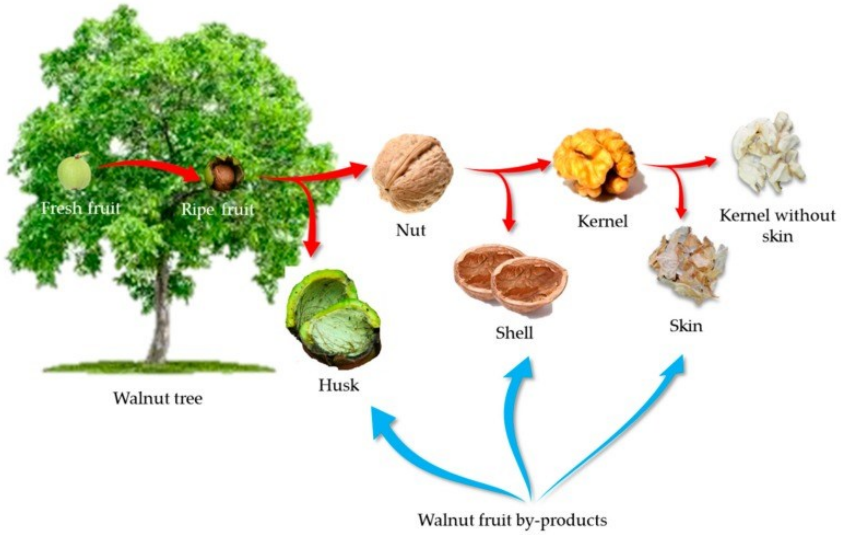

Figure 1. Different parts of walnut fruit: kernel, skin, shell, and green husk. The shell and husk are the significant by-products of walnut fruit (Jahanban-Esfahlan et al., 2019)

Chemical Composition and Bioactive Compounds of Green Walnut Husk

The green walnut husk is predominantly composed of water, which makes it the most abundant component of its fresh weight; however, its water content varies depending on the stage of maturity. Carbohydrates are the dominant macronutrient, making up approximately 8.13% of the husk's total mass, including both soluble sugars and dietary fiber. Glucose (3.12%), fructose (1.35%), sucrose (0.35%), and raffinose (0.22%) are the most prevalent sugars, while dietary fiber contributes around 2.11% (Solène and Verheggen, 2024). Nevertheless, recent studies suggest that carbohydrates may account for up to 42% of the husk's dry matter (Barekat et al.,

2023), confirming their status as the dominant macronutrient. In contrast, the green walnut husk contains minimal amounts of protein, approximately 0.48% (Barekat et al., 2023) and fat (approximately 0.05%), with saturated fatty acids being the most common lipid type.

Despite its historical classification as waste, the green walnut husk is increasingly recognized for its high content of phenolic compounds, which play a central role in its biological activity. These compounds are known for their potent antioxidant, anti-inflammatory, and antimicrobial effects, making the husk a promising natural source of bioactive substances. Among the most prominent phenolics found in green walnut husk are juglone, vanillic acid, syringic acid, o-coumaric acid, and ferulic acid (Cosmulescu et al., 2010). These secondary metabolites contribute significantly to the husk's therapeutic potential.

Juglone (5-hydroxy-1,4-naphthoquinone) is a naphthoquinone derivative predominantly located in the husk, roots, bark, and leaves of the walnut tree. It exhibits strong in vitro antioxidant, cytotoxic, and antimicrobial properties in multiple cellular and microbial assays (e.g., decreased cell viability in fibroblast and plant cells, mutagenic potential in bacterial assays) (Erisen et al., 2020), and its phytotoxic effects have been explored for biocidal applications in organic farming due to inhibition of plant growth and allelopathy.

The biological effects of juglone are attributed to its naphthoquinone structure, as shown in Figure 2.

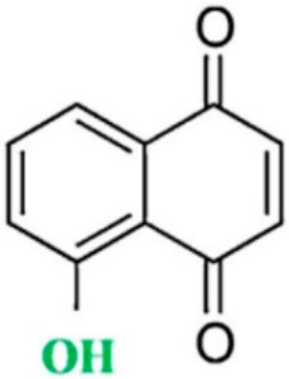

Figure 2. Chemical structure of juglone

Vanillic acid, a benzoic acid derivative, is known for its antioxidant, anti-inflammatory, and flavor-enhancing properties. It is commonly found in a range of plant-derived foods and contributes to the sensory profile of natural products (Ullah et al., 2020). Syringic acid, another hydroxybenzoic acid, has demonstrated anticancer, antidiabetic, and neuroprotective effects. It modulates oxidative stress and inflammation, enhancing its therapeutic appeal (Bujdoso et al., 2022). o-coumaric acid, a hydroxycinnamic acid, contributes to cellular defense mechanisms and has been linked to cardiovascular health. It also plays a role in UV protection in plants and may inhibit the formation of harmful food processing by-products such as nitrosamines (Chrzanowski et al., 2010). Ferulic acid is distinguished by its broad biological activity, including antioxidant, anti-inflammatory, antidiabetic, and

cardioprotective properties. It also has potential as a natural preservative and functional food ingredient (Soto-Madrid et al., 2021).
The combination of these phenolic compounds positions green walnut husk as a valuable bioresource. Their presence not only highlights the husk's pharmacological and nutritional relevance, but also provides a foundation for sustainable industrial applications in the food, pharmaceutical, and cosmetic sectors.

Extraction methods

The green husk of the walnut (*Juglans regia* L.) is a rich source of bioactive compounds such as phenolics, flavonoids, and tannins. Efficient extraction of these compounds, typically carried out using conventional methods such as solid–liquid or Soxhlet extraction with organic solvents like ethanol, methanol, or acetone, is a key step in their valorization (Jahanban-Esfahlan et al., 2019). In addition to these established techniques, simpler approaches such as maceration based on prolonged soaking of plant material in a suitable solvent at room temperature are also employed, offering a low-cost and accessible alternative. Another method, percolation, involves a continuous extraction process in which solvent slowly passes through a bed of powdered plant material, enabling gradual and efficient recovery of active compounds. Compared to maceration and Soxhlet, percolation allows continuous contact with fresh solvent, while Soxhlet uses heat and condensation to enhance extraction efficiency. These techniques are widely recognized (Cao et al., 2025) for their reliability and reproducibility in isolating bioactive compounds from plant materials. However, they are often associated with significant drawbacks. Conventional methods typically require large volumes of organic solvents, which not only increase operational costs but also raise environmental and safety concerns due to their toxicity and the challenges of solvent disposal. Additionally, these processes often involve prolonged extraction times ranging from several hours to days to achieve satisfactory yields (Ramesh et al., 2024). The study by Jakopič et al. (2009) emphasized the influence of solvent polarity and extraction conditions on the recovery of phenolic compounds, highlighting the importance of optimizing parameters such as temperature, extraction time, solvent-to-solid ratio, and the application of agitation or pressure. The efficiency of phenolic compound recovery from green walnut husk largely depends on the chosen method and operational conditions. Furthermore, the polarity and chemical properties of the solvent significantly affect extraction yield, selectivity, and the stability of the recovered bioactive compounds (Ramesh et al., 2024).
In response to the limitations of conventional extraction techniques such as high solvent consumption, long processing times, and environmental concerns, there has been a growing interest in the development and application of modern, environmentally friendly ("green") extraction methods. These innovative approaches aim to improve extraction efficiency while minimizing ecological impact, energy consumption, and the use of hazardous solvents (Matić et al., 2024). Techniques such as ultrasound-assisted extraction, microwave-assisted extraction and supercritical fluid extraction have gained significant attention due to their ability to enhance mass transfer, reduce extraction time, and operate under milder conditions, thereby

preserving the integrity of thermolabile bioactive compounds. Figure 4 presents the content of polyphenolic compounds extracted from green walnut husk using water, ethanol, methanol, and supercritical CO_2 with ethanol as solvents. The results show that the combination of supercritical CO_2 and ethanol yields the highest amounts of total polyphenols, syringic acid, ferulic acid, o-coumaric acid, and juglone. As reported by Chew et al. (2011), binary solvent systems have a higher capacity for extracting phenolic compounds compared to single-solvent systems. Supercritical CO_2 with ethanol is considered a binary solvent system, which explains the highest extraction efficiency for polyphenolic compounds. Wenzel et al. (2017) reported that the addition of 20% ethanol to supercritical CO_2 provides optimal conditions for the extraction of polyphenolic compounds. The results also confirm, in line with literature data, that juglone is the predominant polyphenolic compound in green walnut husk.

Table 1. Total polyphenol contents (mg GAE/100 g extract) and individual phenolic compounds (mg/100 g extract) in the extracts. a-d: different letters in the same line indicate statistically significant differences ($P < 0.05$), LOQ, 0.1 mg/100 g (Romano et al., 2021)

	Water	**Ethanol**	**Methanol**	**Supercritical CO_2 + Ethanol**
Total polyphenols	3038.32 ± 1.26^{c}	3640.25 ± 3.24^{c}	5809.12 ± 0.89^{b}	10750.03 ± 5.00^{a}
Syringic acid	161.07 ± 7.06^{c}	254.64 ± 6.47^{b}	1.07 ± 0.013^{d}	631.78 ± 39.70^{a}
Ferulic acid	11.72 ± 1.34^{c}	14.67 ± 1.16^{c}	64.26 ± 5.76^{b}	986.96 ± 16.80^{a}
o-coumaric acid	40.23 ± 1.05^{c}	16.39 ± 1.05^{c}	3.65 ± 0.14^{d}	77.03 ± 5.06^{a}
Juglone	360.34 ± 5.03^{c}	324.04 ± 16.18^{c}	475.55 ± 7.62^{b}	1192.04 ± 17.26^{a}

The results presented in Table 1 (Ramano et al., 2021) clearly show that the concentration of polyphenolic compounds varies significantly depending on the extraction method used. Among all identified compounds, juglone was consistently the most abundant, confirming its status as the dominant polyphenol in green walnut husk. Its concentration ranged from 324.04 ± 16.18 mg/g with ethanol to as much as 1192.04 ± 17.26 mg/g when extracted using supercritical CO_2 with ethanol. In terms of total polyphenols, the supercritical CO_2 + ethanol system also achieved the highest yield (10750.03 ± 5.00 mg/g), followed by methanol (5809.12 ± 0.89 mg/g), ethanol (3640.25 ± 3.24 mg/g), and water (3038.32 ± 1.26 mg/g). Similar trends were observed for individual phenolic acids. For example, syringic acid was best extracted with supercritical CO_2 + ethanol (631.78 ± 39.70 mg/g), while methanol showed poor performance (1.07 ± 0.013 mg/g). Ferulic and o-coumaric acids also reached significantly higher concentrations with supercritical extraction compared to conventional solvents.

In conclusion, the green walnut husk is a rich source of polyphenolic compounds, particularly juglone, making it a promising raw material for applications in the food

and cosmetic industries. The results highlight the potential of modern extraction techniques, especially supercritical fluid extraction for significantly enhancing the yield of valuable bioactives while reducing the reliance on large volumes of organic solvents.

CONCLUSION

Although often regarded as agricultural waste, the green walnut husk is in fact a promising by-product with significant potential for valorization. Rich in polyphenolic compounds especially phenolic acids and juglone it represents a valuable natural source of bioactive substances with demonstrated antioxidant, antimicrobial, and therapeutic properties. Reviewed data highlight that modern extraction techniques, particularly supercritical CO_2 extraction with ethanol as a co-solvent, enable efficient recovery of these compounds in high concentrations, although their practical application may be constrained by high costs, scalability issues, and regulatory challenges. By shifting the perspective on the green walnut husk from waste to resource, this work supports a more sustainable and circular approach in the agri-food sector, encouraging the integration of such by-products into high-value applications across the food, pharmaceutical, and cosmetic industries.

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CONSUMER ATTITUDES ON FUNCTIONAL FOOD IN THE BRČKO DISTRICT

Emina Lejlić[1], Sajma Huremović[1], Selma Kunić[1*], Semira Karijašević[2]

[1]JU Veterinarski zavod Tuzlanskog kantona, 2. Tuzlanske brigade broj 28, 75 000 Tuzla, Tuzla, Bosnia and Herzegovina
[2]NutritVibe d.o.o. Tuzla, Mehmedalije Maka Dizdara bb, PZC Stupine, PP 38/P, Tuzla 75 000, Bosnia and Herzegovina
[*]smkunic@gmail.com

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ABSTRACT

Functional food is a type of food that, in addition to its basic energy and nutritional value, has a positive effect on one or more target functions of the organism, thereby contributing to the reduction of the risk of developing certain diseases. The aim of this paper was to analyze the attitudes of consumers from the Brčko District towards functional food and to examine the connection between a healthy lifestyle and willingness to consume functional food. It was investigated whether motivational and barrier factors influence the acceptance of functional food and to what extent healthy eating habits correlate with its consumption. The research was conducted using an online questionnaire containing 18 questions, seven of which related to the general demographic data of the respondents. A total of 142 respondents from the Brčko District participated. The questionnaire was adapted from the research by Küster-Boluda and Vidal-Capilla, Downes and Urala and Lähteenmäki. The obtained data were statistically analyzed using the SPSS 22.0 program (Software Inc., USA). The results showed that the main motives for adopting healthy lifestyle habits are health preservation and maintenance of optimal body weight, while the most common barrier is the perception that healthy habits require additional time. About 50% of respondents do not consider themselves to have developed healthy habits, and 40% show a negative attitude towards the positive effects of functional food. A positive attitude towards functional food was recorded in 42% of respondents, while 46% show some reservation or distrust. A positive correlation was identified between a healthy lifestyle and a tendency to consume functional food.

Keywords: functional food, consumers attitudes, Brčko District, Bosnia and Herzegovina

INTRODUCTION

Diet is one of the most important factors that directly affect human health and the risk of developing various chronic noncommunicable diseases. According to the US Department of Health and Human Services, diet plays a role in the development of five of the ten leading causes of death, including coronary heart disease, type 2 diabetes, stroke, atherosclerosis, and certain types of cancer (Hasler, 2002). The diet typical of modern, highly industrialized countries is often associated with excessive intake of saturated fat, cholesterol, sodium, and refined sugars, and with insufficient intake of grains, fruits, vegetables, and unsaturated fatty acids (Nordstrom and Bistrom, 2002). Such an unbalanced diet contributes to the development of metabolic disorders and increases the risk of mortality associated with chronic diseases.

In recent decades, with the growing awareness of the connection between nutrition and health, the concept of functional foods has been developed. In 1994, the National Academy of Sciences' Food and Nutrition Board defined functional foods as any modified food or food ingredient that provides a health benefit in addition to naturally occurring nutrients (Hasler, 2002). Similarly, the International Life Sciences Institute (ILSI) defines functional foods as those that, thanks to physiologically active components, can improve health and reduce the risk of disease (Landström et al., 2009). Functional foods, therefore, do not only satisfy basic energy and nutritional needs, but also contribute to the improvement of body functions, immunity, metabolism and the general condition of the organism (Čalić et al., 2011).

The modern concept of functional food developed from ancient knowledge about the connection between food and health. Even Hippocrates, the father of medicine, emphasized that "food should be medicine, and medicine should be food", emphasizing the importance of proper nutrition for disease prevention. Today, in the context of global public health challenges, functional food occupies an increasingly important place in the promotion of a healthy lifestyle. The World Health Organization (WHO) recognizes obesity as the "epidemic of the 21st century" (WHO, 2000). According to the World Obesity Atlas report (2022), it is estimated that by 2030, more than one billion people on the planet will have a body mass index (BMI) greater than 30 kg/m², which means that one in five women and one in seven men will live with obesity. This trend is of particular concern to low- and middle-income countries, whose health systems are not ready to handle the burden of treating the consequences of obesity. In the European region, it is predicted that almost a third of the population (around 30%) will have a problem with excess body weight by 2030.

Obesity is strongly associated with unhealthy eating habits, low levels of physical activity and a stressful lifestyle, which further emphasizes the importance of functional foods in disease prevention and health maintenance. Educating the population about proper nutrition and the role of functional foods could contribute to reducing the prevalence of obesity, diabetes and cardiovascular diseases, which would also reduce healthcare costs (Čalić et al., 2011).

Functional foods occupy a significant place in the modern food industry as an innovative product category that combines nutritional values and health benefits. These are products that may contain probiotics, prebiotics, phytosterols, omega-3 fatty acids, vitamins, minerals and other bioactive components that contribute to reducing

the risk of disease and maintaining the homeostasis of the organism (Krešić, 2012). As stated by Menrad (2003), functional foods appeared on the European market in the mid-1990s, while the United States already represented about 50% of global production in the early 2000s. Today, the functional food market is one of the fastest growing segments of the food industry, and its growth is driven by socio-demographic factors such as increased life expectancy, increased living standards, better education and growing awareness of the importance of a healthy diet (Čalić et al., 2011).

Given that functional foods represent a combination of scientific research, food technology and the health needs of the population, understanding consumer attitudes towards such foods is of utmost importance for market development. Namely, research shows that factors influencing the choice of functional foods can be divided into three main categories: characteristics of the food itself (taste, availability, price, nutritional value), consumer characteristics (attitudes, knowledge, sociodemographic characteristics) and economic and environmental factors (Cox et al., 2004; Urala and Lähteenmäki, 2003). Individual consumer attitudes and beliefs about health and nutrition are particularly important, as they determine the willingness to change eating habits and accept new products (Roininen et al., 1999).

In the context of Bosnia and Herzegovina and the wider area of the Western Balkans, functional food is still not sufficiently researched either on the market or in terms of consumer habits. The lack of legal regulations, poor availability of information and a limited offer of functional products represent challenges for the development of this branch of the food industry. Nevertheless, the increased interest in a healthy lifestyle and the growing awareness of disease prevention open up space for the improvement and popularization of functional food.

The aim of this paper is to analyze the attitudes of consumers in the Brčko District towards functional foods, and to examine to what extent awareness of a healthy lifestyle influences their willingness to consume such products. The research will focus on identifying factors that motivate or prevent consumers from choosing functional foods, as well as on the connection between dietary habits and the frequency of consumption of functional products. The results obtained can serve as a basis for the development of educational programs, the improvement of public health policies and further research into the functional food market in Bosnia and Herzegovina.

MATERIALS AND METHODS

For the purposes of this study, a questionnaire adapted from previous validated studies by Küster-Boluda and Vidal-Capilla (2017.), Downes (2008.), and Urala and Lähteenmäki (2007.) was used. The questionnaire was designed to include questions related to consumers' attitudes towards functional foods, their eating habits, as well as motivational and sociodemographic factors that influence the choice of these products. A five-point Likert scale was used to measure attitudes and perceptions, where respondents rated their level of agreement with the offered statements (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree). This type of scale allows for the quantification of subjective attitudes and facilitates statistical processing and interpretation of the obtained data (Joshi et al.,

2015). The data were collected anonymously, with participants previously informed about the purpose and objectives of the research, which ensured the ethical acceptability of the procedure.
Participation in the study was voluntary, and respondents could withdraw at any time without any consequences. The study was conducted in the Brčko District of Bosnia and Herzegovina. The criteria for inclusion in the study were: age over 18 years and residence in the Brčko District.
The collected data were statistically processed using the SPSS Statistics 22.0 program (IBM Corp., USA). Descriptive statistics included frequencies, means, and standard deviations, while inferential methods, including Pearson's correlation coefficient, were used to examine the relationship between variables. Pearson's coefficient was used to determine the relationship between variable and non-variable parameters, thus analyzing the correlations between socio-demographic characteristics and attitudes towards functional foods. All obtained results were interpreted in accordance with the main research objectives, with comparison with relevant findings from previous studies. Statistical significance was determined at the probability level of $p < 0.05$.

RESULTS AND DISCUSSION

The research was conducted on 142 respondents from the Brčko District. The research was conducted via an online questionnaire containing 18 questions, 7 of which referred to general information that provides a picture of the respondents and categorizes them into groups. The research was conducted over 4 months, from April to July 2023. Table 1. presents information related to the socio-demographic profile of the research sample.

Table 1. Socio-demographic data of the respondents

Characteristics	**%**
Gender	
Male	21.8
Female	79.2
Age	
29 years and under	23.9
30 – 39 years	66.9
40 – 49 years	5.6
50 – 59 years	2.8
60 years and older	0.8
Level of education	
No school	1.4
Elementary school	1.4
High school	35.9
Graduate studies	53.5
Master's or doctoral studies	7.8
Total monthly income	
Less than 500 KM	24.7
From 501 to 1000 KM	23.9
From 1001 to 2000 KM	38.0
From 2001 to 4000 KM	9.9
Over 4001 KM	3.5
Household composition	
Children under 6 years old	21.8
Senior 65+ years	11.9
Total number of household members including yourself?	
1-2 members	21.1
3-4 members	55.6
5-6 members	20.4
6 members and more	2.9

Table 2. presents the characteristics of the sample, i.e. a profile representing food purchasing and consumption habits, dietary restrictions, as well as dietary habits and beliefs.

Table 2. Sample characteristics: consumption and anthropometric data

Characteristic	**%**
Who in your household does most of the shopping in stores (food, drinks and other household items)?	
Mother or father	43.0
Partner	16.2
Independently	40.8
Someone else	0.0
Does any of the family members have any dietary restrictions?	
Yes	28.2
No	71.8
Do you have any dietary restrictions?	
Yes	23.2
No	76.8
Main health problems/dietary characteristics:	
Cholesterol	34.0
Allergies	20.3
Triglycerides	16.1
Hypertension	12.7
Lactose	11.0
A vegetarian	3.4
Celiac disease	1.7
Vegan	0.8

Table 3. The relationship between the correlation coefficient and the determination coefficient (Fazlović, 2010)

Absolute value of the linear correlation coefficient	**Interpretation**	**Coefficient of determination**
0	Absence of correlation	0
do 0.20	Insignificant correlation-almost non-existent	do 0.04
0.20-0.40	Low correlation-connection is small	0.04-0.16
0.40-0.70	Moderate correlation	0.16-0.49
0.70-0.90	High correlation - strong association	0.49-0.81
0.90-1	Very high correlation	0.81-1
1	Full (perfect) correlation	1

Analysis of respondents' lifestyle habits and overall lifestyle

In order to gain a better insight into the attitudes of the respondents who participated in the research, a set of questions was created, divided into three categories, which analyze the respondents' lifestyle habits (Table 4.) from the aspect of habits and customs that positively affect the health of the respondents, and the reasons for motivation or demotivation to implement or not implement them, with the aim of making them a habit.

Table 4. Respondents' lifestyle habits

Code	Habits (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
ZN1	I participate in moderate physical activity such as running, cycling, walking or swimming for 30 minutes five to seven days a week	20	47	13	6	14	2.46	1.26
ZN2	I eat 2 pieces of fruit a day	23	52	14	4	7	2.19	1.05
ZN3	I eat vegetables every day	15	47	12	7	19	2.68	1.34
ZN4	I usually avoid foods high in fat and calories such as chips, soft drinks or fatty meats	22	44	11	9	14	2.50	1.31

* St.dev. – standard deviation

Analysis of the respondents' responses shows that around 50% of them do not practice lifestyle habits that have a positive effect on health, including regular physical

activity, consumption of fruits and vegetables, and avoidance of foods rich in fats and calories. Additional analysis by age shows that around 74% of respondents who do not have healthy habits are between the ages of 30 and 39. Also, more than two thirds of respondents who do not practice healthy habits are women, and all respondents from that group are highly educated according to their profession. The results indicate a low frequency of application of healthy daily habits among the respondents, which suggests the need for additional education and promotion of a healthy lifestyle.

Table 5. Analysis of motivators for positive lifestyle habits

Code	Motivators (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
M1	Maybe I'll live longer	16	41	12	9	22	2.82	1.41
M2	I want to be healthy	4	32	10	7	47	3.59	1.44
M3	I believe God wants me to take care of my body	14	32	18	9	27	3.03	1.43
M4	I feel more energetic	6	32	16	11	35	3.40	1.39
M5	I want to manage my weight	6	30	17	11	36	3.42	1.38
M6	I have someone to encourage me or to help me	18	32	18	9	23	2.89	1.43
M7	I see how other people's bad health habits affect their health	10	28	18	9	35	3.32	1.44

* St.dev. – standard deviation

Analysis of the motivators that positively influence the adoption of healthy habits shows that the primary motive for about 50% of respondents is the desire to be and stay healthy (M2). Body weight management, which is related to external appearance, was highlighted as a motivator for incorporating healthy habits by more than 30% of respondents (M5). Other significant motivators include feeling more energized (M4)

and witnessing the negative consequences of unhealthy habits in others (M7). The average values of the motivators range from 2.82 to 3.59, while the standard deviation is approximately 1.38–1.44, which indicates a moderate dispersion of responses among respondents. The analysis of demotivators, i.e. factors that negatively affect the adoption of healthy lifestyle habits, shows that the largest number of respondents cite lack of time and other obligations (DM4) as the main reason for not leading a healthy lifestyle. On the other hand, respondents rarely point out living in an unsafe neighborhood (DM3) or health problems (DM5) as an obstacle, which indicates relatively favorable external conditions for adopting healthy habits. The conclusion of the analysis shows that there is a common belief that healthy habits require additional time, while in fact regular activities can be simply integrated into the daily routine and contribute to increasing energy, rather than wasting it. The average values of demotivators range from 1.43 to 2.39, with a standard deviation of 0.82 to 1.33, indicating moderate variability in attitudes among respondents.

Table 6. Analysis of demotivators for positive life habits

Code	Demotivators (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
DM1	I'm not motivated	30	43	16	1	10	2.18	1.17
DM2	I have no one to encourage or help me	56	30	7	1	6	1.72	1.07
DM3	I live in an unsafe neighborhood	71	20	6	1	2	1.43	0.82
DM4	I have too many other things to do	27	41	12	5	15	2.39	1.33
DM5	I have health problems	70	19	6	1	4	1.49	0.94
DM6	I don't know what to do	54	30	9	2	5	1.77	1.08
DM7	I can't afford healthy food	47	36	12	1	4	1.81	0.99

* St.dev. – standard deviation

Analysis of the use of functional food

The results related to product category descriptions, the share of respondents who recognized or used them, or were willing to try them, are shown in Table 7.

Table 7. Overview of the use or readiness to use functional food

Product category - functional food	Share of users who are users or would use the product (%)
Probiotic yogurt	17.7
Reduced fat spreads	14.7
Energy drinks	12.9
Chocolate bars with added fiber	12.7
Low-fat cheese	11.1
Organic bread	11.1
Oatmeal with added beta-glucan	6.5
Dairy drink for lowering blood pressure	5.4
Juice enriched with calcium	5.2
Candies and chewing gum with xylitol	2.7

In this part of the questionnaire, respondents indicated the products they had tried or would try. The product categories are listed according to the names used in the market to highlight nutritional values and functional claims. The results show that most of the respondents (17.7%) chose probiotic yogurt, while a slightly smaller proportion (14.7%) marked the spread with reduced fat. A total of 14% of respondents marked only one product, while the remaining 122 respondents (about 86%) marked two or more products.
Interestingly, 35% of respondents with elevated cholesterol or triglyceride levels did not choose a low-fat spread, even though it would be advisable for their health condition. A small proportion of respondents (<10%) marked categories such as oatmeal with added beta-glucan or sweets and chewing gum with xylitol, which may indicate a lack of knowledge of the purpose of these products and the terminology used in the name. Miles et al., (2005) state that the lack of information and trust in functional foods is one of the main barriers to their consumption, which confirms the need for clear, transparent and educational product labeling in order to increase their use and acceptance among consumers.

Analysis of the desire to consume functional food

The analysis of respondents' attitudes towards functional foods shows that around 40% of respondents expressed a negative connotation (answers "disagree" and "strongly disagree") towards the stated effects of functional foods. The results indicate a generally negative attitude towards the potential positive effects of consuming functional foods, although they are defined as foods that can improve the general health of the body and reduce the risk of various diseases. The average values of all

dimensions ranged between 2.57 and 3.15, which is in line with the findings of a study conducted in 2002 on 1,156 respondents in Finland (Ural and Lähteenmäki, 2005). Poor knowledge of the positive health effects of functional foods implies low interest in their consumption, which was also confirmed in the study by Raghunathan et al., (2006). The conclusion is that educating and informing consumers about the benefits of functional foods is a key factor in increasing interest and application of these products in everyday nutrition.

Table 8. Overview of the share of attitudes according to the desire to consume functional food (I. part)

Code	Attitudes (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
REW3	Functional food helps to improve mood	8.5	45	14	8.5	24	2.94	1.35
REW2	My performance improves when I eat functional foods	8.5	41.5	21	8	21	2.92	1.29
REW8	Functional food makes it easier to follow a healthy lifestyle	8	38	15	10	29	3.15	1.39
REW6	I can prevent disease by regularly eating functional foods	8	38	19	12	23	3.05	1.32
REW1	The idea of taking care of my health by eating functional food gives me pleasure	14	38	15	13	20	2.87	1.37

Table 8. Overview of the share of attitudes according to the desire to consume functional food (II. part)

Code	Attitudes (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
REW5	Functional foods can repair the damage caused by an unhealthy diet	11	38	18	13	20	2.92	1.32
REW7	I am willing to compromise on the taste of the food if the product is functional	11	40	19	11	19	2.88	1.30
REW9	I am actively looking for information on functional foods	17	44	18	7	13	2.57	1.24

* St.dev. – standard deviation

Analysis of opinions on functional foods in terms of the need to use them

The overall analysis shows that about 42% of respondents took a positive attitude towards the use, application and effects of functional food. Although in this analysis the NEC statements are negatively worded, the reverse coding of the dimensions allows comparison with previous research. The results are consistent with the findings of Ural and Lähteenmäki (2005), with means and deviations being very similar or lower than those of previous studies, indicating uniformity and low dispersion of respondents' responses.

Table 9. Overview of opinion shares about functional foods (I. part)

Code	Opinion (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
NEC1	Functional food is completely unnecessary	55	38	3	2	2	1.58	0.82
NEC3	Functional food is a complete lie	63	28	6	1	2	1.51	0.82
NEC2	The increasing number of functional foods on the market has a bad trend for the future	45	44	4	1.5	5.5	1.79	1.01
NEC4	For a healthy person, it is worthless to use functional food	57	33	3	2	5	1.65	1.00
REW10	It is great that modern technology allows the development of functional food	12	41.5	14	8	24.5	2.92	1.40
NEC5	I want to eat only foods that do not have drug-like effects	23	42	16	4	15	2.44	1.28
NEC6	Health effects are not appropriate in delicacies	23	51	16	4	6	2.20	1.04

Table 9. Overview of opinion shares about functional foods (II. part)

Code	Opinion (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
NEC7	Functional foods are mostly consumed by people who do not need them	42	37	10	4	7	1.96	1.14
NEC9	It is pointless to add health effects to junk food	35	38	12	3	12	2.18	1.28

* St.dev. – standard deviation

Table 10. Mean value and deviation of NEC dimensions

Dimensions	NEC1	NEC3	NEC2	NEC4	NEC5	NEC6	NEC7	NEC9
Average value	4.42	4.49	4.19	4.35	3.56	3.80	4.04	3.82
Standard deviation	0.82	0.82	1.04	1.00	1.28	1.04	1.14	1.28

Analysis of trust in functional food

This analysis focuses on consumer trust in functional foods and observing the level of consumer trust in them (Table 11.).
In the overall analysis of the responses, around 46% of respondents showed negative trust, i.e. it is noticeable that animosity towards functional food prevails. The average value is around 3 and is very close to each other in all responses or statements. It is interesting to note that in all previous analyses, which were related to the analysis of desire, opinion and trust, 70% of respondents who make up the critical mass of the conclusion are from the group of respondents aged 30-39. In this age group, the largest share of users and connoisseurs of functional food is to be expected, and therefore this result of the analysis is surprising. The conclusion is low knowledge of its benefits. Similarly, Abood et al., (2003) postulate that lack of knowledge about nutrition has an inverse effect on the choice of healthy food. According to Siro et al., (2008), Europeans are much more critical of new food products and technologies compared to American consumers. In addition to doubts about the safety of these foods, they are more critical of processes that are far removed from traditional methods (Poppe and

Kjærnes, 2003). Therefore, Europeans accept functional foods less unconditionally and with more reservations than Americans.

Table 11. Overview of the share of statements of trust towards functional foods

Code	Statements (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
REW4	Functional foods boost my well-being	8	45	18	4	25	2.94	1.35
CON1	The safety of functional foods has been thoroughly studied	13	45	25	8	9	2.56	1.10
CON3	I believe functional foods deliver on their promises	10	45	25	9	11	2.69	1.16
CON4	Functional foods are premium products based on science	11	50	20	8	11	2.58	1.14

* St.dev. – standard deviation

Safety analysis of functional food

The analysis of attitudes towards the safety of functional foods shows that around 48% of respondents expressed a positive attitude towards the safety of use and the impact of functional foods. The mean values for the NEC and CON dimensions show that respondents recognise potential risks in case of excessive use and new product properties, but at the same time a certain part of respondents believes that the use of functional foods is completely safe or that information about their effects is exaggerated. Comparing these results with the research by Ural and Lähteenmäki (2005), the values are very similar, and the standard deviations are even lower, which indicates uniformity of responses and low dispersion of attitudes among respondents. The conclusion is that respondents generally recognise the safety aspects and risks of functional foods, but there is a need for additional information and education in order to increase confidence in their use, especially with new and less well-known products.

Table 12. Analysis of the results on the safety of functional food

Code	Results (%)	I do not agree at all	I do not agree	I neither agree nor disagree	I agree	I completely agree	Average value	St.dev.
CON7	If used in excess, functional foods can be harmful to health	21	49	17	2	11	2.58	1.14
NEC8	In some cases, functional foods can be harmful to healthy people	26	48	14	2	10	2.34	1.17
CON2	The use of functional foods is completely safe	13	47	23	8	9	2.22	1.15
CON5	New properties of functional foods carry unforeseen risks	23	49	18	6	4	2.51	1.09
CON6	Exaggerated information about health effects has been given	23	48	22	3	4	2.18	0.99

* St.dev. – standard deviation

Table 13. Mean value and deviation of NEC and CON dimensions

Dimensions	CON7	NEC8	CON2	CON5	CON6
Average value	3.66	3.78	2.51	3.82	3.80
Standard deviation	1.17	1.15	1.09	0.99	0.98

CONCLUSION

The results of the study indicate that the possession of healthy lifestyle habits and awareness of their benefits is at a relatively low level. It was observed that among the respondents there is a deep-rooted lack of importance attached to "small", but important habits, such as daily consumption of fruits and vegetables. Although these behavioral patterns are recognized as key to long-term health preservation, they are still not sufficiently integrated into the daily lives of the respondents. When it comes to motives for adopting and maintaining healthy habits, the most frequently cited reasons are health preservation and achieving or maintaining the desired body weight. Analysis of factors that hinder the implementation of a healthy lifestyle showed that the prevailing opinion among the respondents is still that healthy habits require additional time and effort. However, such a perception indicates insufficient understanding of the fact that healthy habits do not require additional energy, but rather contribute to its increase and a better general condition of the organism.

The analysis of recognition and knowledge of functional foods led to the conclusion that it is crucial that the labeling of functional products is clear, understandable and concise, in order to successfully convey information about their positive effects on health to the target population. Product names and trade names must be simple and easily recognizable to the general public, as incomprehensible terms can arouse suspicion and aversion among potential consumers. Therefore, the importance of transparent communication and adequate consumer information about the health benefits of functional foods is emphasized. Furthermore, the results showed that the use of functional foods will not have a positive effect without proper consumer information and education. Raising awareness about the importance of proper nutrition and the availability of healthier alternatives allows for faster recognition and easier selection of functional products on the market.

A statistically significant positive correlation was established between the attitude towards functional foods and the willingness to consume them ($p < 0.01$). This finding confirms that respondents, although sometimes skeptical, are willing to consume functional foods even at the expense of taste, provided that the product has a proven positive impact on health, and not drug-like effects. An analysis of consumer trust showed that about 46% of respondents express negative trust towards functional foods, which indicates a certain level of distrust and reservations towards new food trends. A very high positive correlation was identified between motivation and a healthy lifestyle, while no significant correlation was established between barriers and the adoption of healthy habits. Among the barriers that are still associated with a lower level of implementing healthy habits, the inability to regularly purchase vegetables and unfavorable conditions for physical activity in certain living environments stand out. An absolute correlation was confirmed between consumers who eat healthily and their willingness to consume functional food, which clearly indicates that there is a connection between awareness of healthy eating and a positive attitude towards functional products.

Finally, the research results confirm that attitudes and beliefs significantly influence food choices, along with demographic, economic and environmental factors. Education, information and the availability of adequate products have proven to be

key elements that can contribute to increasing trust and wider use of functional food among consumers in the Brčko District.

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FOODS THAT NATURALLY STIMULATE GLP-1 SECRETION IN PEOPLE WITH OVERWEIGHT AND OBESITY

Dražen Sitaš*, Daniela Čačić Kenjerić

Sveučilište Josipa Jurja Strossmayera u Osijeku, Prehrambeno-tehnološki fakultet
Osijek, Franje Kuhača 18, 31 000 Osijek, Hrvatska
**dsitas@ptfos.hr*

pregledni rad / *review*

SAŽETAK

Problem prekomjerne tjelesne mase i pretilosti postaje sve veći javnozdravstveni izazov, kako u svijetu tako i u Hrvatskoj. Cilj ovog rada jest pružiti uvid u hranu koja može prirodno stimulirati izlučivanje inkretinskih hormona i tako doprinijeti smanjenju tjelesne mase. Glukagonu sličan peptid 1 (GLP-1) središnji je medijator metabolizma glukoze koji izlučuje L stanice u crijevima kao odgovor na unos hrane, a pomaže regulaciji razine šećera u krvi i potiče osjećaj sitosti. Postprandijalno izlučivanje GLP-1 posredovano je detekcijom hranjivih tvari. Izlučivanje GLP-1 može biti niže kod osoba s povećanom tjelesnom masom i pretilošću. Fiziološki stimulirano izlučivanje GLP-1 prehranom može biti preventivna ili sinergistička metoda za poboljšanje metabolizma glukoze kod osoba s povećanom tjelesnom masom i pretilošću. Rad pokazuje mogućnost izlučivanja GLP-1 egzogeno modificiranim prehrambenim intervencijama. Hrana bogata proteinima, vlaknima i nezasićenim mastima, a posebice namirnice poput jaja, orašastih plodova, žitarica s visokim udjelom vlakana, avokada, maslinova ulja, zobi, mahunarki, bobičastog voća te lisnatog povrća mogu potaknuti oslobađanje GLP-1. Unatoč brojnim spoznajama o poticajnom učinku, potrebna su daljnja istraživanja o koncentracijama GLP-1 natašte i nakon obroka hranom koja prirodno stimulira izlučivanje GLP-1.

Ključne riječi: hrana, izlučivanje GLP-1, povećana tjelesna masa, pretilost

Keywords: foods, stimulate secretion, GLP-1, overweight, obesity

UVOD

U posljednjih 40-ak godina povećana tjelesna masa i pretilost predstavljaju kritičan problem za zdravlje. Rastuća stopa tih stanja zabrinjavajuća je. Procjenjuje se da se oko dvije milijarde ljudi diljem svijeta suočava s problemima povećane tjelesne mase, a većina njih pretila je (Hoffmaan i sur., 2021). Prema definiciji i graničnim vrijednostima, ako osoba ima indeks tjelesne mase (BMI) veći ili isti od 25 kg/m^2, a manji od 30 kg/m^2, ima povećanu tjelesnu masu, a ako je BMI veći od 30 kg/m^2, tada govorimo o pretilosti (Frank i sur., 2021).

Pretilost odražava kroničnu energetsku neravnotežu, s većom potrošnjom kalorija nego potrošnjom energije, a na njezin razvoj utječu brojni čimbenici. Većina oblika pretilosti ima poligenske čimbenike rizika s nekoliko varijanti snažno povezanih s indeksom tjelesne mase, dok je pretilost zbog jedne genske varijante rijetka. Okoliš utječe na odnos između genetike i rizika od pretilosti. Nepovoljno radno, školsko, društveno i kućno okruženje utječe na fizičke i društvene strukture. Tako, primjerice, veća dostupnost restorana brze hrane, loša dostupnost pješačkih staza u susjedstvu i percipirani sigurnosni rizici mogu ograničiti tjelesnu aktivnost i zdrave prehrambene opcije (Elmaleh i sur., 2023). Pretilost nije karakterizirana samo prekomjernim nakupljanjem tjelesne masti već i neuravnoteženim metabolizmom lipida i glukoze, kroničnom upalom i oksidativnim stresom (Angelini i sur., 2024).

Za smanjenje tjelesne mase preporučuje se smanjeni energijski unos (deficit od 500 do 750 kcal/dan, prilagođen individualnoj tjelesnoj masi i aktivnosti). Specifične strategije koje mogu smanjiti unos energije i potaknuti održavanje gubitka tjelesne mase uključuju kontrolu porcija, smanjenje ili uklanjanje ultraprerađene hrane (npr. pića zaslađena šećerom) te povećan unos voća i povrća. Pristupi prehrani temeljeni na dokazima mogu se odabrati na temelju individualnih preferencija, metaboličkog rizika i vjerojatnosti dugoročnog pridržavanja (Elmaleh i sur., 2023).

Glukagonu sličan peptid 1 (GLP-1) jest gastrointestinalni peptid i središnji medijator metabolizma glukoze koji izlučuju L stanice u crijevima kao odgovor na unos hrane. Pomaže regulaciji razine šećera u krvi i potiče osjećaj sitosti te tako utječe na unos hrane. Izlučivanje GLP-1 pod utjecajem je sastava hrane, što ukazuje na potencijal usmjerenih prehrambenih intervencija u liječenju povećane tjelesne mase i pretilosti (Bodnaruc i sur., 2016).

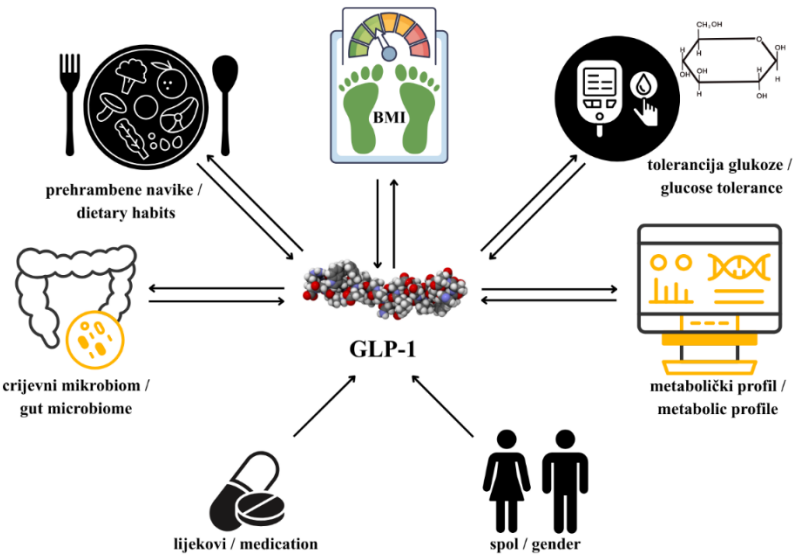
Za izradu ovog preglednog rada proveden je sustavan pregled relevantne literature pretraživanjem elektroničkih znanstvenih baza. Pretraga je ograničena na radove na engleskom jeziku. Pretraga je obuhvatila radove objavljene od 2008. do 2025. godine koristeći kombinacije ključnih riječi. Relevantnost studija procijenjena je na temelju naslova i sažetka, nakon čega je provedena analiza odabranih radova. Cilj ovog rada jest kroz narativni pregled literaturnih spoznaja pružiti uvid u hranu koja može prirodno stimulirati izlučivanje inkretinskih hormona, specifično GLP-1, i tako doprinijeti smanjenju tjelesne mase kroz doprinos u regulaciji razine šećera u krvi i poticanje osjećaja sitosti.

Struktura, koncentracije i uloge GLP-1 u organizmu

GLP-1 gastrointestinalni je peptid od 30 aminokiselina prvi put otkriven u grdobine 1982. godine. Pet godina kasnije, 1987. godine, utvrđeno je izlučivanje GPL-1 inducirano obrokom kod ljudi, štakora i svinja. GLP-1 uglavnom sintetiziraju i izlučuju enteroendokrine L stanice gastrointestinalnog trakta, koje se smatraju ključnim komponentama osovine crijeva-mozak-gušterača (Huber i sur., 2024).
Kod zdravih ispitanika razine GLP-1 u plazmi natašte kreću se od 5 do 10 pmol/L i povećavaju se dva do tri puta nakon unosa obroka. Razine GLP-1 dosežu vrhunac oko 20 minuta nakon oralnog unosa glukoze i oko 60 – 90 minuta nakon unosa miješanog obroka, a zatim se razine postupno smanjuju prema razinama natašte (Chia i Egan, 2020). Koncentracije GLP-1 u plazmi niske su nakon noćnog posta i povećavaju se nakon unosa hrane (Huber i sur., 2024).
GLP-1 pokazuje pozitivne učinke na mnoge organe i sustave ljudskog organizma uključujući mozak, bubrege, srce i krvne žile, želudac, odnosno probavni trakt u cjelini, jetru te, u konačnici, masno tkivo budući da igra važnu ulogu u prijenosu informacija o skladištenju energije (Kalra i sur., 2019).

Čimbenici koji utječu na izlučivanje GLP-1

Izlučivanje GLP-1 pod utjecajem je većeg broja čimbenika uključujući crijevni mikrobiom, prehrambene navike, razine glukoze u plazmi, metabolički profil, spol, upotrebu lijekova i indeks tjelesne mase (Slika 1). Istovremeno, uočava se i povratna sprega, odnosno utjecaj GLP-1 na većinu tih čimbenika te se dodatno bilježi neuroprotektivna svojstva GLP-1 (Huber i sur., 2024).



Slika 1. Glavni čimbenici koji utječu na izlučivanje glukagonu sličnog peptida 1 (GLP-1)
Figure 1. *Main influencing factors of glucagon-like peptide 1 (GLP-1) secretion*

GLP-1 u osoba s povećanom masom i pretilošću

Pretilost i povećana tjelesna masa povezani su s promjenama u sastavu tijela, poremećajem hormonalnog izlučivanja i neučinkovitošću endokrino-živčanog sustava (Haley i sur, 2018). Kod pretilih osoba smanjena je proizvodnja GLP-1 (Huber i sur., 2024) koji je odgovoran za unos energije u probavnom traktu, što dovodi do razvoja inzulinske rezistencije. Disregulacija izlučivanja i djelovanja inkretina povezana je s bolestima poput pretilosti i dijabetesa (Bodnaruc i sur., 2016).

Crijevni mikrobiom i izlučivanje GLP-1 u osoba s povećanom tjelesnom masom i pretilošću

Crijevni mikrobiom razlikuje se među pojedincima zbog više čimbenika uključujući prehranu. Tako, primjerice, prehrana bogata složenim ugljikohidratima i vlaknima povećava raznolikost i brojnost crijevnih mikroorganizama, dok prehrana s niskim udjelom ugljikohidrata smanjuje brojnost bakterija koje proizvode maslačnu kiselinu, uključujući *Bifidobacterium i Roseburia*. Povećani unos fermentiranog mlijeka i probiotika povećava količinu *Bifidobacteriuma* u crijevnom mikrobiomu (Ma i Lee, 2025). Prehrana koja uključuje konzumaciju životinjskih proteina i masti povezana je s enterotipom kojim dominiraju *Bacteroides*, dok je prehrana bogata ugljikohidratima povezana s enterotipom kojim dominira *Prevotella* (Merra i sur., 2020). Mediteranska prehrana, koju karakterizira velika količina prehrambenih vlakana, a također i polifenola koji imaju prebiotičko djelovanje na određene sojeve, modulira i utječe na raznolikost i omjer pojedinih bakterija (Merra i sur., 2020).
Crijevni mikrobiom ključan je u upravljanju metaboličkim procesima i razinom energije. Promjene crijevnog mikrobioma mogu dovesti do povećanog apetita i metaboličkih poremećaja, a oboje može utjecati na razvoj pretilosti (Yarahmadi i sur., 2024). Mikrobna raznolikost povezana je s metaboličkom funkcijom crijevne mikrobiote, a niska raznolikost sugerira se kao čimbenik rizika za pretilost i upalu (Cunninngham i sur. 2021). Crijevni mikrobiom oslobađa metabolite koji imaju značajnu ulogu u kontroli apetita izravnim utjecajem na središnji živčani sustav ili izravno putem izlučivanja hormona (Zheng i sur., 2020). Zabilježeno je da pretile osobe imaju viši omjer *Firmicutes/Bacteroidetes*, viši broj *Fusobacteria, Firmicutes, Lactobacillus (reuteri), Mollicutes i Proteobacteria* (Ma i Lee, 2025). U nekim studijama povećani omjer *Firmicutes* i *Bacteroides* povezan je s pretilošću, dok u drugima taj odnos nije uočen (Angelini i sur., 2024). *Akkermansia muciniphila* ključna je bakterija za gubitak tjelesne mase, a njezina suplementacija poboljšava metaboličke parametre kod osoba s pretilošću (Angelini i sur., 2024).

GLP-1 i prehrana

Inkretinski hormoni, pa tako i GLP-1, mogu biti odgovorni za do 70 % postprandijalnog izlučivanja inzulina. Njihovi učinci pojačavaju se progresivno od početka obroka kao odgovor na povećanje koncentracije glukoze u plazmi (Kalra i sur., 2019).
Utjecaj prehrane na izlučivanje GLP-1 može se promatrati s aspekta nutrijenata, pojedinačnih namirnica ili sveobuhvatno s apekta prehrambenog režima.

GLP-1 i nutrijenti

Sastav hranjivih tvari unesene hrane i obroka znatno varira među pojedincima, pa čak i kod iste osobe tijekom dana. Kao rezultat varijacije prehrambenog unosa mijenja se i metabolički odgovor uključujući glikemiju i inzulinemiju (Bodnaruc i sur., 2016).
Fermentacijom prehrambenih vlakana u crijevnom mikrobiomu, koji pripadaju *Firmicutes*, nastaju kratkolančane masne kiseline (SCFA) koje utječu na metabolizam domaćina. Kod ljudi koncentracije SCFA kreću se od ~130 mmol/L u cekumu do ~80 mmol/L u silaznom debelom crijevu. Čini se da je acetat najzastupljenija SCFA u debelom crijevu, a slijede propionat i butirat (Bodnaruc sur., 2016). Opskrba mikrobiote debelog crijeva supstratom ima velik utjecaj na mikrobnu populaciju i metabolite koje proizvode, posebice SCFA. Istraživanja pokazuju da konzumacija fermentabilnih ugljikohidrata i primjena SCFA rezultiraju širokim rasponom pozitivnih zdravstvenih učinaka uključujući poboljšanje sastava tijela, homeostaze glukoze, profila lipida u krvi te smanjenje tjelesne mase i rizika od raka debelog crijeva (Byrne i sur., 2015). Byrne i sur. (2015) istraživali su utjecaj SCFA na regulaciju apetita i energetsku homeostazu. SFCA mogu stimulirati oslobađanje GLP-1 i peptida YY, što utječe na mozak i gušteraču, a acetat može poboljšati skladištenje masti djelovanjem izlučivanja grelina (Aragon-Vela i sur., 2021). GLP-1 ostvaruje svoje djelovanje putem GLP-1R u više tkiva uključujući gušteraču, bubrege, srce, pluća, masno tkivo i glatke mišiće, kao i u specifičnim jezgrama u središnjem živčanom sustavu (Huber i sur., 2024).
Proteini se smatraju esencijalnim nutrijentom jer se neke aminokiseline moraju osigurati putem prehrane. Obnavljanje zaliha aminokiselina odgovarajućom količinom i kvalitetom proteina potrebno je da bi se spriječio prekomjerni gubitak mišićne mase tijekom mršavljenja (Volek i sur., 2024). Mehanizam utjecaja unosa proteina na sekreciju GLP-2 nije u potpunosti razjašnjen (Bodnaruc i sur., 2016).

GLP-1 i odabrane namirnice

Malo je namirnica koje u svojem sastavu imaju samo jedan makronutrijent te se na njih može primijeniti gore navedene utjecaje pa primjeri složenijih namirnica koje sadržavaju kombinaciju hranjivih tvari bolje odražavaju ono što ljudi konzumiraju i mogle bi omogućiti ciljanje kombinacije enteroendokrinih puteva koji bi sinergijski pojačali izlučivanje GLP-1 (Bodnaruc i sur., 2016). Pregledom znanstvene i stručne literature uočava se mogući učinak specifičnih namirnica poput zelenog lisnatog povrća, bobičastog voća, orašastih plodova, maslinovog ulja, avokada, jaja, cjelovitih žitarica i fermentiranih prizvoda kao namirnica koje prirodno mogu stimulirati izlučivanje GLP-1 te na taj način doprinijeti smanjenju tjelesne mase. Specifičan nutritivni sastav i prisutnost bioaktivnih spojeva u tim namirnicama mogu doprinijeti kontroli tjelesne mase, prevenciji pretilosti i metaboličkim posljedicama pretilosti. Mogući mehanizmi uključuju učinak na sitost, apsorpciju lipida, beta-oksidaciju masnih kiselina, stimulaciju termogeneze i slično (Konstantinidi i Koutelidakis, 2019).
Konzumacija **jaja** (dvaju do triju), koja su bogata proteinima ali istovremeno sadrže i masti, odnosno mononezasićene masne kiseline, za doručak ili ručak, poboljšava subjektivan osjećaj sitosti nakon obroka. Nadalje, u usporedbi s doručkom u pecivu,

konzumacija doručka koji sadrži jaja (3) kod odraslih muškaraca bila je povezana s nižim koncentracijama glukoze u krvi nakon obroka, smanjenom gladi i smanjenim unosom energije u sljedećih 24 sata. Muškarci su također prijavili veće subjektivno zadovoljstvo nakon konzumacije jaja (Bodnaruc i sur., 2016). Wright i sur. (2018) istraživali su učinak prehrane bogate proteinima, uključujući cijela jaja, na sastav mišića i indekse kardiometaboličkog zdravlja i sistemske upale kod starijih osoba s povećanom tjelesnom masom ili pretilošću. Istraživanje je pokazalo da kod starije odrasle osobe s povećanom tjelesnom masom i pretilošću konzumacija prehrane bogate proteinima s cijelim jajima tijekom 12 tjedana potiče zadržavanje nemasne mase nakon umjerenog gubitka tjelesne mase (Wright i sur., 2018). Vander Wal i sur. (2008) testirali su hipotezu da bi doručak s jajima, za razliku od doručka s pecivima usklađenog po energetskoj gustoći i ukupnoj energiji, potaknuo gubitak tjelesne mase kod ispitanika s povećanom tjelesnom masom i pretilosti. Ta studija jedinstveno pokazuje da se gubitak tjelesne mase može poboljšati uobičajeno dostupnom povoljnom hranom poput jaja (Vander Wal i sur., 2008).

Zeleno lisnato povrće ključan je element uravnoteženih prehrambenih navika i važan izvor vitamina C i E, karotenoida – uglavnom β-karotena i luteina – te mineralnih tvari (Nurzyńska-Wierdak, 2025). Konzumacija biljnih proizvoda potiče se kao dio edukacije o prehrani za pretile i inzulinsko rezistentne pacijente. Maruyuma i sur. (2013) proučavali su učinke unosa špinata, zelenog lisnatog povrća bogatog dijetalnim vlaknima i alfa-tokoferolom, s obrokom bogatim mastima na postprandijalne glikemijske i lipidemijske promjene. Budući da povrće daje malo energije, a bogato je dijetalnim vlaknima, raznim mineralima i vitaminima, potiče se povećana konzumacija povrća niske energetske vrijednosti da bi se osigurala odgovarajuća količina obroka u terapijskim dijetama za pretile i inzulinsko rezistentne pacijente (Maruyuma i sur., 2013). Zeleno lisnato povrće pripada proizvodima koji smanjuju kiselost tijela. Postoji izravna veza između konzumiranja voća i povrća i njihovih učinaka na sprječavanje bolesti. Prema analizama temeljenim na 95 studija, konzumiranje 200 g voća i povrća dnevno može smanjiti rizik od bolesti za 13 %. Ako je unos voća i povrća znatno niži od preporučenog, može utjecati na razvoj kardiovaskularnih bolesti, dijabetes tip 2, pretilost i neke vrste karcinoma. Također, manji je rizik i za razvoj neurodegenerativnih bolesti, bolesti probavnog sustava i osteoporoze. Unosom od 800 g dnevno smanjenje rizika doseže gotovo 30 %. Postoji otprilike 10 000 biljnih vrsta koje se koriste kao povrće diljem svijeta. Njihova klasifikacija može se temeljiti na zajedničkim morfološkim karakteristikama (korijenje, stabljike, plodovi, listovi i slično), upotrebi ili nutritivnim/zdravstvenim prednostima (Nurzyńska-Wierdak, 2025).

Avokado je jedinstveno voće koje sadrži masti i prehrambena vlakna. Jedan svježi avokado srednje veličine (~136 g) sadrži oko 72 % vode i ~13,3 g mononezasićenih masti, 10 g vlakana i razne karotenoide i druge bioaktivne komponente. Wien i sur. (2013) izvijestili su da je dodavanje otprilike polovice avokada u ručak potisnulo želju za jelom i povećalo osjećaj zadovoljstva sudionika tijekom pet sati u usporedbi s obrokom bez avokada. Međutim, dodavanje avokada povećalo je energetski sadržaj obroka. U istoj studiji, postprandijalne koncentracije inzulina smanjene su nakon zamjene dijela energije iz masti i ugljikohidrata (preljevi za salatu i porcije kolačića) avokadom. Ti podaci sugeriraju da bi strateška manipulacija obrocima s avokadom,

izvorom masti i vlakana mogla potaknuti i sitost i metaboličke koristi. Postizanje obiju koristi bez povećanja energije bilo bi idealno, posebice za osobe s problemima s tjelesnom masom ili kontrolom glukoze (Zhu i sur., 2019).
Khan i sur. (2021) istraživali su učinke konzumacije avokada na abdominalnu pretilost, inzulinsku rezistenciju, oralni test tolerancije glukoze i procijenjenu funkciju β-stanica. Dnevna konzumacija jednog svježeg avokada promijenila je raspodjelu abdominalne masnoće među ženama, ali nije olakšala poboljšanje periferne osjetljivosti na inzulin ili funkcije β-stanica kod odraslih osoba s povećanom tjelesnom masom i pretilošću. To istraživanje otkrilo je da konzumiranje dnevnog obroka s avokadom poboljšava raspodjelu masti, što je naznačeno nižim omjerom viscelarne debljine među sudionicama. U odnosu na druga depoa masnog tkiva, nakupljanje viscelarnog masnog tkiva u okolnim unutarnjim organima poput jetre povezano je s dijabetesom tipa 2, dislipidemijom, upalom, povećanim rizikom od tromboze i nealkoholnom masnom bolešću jetre. Viscelarna debljina među sudionicima u skupini liječenja sugerira da unos avokada daje koristan profil abdominalne masti. Budući da te koristi nisu uočene među muškarcima, robusnost učinka liječenja ograničena je i potrebna su dodatna eksperimentalna istraživanja da bi se nadalje okarakterizirali učinci dnevne konzumacije avokada na raspodjelu masti (Khan i sur., 2021). Druga studija ispitivala je učinke sitosti zamjene energije ugljikohidrata u obroku s polovicom ili cijelim avokadom u usporedbi s kontrolnim obrokom bez avokada kod osoba s povećanom tjelesnom masom, odnosno pretilosti. Primarni ishod istraživanja bila je promjena subjektivnih mjera sitosti kao odgovor na obroke tijekom šest sati. Sekundarni ishodi bile su promjene varijabli poput umora i budnosti te karakterizacija povezanosti između hormona povezanih sa sitošću/apetitom (PYY, GLP-1, grelin i inzulin) i subjektivne sitosti nakon cijelog avokada u odnosu na kontrolne obroke. Radna hipoteza jest da će, pod uvjetima ekvivalentne energije, zamjena ugljikohidrata kombinacijom masti i vlakana iz avokada povećati sitost, a učinci će biti povezani s promjenama hormona koji posreduju sitost u obroku (Zhu i sur., 2019).
Hrana bogata antioksidansima uključuje onu iz biljnih izvora, poput bobičastog voća, voća, povrća, žitarica i začinskog bilja. Znanstvenu znatiželju posebice privlači **bobičasto voće** zbog svoje visoke antioksidativne aktivnosti temeljene na raznim vrstama fitokemikalija uključujući flavonoide. Među uobičajeno konzumiranim bobičastim voćem borovnice, brusnice i jagode imaju visok ukupni sadržaj polifenola, kao i vitamina C i E, a sve to doprinosi njihovim snažnim antioksidativnim učincima (Helm i sur., 2023). Postoji nekoliko komponenti bobičastog voća koje mogu izazvati blagotvorne učinke na zdravlje uključujući vitamine, minerale, vlakna i polifenole. Polifenolni spojevi skupina su sekundarnih metabolita koji su sveprisutni u mnogim biljkama i hrani. Novi dokazi pokazuju da neki polifenoli mogu inducirati lučenje GLP-1 iz L-stanica putem različitih mehanizama. Konkretno, polifenoli mogu funkcionirati kao ligandi GPCR-a ili regulirati unutarstanične signalne molekule da bi modulirali lučenje GLP-1. Osim toga, neki polifenoli mogu neizravno uzrokovati lučenje GLP-1 posredovano crijevnom mikrobiotom (Wang i sur., 2021). Različite bobice imaju različite količine i udjele tih fitonutrijenata, a broj i udio bioaktivnih spojeva varira čak i unutar jedne vrste bobice zbog genetskih svojstava, uvjeta uzgoja, zrelosti i uvjeta skladištenja. Budući da sadrže obilje bioaktivnih spojeva, bobice

imaju potencijal pomoći smanjenju upale uzrokovane pretilošću i povezane kardiometaboličke disfunkcije (Lail i sur., 2021). Nekoliko je studija provedeno na predkliničkim modelima glodavaca da bi se utvrdio mehanizam kojim borovnice ili njihove bioaktivne komponente utječu na upalu uzrokovanu pretilošću. Mnoge od tih studija otkrile su da su borovnice ili njihovi ekstrakti učinkoviti u smanjenju upale i istovremenom poboljšanju drugih biomarkera metaboličkog zdravlja (Lail i sur., 2021). Studije koje su ispitivale konzumaciju bobičastog voća kod ljudi pokazale su učinkovitost bobičastog voća u smanjenju upale i drugih čimbenika rizika za dijabetes tip 2 i kardiovaskularne bolesti. Prekliničke studije na glodavcima i staničnim kulturama pružaju čvrste dokaze da bobičasto voće i njihove bioaktivne komponente imaju blagotvorne učinke ne samo na upalu već i na biomarkere mnogih od tih kroničnih bolesti.

Orašasti plodovi sastavnica su ljudske prehrane stoljećima, međutim, razina konzumacije orašastih plodova može varirati globalno među različitim populacijama. Bademi su najčešće konzumirani orašasti plodovi i poznati su kao bogat izvor proteina, mononezasićenih masnih kiselina, esencijalnih minerala i prehrambenih vlakana (Ojo i sur., 2021). Imaju nizak sadržaj ugljikohidrata te nizak glikemijski indeks. Polifenoli i vlakna u bademima mogu se koristiti kao supstrati za rast crijevne mikroflore i regulaciju crijevne mikrobiote. Istraživanja ukazuju da postoji obrnuta proporcionalnost između konzumacije orašastih plodova i rizika od razvoja dijabetesa tip 2. Konzumacija badema povećava osjećaj sitosti, smanjuje postprandijalnu glikemiju i regulira oksidativni stres. Konzumacija badema, također, može smanjiti brzinu probave hranjivih tvari, smanjiti odgovor na glukozu te stimulirati inkretin i proizvodnju GLP-1 (Ojo i sur., 2021). Redovita konzumacija orašastih plodova povezana je s nižom adipoznošću i smanjenim debljanjem u odraslih. Studije o prehrani s orasima uočile su minimalan učinak na tjelesnu masu unatoč potencijalnom dodatnom unosu energije. Nekoliko mehanizama može objasniti zašto konzumacija orašastih plodova potiče kontrolu tjelesne mase uključujući povećanu sitost u ranoj fazi, što se vjerojatno odražava u postprandijalnom odgovoru gastrointestinalnih i gušteračnih peptida za koje se pretpostavlja da utječu na apetit (Rock i sur., 2017).

Mette i sur. (2015) dokazali su da unos 20 mL ekstra djevičanskog maslinovog ulja inducira porast koncentracije GLP-1 u plazmi, kao i veće oslobađanje GIP-a u usporedbi s drugim ispitivanim skupinama. Također, došlo je do smanjenja odgovora glukoze u plazmi, što bi moglo biti posljedica kombiniranog učinka povećanih koncentracija inzulina, inkretinskih hormona i kolecistokinina, za koje se zna da odgađaju pražnjenje želuca.

Sørensen i sur. (2021) istraživali su učinak maslinovog ulja s odgođenim oslobađanjem i hidroliziranog ulja pinjola na toleranciju glukoze, izlučivanje inkretina i apetit kod ljudi. Rezultati istraživanja potvrđuju prethodne rezultate budući da je 6 g hidroliziranog ulja pinjola s odgođenim oslobađanjem pojačalo postprandijalno izlučivanje GLP-1 i smanjilo apetit. Međutim, nije uočen sinergistički učinak kombiniranja hidroliziranog ulja pinjola i maslinovog ulja na izlučivanje GLP-1, a rezultate treba nadalje procijeniti u dugoročnim studijama uključujući učinke na tjelesnu masu i osjetljivost na inzulin.

GLP-1 i prehrambeni obrasci

Velik broj znanstvenih istraživanja podržava prehrambene obrasce s niskim udjelom ugljikohidrata uz umjereno povećane unose proteina (1,2 do 2,0 g / kg tjelesne mase) iz izvora hrane s visokom biološkom vrijednošću kao učinkovite u promicanju klinički značajnog smanjenja masnog tkiva bez neželjenog gubitka mišićne mase. Prehrambeni obrasci s niskim udjelom ugljikohidrata, posebice oni koji postižu prirodno stanje euketonemije, istovremeno poboljšavaju mnoga patološka stanja, posebice dijabetes tip 2 i druga stanja povezana s inzulinskom rezistencijom. Istraživanje pozitivnih učinaka prehrane s niskim udjelom ugljikohidrata i ketogene prehrane obuhvaćaju stanja poput dijabetesa tipa 1 i tipa 2, raka, epilepsije, Alzheimerove bolesti, Parkinsonove bolesti, multiple skleroze, traumatske ozljede mozga, reumatološkog artritisa, ozljede leđne moždine i psihijatrijskih poremećaja, ali i redukcije tjelesne mase (Volek i sur., 2024).

ZAKLJUČAK

Rastuće stope pretilosti tijekom posljednjih nekoliko desetljeća, s ograničenim uspjehom u preokretanju trendova, intenzivirale su istraživanja da bi se bolje razumjelo kako hrana i sastojci utječu na apetit i sitost, unos energije i kontrolu tjelesne mase. Na stimulaciju izlučivanja GLP-1 utječu mnogi čimbenici, a prehrana i izbor namirnica jedan su od najznačajnijih. Kroz ovaj pregled prikazano je kako se na jednostavan i prihvatljiv način odabirom namirnica i njihovih kombinacija može prirodno stimulirati izlučivanje GLP-1, a posljedično i snižavati tjelesnu masu i brinuti o zdravlju crijevne mikroflore. Fiziološki stimulirano izlučivanje GLP-1 prehranom može biti preventivna ili sinergistička metoda za poboljšanje metabolizma glukoze kod osoba s prekomjernom tjelesnom masom i pretilošću. Usto, navedeni prehrambeni pristupi koji naglašavaju konzumaciju neprocesuirane hrane, unos biljnih masti i proteina uz naglasak na voće, povrće, mahunarke, orašaste plodove i cjelovite žitarice, imaju istovremeno preventivne učinke i za bolesti srca i krvožilnog sustava, različite vrste karcinoma te dijabetes tip 2.

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PRIHVATLJIVOST NUTRITIVNO OBOGAĆENIH MEDENJAKA

ACCEPTABILITY OF NUTRITIONALLY ENRICHED GINGERBREAD

Svjetlana Škrabal*, Ivana Jarabek, Valentina Obradović, Maja Ergović Ravančić

Sveučilište Josipa Jurja Strossmayera u Osijeku, Fakultet turzima i ruralnog razvoj u Požegi, Vukovarska 17, 34 000 Požega, Hrvatska
**sskrabal@ftrr.hr*

stručni rad */ professional paper*

SAŽETAK

Medenjaci su slatki keksi posebnog okusa koji ih čini jedinstvenim i popularnim desertom. Njihov karakterističan okus dolazi od meda, začina poput cimeta, klinčića i đumbira te brašna, uz dodatak jaja, mliječnih sastojaka i masti. Osim svoje kulturne i gastronomske vrijednosti, medenjaci također imaju određene nutritivne prednosti. Cilj ovog istraživanja bio je razviti tri inovativne recepture medenjaka zamjenom konvencionalnih sastojaka nutritivno i funkcionalno vrjednijim alternativama. Pripremljena su četiri uzorka medenjaka: jedan po tradicionalnoj recepturi vukovarskog kraja te tri varijante s modificiranim sastojcima (s javorovim sirupom i kokosovom masti, bezglutenski s chia sjemenkama i avokadom te s avokadom i sirupom od datulja). Na svim uzorcima provedena je senzorska analiza pomoću educiranog panela (n = 13). Senzorski su ocjenjivani izgled, boja, struktura, miris i okus metodom bodovanja s ponderima važnosti. Rezultati su pokazali značajnu razliku uzoraka u organoleptičkim svojstvima. Najviše ocjene za oblik, boju i strukturu postigao je uzorak s avokadom i sirupom od datulja (uzorak 4), dok je tradicionalni uzorak (uzorak 3) imao najviše ocjene za okus i miris. Bezglutenski uzorak s chia sjemenkama (uzorak 2) postigao je najniže ocjene zbog slabije teksture i izraženijih odstupanja u aromi. Test potrošačke percepcije potvrdio je da su uzorci 3 i 4 najprihvatljiviji, pri čemu je tradicionalni uzorak prepoznat kao najsličniji klasičnom medenjaku, a uzorak 4 kao najukusnija inovativna varijanta. Uzorci 1 (javorov sirup i kokosova mast) i 2 (bezglutenski) najčešće su prepoznati kao „zdraviji“ proizvodi. Rezultati potvrđuju mogućnost razvoja funkcionalnih i nutritivno poboljšanih medenjaka koji zadržavaju senzorsku prihvatljivost, pri čemu kombinacija avokada i prirodnih zaslađivača pokazuje najveći potencijal za proizvodnju inovativnih, ali potrošački prihvatljivih medenjaka.

Ključne riječi: medenjaci, začini, funkcionalna hrana, senzorska evaluacija

Keywords: gingerbread, honey, spices, functional food, sensory evaluation

UVOD

Medenjaci su jedan od najprepoznatljivijih tradicionalnih slatkih pekarskih proizvoda u mnogim europskim kuhinjama uključujući i hrvatsku gastronomsku baštinu. Svojom specifičnom aromom, koja proizlazi iz kombinacije meda i začina poput cimeta, klinčića, đumbira i muškatnog oraščića, te karakterističnom teksturom, medenjaci zauzimaju značajno mjesto u blagdanskoj i svakodnevnoj prehrani (UNESCO, url). Međutim, tradicionalne recepture, koje uključuju značajne količine rafiniranog šećera, pšeničnog bijelog brašna i zasićenih masti, ne odgovaraju u potpunosti suvremenim prehrambenim smjernicama koje promiču smanjen unos šećera i zasićenih masnoća, a povećan unos prehrambenih vlakana, vitamina, minerala i bioaktivnih spojeva (World Health Organization, url). Tradicionalni medenjaci sastoje se od brašna, meda i šećera, masnoća (najčešće svinjske masti ili maslaca), jaja i raznih začina (Lebkuchen-gandl. url). Iako med kao prirodni zaslađivač ima blagotvorna svojstva, često se u komercijalnim proizvodima koristi u kombinaciji s rafiniranim šećerom, čime se znatno povećava energetska vrijednost, a smanjuje nutritivna vrijednost proizvoda (Dana i Sonia, 2024). Osim toga, korištenje bijelog pšeničnog brašna doprinosi nižem sadržaju prehrambenih vlakana, što dodatno umanjuje funkcionalni potencijal takvih proizvoda (Shewry, i sur. 2023). Zbog rastuće svijesti potrošača o povezanosti prehrane i zdravlja u posljednjem desetljeću sve više istraživanja usmjereno je na modifikaciju tradicionalnih pekarskih proizvoda, uključujući i kekse i kolače, s ciljem razvoja nutritivno kvalitetnijih alternativa (Chakraborty i Chakraborty, 2023). U literaturi se navode brojni primjeri obogaćivanja keksa i kolača brašnima od pseudožitarica (amarant, kvinoja), dodacima biljnog podrijetla (chia sjemenke, lanene sjemenke, spirulina) te antioksidansima iz prirodnih izvora (antocijanini iz voća, ekstrakti zelenog čaja) (Sharif i sur., 2021., Tovle i Simonato, 2024). Jedan od najčešćih pristupa uključuje djelomičnu ili potpunu zamjenu bijelog brašna integralnim brašnima (pšenično, zobeno, heljdino) koja povećavaju udio prehrambenih vlakana, mikronutrijenata i fitokemikalija (Chauhan i sur. 2018). Pšenično brašno moguće je zamijeniti zobenim brašnom, ali pritom treba pronaći optimalne omjere da bi se zadržalo potrebne fizikalno-kemijske i reološke parametre tijesta (Gómez i sur. 2003). Dodavanje orašastih plodova, sjemenki i sušenog voća dodatno obogaćuje nutritivni sastav proizvodima nezasićenim masnim kiselinama, antioksidansima i esencijalnim mineralima (Gómez i sur. 2019). Umjesto hidrogeniziranih masti i višestruko nezasićenih ulja preporučava se uporaba ekstra djevičanskog maslinovog ulja i nerafiniranog lanenog ulja te kokosovog ulja. Navedena ulja sadrže oko 90 % zasićenih masti te male količine oleinske i linolne kiseline (Fallon, 1995). Smanjenje ili zamjena šećera također je predmet mnogih studija. Korištenje prirodnih zaslađivača poput meda, javorovog sirupa, agavinog sirupa, pa čak i stevije i eritritola, pokazalo se uspješnim u smanjenju glikemijskog indeksa i ukupne energetske vrijednosti proizvoda, bez značajnog narušavanja senzorskih svojstava (Struck i sur., 2014). Medenjaci, zbog svoje fleksibilne recepture i blage arome koja se lako nadopunjuje različitim sastojcima, predstavljaju idealnu osnovu za uvođenje funkcionalnih komponenti (Topka i sur. 2023, Kasprowicz-Pawlak i sur., 2025). Te inovacije omogućuju razvoj proizvoda s potencijalnim preventivnim učinkom na kronične bolesti poput dijabetesa tipa 2,

pretilosti i kardiovaskularnih bolesti (Gómez i sur., 2019). Budući da su medenjaci proizvod koji se konzumira prije svega radi užitka, ključnu ulogu pri formuliranju recepture za medenjake ima postizanje zadovoljavajućih organoleptičkih svojstava (izgled, boja, tekstura, miris i okus). Veliki je izazov kreirati proizvod s poboljšanim funkcionalnim svojstvima, a da pritom ne budu narušena organoleptička očekivanja konzumenata (Topka i sur. 2023). Senzorska evaluacija metodama deskriptivne analize i testiranja preferencija omogućuje procjenu subjektivne prihvatljivosti proizvoda kod potrošača, ali i identifikaciju parametara koji bi mogli biti optimizirani (Singh-Ackbarali i Maharaj, 2014). Brojne studije pokazuju da je moguće postići visoku razinu prihvaćenosti i kod proizvoda sa znatno izmijenjenim sastavom, pod uvjetom da se pažljivo odabere vrsta i količina funkcionalnih sastojaka (Myrisis,2022).

MATERIJAL I METODE

Cilj ovog istraživanja jest razviti tri inovativne recepture medenjaka zamjenom konvencionalnih sastojaka nutritivno i funkcionalno vrjednijim alternativama. U tu svrhu pripremljeni su uzorci medenjaka prema tradicionalnoj recepturi te prema trima razvijenim varijantama. Na svim uzorcima provedena je senzorska evaluacija u svrhu ocjene organoleptičkih svojstava proizvoda (izgled, boja, miris, tekstura i okus) pomoću educiranog panela.
Dobiveni rezultati senzorskog ocjenjivanja koristili su se za procjenu utjecaja pojedinih modificiranih receptura na ukupnu prihvatljivost proizvoda s ciljem identifikacije optimalne formulacije koja zadovoljava prehrambene standarde te ujedno odgovara potrošačkim preferencijama.

Recepture za medenjake

Za provedbu ovog istraživanja priređeni su uzorci četiriju vrsta medenjaka (Tablica 1). Jedna vrsta priređena je po tradicionalnoj recepturi vukovarskog kraja, tri su inovativne u kojima su pojedine sirovine zamijenjene zdravstveno prihvatljivijim sirovinama. Svi uzorci prilikom oblikovanja po dimenzijama i obliku bili su jednaki, pečeni u pećnici šest minuta pri temperaturi pečenja 180 °C, ohlađeni na sobnoj temperaturi i ukrašeni pojedinačno priređenim preljevom (dva bjelanjka, šest žlica šećera u prahu i nekoliko kapi limunovog soka).

Tablica 1. Sirovinski sastav pojedinih uzoraka medenjaka
Table 1. *Ingredient composition of individual gingerbread samples*

Sastojak	UZORAK 1 Medenjaci s javorovim sirupom i kokosovim uljem	UZORAK 2 Bezglutenski medenjaci s chia sjemenkama	UZORAK 3 Tradicionalni medenjaci	UZORAK 4 Medenjaci s avokadom i sirupom od datulja
Integralno brašno (g)	700	-	-	700
Bezglutensko brašno (g)	-	700	-	-
Glatko pšenično brašno (g)	-	-	700	-
Med (g)	150	150	150	150
Jaja (kom.)	4	-	4	4
Soda bikarbona (g)	10	10	10	10
Javorov sirup (g)	250	-	-	-
Kokosova mast (g)	60	-		-
Mješavina začina (cimet, klinčić, đumbir, kardamom) (žličica)	1	1	1	1
Ribana korica naranče (žličica)	1	1	1	1
Chia sjemenke (g)	-	50	-	-
Smeđi šećer (g)	-	250	-	-
Avokado (g)	-	60	-	60
Šećer (g)	-	-	250	
Maslac (g)	-	-	60	
Sirup od datulja (g)	-	-	-	250

U uzorku 1, medenjaci s javorovim sirupom i kokosovim uljem (Slika 1), šećer je u potpunosti zamijenjen javorovim sirupom, a umjesto pšeničnog brašna korišteno je integralno brašno.

Slika 1. Medenjaci s javorovim sirupom i kokosovom masti
Figure 1. *Gingerbread with maple syrup and coconut fat*

U uzorku 2, bezglutenski medenjaci s chia sjemenkama (Slika 2), pšenično brašno u potpunosti je zamijenjeno bezglutenskim brašnom. Umjesto jaja korištene su chia sjemenke (mljevene, natopljene u dvama decilitrima hladne vode), umjesto rafiniranog šećera korišten je smeđi šećer, a umjesto maslaca korišten je avokado.

Slika 2. Bezglutenski medenjaci s chia sjemenkama
Figure 2. *Gluten-free gingerbread with chia seeds*

Uzorak 3 tradicionalni su medenjaci (Slika 3), priređeni prema tradicionalnoj recepturi vukovarskog kraja.
Ti medenjaci rađeni su po tradicionalnoj recepturi vukovarskog kraja.
Sastojci: 70 dag glatkog pšeničnog brašna, 15 dag meda, 4 jaja, 1 dag sode bikarbone, 25 dag šećera, 6 dag maslaca, 1 žličica mješavine začina (cimet, klinčići, đumbir, kardamom), ribana korica naranče.
Preljev: 2 bjelanjka, 6 žlica šećera u prahu i nekoliko kapi limunovog soka.

Slika 3. Tradicionalni medenjaci
Figure 3. *Traditional gingerbread*

U uzorku 4, medenjaci s avokadom i sirupom od datulja (Slika 4), korišteno je integralno pšenično brašno, umjesto šećera korišten je sirup od datulja, a umjesto maslaca korišten je avokado.

Slika 4. Medenjaci s avokadom i sirupom od datulja
Figure 4. *Gingerbread with avocado and date syrup*

Senzorsko ocjenjivanje medenjaka metodom bodovanja

Za senzorsko ocjenjivanje priređenih uzoraka medenjaka (slika 5) izrađen je obrazac s pitanjima koja su se odnosila na parametre senzorske kvalitete. Senzorska analiza provedena je pomoću metode bodovanja s čimbenicima važnosti (ponderirano ocjenjivanje), kojom se kvantificiraju ključna organoleptička svojstva medenjaka. Ocjenjivanje je provelo 13 educiranih panelista u standardiziranim uvjetima koristeći unaprijed pripremljeni senzorski list. Analizirani parametri kakvoće uključivali su: oblik i površinu, boju i ispečenost, strukturu i mastikaciju, miris i okus. Za svaki parametar određeni su opisni kriteriji unutar skale od 1 do 5 bodova, pri čemu viša ocjena označava veću razinu kvalitete. Svakom parametru pridružen je odgovarajući čimbenik važnosti (ponder) koji odražava njegov relativni doprinos ukupnoj prihvatljivosti proizvoda. Ponderi su dodijeljeni kako slijedi: oblik i površina (0,7), boja i ispečenost (0,7), struktura i mastikacija (1,2), okus i miris (1,4).
Ukupna senzorska ocjena izračunata je kao zbroj ponderiranih bodova svih analiziranih parametara. Dobiveni rezultati korišteni su za procjenu razlika u

senzorskoj kvaliteti između uzoraka proizvedenih prema različitim recepturama te za identifikaciju recepture s najvišom ukupnom prihvatljivošću. Rezultati senzorskog ocjenjivanja obrađeni su pomoću programa Microsoft Excel.

Senzorsko ispitivanje potrošačke percepcije i preferencije

U svrhu procjene ukupne prihvatljivosti uzoraka medenjaka iz perspektive potrošača, provedeno je senzorsko ispitivanje preferencije, percepcije tradicionalnosti i percipirane zdravstvene prihvatljivosti. Ispitivanje je provedeno u kontroliranim uvjetima s ukupno 13 sudionika, koji nisu prethodno informirani o sastavu uzoraka (test naslijepo). Svakom ispitaniku su istovremeno prezentirana četiri uzorka medenjaka.

Senzorski upitnik sadržavao je tri zadatka:

1. Test rangiranja preferencije: Ispitanici su zamoljeni da poredaju četiri uzorka od najprihvatljivijeg (1. mjesto) do najmanje prihvatljivog (4. mjesto), prema vlastitim preferencijama u ukupnom dojmu (izgled, tekstura, okus, aroma). Uz uzorak koji su rangirali na prvo mjesto, ispitanici su upisivali i razlog odabira, čime se kvalitativno dopunjuje test rangiranja.
2. Test prepoznavanja tradicionalnog uzorka: Ispitanici su trebali pokušati prepoznati uzorak koji, prema njihovom mišljenju, najviše odgovara senzor karakteristikama tradicionalnog medenjaka. Rezultati su korišteni za procjenu perceptivne bliskosti pojedinih uzoraka s tradicionalnim referentnim proizvodom.
3. Evaluacija percipirane zdravstvene prihvatljivosti: Ispitanici su označili koji od ponuđenih uzoraka smatraju da bi mogao pripadati kategoriji tzv. „zdravih medenjaka“, temeljem senzorne percepcije (npr. manje slatkoće, prirodnijih aroma, teksture, itd.).

Dobiveni podaci korišteni su za analizu potrošačke prihvatljivosti pojedinih receptura, prepoznatljivosti tradicionalnog uzorka i percepcije zdravstvene vrijednosti, u svrhu identifikacije optimalne formulacije medenjaka.

Slika 5. Priređeni (ispečeni) uzorci medenjaka
Figure 5. *Prepared (baked) gingerbread samples*

REZULTATI I RASPRAVA

Senzorskim ocjenjivanjem medenjaka pripremljenih prema četiri različite recepture (Tablica 2) utvrđene su značajne razlike u organoleptičkim svojstvima među uzorcima, što se može povezati s vrstom i količinom korištenih zamjenskih sastojaka. Slična su opažanja zabilježena su u studijama koje su istraživale modifikacije tradicionalnih pekarskih proizvoda radi poboljšanja nutritivne vrijednosti i funkcionalnosti (Vu i sur., 2025).

Tablica 2. Prosječne ocjene senzorskih svojstava medenjaka
Table 2. *Average scores of sensory properties of gingerbread*

Parametar senzorske kvalitete	Maks. ocjena	Uzorak 1	Uzorak 2	Uzorak 3	Uzorak 4
Oblik i površina	3,5	3,12	2,36	2,81	3,38
Urednost i boja preljeva	3,5	2,85	2,62	2,75	3,34
Struktura i mastikacija	6,0	5,14	3,97	5,08	5,42
Okus i miris	7,0	6,46	4,42	6,66	5,71

Legenda: UZORAK 1 (Medenjaci s javorovim sirupom i kokosovim uljem); UZORAK 2 (Bezglutenski medenjaci s chia sjemenkama); UZORAK 3 (Tradicionalni medenjaci); UZORAK 4 (Medenjaci s avokadom i sirupom od datulja)

Najviše ocjene za oblik i površinu postigao je uzorak 4 (3,38), medenjaci s avokadom i sirupom od datulja. Njihova je površina bila ujednačena, glatkih rubova i pravilnog oblika. Takvi rezultati mogu se povezati s prisutnošću jaja i integralnog brašna, koji doprinose stabilnoj strukturi tijesta i boljem zadržavanju oblika tijekom pečenja (Lončar i Ugarčić-Hardi, 2014; Pomeranz, 1988). S druge strane, bezglutenski uzorak 2 (2,36) pokazao je najslabije rezultate, što je očekivano s obzirom na odsutnost glutena, komponente koja je ključna za elastičnost i koheziju tijesta. Nedostatak glutenske mreže uzrokuje veću lomljivost i neujednačenu površinu (Belitz i sur., 2009; Gallagher i sur., 2004). Najbolje ocjene urednosti i boje preljeva također je ostvario uzorak 4 (3,34). Integralno brašno i prirodni zaslađivači poput sirupa od datulja doprinose ravnomjernijem pečenju i ujednačenoj boji, što potvrđuju i slična istraživanja o zamjeni rafiniranog šećera prirodnim sirupima (Santos i sur., 2024). Niže ocjene bezglutenskog uzorka 2 mogu se povezati s većim sadržajem vlage te manjom sposobnošću zadržavanja oblika i preljeva, što je u skladu s opažanjima Vu i sur. (2025) koji su zabilježili slične probleme kod kolača u kojima su jaja zamijenjena chia sjemenkama. Najpovoljniju strukturu i mastikaciju imao je uzorak 4 (5,42), dok su uzorci 1 (5,14) i 3 (5,08) također pokazali zadovoljavajuću teksturu. Uspješna primjena avokada kao zamjene za maslac objašnjava se njegovim visokim udjelom nezasićenih masnih kiselina i prirodnih emulgatora, koji poboljšavaju mekoću i

elastičnost tijesta (Pongprajak i sur., 2022; Santos i sur., 2024). Suprotno tomu, bezglutenski uzorak 2 (3,97) imao je tvrđu i manje homogenu strukturu, što potvrđuje da chia sjemenke, iako mogu djelomično zamijeniti jaja, ne osiguravaju jednaku povezanost sastojaka (Vu i sur., 2025). Najviše ocjene za okus i miris postigao je tradicionalni uzorak 3 (6,66), što potvrđuje važnost prepoznatljivog profila aroma koji potrošači povezuju s klasičnim medenjacima. Uzorak 1 (6,46) s javorovim sirupom i kokosovom masti, pokazao je gotovo jednaku prihvatljivost, što se može objasniti uravnoteženom aromom javorovog sirupa i blago egzotičnim notama kokosa koje su doprinijele kompleksnosti okusa. Uzorak 4 (5,71) imao je nešto niže ocjene, vjerojatno zbog intenzivne arome datuljinog sirupa koja odstupa od tipičnog profila medenjaka. Najniže ocjene ponovno je ostvario bezglutenski uzorak 2 (4,42), što potvrđuje da kombinacija chia sjemenki i avokada rezultira manje atraktivnim okusom i mirisom (Vu i sur., 2025).

Tablica 3. Preferencije potrošača i percepcija tradicionalnosti te zdravlja medenjaka (I. dio)
Table 3. *Consumer preferences and perception of traditionality and healthiness of gingerbread (I.part)*

OCJENJIVAČ	Poredajte uzorke prema vlastitoj preferenciji (na prvom mjestu najprihvatljiviji).	Za uzorak na prvom mjestu navedite zašto je za Vas najprihvatljiviji.	Prepoznajete li među kušanim uzorcima tradicionalni medenjak?	Koji od uzoraka bi mogao biti u kategoriji „zdravih medenjaka“?
1.	Uzorak 3 Uzorak 1 Uzorak 4 Uzorak 2	-	Uzorci 1 i 3	Uzorak 2
2.	Uzorak 3 Uzorak 4 Uzorak 1 Uzorak 2	Lako se otapa u ustima, ukusan je za jesti, ima sve karakteristike odličnog medenjaka.	Uzorak 3	Uzorak 1
3.	Uzorak 4 Uzorak 1 Uzorak 3 Uzorak 2	Lako se lomi i žvače, okusom ujednačen i nije presladak, ali karakterističan. Najmanja odstupanja u pečenju.	Uzorak 1	Uzorak 2

Legenda: UZORAK 1 (Medenjaci s javorovim sirupom i kokosovim uljem); UZORAK 2 (Bezglutenski medenjaci s chia sjemenkama); UZORAK 3 (Tradicionalni medenjaci); UZORAK 4 (Medenjaci s avokadom i sirupom od datulja)

Tablica 3. Preferencije potrošača i percepcija tradicionalnosti te zdravlja medenjaka (II. dio)

Table 3. *Consumer preferences and perception of traditionality and healthiness of gingerbread (II.part)*

4.	Uzorak 4 Uzorak 1 Uzorak 3 Uzorak 2	Lijep oblik, jednolik preljev, najmekši.	Uzorak 1 ili 4	Uzorak 4
5.	Uzorak 4 Uzorak 2 Uzorak 3 Uzorak 1	Okusom i strukturom najviše odgovara medenjaku.	Uzorak 4	Uzorak 2
6.	Uzorak 4 Uzorak 3 Uzorak 1 Uzorak 2	Ima sočnost, a općenito je najslađi u odnosu na ostale uzorke.	Uzorak 2	Uzorak 1
7.	Uzorak 3 Uzorak 1 Uzorak 4 Uzorak 2	Najbolje se osjete arome, poput pravog medenjaka.	Uzorak 3	Uzorak 1
8.	Uzorak 4 Uzorak 1 Uzorak 3 Uzorak 2	Najmekši, punog okusa, osjete se sve arome, najukusniji.	Uzorak 3	Uzorak 2
9.	Uzorak 3 Uzorak 1 Uzorak 4 Uzorak 2	Malo prepečen, no najbolji po pitanju arome i zrnatosti.	Uzorak 3	Uzorak 2
10.	Uzorak 1 Uzorak 3 Uzorak 4 Uzorak 2	Najbolji izgled i prepoznatljiv okus.	Uzorak 3	Uzorak 2
11.	Uzorak 1 Uzorak 4 Uzorak 3 Uzorak 2	Sve karakteristike zajedno najbolje odgovaraju.	Uzorak 1	Uzorak 2
12.	Uzorak 1 Uzorak 3 Uzorak 4 Uzorak 2	Okus karakterističan za tradicionalni medenjak.	Uzorak 1	Uzorak 2
13.	Uzorak 1 Uzorak 2 Uzorak 4 Uzorak 3	-	Uzorak 1	Uzorak 4

Legenda: UZORAK 1 (Medenjaci s javorovim sirupom i kokosovim uljem); UZORAK 2 (Bezglutenski medenjaci s chia sjemenkama); UZORAK 3 (Tradicionalni medenjaci); UZORAK 4 (Medenjaci s avokadom i sirupom od datulja)

Analiza preferencija ocjenjivača (Tablica 3.) pokazuje jasno istaknute uzorke koji su najviše prihvaćeni, kao i one koji su smatrani prikladnima za kategoriju „zdravih medenjaka“. Većina ocjenjivača (10 od 13) preferirala je uzorak 3 (tradicionalni medenjak) ili uzorak 4 (medenjak s avokadom i sirupom od datulja), što ukazuje na dva dominantna profila senzorskih svojstava koja su potrošači prihvatili. Uzorak 3 prepoznat je kao najprihvatljiviji zbog svojeg klasičnog okusa, lakoće otapanja u ustima te autentičnih aroma medenjaka („Lako se otapa u ustima, ukusan je za jesti, ima sve karakteristike odličnog medenjaka“; „Najbolje se osjete arome, poput pravog medenjaka“). Takvi komentari ukazuju na važnost senzorskog prepoznavanja i očekivanja potrošača kod tradicionalnih proizvoda, što potvrđuju i istraživanja o važnosti senzorne dosljednosti u potrošačkoj percepciji (Yang i Lee, 2019). S druge strane, uzorak 4 istaknut je zbog svoje mekoće, uravnoteženog okusa i blagih aroma („Najmekši, punog okusa, osjete se sve arome“; „Ima sočnost, a općenito je najslađi“). To ukazuje na uspjeh u kreiranju proizvoda koji kombinira zdravije sastojke, poput integralnog brašna i prirodnih zaslađivača, a da pritom ne naruši senzorski doživljaj. Većina ocjenjivača prepoznala je tradicionalni medenjak upravo u uzorku 3, što potvrđuje da se senzorski profil tog uzorka najviše poklapa s očekivanjima potrošača u pogledu autentičnosti (komentare poput „Okus karakterističan za tradicionalni medenjak“). U nekoliko slučajeva uzorci 1 i 4 označeni su kao tradicionalni medenjak, što pokazuje da i ti uzorci imaju osnovne senzorske karakteristike unatoč modifikacijama sastojaka. Za „zdrave medenjake“ najčešće su označeni uzorci 1 i 2 te, u manjoj mjeri, uzorak 4. Uzorak 2 (bezglutenski medenjak s chia sjemenkama i avokadom), iako je u većini ocjena bio na posljednjem mjestu po ukupnom dojmu okusa i teksture, prepoznat je kao primjer zdravijeg proizvoda zbog zamjene klasičnih sastojaka s funkcionalnim i nutritivno bogatijim alternativama. Uzorak 1, s javorovim sirupom i kokosovom masti, također je ocjenjivan kao zdraviji izbor, što potvrđuju i komentari ocjenjivača („Uzorak 1“, „Uzorak 4“ u kategoriji zdravih). Ti rezultati potvrđuju da potrošači prepoznaju zdravlje proizvoda ne samo kroz okus već i na temelju sastojaka koje medenjaci sadrže, što je u skladu s trendovima povećane potražnje za funkcionalnom i zdravom hranom (Verbeke, 2005).

ZAKLJUČAK

Dobiveni rezultati pokazuju da je moguće razviti nutritivno i funkcionalno poboljšane medenjake bez značajnog kompromisa u senzorskoj kvaliteti, posebice kada se koriste prirodni zaslađivači i zdrave masnoće koje pozitivno utječu na teksturu i okus proizvoda. Potrebna je daljnja optimizacija recepture bezglutenskih medenjaka, posebice u smislu uravnoteženja sadržaja vlage i učinkovitosti vezivnih sastojaka, da bi se unaprijedila teksturalna svojstva i senzorska kvaliteta proizvoda. Rezultati upućuju na jasnu podjelu u preferenciji između tradicionalnih medenjaka koji zadovoljavaju očekivanja po okusu i teksturi te zdravijih varijanti koje su prepoznate kao zdravije, ali nisu uvijek senzorski najprivlačnije. Najbolji pristup mogao bi biti daljnja optimizacija receptura zdravijih medenjaka (posebice bezglutenskih) s ciljem podizanja njihove senzorske kvalitete da bi se postigao kompromis između zdravlja i užitka u konzumaciji. Ukupno gledajući, istraživanje potvrđuje da se tradicionalni pekarski proizvodi poput medenjaka mogu uspješno unaprijediti korištenjem

integralnog brašna, prirodnih zaslađivača i biljnih masti, uz očuvanje senzorskih svojstava prihvatljivih potrošačima. Takvi proizvodi predstavljaju značajan potencijal u razvoju suvremenih prehrambenih trendova koji spajaju tradiciju i zdravu prehranu.

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HEALTHY LIFESTYLES

DIETARY HABITS OF PHYSICALLY ACTIVE INDIVIDUALS DURING GRAPE HARVEST IN CHAMPAGNE REGION

Valentina Obradović*, Lara Zadravec, Maja Ergović Ravančić, Sunčana Včelik, Svjetlana Škrabal

Faculty of tourism and rural development in Požega, Vukovarska 17, 34 000 Požega, Croatia
*vobradovic@ftrr.hr

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ABSTRACT

During the grape harvest in the French region of Champagne, a weekly food diary was kept for workers engaged in physically demanding vineyard activities. Based on the recorded meals, an analysis of dietary habits was conducted using the online application *Program prehrane*. The reference model in the application was set as an average harvest worker: a 40-year-old man, 180 cm tall, weighing 75 kg, with a moderate to high level of physical activity. The recommended daily energy intake for this profile was 3242 kcal. The analysis showed that daily energy intake was generally below the recommended level, ranging from 2561.4 to 3242 kcal. The proportion of carbohydrates ranged from 28.6% to 53.3% of total energy intake (recommendation: 45-65%), protein from 9.6% to 20.0% (recommendation: 10-20%), while fats accounted for up to 51.4% of total energy intake (recommendation: 20-35%). Saturated fat intake regularly exceeded the recommended maximum of 44.6 g, with the highest recorded value at 54.2 g. Cholesterol levels reached up to 477 mg per day (recommendation: ≤300 mg), and sodium up to 4066.1 mg (recommendation: ≤2300 mg). It is recommended to introduce snacks, reduce the intake of fatty and processed foods, and increase the share of whole grains.

Keywords: nutrition, grape harvest, Champagne, physical activity

INTRODUCTION

Traditional food products represent an important part of French heritage and continue to shape both the national identity and culture. The diversity and refinement of French cuisine have greatly contributed to its international reputation, and in 2010, the gastronomic meal of the French was inscribed on the UNESCO Representative List of the Intangible Cultural Heritage of Humanity (Julien-David and Marcic, 2020). Since Renaud and de Lorgeril (1992) introduced the term French paradox, French dietary habits have become the focus of numerous studies worldwide. From a nutritional standpoint, however, French gastronomy does not strictly follow conventional dietary recommendations. The French diet is characterized by a high total fat intake, particularly saturated fats, as noted by Renaud and de Lorgeril (1992), the mortality rate from cardiovascular diseases remains significantly lower than in other Western countries.

This paradox was initially attributed to the regular consumption of wine, specifically to the compound resveratrol. Nevertheless, Rozin et al. (2003) argued that the impact of dietary fat intake on cardiovascular risk has been overstated and should not be viewed as an isolated factor. Instead, a range of additional determinants must be considered, including genetics, stress levels, attitudes toward illness, eating patterns, and physical activity. The same authors introduced the concept of the ecology of eating, emphasizing portion size and meal duration, a relationship later confirmed empirically (Rozin, 2005). Slow eating, minimal snacking, and regular physical activity have been identified as key characteristics of French eating behavior (Petyaev and Bashmakov, 2012; Rozin et al., 2003) .

Other hypotheses have suggested that the high consumption of mold-ripened cheeses may also play a beneficial role, given that France ranks among the world's top consumers of cheese, second only to Greece. This has been linked to the positive effects of secondary metabolites produced by mold cultures (Petyaev and Bashmakov, 2012). However, national dietary surveys conducted in France during the 21st century (the second cross-sectional dietary survey, 2006–2007, and the third national survey, 2014–2015) indicate generally poor nutritional outcomes. French diets tend to include large amounts of processed foods and salt, low levels of dietary fiber, and are associated with overweight, sedentary lifestyles, and insufficient physical activity (Gazan et al., 2016, Dubuisson et al, 2019). Despite these findings, it is evident that food culture itself plays a crucial role in the relationship between diet and health. A deeper understanding of food culture, which encompasses attitudes, beliefs, and traditions related to food and eating, as well as the social relationships that emerge around food, is essential (Dao et al., 2021; Rozin et al., 1999).

In this context, studying specific dietary niches can provide valuable insight. The workplace, for instance, may serve as an important setting for promoting healthy eating habits (Tanaka et al., 2019), although occupational differences must be carefully considered. Poulianiti et al. (2019) reported that agricultural work ranks among the most energetically demanding professions compared with other industries such as construction, manufacturing, transport, or tourism. Their conclusions were based on 61 studies, 27 of which were related to agriculture. However, only five studies examined energy intake during crop harvesting, and just one specifically

focused on grape harvesting. Environmental conditions, particularly heat stress, represent a significant factor in physically demanding work (Merritt et al., 2024; Ioannou et al., 2017), and grape harvesting in the Champagne region often takes place under relatively high temperatures. Grimbuhler and Viel (2021) also reported the high physical demands of vineyard work, though not specifically during grape harvest, and emphasized the lack of targeted studies in this agricultural sector as well as the difficulty of comparing existing data due to varying working conditions.

Therefore, this study aimed to monitor the dietary habits of grape pickers in the Champagne-Ardenne region over a one-week period and to evaluate the energy and nutrient composition of their daily diets. By focusing on a physically demanding and culturally specific occupation, the study seeks to better characterize the eating patterns present in this context and to determine the extent to which they meet the nutritional requirements associated with such labor-intensive work..

MATERIALS AND METHODS

During the grape harvest week in the Champagne-Ardenne region, meals served to vineyard workers were recorded daily. The harvest took place in the village of Champillon at the family-owned Roualet winery. On average, approximately 20 pickers participated in harvest every day. The workday began at 7:00 a.m. with a substantial French breakfast, followed by the start of grape picking at 7:30 a.m. Lunch was served at 12:00 p.m., followed by a break until 1:30 p.m. Each day, harvesting activities concluded around 6:00 p.m., while dinner and evening social gatherings began at 7:00 p.m.

Menu analysis and data processing were conducted using the web application *Program prehrane*. Within the application, dietary standards were established for each meal, and analyses were performed to determine total energy intake as well as the quantities of macro and micronutrients. For the purpose of the analysis, the client profile was set as a male representative picker, aged 40 years, with a height of 180 cm and body weight of 75 kg. The level of physical activity during vineyard work was classified as moderate to high intensity.

RESULTS AND DISCUSSION

Table 1 provides an overview of all recorded meals consumed by grape pickers over the seven-day monitoring period, presented separately for breakfast, lunch, and dinner. It summarizes the structure and composition of each meal, including main dishes, accompanying items, beverages, and any snacks consumed during the day. This detailed daily overview served as the basis for examining dietary patterns, meal organization, and overall intake across the workweek.

Table 1. 7-day overview of daily meals and beverages (I. part)

	Breakfast	**Lunch**	**Dinner**
Day 1	Cheese and sausage baguette sandwich, chocolate bar, black filter coffee, water.	Starter: potato salad with tomato and onion, carrot salad, and cabbage salad, served with baguette bread. Main course: beef in a mustard, onion, honey, and beer sauce, served with mashed potatoes. Dessert: apple crumble and a selection of French cheeses. Beverage: a glass of red wine, water.	Soup: cold soup made with mint, zucchini, and cucumber. Main course: ham and cheese quiche, lettuce. Dessert: selection of cheeses. Beverage: a glass of champagne, water.
Day 2	Brioche and black filter coffee. Morning snack: Orange juice and a banana.	Starter: green salad with eggs, spring onions, and baguette bread. Main course: braised sauerkraut with sausages and boiled potatoes. Dessert: a selection of cheeses. Beverage: a glass of champagne, water.	Soup: carrot and pumpkin soup. Salad: couscous salad with tomato, parsley, bell pepper, and mint. Dessert: sponge cake and apple tart. Beverage: a glass of red wine, water.
Day 3	Baguette sandwich with Camembert cheese and liver sausage and black filtar coffee. Morning snack: an apple.	Starter: tomato salad and baguette bread. Main course: boiled beef, boiled vegetables, and spiral pasta with mushroom sauce. Dessert: crème brûlée and cheeses. Beverage: a glass of champagne, water.	Soup: fresh asparagus soup. Salad: couscous salad with tomato, corn, bell pepper, and parsley. Cheese plate: traditional French cheeses served with fresh baguette bread, fruit, and nuts. Dessert: sponge cake with fresh cheese and raspberries. Beverage: a glass of red wine, water.

Table 1. 7-day overview of daily meals and beverages (II. part)

	Breakfast	**Lunch**	**Dinner**
Day 4	Butter croissant and coffee, orange juice Morning snack: two small chocolates.	Starter: green salad with corn, tomato, and onion, served with baguette bread. Main course: potato and beef pie. Dessert: classic apple tart. Beverage: a glass of champagne, water.	Before dinner: a glass of bear Soup: pumpkin cream soup with pumpkin seeds. Main course: cheese and ham quiche served with fresh green salad. Dessert: plain sponge cake Beverage: a glass of red wine, water.
Day 5	Fresh brioche pastry, coffee, and two glasses of orange juice. Morning snack: a slice of baguette bread with a small piece of Camembert cheese.	Starter: beetroot salad and baguette bread. Main course: lasagna with potatoes and green salad. Dessert: a selection of cheeses. Beverage: a glass of champagne, water.	Soup: a pumpkin soup. Main course: chicory stuffed with ham and cheese, served with green salad. Dessert: traditional French cheeses and plum tart. Beverage: a glass of red wine, water.
Day 6	Sandwich with ham, cheese, and cucumber and coffee. Morning snack: chocolate biscuits.	Starter: beetroot salad and couscous salad with tomato and corn, served with a slice of French bread. Main course: potato and beef pie baked with cream. Dessert: a selection of cheeses. Beverage: a glass of champagne, water.	Soup: zucchini soup, served with a slice of baguette bread. Main course: tuna salad with pasta, tomato, and corn. Dessert: moist sponge cake with sweet cream and berries. Beverage: a glass of red wine, water.
Day 7	Two croissants with jam and butter, served with orange juice and coffee.	Starter: tuna salad with corn, tomato, onion, and pasta. Main course: roast duck served with rice. Dessert: French cheeses. Beverage: a glass of champagne, water.	Starters: various tarts and pies with ham, cheese, and tomato, served with a glass of champagne. Main course: wild boar with trumpet mushroom sauce, accompanied by mashed potatoes with a glass of red wine. Dessert: traditional French apple cake. Beverage: a glass of red wine, water.

Table 2 shows the distribution of daily caloric intake by meals. The analysis of daily energy distribution among vineyard workers during the grape harvest revealed

noticeable variability between days but an overall pattern is consistent with recommendations for adults performing physically demanding work. Nutritional guidelines generally suggest that total daily energy intake should be divided as approximately 20-25% for breakfast, 35-40% for lunch, and 30-35% for dinner (EFSA, 2013; Gibney et al., 2018; USDA, 2020). In this study, breakfast contributed 23-36%, lunch 31.7-48.8%, and dinner 25.8-37.7% of total energy. The relatively high breakfast values on some days exceed the upper recommended limit but are likely justified by the early start and continuous manual labor typical of vineyard work. Previous research indicates that higher morning energy intake supports better physical performance and cognitive alertness during extended work periods (Betts et al., 2014). Lunch consistently represented the main source of daily energy, often exceeding 40%, which is compatible with findings from agricultural contexts where midday meals coincide with peak workload and energy expenditure. Dinner energy contribution was generally within or slightly above recommended levels, a pattern observed in physically active populations where post-work recovery requires adequate refueling without promoting excess caloric intake (Lopez-Minguez et al., 2019). Compared with population-based cohorts, in which energy distribution typically averages 15-20% at breakfast, 35-40% at lunch, and 30% at dinner (Hermengildo et al. 2016), the present data demonstrate a shift toward higher morning and midday energy intake, reflecting the physiological and cultural adaptation to vineyard labor. Overall, the observed pattern suggests an appropriate alignment between energy intake timing and work intensity, supporting the premise that dietary recommendations should be adjusted to the occupational and temporal demands of manual agricultural work. If the total daily caloric intake is observed, it ranges from 2561 kcal on day 3 to 3284 kcal on day 7 (with an average of 2817 kcal). According to the web aplication *Program prehrane*, the recommended energy intake for the selected picker profile is 3242 kcal, which, based on the meal standards, was met only on day 7. However, it should be noted that additional amounts of food could be taken if needed, as the meals were served buffet-style, allowing each individual to choose their desired portion size.

Table 2. Caloric intake per meal over a week

	Breakfast		**Lunch**		**Dinner**	
	Energy (kcal)	**Energy share (%)**	**Energy (kcal)**	**Energy share (%)**	**Energy (kcal)**	**Energy share (%)**
Day 1	623.2	23	1324.1	48.8	766.4	28.2
Day 2	951.8	34	886.6	31.7	962.2	34.4
Day 3	695.3	27.1	991.9	38.7	874.2	34.1
Day 4	1006.1	36.1	1005.9	36.1	862.8	30
Day 5	657.9	25	978.1	37.2	991.9	37.7
Day 6	761.2	26.6	1111.2	38.9	986.8	34.5
Day 7	959	29.2	1477.5	45	847.8	25.8

The contribution of individual macronutrients to the total daily caloric intake is shown in Table 3. According to current recommendations (National Academies of Sciences, Engineering, and Medicine, 2006) the proportion of energy derived from carbohydrates should range between 45% and 65%, energy from proteins should account for 10% to 20%, and energy from fats should make up 20% to 35%. As shown in the table 3, protein intake was adequate throughout all days, while the ratio of carbohydrates to fats was in line with the recommendations only on days 2 and 6. On all other days, carbohydrate intake was insufficient, and fat intake was excessive.

The high proportion of fats in the daily energy intake, approximately 50% on days 1, 4, 5, and 7, can primarily be attributed to the consumption of cheese in all three meals, as well as croissants and butter (on days 4 and 7). In addition to these typical French foods, the use of cream, béchamel sauce, and the preparation of sponge cakes and quiches further increased fat intake. Such a macronutrient structure is not unusual for French cuisine (Julien-David and Marcic, 2020; Petyaev and Bashmakov, 2012) and is therefore expected. However, Brassard et al. (2018) investigated how saturated fats from cheese and butter differently affect blood lipids and heart health. They found that cheese consumption, despite its high content of saturated fat and sodium, is not linked to an increased risk of coronary artery disease. Saturated fats from cheese had a neutral effect on both LDL and HDL cholesterol levels, while those from butter increased LDL cholesterol. These findings support the idea that the structure of a food product influences how its nutrients affect metabolism, with cheese showing a more favorable impact than butter.

Furthermore, each day a glass of wine was served at the end of lunch and dinner (usually champagne with lunch and red wine with dinner), which is another characteristic of the French diet, and it has been widely investigated especially in the context of French Paradox (Ferrières, 2004). Daily consumption of white bread should also be highlighted. It would be advisable to introduce whole-grain alternatives, reduce cheese intake to once per day, and increase the consumption of fruit and nuts, which are currently underrepresented in the provided meals. Komati et al. (2024) and Maillot et al. (2009) have similarly highlighted that a substantial proportion of the French population consumes insufficient amounts of fruits and vegetables and generally follows a diet that does not meet established nutritional recommendations.

Table 3. Macronutrient contribution to total energy intake

	Ratio in energy value of the meal (%)		
	Carbohydrates	**Proteins**	**Fats**
Day 1	34.6	15.6	49,8
Day 2	53.3	12.5	34.3
Day 3	41.9	17.1	41.1
Day 4	39.6	9.6	50.9
Day 5	28.6	20.0	51.4
Day 6	48.7	18.2	33.1
Day 7	31.7	17.1	51.2

Table 4 summarizes the daily intake of selected micronutrients, highlighting those that deviated most markedly from recommended dietary reference values. The intake of saturated fatty acids exceeded the set upper limit of 22.3 g/day on all days except for day 2. Similarly, cholesterol intake substantially exceeded the recommended upper limit of 300 mg/day on days 1, 4, and 5, coinciding with the days of highest total fat contribution to daily energy intake. It is well recognized that foods high in cholesterol are also important sources of saturated fatty acids. Nevertheless, Soliman (2018) reported that current evidence does not support the hypothesis that dietary cholesterol increases the risk of heart disease in healthy individuals. Conversely, substantial evidence indicates that saturated fatty acids and trans fats are associated with an elevated risk of cardiovascular disease. Polyunsaturated fatty acid intake was consistently inadequate across all days, except in day 6. As previously discussed, incorporating dietary sources such as nuts or seeds would improve unsaturated fats intake. Sodium intake fell well below the maximum recommended level of 2300 mg only on day 4, likely due to the absence of traditional cheese platters in the menu that day. According to the World Health Organization (2012), sodium intake should not exceed 2 g per day (equivalent to approximately 5 g of salt). This guideline supports the observation that the day with notably lower sodium intake was nutritionally more appropriate and clinically significant in terms of cardiovascular risk reduction. According to EFSA (2015), the recommended adequate intake of vitamin E for adults is 11-13 mg/day. The present analysis showed that intake was insufficient on most days (except in day 6), highlighting the need to include vitamin E-rich foods, such as nuts, seeds, or vegetable oils, to meet dietary requirements. Vitamin C intake met recommendations on all days except day 7 (IOM, 2000), indicating that the diet was generally sufficient in this micronutrient.

Table 4. Selected micronutrients in daily meals

	Saturated fats	**Polyunsaturated fats**	**Cholesterol**	**Sodium**	**Vitamin E**	**Vitamin C**
	Daily intake (g) UL=22.3 g	**Daily intake (g) RDA=17.8 g**	**Daily intake (mg) UL=300 mg**	**Daily intake (mg) UL=2300 mg**	**Daily intake (mg) RDA=15 mg**	**Daily intake (mg) RDA=75 mg**
Day 1	54.2	9.6	340.8	3196.8	10	152
Day 2	13.4	2.9	252.5	2636.5	4.8	295
Day 3	34.7	6.7	247.8	3465.6	7.2	210.8
Day 4	25.7	1.8	477	645.9	3.5	117.8
Day 5	43.1	7.3	435	2469.5	4.7	90
Day 6	47.2	17.1	262.4	4066.1	15.5	76.1
Day 7	40.1	5.5	298.8	2028.5	3.8	55.2

*UL-Tolerable Upper Intake Level; *RDA-Recommended Dietary Allowance (source: *Program prehrane* according to U.S. National Academies of Sciences, Engineerng and Medicine)

CONCLUSION

This study analyzed the dietary habits of vineyard workers during the grape harvest in the Champagne region. Results showed that daily energy intake was generally below recommended levels, with excessive fat and sodium intake and insufficient carbohydrates and polyunsaturated fats. Despite this, the energy distribution across meals corresponded well to the physical demands of vineyard work. The findings confirm the strong influence of cultural eating patterns on nutritional adequacy and highlight the need to adapt dietary guidelines to specific occupational contexts. Future research should include a larger sample, direct physiological measurements, and seasonal comparisons to better understand the relationship between nutrition, workload, and performance in agricultural labor.

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