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RESEARCH

Uncovering the Probiotic Supplement Landscape: Market Offerings, Sales Patterns, and Future Forecasts Using Machine Learning Approach — A Case Study of Montenegro

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Abstract
Global increasing awareness about the health benefits of probiotics resulted to explorational growth in probiotic food supplement market. However, in some countries such as Montenegro, specific probiotic supplement regulation and comprehensive market analysis are absent, hampering the understanding of consumer preferences, market trends, and potential economic impacts of this industry. This article aims to delve into the Montenegrin market of probiotic food supplements, thoroughly examining various product types and their key characteristics. Using the case study of a pharmacy chain, as an example of organizational level, the sales, sale patterns, and trends are examined. Furthermore, we developed and employed a machine learning model for forecasting future sales. The market analysis highlighted the importance of setting national probiotic supplement regulations to enhance Montenegrin consumer understanding and trust, ensuring product efficacy and safety. Our study clearly showed increased interest in probiotic supplements as well as a constant positive trend in probiotic supplement sales. Furthermore, we found the correlation between foreign tourist visits in Montenegro and the yearly seasonality of probiotic supplement sales. Developed support vector regression machine learning model on time series data showed a good forecasting accuracy, clearly indicating that the same could be used for national sales forecasting. The insights from this study could promote the establishment of national probiotic supplement regulations, enhancing consumer protection and market credibility. Additionally, developed machine learning model provides the industry with valuable predictive tool, enabling companies to optimize their supply chains, effectively meet demand, and make data-driven decisions that could support sustainable market growth.

Keywords Artificial intelligence · COVID-19 · Health · Probiotics · Prediction · Regulations

Introduction

An extensive pool of research has highlighted multifaced health benefits of probiotics, including improvement of gut-barrier function, normalization of the disturbed gastrointestinal tract, metabolic improvements, immunomodulatory, as well as positive effects on sleep, cognitive reactions, and mental condition [1–3]. Due to increased scientific evidences and demand for health-based products the global probiotic market witnesses significant growth, and it is expected to grow at a compound annual growth rate (CAGR) of 14.0% from 2023 to 2030 [4]. "Probiotics are microorganisms, that when administered in adequate amounts, confer a health benefit on the host" [5]. It is important to note that each probiotic strain has specific traits, thus providing strain-specific health benefits, whereas generally, a recognized effective probiotic quantity at the time of consumption is a minimum of 10^6 colony-forming units (CFU)/g [6]. Commercial probiotics include mainly strains of genera *Lactobacillus* and *Bifidobacterium*, the genius *Bacillus*, and yeast *Saccharomyces cerevisiae* var. *boulardii*. Probiotics are orally administrated as foods (if the food is fermented using a microbe proven to be a probiotic or have had a probiotic microbe added in adequate amounts to provide a health benefit),

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food supplements (tablets, capsules, powder, ampoules), or drugs (i.e., medicinal products and pharmaceuticals) [7]. Consumption of probiotic supplements over probiotic food has multiple advantages including convenience, controlled dosages, longer shelf-life, allergen-free, and no-calorie products [8].

For centuries, the traditional cuisine of Montenegro has included a variety of probiotic-like beneficial microbes fermented foods such as fermented milk, yogurt, various cheeses, and sauerkraut [9]. Therefore, the consumption of probiotics through food is deeply ingrained in the dietary habits of the Montenegrin population. On the other hand, the Montenegrin population just recently started to be more familiar and interested in the consumption of probiotic food supplements. In Montenegro, alike in the rest of the world, the probiotic food supplement landscape witnessed significant growth after the transformative event of the past — the COVID-19 pandemic [10]. Usually, healthcare practitioners primarily have recommended probiotic supplements as a supportive measure for antibiotic therapy, targeting the prevention/management of antibiotic-associated diarrhea (AAD) [11]. As additional evidence surfaced, their use also extended to boosting immunological health. The COVID-19 pandemic further has brought attention to the critical role of gut health in overall well-being, highlighting the potential substantial contributions of probiotic intervention [3, 10, 12].

Following the strategic decision of joining the European Union (EU), Montenegro has engaged in preparing and adopting novel policies that are in line with the EU, such as The Law on Food Safety [13], governing food supplements. However, when it comes to probiotic food supplements, Montenegro finds itself in a "gray zone"—lacking specific probiotic regulations and guidelines. This complexity is heightened by Montenegro's heavy dependence on imports from various countries, each with different regulatory standards. Numerous authors have highlighted issues with the quality of commercial probiotics, even in countries with robust regulations [14, 15]. As a result, the Montenegrin market remains open to both high-quality and low-quality probiotic food supplements. Moreover, lack of regulatory standards drives inconsistent labeling, unverifiable health claims, and varying product quality, which can lead to products that are ineffective or even unsafe. The lack of regulation also could encourage misleading marketing practices, undermining consumer trust while disturbing industry growth and innovation. Consequently, these regulatory gaps restrict consumer access to reliable, scientific-backed probiotics, potentially leading to a consumers' lack of trust in the probiotic industry, as well as compromise the overall confidence of consumers in incorporating probiotic supplements into their healthy habits. Implementing thorough regulatory measures and conducting marketing studies are crucial steps to ensure that consumers receive accurate information and can make informed decisions about the probiotic products they choose to purchase.

In addition, Montenegro lacks probiotic supplement marketing data including sales, sales patterns, and trends, as well as future sales forecasts. Understanding them is crucial for multiple reasons including obtaining insight into public awareness, planning national healthcare initiatives, assessing the probiotic supplement industry economic impact, facilitating, and enforcing regulatory considerations, supporting research and development, as well as guiding public health interventions [16]. For a healthcare organization (e.g., pharmacy), marketing information and forecasts are essential for ensuring optimal inventory management (e.g., ensure enough stock to meet demand during peak periods and avoid excess inventory during slower times), tailoring marketing strategies to meet local demand, staying competitive in the local market, maximizing profitability through strategic product placement, and adapting to changes in consumer health and wellness preferences [17], therefore contributing to overall organizational sustainability. Recently, artificial intelligence, specifically machine learning (ML) models, has been increasingly applied for healthcare products consumption forecasting purposes [18]. These models rely on mathematical methods, which enable them to capture complex relationships between variables and to make predictions based on current and past values of the time series whose future movement is predicted, as well as of other time series that can have an impact [19]. The commonly used models include the random forest algorithm [20], support vector regression (SVR) [21], and long short-term memory (LSTM) [22].

Through this article, we will deliver into Montenegrin market of probiotic supplements examining probiotic supplement product types and their main characteristics. Using an organizational-level example, in the case study of pharmacy chain, we will examine sales, sale patterns, and trends as well as develop and employ ML approach to forecast future sales patterns. The ultimate goal is to inform and promote a better understanding of Montenegrin probiotic supplement market as well as to outline the importance of conducting market analysis and forecasts for both organizational and potentially national level sustainability.

Materials and Methods

Mapping Probiotic Food Supplements: Overview of the Key Product Characteristics

In this study, we performed mapping of food supplements containing single strain and/or multistrain/multispecies probiotics, formulated with/without prebiotics, with/without

botanicals (e.g., *Cinnamomum cassia*), and minerals and/or vitamins (Table 1). For mapping of such products available on the Montenegrin market during the period November 30, 2023–March 1, 2024, the information from the following sources was used: pharmacies (as the main sales channel), specialty health food stores, websites, and online pharmacy web addresses (Supplementary Table 1). We have selected the largest pharmacy chains and health food stores in all three regions of Montenegro to ensure comprehensive market representation across various regions. For online platforms, we focused on online pharmacies web sites commonly known by Montenegrin consumers. This approach aimed to capture a diverse and representative overview of available probiotic products. Every identified product was listed, and the following information was recorded: commercial product name, probiotic strain(s), number of live cells (in colony forming units — CFU), dosage and type of product form (capsule, sachets, liquid), health claims specifically addressed to probiotics (if stated on the package), other active ingredients within the product, producer, and country of production (Table 1). The products were then categorized into distinct groups based on the application purposes (gut health improvement, immunity, oral health, women's health, and probiotics intended for infants and children) (Table 1).

A Case Study of Montenegro

Data Collection and Criteria

The case study included a pharmacy chain selected for its representative nature within all three Montenegrin regions — the south, central, and north regions. The chosen pharmacy chain, which included time series data from 45 pharmacies, offers a diverse range of probiotic supplements for various applications. Available time series data for 5 years, starting from January 2018 to December 2023, were selected to capture probiotic supplement sales, sales patterns, analyze sale trends, and seasonal variations as well as to forecast future sales using statistical and ML approaches. This time frame that was available from pharmacy chain's system was sufficient to develop the ML model. From the same pharmacy chain available time series data of antibiotic sales were collected and included in ML forecasting model. Time series data of both probiotic supplements and antibiotics were extracted from the pharmacy chain's centralized electronic point-of-sale (POS) system.

Data for the foreign tourists' visits over the analyzed period of 5 years were sourced from the Statistical Office of Montenegro, MONSTAT [24]. The data for both collective (e.g., hotels, motels, holiday villages, tourist resorts, camps) and individual (e.g., houses, rooms for rent), tourist apartments foreign tourist accommodation were considered. Data of the active monthly COVID-19 cases for the period of 2018 to 2023 were sourced from the Institute of Public Health of Montenegro [25].

Google Trends Data

Interest in web research for probiotic supplement products in Montenegro was represented by 2018–2023 Google Trends data. Google Trends data is an online log that indicates how often a particular search term is entered in the Google search engine relative to the total search volume across various time. This analysis indicates the likelihood of a random user searching for a particular term from a certain location at a certain time. The data are displayed on a scale of 0 to 100. The data are first normalized in accordance with the total search volume in that region in the given period. If the data were not normalized, regions with the most search volume would always have the highest ranking. A value of 100 is the peak popularity for the term. A value of 50 means that the term is half as popular. A score of 0 means there was not enough data for this term. We researched the term "probiotik/c."

Statistical Analysis

Tools All data preprocessing, model training and statistical analyses were conducted using Python programming language (version 3.9.16) and relevant libraries and packages included NumPy, Pandas, Sklearn, Scikit-learn Matplotlib, Statsmodels, and Scipystats.

Statistical Analysis For identifying seasonal patterns in time series data, the decomposition task was employed. The most used decomposition techniques include classical decomposition, fast Fourier transformation (FFT), discrete wavelet transform (DWT), and seasonal-trend decomposition using LOESS (STL) decomposition. In this article, the STL decomposition was used that separated a time series data into three components: a trend (representing the slow-moving changes in the dataset), seasonal components (capturing the periodic pattern in the time series data), and residuals (representing residuals which refers to random error, noise, or any irregularity that cannot be explained by the trend or the seasonal component) [26]. Decomposition enabled better understanding of time series datasets, necessary for selecting relevant forecasting models.

Additionally, the Granger causality test was used to investigate if time series data from tourism, antibiotic sales, and monthly COVID-19 active cases could be used as additional features for forecasting probiotic supplement sales. For determining the stationarity of probiotics supplement sales time series data, the augmented Dickey-Duller (ADF) test was utilized. This test enabled determining if the time series data for forecasting could be used directly or

Table 1 Mapped probiotic food supplements on Montenegrin market

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
Gut health						
BULARDI® PLUS	*Saccharomyces cerevisiae* var. *boulardii*	5×10^9	1 capsule			Abela pharm (Serbia)
BULARDI® Junior	*Saccharomyces cerevisiae* var. *boulardii*	5×10^9	1 capsule		Zn	Abela pharm (Serbia)
FLOBIAN®	*Lactobacillus plantarum* 299v	20×10^9	1 capsule	For *reduction of bowel irritation and flatulence*		Abela pharm (Serbia)
Entero-Biotik®	*Saccharomyces boulardii*, *Lactobacillus rhamnosus* LGG, *Lactobacillus plantarum* 6595, *Lactobacillus plantarum* HEAL9	5.5×10^9	1 capsule			Abela pharm (Serbia)
EsenBak®	*Lactobacillus rhamnosus* Lr-G14, *Bifidobacterium breve* BB-G95, *Bifidobacterium longum* BL-G301	5×10^9	10 drops		SCFA	Esensa (Serbia)
EsenBak® Direct	*Bifidobacterium animalis* ssp *lactis* BL-G101, *Bifidobacterium longum* ssp *infantis* BL-G201, *Lactobacillus fermentum*LF-G89, *Lactobacillus rhamnosus* Lr-G14	20×10^9	1 sachet		DHA, taurine	Esensa (Serbia)
EsenBak® Pro and Byo	*Saccharomyces boulardii*	5×10^9	1 capsule			Esensa (Serbia)
EsenBak® Pro and Byo IMUNO	*Bifidobacterium breve* BB-G95, *Bifidobacterium bifidum* BB-G95, *Bifidobacterium animalis* subsp. *lactis* BL-G101, *Bifidobacterium longum* subsp. *longum* BL-G301, *Bifidobacterium longum* subsp. *longum* BL-G201, *Lactobacillus acidophilus* LA-G80, *Lactobacillus plantarum* Lp-G18, *Lactobacillus rhamnosus* Lr-G14, *Lactobacillus paracasei* LPC-G110, *Lactobacillus reuteri* LR-G100	10×10^9	1 capsule		Zn, vitamins B1, B2, B6	Esensa (Serbia)

Table 1 (continued)

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
EsenBak® Pro and Byo Ultra Direct Strong	*Bifidobacterium lactis* BL-G101*; Lactobacillus plantarum* Lp-G18; *Lactobacillus rhamnosus* Lr-G14; *Lactobacillus johnsonii* LJ-G55; *Lactobacillus gasseri* LG-G12; *Bifidobacterium longum* BL-G301; *Lactobacillus acidophilus* LA-G80; *Bifidobacterium adolescentis* BQ-G50	50×10^9	1 sachet		FOS, XOS, Fibersol®	Esensa (Serbia)
Microflora complex	*Lactobacillus plantarum* (Rosell-1012), *Lactobacillus casei* (Rosell-215), *Lactobacillus rhamnosus* (Rosell-11), *Lactobacillus acidophilus* (Rosell-52), *Bifidobacterium lactis* (CHR Hansen BB-12)	3.5×10^{9c}	1 capsule		*Arctium lappa* root *Beta vulgaris* leaf *Oryza sativa* FOS Arabinogalactan from the larch tree	Terranova (UK)
Probielle® IBSolution	*Lactobacillus plantarum* CECT 7484, *Lactobacillus plantarum* CECT 7485, *Pediococcus acidilactici* CECT 7483	3×10^{9c}	1 sachet		Vitamin D3	Hemofarm (Serbia)
S. BOULARDI® BULACOL 500	*Saccharomyces cerevisiae* var. *boulardii* Bulacol 500	5×10^{9c}	1 capsule			Hemofarm (Serbia)
PROBIOTIC®	*Lactobacillus acidophilus* Rosell — 52, *Lactobacillus rhamnosus* Rosell — 11, *Bifidobacterium longum* Rosell—175	5×10^9	1 capsule	*Helps to establish and maintain digestive system natural balance*		Ivancic i sinovi (Serbia)
PROBIOTIC® FORTE	*Saccharomyces boulardii*, *Lactobacillus Rosell*−52, *Lactobacillus Rosell*−11, Bifidobacterium Rosell-175	14×10^{9c}	1 capsule	*A unique shield for intestinal flora preservation*		Ivancic i sinovi (Serbia)
BIORELA®	*Lactobacillus acidophilus* NCFM®, *Lactobacillus paracasei* Lpc-37, *Bifidobacterium lactis* Bl-04, *Bifidobacterium lactis* Bi-07, *Bifidobacterium bifidum*Bb-02	20×10^{9c}	2 capsules			Pharcoterm (Italy)
BIORELA AB	*L. acidophilus* NCFM®, *L. paracasei* Lpc-37® Bifidobacterium species *B. lactis* Bi-07®, *B. lactis* Bl-04®	20×10^9	1 capsule	*Improves the number of beneficial microbes in intestine*	Inulin	Pharcoterm (Italy)

Table 1 (continued)

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
BIORELA Daily	*Lactobacillus acidophilus* (La-14)®, *Bifidobacterium lactis* (Bi-07)®, *Lactobacillus rhamnosus* (Lr-32)®	10×10^9	1 capsule	*Improves the number of beneficial microbes in intestine*		Pharcoterm (Italy)
PROLIFE® suspension	*Lactobacillus acidophilus* La-14®, *Bacillus coagulans* BC4®, *Bifidobacterium lactis* HN019®, *Bifidobacterium lactis* Bl-04® *Lactobacillus plantarum* LP115®	2.1×10^9	10 ml		GOS, vitamins B1, B2, B6, B14	JGL (Croatia)
PROLIFE® caps	*Bacillus coagulans* BC4®	7×10^8	1 capsule		GOS, vitamins B1, B2, B6, B13	JGL (Croatia)
DuoBiotic®	*Saccharomyces cerevisiae* var. *boulardii*	5×10^9	1 capsule	*Contributes to the establishment of the balanced intestinal microflora, helps in regulating the intestine and digestion*	Inulin	Pharmanova (Serbia)
Flonivin® PLUS	*Saccharomyces boulardii*, *Bifidobacterium bifidum*	5×10^9	1 capsule		Zn	Galenika (Serbia)
Flonivin® BOULARDII	*Saccharomyces boulardii*	10×10^9				Galenika (Serbia)
Flonivin® FORTE	*Lactobacillus acidophilus* LA-14, *Lactobacillus rhamnosus* GG (ATCC 53103), *Bifidobacterium longum* Bl-05TM	10×10^9			Inulin	Galenika (Serbia)
PROLIFE® PASTILE	*Bacillus coagulans* BC4®	5×10^8	2 pastils		GOS, vitamins B1, B2, B6, B12	JGL (Croatia)
Fermental MAX	*B. coagulans* LMG S-24828	2×10^9	1 capsule	*Helps maintain the equilibrium of intestinal flora*	Vitamins group B, aloe vera and FOS	ESI (Italy)
Enterogermina®	*Bacillus coagulans* O/C, N/R, SIN and T	2×10^9	5 ml bottle			Sanofi (France)

Table 1 (continued)

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
MULTILAC® SIMBIOTIC	*Bifidobacterium animalis* ssp. *lactis* BIFOLAC™12, *Lactococcus lactis* Ll-23, *Lactobacillus plantarum* LP-115, *Lactobacillus acidophilus* LA-14, *Lactobacillus rhamnosus* BIFOLAC™GG, *Streptococcus thermophilus* ST-21, *Bifidobacterium breve* BB-03, *Bifidobacterium bifidum* Bb-02, *Lactobacillus casei* Lc-11	4.50×10^9	1 capsule		FOS	Pharmaswiss (Serbia)
ProBiovit® BOULARDI	*Saccharomyces cerevisiae* var. *boulardii*	5×10^9	10 ml		Zn, D3	Api Pharma (Croatia)
BOULARDII	*Saccharomyces cerevisiae* var. *boulardii* I-3799	5×10^{9c}	1 capsule			PharmaS (Croatia)
5-BIOTIC	*Lactobacillus acidophilus* NCFM®, *Lactobacillus paracasei* Lpc-37®, *Bifidobacterium lactis* Bi-07™, *Bifidobacterium lactis* Bl-04®, *Lactobacillus rhamnosus*	12×10^9	1 capsule		Inulin	Inpharm (Serbia)
LACTIBIANE Imedia	*Bifidobacterium longum* LA101, *Lactobacillus helveticus* LA102, *Lactococcus lactis* LA103, *Streptococcus thermophilus* LA104	30×10^9	1 sachet			PileJe (France)
LACTIBIANE H-PY	*Lactobacillus plantarum* LA 301, *Lactobacillus salivarius* LA 302	10×10^9	1 capsule		Cinnamomum cassia, *Glycyrrhiza glabra* root extract, proanthocyanin	PileJe (France)
LACTIBIANE Tolerance	*Bifidobacterium lactis* LA 303, *Lactobacillus acidophilus* LA 201, *Lactobacillus plantarum* LA 301, *Lactobacillus salivarius* LA 302, *Bifidobacterium lactis* LA 304	11×10^9	1 capsule			PileJe (France)
LACTIBIANE ATB	*Lactobacillus rhamnosus* LA 801	1×10^9	1 capsule			Save Health (France)
LACTIBIANE RÉFÉRENCE	*Bifidobacterium longum* LA 101, *Lactobacillus helveticus* LA 102, *Lactococcus lactis* LA 103, *Streptococcus thermophilus* LA 104	10×10^9	1 capsule			Save Health (France)

Table 1 (continued)

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
LACTIBIANE Cnd	*Lactobacillus gasseri* LA806, *Lactobacillus helveticus* LA401 *candidiasis*	11×10^9	1 capsule			Save Health (France)
LINEX®	*Lactobacillus acidophilus* LA-5®, *Bifidobacterium animalis* ssp. *lactis* BB-12®	1.2×10^9	1 capsule			Sandoz (Switzerland)
LINEX® FORTE	*Lactobacillus acidophilus* LA-5, *Bifidobacterium animalis* subsp. *lactis* BB-12	2×10^9	1 capsule			Sandoz (Switzerland)
Probiotic-10™	*Lactobacillus acidophilus* (La-14), *Bifidobacterium lactis* (BI-04), *Lactobacillus plantarum* (Lp-115), *Lactobacillus casei* (Lc-11), *Lactobacillus rhamnosus* (Lr 32), *Lactobacillus paracasei* Lpc-37), *Bifidobacterium breve* (Bb-03), *Streptococcus thermophilus* (St-21), *Lactobacillus salivarius* (Ls-33), *Bifidobacterium longum* (BI-05)	25×10^9	1 capsule	*Healthy intestinal flora*		Now Foods (US)
8 Bilion *acidophilus* and *bifidus*	*Lactobacillus acidophilus* (La-14), *Bifidobacterium lactis* (Bl-04), *Bifidobacterium longum* (Bl-05)	8×10^9	1 capsule	*Healthy intestinal flora*; *Promotes positive probiotic balance*		Now Foods (US)
Saccharomyces boulardii	*Saccharomyces cerevisiae* var. *boulardii* I-3799	10×10^9	1 capsule	*Supports a Healthy Balance of Intestinal flora; Useful When Traveling*		Now Foods (US)

Table 1 (continued)

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
Probiotic 30 billion	*Lactobacillus gasseri* (UALg-05), *Lactococcus lactis* (UALI-08) *Lactobacillus rhamnosus* (UALr-06), *Bifidobacterium animalis lactis* (UABIa-12), *Bifidobacterium breve* (UABbr-11), *Lactobacillus paracasei* (UALpc-04), *Lactobacillus rhamnosus* (UALr-18), *Lactobacillus acidophilus* (DDS −1), *Lactobacillus plantarum* (UALp-05), *Bifidobacterium longum* subsp. longum (UABI-14), *Bifidobacterium bifidum* (UABb-10), *Lactobacillus casei* (UALc-03), *Lactobacillus reuteri* (UALre-16), *Bifidobacterium longum* subsp. *infantis* (UABi-13)	30×10^9	1 capsule	*For complete intestinal and digestive health*		Jamieson (Canada)
Floramax colon	*Lb. reuteri* (DSM 20016), *Bifidus longum* (DSM 20219), *Bifidus bifidum* (DSM 20456)	11×10^9	3 capsules		Inulin from *Cichorium intybus* L. root, *Acacia laeta* ex. *Benth* powder,. *Melissa officinalis* L. dry extract leaf, *Curcuma longa* L. rhizome, *Boswellia serrata Roxb*. resin, *Foeniculum vulgare* Mill. seed	Cosval (Italy)
WAYA® LGG FORTE PRO	*Lactobacillus rhamnosus* GG	10×10^9	1 capsule			Medis (Serbia)
Immunity						
PROBIOTIC® DAILY	*Lactobacillus helveticus* Rosell-52, *Bifidobacterium longum* Rosell-175, *Lactobacillus rhamnosus* Rosell-11	15×10^{9c}	1 capsule			Hemofarm (Serbia)
LATOPIC	*Lactobacillus casei* LOCK 0919, *Lactobacillus rhamnosus* LOCK 0908, *Lactobacillus rhamnosus* LOCK 0900	1×10^9	1 capsule			IBSS BIOMED (Poland)
LACTIBIANE ALR	*Lactobacillus salivarius* LA 302	4×10^9	1 capsule		Onion extract and rosemary extract	Save Health (France)

Table 1 (continued)

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
Probio Balance	*Lactobacillus acidophilus*, *Bifidobacterium longum*, *Lactobacillus rhamnosus*	4×10^{9c}	1 capsule		FOS	Calivita (US)
IMUNOLAK	*Lactobacillus casei* BL 2401, *Lactobacillus salivarius* BL 2201, *Bifidobacterium breve* BL 3406	5×10^{9}	1 capsule			Save Health (France)
IMUNOLAK Adults D3 + Zn	*Lactobacillus casei* BL 2401, *Lactobacillus salivarius* BL 2201, *Bifidobacterium breve* BL 3406	5×10^{9}	1 capsule		D3 + Zn	Save Health (France)
Oral health						
OralBiotic®	*S. salivarius* K12	1×10^{9}	1 capsule	*Supports ear, nose & throat health; Helps maintain fresh breath*		Now Foods (US)
Women health						
LACTOGYN®	*Lactobacillus rhamnosus* GR1, *Lactobacillus reuteri* RC-14	1×10^{9}	1 capsule	*For the vaginal flora balance*		JGL (Croatia)
Floeàl'aise (Lactobacilli and vitamin A)	*Lactobacillus rhamnosus* LR-35	1×10^{9}	1 capsule	*Contributes to the feeling of comfort in women*	Vitamin A	Biose Industrie (France)
FemmaBiotic®	*Lactobacillus acidophilus* La-14, *Lactobacillus rhamnosus* HNO01, *Lactobacillus gasseri* Lg-36, *Lactobacillus crispatus* LCr-86	7×10^{9}	1 capsule			Optimus Pharmaceuticals (Serbia)
BIOFEMINN®	*Lactobacillus rhamnosus* LRH020, *Lactobacillus plantarum* PBS067, *Bifidobacterium animalis* subsp. *lactis* BL050	3×10^{9}	1 capsule			INNVenta (Serbia)
Womens's probiotic 20 Bilion	*Bifidobacterium lactis* (HN019), *Lactobacillus acidophilus* (La-14), *Lactobacillus rhamnosus* (HN001)	20×10^{9}	1 capsule	*Supports Vaginal Health; Reduces Occasional Bloating*		Now Foods (US)
Probiotics intended for infants and children						
PEDIAKID® GOMMES IMMUNITÈ	*Lactobacillus casei* HA-108, *Lactobacillus acidophilus* HA-122, *Lactobacillus plantarum* HA-119, *Streptococcus thermophilus* HA-110	1×10^{9}	2 gums			Pediakid (France)

Table 1 (continued)

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
PEDIAKID® Probiotiques–10 M	*Lactobacillus casei* HA-108, *Lactobacillus acidophilus* HA-122, *Lactobacillus plantarum* HA-119, *Streptococcus thermophilus* HA-110	10×10^9	1 sachet		Chicory inulin fibers, Zn	Pediakid (France)
MULTILAC® Baby	*Bifidobacterium animalis* ssp. *lactis* BIFOLAC™12, *Lactococcus lactis* Ll-23, *Lactobacillus plantarum* LP-115, *Lactobacillus acidophilus* LA-14, *Lactobacillus rhamnosus* BIFOLAC™GG, *Streptococcus thermophilus* ST-21, *Bifidobacterium breve* BB-03, *Bifidobacterium bifidum* Bb-02, *Lactobacillus casei* Lc-11	1×10^9	1 sachet		FOS	Pharmaswiss (Serbia)
ProBiovit® BOULARDI Kinds	*B. lactis* SD5217, *L. rhamnosus* SD5219, *L. reuteri* DSM 2688	6×10^9	5.5 ml		Vitamin groups B, D3	Api Pharma (Croatia)
PROBIOKID IMUNO D3	*Lactobacillus helveticus* Rosell-52, *Bifidobacterium bifidum*Rosell-7, *Bifidobacterium infantis* Rosell-33	15×10^{9c}	1 capsule		FOS, D3	Hemofarm (Serbia)
BOULARDII JUNIOR	*Saccharomyces cerevisiae* var. *boulardii* I-3799	5×10^{9c}	1 capsule			PharmaS (Croatia)
WAYA® LGG	*Lactobacillus rhamnosus* GG	1.4×10^9	7 drops			Medis (Serbia)
Flonivin® Baby	*Saccharomyces boulardii*	NR	20–40 drops			Galenika (Serbia)
Flonivin® KIDS IMMUNO	*Saccharomyces boulardii*, *Lactobacillus acidophilus* NCFM, *Bifidobacterium lactis* Bi-07®	15×10^9	1 sachet		Inulin, D3, Zn	Galenika (Serbia)
BioGaia	*Lactobacillus reuteri* Protectis	1×10^8	5 drops	*For healthy intestine and stronger immunity*		Biogaia (US)
IMUNOLAK Kids D3 + Zn	*Lactobacillus casei* BL 2401, *Lactobacillus salivarius* BL 2201, *Bifidobacterium breve* 3406	3×10^9	1 capsule		D3 + Zn	Save Health (France)

Table 1 (continued)

Probiotic	Strain(s)[a]	CFU	Dosage	Health claims[b]	Other active ingredients	Producer (Country)
LACTIBIANE Enfant	*Bifidobacterium longum* LA 101, *Lactobacillus helveticus* LA 102, *Lactococcus lactis* LA 103, *Streptococcus thermophilus* LA 10, *Lactobacillus rhamnosus* LA 801	4×10^9	1 sachet		D3	PileJe (France)

Abbreviations: *SCFA* short-chain fatty acids, *DHA* docosahexaenoic acid, omega-3 fatty acid, *FOS* fructo-oligosaccharides, *XOS* xylooligosaccharides, *GOS* galacto-oligosaccharides

[a]Strain designations reported as on packaging. New nomenclature of genius *Lactobacillus* [23]

[b]Health claims translated in English

[c]Manufacturers reported CFU counts at the time of production, not by best date (at the time of consumption)

if their transformation is needed [26]. To find the correlation between time series data of probiotic supplement sales and foreign tourist visits Spearman's correlation test was employed, significance was set at $p < 0.05$.

ML Forecasting Model

Among all machine learning models used for forecasting healthcare product consumption, the SVR model is the most applied. Generally, The SVR model was proposed in 1992 and it is used to solve non-linear classification, regression, and prediction problems [21]. To carry out non-linear tasks, the SVR model uses a kernel approach which enables the mapping of the data from an n-dimensional space to an n + 1 dimensional space. The mapping of data is very important because it enables the dependencies to become linear and that can be modeled using hyperplanes. The kernel approach relies on using kernel functions such as linear kernel (linear), radial basis function kernel (poly), and polynomial kernel (poly) (Fig. 1) [27]. According to the literature, the most prevalent and most effective kernel function is RBF and, for this reason, it will be employed in this article [28]. The training of the SVR model is reduced to the selection of the optimal combination parameters from the RBF kernel function including gamma, epsilon, and C. To measure the accuracy of the forecast probiotics supplement consumption model, standard metrics for predictive regression models were used, including relative error (RE) and squared correlation (R^2).

Predictive Procedure For model training, time series cross-validation was used, splitting the time series into multiple training and validation sets, where the validation sets always come after the corresponding training sets in time. This principle is different than traditional cross-validation methods, such as k-fold cross-validation, which ignore the temporal sequence of the time series data and can lead to overly optimistic performance estimates. After completing multiple iterations, the performance metrics of the obtained models from these iterations are combined to determine the time series cross-validation accuracy. To choose the optimal parameters for the SVR model, the grid-search technique was used. This technique tests all parameter combinations using time series cross-validation based on the defined parameter ranks. The optimal combination of parameters from the one with the best time series cross-validation accuracy is chosen as the optimal combination of parameters. The trained model was applied to the test data comparing the actual and predicted values. Figure 2 shows data procedure for the ML forecasting model.

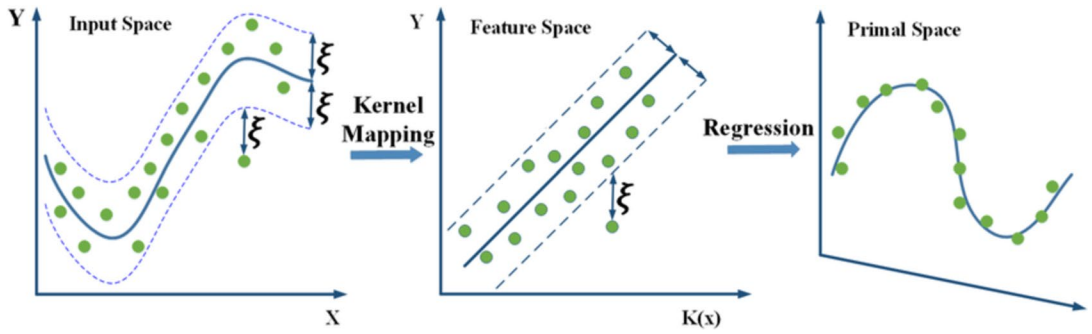

Fig. 1 The *principle* of support vector regression (SVR)

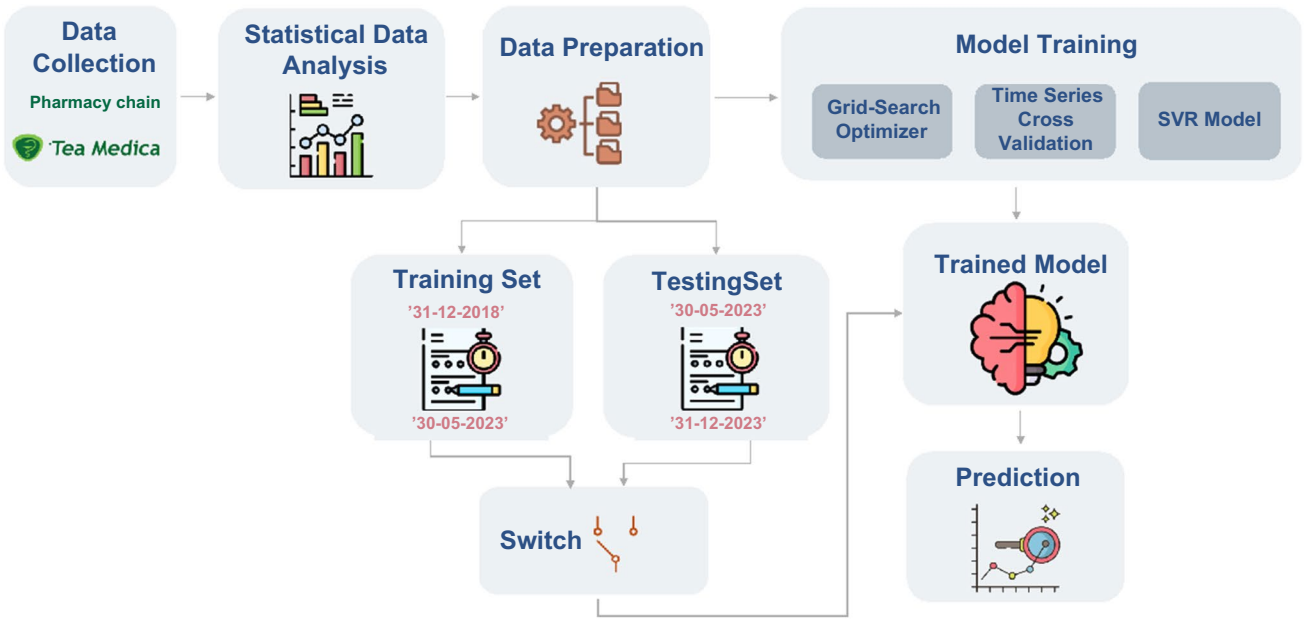

Fig. 2 Predictive machine learning forecasting model procedure

Results

Mapping Probiotic Food Supplements: Overview of the Key Product Characteristics

Table 1 shows products containing probiotics sold as food supplements on the Montenegrin market. Mapped products originate from EU (46%), Serbian (40%), US (9%), Swiss (3%) and Canadian (1%) producers. We mapped a total of 68 food supplements containing probiotics and divided them according to application purposes. Related to this, our mapping identified probiotic supplements targeting gut issues, as well as immune, oral, and women's health. Further, we mapped probiotic supplements that are specifically formulated as probiotics for infants and children. On the Montenegrin market both single and multi-strain/multi-species probiotic supplement products are sold, including the bacterial strains belong to the genera *Lactobacillus*, *Bifidobacterium*, and *Bacillus* as well as the yeast strain *Saccharomyces cerevisiae* var. *boulardii*. Nearly all manufacturers, with only a few exceptions (Table 1; e.g., Supplementary Fig. 1) declared probiotic designation up to the strain level. However, when declaring probiotic microorganisms spelling mistakes such as *Lactobacillus Casei* (instead of *Lacticaseibacillus casei*), *Lactobacillus Salivarius* (instead of *Ligilactobacillus salivarius*) were identified. Further, manufacturers did not take into consideration the new nomenclature for genus *Lactobacillus* [23] (e.g., reported *Lactobacillus plantarum* instead of *Lactiplantibacillus plantarum; Lactobacillus rhamnosus* instead of *Lacticaseibacillus rhamnosus*) (Table 1; Supplementary Fig. 2). Probiotic supplement products are

accessible in various forms, including capsules, sachets, or liquids, with highly variable CFU counts, ranging from 1×10^8 to 50×10^9 CFU per dosage. Furthermore, we have noticed that certain producers (where ^{c} is assigned to CFU counts; Table 1) do not ensure these quantities up to the best by date; instead, they report and guarantee the probiotics amount at the time of the product manufacturing.

Furthermore, we noticed that on the Montenegrin market there are present products that both contain (e.g. "For reduction of bowel irritation and flatulence") and do not contain health-related claims on the packaging (Table 1). Also, a vast number of probiotic microorganisms are formulated with some other active ingredients such as prebiotic compounds (FOS, GOS) and/or vitamins (e.g., vitamin D, vitamin group B) or minerals (e.g., Zn).

A Case Study of Montenegro

Probiotic Supplement Sales

In the case study, we collected and analyzed data of pharmacy's chain sales of all food supplements containing probiotics (including probiotics, probiotics + prebiotics and/or vitamins/minerals) within the period from 2018 to 2023. The number of available probiotic supplement product types showed a trend of increase over the examined period of 5 years (Supplementary Fig. 3). The data shows that the number of probiotic supplement products sold in the Montenegrin pharmacy chain almost doubled in 2023 compared to 2018. Particularly, in 2018, there were 33 probiotic supplement types, compared to 2023, where 60 different product types in this pharmacy chain were available (Supplementary Fig. 3).

Figure 3a shows yearly sales numbers of probiotic food supplements. The lowest sales of probiotic supplements were in 2020 (68.226 sold probiotic supplement products) and the highest in 2023 (145.151 sold probiotic supplement products). Within the analyzed period of 5 years, probiotic supplement sales increased for 46% in 2023, compared to 2018. Although there was a decrease in sales of 20% in 2022 compared to 2021, it could be seen higher growth in sales for the last 3 years (period from 2021 to 2023), compared to the period from 2018 to 2020. If we compare the average sales for these two periods, specifically 2018–2020 and 2021–2023, the data show an increase in sales of 38%.

In addition, we analyzed probiotic sales on a monthly basis (time series dataset) for the whole period of 5 years (Fig. 3b). In all 5 years, the monthly probiotic sales show quite a similar pattern. Specifically, probiotic supplement sales start to increase during the spring months (May–June), reaching the peak during summer months (July–August), after which the sales start to decrease (Fig. 3b). The highest sales of probiotic supplements within the analyzed period were in August 2021 and 2023, reaching probiotic supplements sales of 20.482 and 20.680, respectively. The lowest sales within the analyzed period were in May 2020, with 2.928 probiotic supplements sold.

Furthermore, looking at the visual representation of the time series dataset of probiotic supplement sales we hypothesized that there is a seasonal pattern that as already mentioned deviates in 2020 year (Fig. 3a, b).

However, to confirm our assumption, we used a statistical decomposition task (Fig. 4). This task enabled us to separate the observed time series (Fig. 4, observed) into three components: a trend, seasonal components, and residuals (Fig. 4). The statistical analysis confirmed positive and negative trends in probiotics sales for the period 2018–2023 (Fig. 4, trend). Specifically, as assumed the statistical analysis confirmed a negative trend in sales for 2020, where a significantly positive trend in probiotic supplement sales is observed for the periods 2018–2019 and 2021–2023 (Fig. 4,

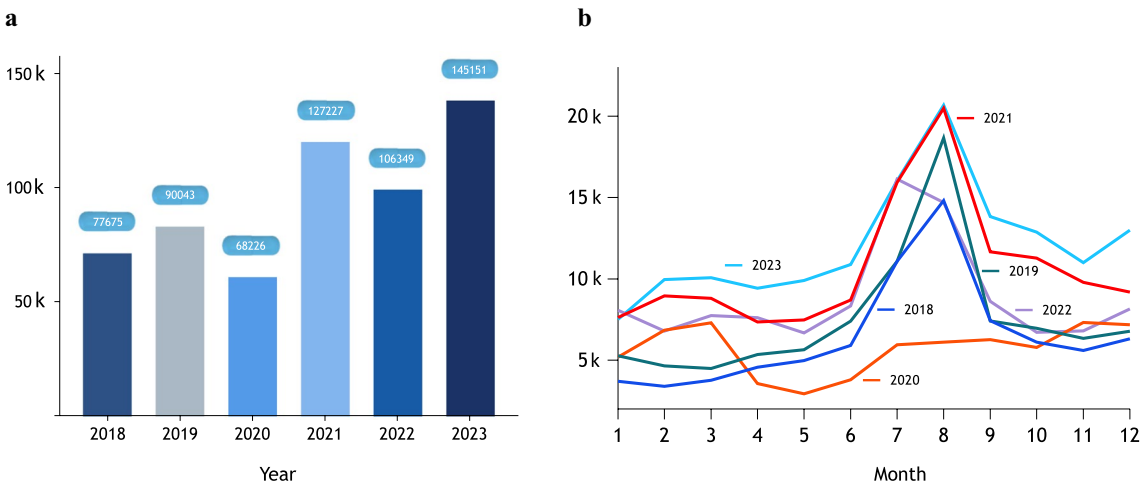

Fig. 3 Yearly (**a**) and monthly (**b**) probiotic supplement sales reported as number of probiotic products sold

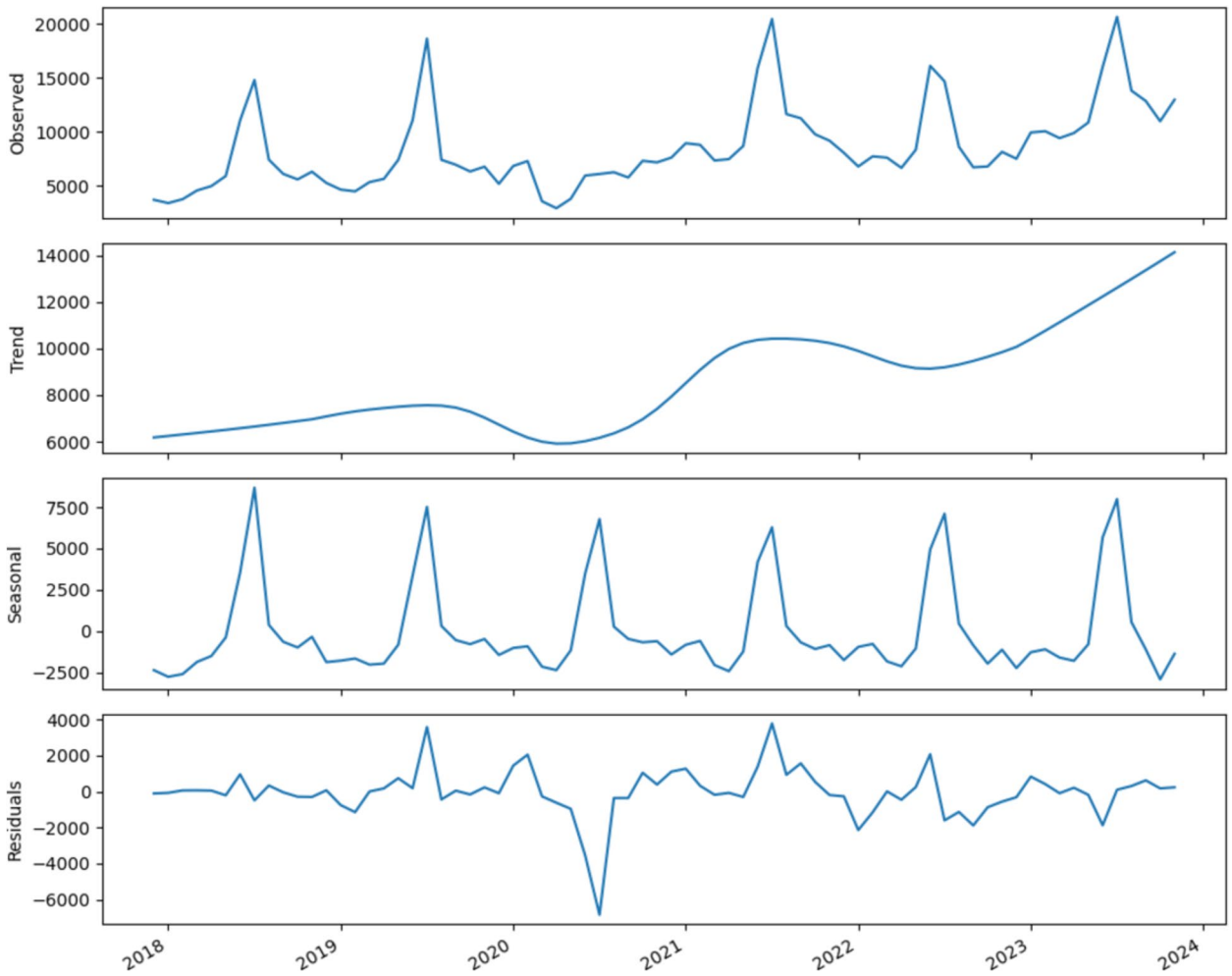

Fig. 4 STL decomposition task of probiotic supplement sales showing division of actual data (observed) into trend, seasonal, and residual components

trend). Particularly, the slope of the positive trend for the period 2021–2023, is significantly higher comparing with the positive trend for the period 2018–2019. Additionally, the decomposition task confirmed the seasonality pattern of probiotic supplement sales (Fig. 4, seasonal), showing the significant occurrence of the peak in sales during the same period of the year (July and August months).

"Probiotic" Term Trend Within Territory of Montenegro

On February 12, 2024, we queried *Google Trends* and downloaded the data for the "probiotik" (eng. probiotic) search input. We searched this term within Montenegro for the analyzed period of 5 years (from January 1, 2018, to December 31, 2023) using the "all categories" query category (Supplementary Fig. 4). By analyzing *Google Trends* data, we observed a notable increase in the search term "probiotik" over the past three years (2020–2023), just after COVID-19 pandemic started. Figure 5 shows search interest on a monthly and yearly basis (line with different colors). The search peaks for "probiotik" happened on August 2021 and 2023. All these data are in accordance with the sales from our case study, where the product sales started to increase during the 2021–2023 period.

Foreign Visiting Tourists in Montenegro

We noticed that each year probiotic supplement sales significantly increase during the summer touristic season (June–August) (Fig. 3b), and that the sales in 2020 strongly decreased when COVID-19 traveling restrictions were in place (Fig. 3a, b). We hypothesized that one of the possible reasons for this pattern could be the number of foreign visiting tourists in Montenegro. Therefore, we decided to collect, include, and analyze both yearly and monthly data of foreign tourist visits in Montenegro (Fig. 6a, b).

Collected data showed that alike the sales of probiotic supplements, the number of foreign visiting tourists in

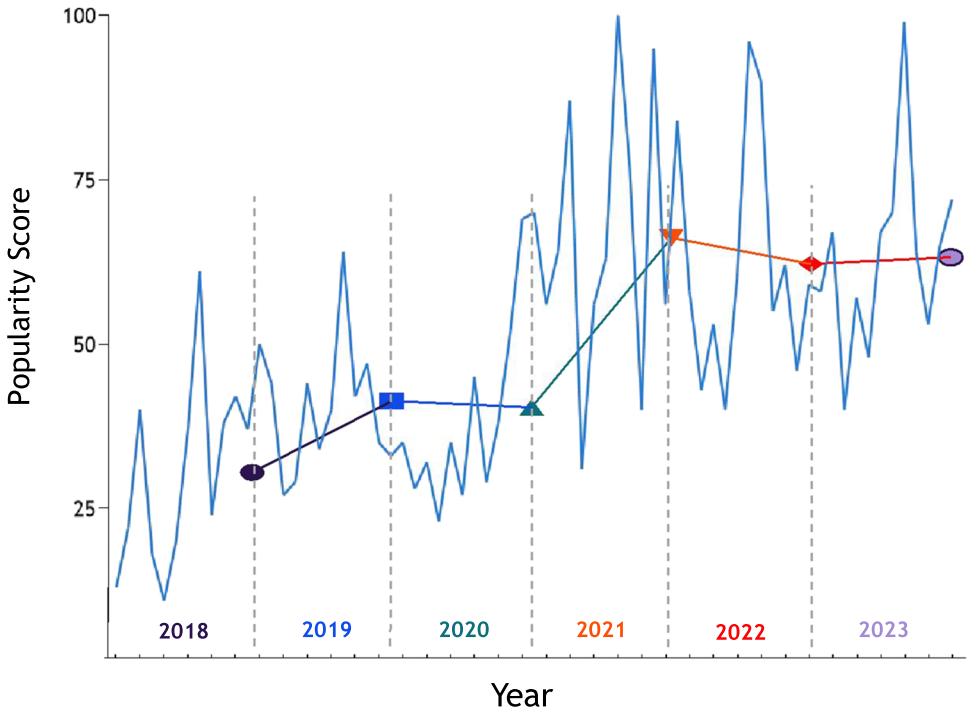

Fig. 5 Popularity of "probiotik" term within the territory of Montenegro searched using Google Trends. Line with different colors represent the average popularity for each year (2018–2023)

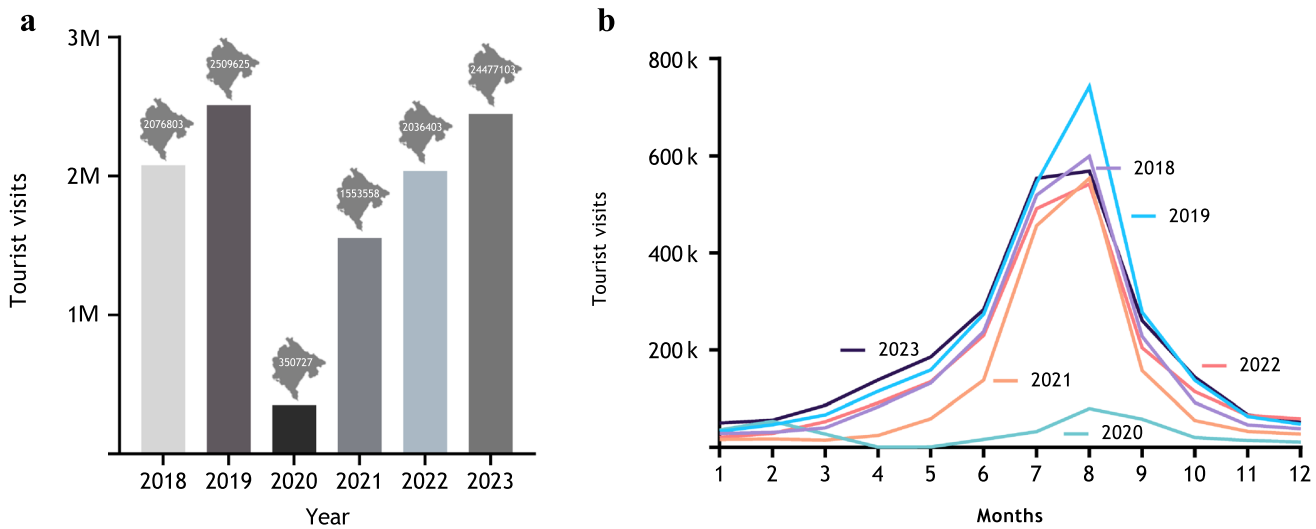

Fig. 6 Yearly (**a**) and monthly (**b**) number of foreign visiting tourists in Montenegro

Montenegro for 2020 year strongly decreased (Fig. 6a). Furthermore, Fig. 6b confirms the peak of foreign tourists visiting Montenegro during the summer months June–August. It can be noted that from all collected and analyzed data, both sales of probiotic supplements (Fig. 3a, b) and foreign visiting tourists in Montenegro (Fig. 6a, b) show quite similar patterns. Indeed, we confirmed a strong correlation between these two parameters (probiotic supplement sales and foreign tourist visits) using Spearman's correlation test, $p = 5.92 \times 10^{-7}$ (Fig. 7).

ML Forecasting Model

In this article, we developed and employed ML model to forecast future probiotic food supplement sales. The first step that preceded the forecasting procedure was the probiotics supplement sales time series stationarity analysis using the ADF test. This test confirmed the stationarity of our predictor data (ADF statistic: − 3.715, *p*-value: 0.0039), meaning that there was no need to apply any transformation of data before training. The next step

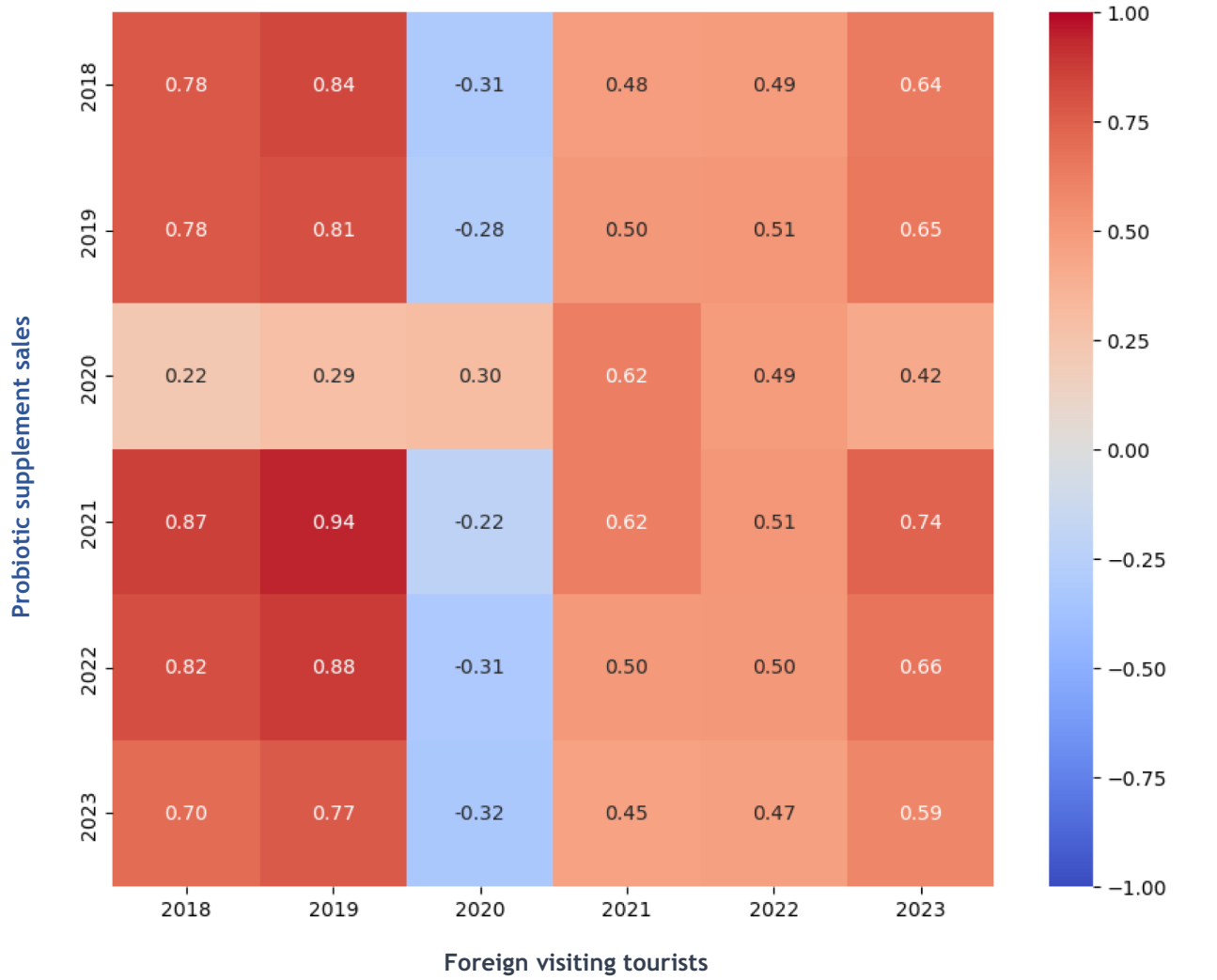

Fig. 7 Heatmap showing Spearman rank correlation coefficient between probiotic supplement sales and foreign tourist visits

included selection of appropriate features that can have an impact on probiotics supplement sales. To do so, except the number of foreign visiting tourists, we decided to include antibiotics sales of a pharmacy chain as well as the monthly number of COVID-19 active cases in Montenegro. The Granger causality test verified the usefulness of these factors to forecast probiotic supplement sales with results $p < 0.05$ for all considered factors (Supplementary Fig. 5).

After that, using the grid search technique, an optimal combination of window size 3 and prediction horizon 1 was obtained. The SVR model was trained following the proposed predictive procedure described in the "Materials and Methods" (section "Predictive Procedure") which included training on multiple training and validation sets (sales period: April 30, 2018–May 31, 2023), and later tested on unknown data (sales period: May 31, 2023–December 31, 2023). In the training phase using grid search and time series cross-validation, we determined the optimal parameters for the SVR model ($C = 16$, $\gamma = 0.01$, $\varepsilon = 0.01$).

The results showed that the SVR model achieved excellent performance on training as well as on test datasets. The ML model achieved relative error (RE) of 7.75% and coefficient of determination (R^2) of 0.90 on the training dataset (Fig. 8a). Furthermore, the test set achieved RE of 6.12%, and R^2 of 0.73, and thus the developed ML model was employed to predict the probiotic sales for the whole 2024 year (Fig. 8b).

Additionally, in Table 2, we give exact values of probiotic supplement sales predicted for the next twelve months increasing the horizon offset from 1 to 12. For this projection, we assumed that antibiotic sales and the number of COVID-19 active cases will remain consistent with those in 2023, while the number of foreign tourists will remain at the 2019 level, which is considered as the best tourist season in Montenegro in the last 5 years.

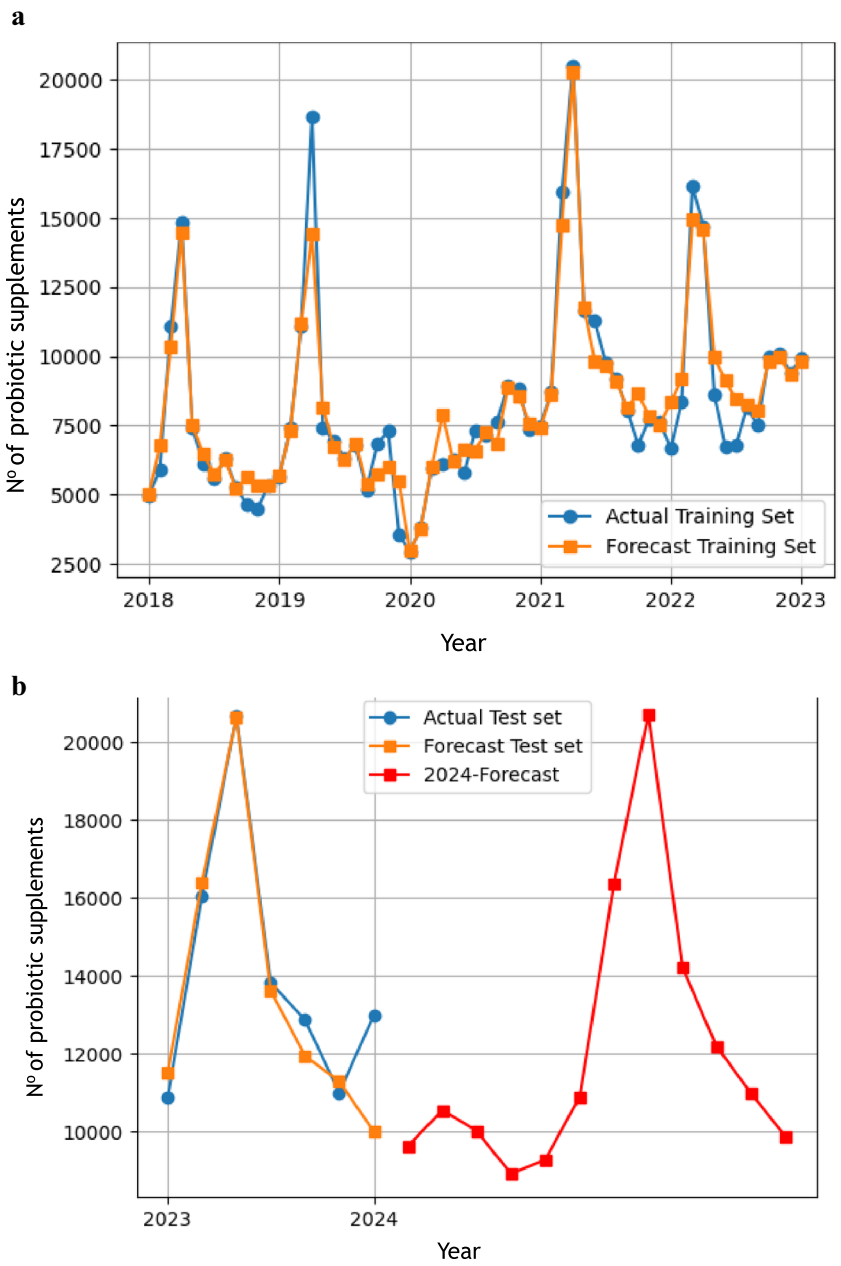

Fig. 8 ML forecasting model showing values of actual and predicted probiotic supplement sales on training and tested dataset (**a**) and prediction for 2024 year (**b**)

The case study results showed increased interest in probiotic supplements as well as a constant positive trend in probiotic supplement sales. The study found the correlation between foreign tourist visits in Montenegro and the yearly seasonality of probiotic supplement sales. Developed and employed SVR ML model on time series data showed excellent performance on both training and test datasets, making it accurate to forecast future probiotic supplement sales.

Discussion

To improve transparency, consistency, and consumer understanding about different probiotic supplements, as well as their awareness, the probiotic supplements should satisfy special label requirements. Laws and regulations for probiotics are country-specific mainly relying

Table 2 Predicted probiotic supplement sales of a case study pharmacy chain by using developed ML forecasting model

Months 2024 year	Predicted probiotic supplements sales
January	9629
February	10,552
March	10,027
April	8925
May	9280
Jun	10,892
July	16,358
August	20,709
September	14,221
October	12,172
November	10,984
December	9877

on FAO/WHO guidelines [29, 30]. According to FAO/WHO guidelines, the labels should clearly indicate the minimum amount of each strain until the date of expiration, expressed in CFU, as well as the suggested serving size to obtain health benefits. In the case of multiple probiotic strains, the total CFU number should be reported, and if technically feasible for each of the strain. Further, the label should declare probiotics up to the strain level. Also, the label should contain information about the appropriate storage conditions, and manufacturer contact details. On the Montenegrin market we mapped total of 68 probiotic supplement with highly variable CFU counts, ranging from 1.2×10^7 to 50×10^9 CFU per dosage. It is crucial to highlight that certain producers do not ensure these quantities up to the *best by date* (amounts at the time of consumption) as recommended by FAO/WHO guidelines; instead, they report and guarantee the amounts at the time of manufacturing. Here one could speculate about the efficacy of probiotics, as the minimal amount required to confer health benefits should ideally reach the gut. Nevertheless, probiotics on Montenegrin market are much less potent comparing with the products in other countries [31]. Regarding designation of probiotics, nearly all mapped probiotic supplements on Montenegrin market, with only a few exceptions, have met the criteria for declaring probiotic designation up to the strain level. This is important because viability and functionality, which contribute to potential health benefits, are traits specific to each strain. The most products contain the lactic acid bacteria strains, following with the strains of the yeast *Saccharomyces cerevisiae* var. *boulardii*, which is commercially the best-known yeast used as probiotic [32]. At the latest spot are the strains of *Bacillus coagulans*, now classified as *Heyndrickxia coagulans* [33] spore-forming bacteria, extremely resistant to the harsh gastrointestinal conditions, enabling better survival [34]. Some manufactures misspelled species names (e.g. *Bifidobacterium longum Rosell-175* instead of *Bifidobacterium longum* Rosell-175) and some names are not concordant with the actual new nomenclature of genus *Lactobacillus* [23].

In most of the global markets, probiotic supplements fall under the Food Law regulations (e.g., in EU: the Food Products Directive and Regulation, regulated by The European Food Safety Authority (EFSA); in US Dietary Supplement Health and Education Act (DSHEA), regulated by the FDA) [14, 35]. It is important to note that (probiotic) food supplements generally target healthy populations, and unlike the drugs they are not intended to treat, cure, or prevent any disease [10, 15]. Therefore, requirements (e.g., required scientific evidence for efficacy and health claims) and length of regulatory process before they are marketed is less rigid than one for the drugs. In-depth insights into the regulatory aspects that govern various countries and probiotic categories (foods, dietary supplements, and drugs) can be found in publications written by Arora and Baldi [36], De Simone [35], Koirala and Anal [37], and Kumar et al. [38]. On Montenegrin market probiotic supplement products originate from manufacturers of various countries including EU, Serbia, USA, Switzerland, and Canada. Probiotic regulations on a global scale lack harmonization, with notable variations in requirements for product development quality, commercialization, and possible claims among different countries [15]. From a consumer perspective, one of the most significant types of information are the health claim statements featured on product packaging. As both EU and USA products present in Montenegro, the two biggest markets EU and USA the health claims differ significantly. In EU, each (health) claim (e.g., "Adequate intake of X may reduce the risk of X") needs to be accurately assessed by the EFSA before being authorized [8, 35]. The approval of health claims for probiotics is highly challenging in the EU (up to now the only probiotic health claim approved by EFSA is for yoghurt containing at least 10^8 CFU/ml strains of *Lactobacillus delbrueckii* subsp. *bulgaricus* and *Streptococcus thermophilus*), with no health claims approved to be placed on EU probiotic food supplements (EFSA NDA, 2010). However, some claims are approved in certain countries such as in Italy ("Promotes the intestinal flora"; Table 1; ESI, Italy). Contrary, in the USA, the pre-marketing approval of food supplements is not required per se, and the manufacturer may use health claims on the product, using disclaimer that the statements have not been evaluated by the FDA [15].

In Montenegro, the probiotic supplements are governed only by The Law on Food Safety and managed by the Montenegrin Ministry of Agriculture, Forestry and Water Management [13]. There are no any specific regulations, and standards addressed to probiotic supplements such as

minimum required dosages for the products, protocols for examining product quality and composition, or the list of health/functional claims authorized. The absence of specific guidelines and regulations for probiotic supplements in Montenegro, combined with the unharmonized global probiotic market, allows the import of products of diverse qualities from around the world, without undergoing rigorous assessment before reaching Montenegrin shelves. The presence of products from markets with widely differing regulatory standards, coupled with the lack of national regulations, may impact consumer trust and purchasing behavior. For example, some Montenegrin consumers may be drawn to the appealing but sometimes unsubstantiated claims of USA products, while others may prefer EU products for their perceived scientific rigor. This regulatory gap ultimately challenges consumer confidence in the probiotic efficacy in Montenegro's supplement market.

Also, without specific probiotic regulations, there is a likelihood of inaccurate labeling. Consumers may encounter challenges in assessing the authenticity of probiotic (health) claims, making it difficult to make informed choices about the products they purchase, therefore, potentially leading consumers to invest in products that do not deliver the anticipated benefits. The absence of specific regulatory standards may pose challenges in addressing cases of false advertising or misleading information, given the generalized, vague, and non-specific health claims used for marketing purposes. Since Montenegro is an EU candidate, there is an urge for adopting regulations and guidelines in line with EU standards as well as establishing national guidelines and acts for this product category.

Market research, such as one in this study, could play the pivotal role in increasing consumer awareness of probiotics by identifying key regulatory and knowledge gaps and misconceptions. Furthermore, comprehensive marketing studies are important for promoting tailored educational campaigns to address these gaps, proper use, and potential health effects of probiotic supplements. Consumer behavior can be significantly shaped by educational campaigns and labeling reforms by providing clear, accessible information that distinguishes products and helps consumers make more informed choices. For example, FOSHU (Foods for Specified Health Uses) program in Japan showed how its labeling reform — seal granted to foods with scientifically proven health benefits — boosted consumer confidence in the efficacy and safety of probiotics products bearing the seal over others without it [39]. Adopting similar strategies supported by the establishment of national regulations, the probiotics market in Montenegro could benefit from increased consumer awareness and demand, driving growth and trust in regulated, well-informed product choices.

Case Study While globally probiotics have been popular for several years, interest for their consumption was significantly shaped by COVID-19 pandemic [3, 40–42]. Before pandemic, probiotics were mainly considered as a strategy to improve digestive issues as well as prescribed after course of antibiotics. In the post-COVID era, there is a growing interest in the use of probiotics for improving the immune system, owing to their established association with improved immune health [3, 11]. Furthermore, the pandemic has heightened awareness of the link between stress, and gut health, thus probiotics are being considered to play important role in managing stress-related digestive issues and overall well-being [2]. Therefore, interest and sales in probiotic supplements have experienced remarkable growth, driven by a focus on holistic health. On the example of the Montenegrin case study, we showed that Montenegro is not an exception as the sales of probiotic supplements, as well as the number of diverse products available increased significantly post-COVID-19 pandemic (Fig. 3; Supplementary Fig. 3).

Specifically, in the case study of pharmacy chain that included data from 45 pharmacies covering all regions of Montenegro, we noticed a trend in increase of different product types over the analyzed period of 5 years. Furthermore, data showed increase of probiotic supplement sales of 46% in 2023, compared to 2018. In addition, the statistical decomposition task confirmed a seasonality trend, specifically increased probiotic sales during summer months, June–August (Fig. 4), for each year over the whole period of 5 years. Prior analysis of these data, we expected that the sales would start to increase starting from 2020 since COVID-19 started previous year. However, in Montenegro, there was a "delay" in the peaks of registered COVID-cases comparing to other EU countries, where the highest number of new cases were registered during January 2021 and 2022 [43]. Therefore, we could hypothesize that one of the reasons for drop in sales in 2020 were quarantine rules and concern of people going in pharmacy where most of the people stayed at their homes, without availability of e-commerce sale channels. Furthermore, this assumption could be confirmed with the case of antibiotic sales, which was used as an additional feature in ML prediction, which showed the same pattern (the lowest sales were in 2020).

In addition, Montenegro is a touristic destination and tourism is the most significant Montenegrin branch of economy accounting around 25% of GDP [44]. The highest number of tourists visiting Montenegro is during the period June–August, which is in accordance with the trends of probiotic supplement sales. Therefore, we assumed and later confirmed a strong correlation between foreign visiting tourists and probiotic supplement sales (Fig. 7), indicating that the drop in sales in 2020 was strongly impacted by

COVID-19 travelling restrictions. Even more, the correlation coefficient allowed us to confirm that the number of foreign visiting tourists in Montenegro actually shapes yearly seasonality of probiotic supplement sale (Fig. 7).

Furthermore, when comparing the yearly number of foreign tourists (especially during the summer months) pre (2018–2019) and post-COVID19 (2022–2023) period, we could observe similarity in these data (Fig. 6a). On the other side, Fig. 3a shows positive trend in increased probiotic supplements sales, thus potentially indicating increased awareness and more interest in probiotic supplements among Montenegrin population. General increased interest over analyzed period (2018–2023) in probiotics was confirmed by Google Trends that provides a free and readily available method for obtaining extensive search data from large population. Google Trends enables the extraction of valuable insights regarding population behavior and its connection to certain interests. Furthermore, *Google Trends* lead to faster and more convenient monitoring of emerging trends and may even outperform traditional surveillance methods [45]. The *Google Trend* data showed a clear growing interest, thus indicating increased awareness among population within Montenegrin territory about the probiotic concept. This increased trend in Montenegro is in line with the global trend that is characterized by a growing awareness and consumption of probiotic products. However, the comparability of exact scale and growth rate of probiotic supplements in Montenegro with global market should be further examined as specific data for Montenegro's market is not readily available.

The last part of this article involved the development and employment of the ML model to forecast the future sales of probiotic supplements. To develop the ML forecasting model, we utilized time series data from 2018 to 2023, collected on a monthly basis. This dataset comprises 72 data points, which is relatively limited for deep learning models, as they typically require more data to perform effectively [46]. Therefore, we opted for an SVR approach over a deep learning model, which can predict accurately with smaller dataset. We conducted Granger causality test which confirmed usefulness of inclusion of the number of foreign visiting tourists, antibiotics sales in a pharmacy chain, and the monthly number of COVID-19 active cases in Montenegro in the forecasting process.

Our model achieved a good performance and accuracy on the training dataset (RE 7.75%; R^2 of 0.90) as well as on the test dataset (RE of 6.12%; R^2 of 0.73). Nevertheless, the larger dataset would probably lead to even better performance. Furthermore, in our current implementation, utilizing a window size of 3 and a prediction horizon of 1, the model leverages data from the previous three months to forecast the following month. As a practical demonstration of our ML developed approach based on SVR model, we provide forecasts for probiotic supplement demand for the entire year of 2024. For this projection, we assumed that antibiotic sales and number of COVID-19 active cases will remain consistent with those in 2023, while the number of foreign tourists will remain at the 2019 level. Through our research, we highlight the importance of data collection, management, and sharing for the purpose of creation of AI-based models that could help in a better business management. Our ML model forecasts a sales trend in 2024 that closely mirrors patterns observed in previous years, with the highest sales projected to occur during the peak of the tourist summer season, reaching the peak in August. Here, we highlight the critical role of integrating modern technologies such as artificial intelligence (AI) into supply management of an organization, in this case specific for pharmacy chain [17–19]. The incorporation of AI offers multiple advantages enables pharmacies to strategically plan their supply chains and utilize data for pricing strategies, enhances operational efficiency, while simultaneously mitigating instances of product unavailability, thus providing benefits for the customers [18].

Conclusion and Future Perspectives

On the Montenegrin market, various probiotic supplement products for diverse applications could be purchased. Our study clearly showed increased interest in probiotic supplements as well as constant positive trend in probiotic supplement sales. However, one of the main challenges that remains is the lack of specific national regulation and guidelines for probiotics. Right now, the probiotic supplements alike the other food supplements are governed by The Law on Food Safety and managed by the Montenegrin Ministry of Agriculture, Forestry and Water Management. Specific regulations and standards (e.g., establishment of clear protocols and standards for examining the probiotic product quality and composition up to the strain level, establishment of the minimum required dosages, authorized health/functional claims) should guarantee the efficacy of probiotic supplements as essential for consumer protection, thus indicating clear need for establishing national guidelines for these health care product categories. Until then, producers could benefit from a transparent means of communicating product quality to consumers via "third-party certification," which is the independent assessment process from the manufacturer, including examination of ingredient sourcing, manufacturing practices, and potency, ensuring manufacturers meet established quality benchmarks. By standardizing quality and reducing the risk of substandard products, this certification may provide consumers with credible assurance of product safety and efficacy, allowing informed decision-making practices [47]. Our study also highlights the importance of

conducting comprehensive marketing studies for informing and educating consumers, as well as improving their ability to differentiate between genuinely effective probiotics and those with dubious claims.

Even tough multiple factors may impact probiotic supplement sales, in our case study, we confirmed that foreign touristic visits in Montenegro strongly shape the yearly seasonality of probiotic sales in Montenegro, with the highest sales during summer touristic season. Furthermore, we observed that probiotic supplements sales in Montenegrin territory shows significant increased trend, especially after COVID-19 pandemic. We also highlight the important role of appropriate data collection and management for the purpose of performing similar studies to assess and forecast sales. The final aim is to improve and optimize business management on organizational and national level.

Finally, the developed ML model showing an excellent accuracy could be implemented and further improved by using the data from all pharmacy chain in Montenegro to assess and predict probiotic supplement sales on national level. Furthermore, the proposed model could be applied for forecasting products in other fields such as drugs and cosmetics. In this way, both organizations and nationalities would benefit from accurate business management such as better sales planning, inventory management, and cost reduction, especially when facing unpredicted situations such as COVID-19 pandemic.

Study Limitations

The results of this case study, for making a conclusion on the whole Montenegrin market, should be confirmed by including data from all pharmacy chains in Montenegro. Nevertheless, our case study covered all Montenegrin regions, with representative data from 45 pharmacies, thus speculating that the same pattern would happen on the whole Montenegrin territory.

Limitations of the ML Modes Used SVR ML model is inherently reliant on historical data patterns for making predictions. Consequently, unforeseen variables, such as economic downturns or regulatory changes, can lead to the emergence of new patterns or behaviors that the model has not previously encountered, thereby diminishing its predictive accuracy. When significant changes occur, SVR models often require re-training to restore their accuracy. However, all ML models need continuous monitoring and adaptation to maintain their effectiveness in dynamic environments.

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Data Availability No datasets were generated or analysed during the current study.

Declarations

Competing Interests The authors declare no competing interests.

References

1. Das TK, Pradhan S, Chakrabarti S et al (2022) Current status of probiotic and related health benefits. Appl Food Res 2:100185. https://doi.org/10.1016/j.afres.2022.100185
2. Marotta A, Sarno E, Del Casale A et al (2019) Effects of probiotics on cognitive reactivity, mood, and sleep quality. Front Psychiatry 10:164. https://doi.org/10.3389/fpsyt.2019.00164
3. Ray M, Manjunath A, Halami PM (2023) Effect of probiotics as an immune modulator for the management of COVID-19. Arch Microbiol 205:182. https://doi.org/10.1007/s00203-023-03504-0
4. Grand view research probiotics market size, share & trends analysis report by product (food & beverages, dietary supplements), by ingredient (bacteria, yeast), by distribution channel, by end-use, by region, and segment forecasts, 2023 - 2030. https://www.grandviewresearch.com/industry-analysis/probiotics-market
5. Hill C, Guarner F, Reid G et al (2014) The International Scientific Association for Probiotics and Prebiotics consensus statement on the

scope and appropriate use of the term probiotic. Nat Rev Gastroenterol Hepatol 11:506–514. https://doi.org/10.1038/nrgastro.2014.66
6. Terpou A, Papadaki A, Lappa I et al (2019) Probiotics in food systems: significance and emerging strategies towards improved viability and delivery of enhanced beneficial value. Nutrients 11:1591. https://doi.org/10.3390/nu11071591
7. Mazzantini D, Calvigioni M, Celandroni F et al (2021) Spotlight on the compositional quality of probiotic formulations marketed worldwide. Front Microbiol 12:693973. https://doi.org/10.3389/fmicb.2021.693973
8. Fusco V, Fanelli F, Chieffi D (2022) Authenticity of probiotic foods and dietary supplements: a pivotal issue to address. Crit Rev Food Sci Nutr 62:6854–6871. https://doi.org/10.1080/10408398.2021.1907300
9. Teneva-Angelova T, Balabanova T, Boyanova P, Beshkova D (2018) Traditional Balkan fermented milk products. Eng Life Sci 18:807–819. https://doi.org/10.1002/elsc.201800050
10. Xavier-Santos D, Padilha M, Fabiano GA et al (2022) Evidences and perspectives of the use of probiotics, prebiotics, synbiotics, and postbiotics as adjuvants for prevention and treatment of COVID-19: a bibliometric analysis and systematic review. Trends Food Sci Technol 120:174–192. https://doi.org/10.1016/j.tifs.2021.12.033
11. Kopacz K, Phadtare S (2022) Probiotics for the prevention of antibiotic-associated diarrhea. Healthcare 10:1450. https://doi.org/10.3390/healthcare10081450
12. Olaimat AN, Aolymat I, Al-Holy M et al (2020) The potential application of probiotics and prebiotics for the prevention and treatment of COVID-19. Npj Sci Food 4:17. https://doi.org/10.1038/s41538-020-00078-9
13. Ministry of Economic Development. The law on food safety (2018) Official Gazette of Montenegro 57/15. https://www.gov.me/dokumenta/c1c7f08e-4d19-4b80-8534-9927e6b0342f
14. Djaoudene O, Romano A, Bradai YD et al (2023) A global overview of dietary supplements: regulation, market trends, usage during the COVID-19 pandemic, and health effects. Nutrients 15:3320. https://doi.org/10.3390/nu15153320
15. Fusco V, Fanelli F, Chieffi D (2022) Authenticity of probiotic foods and supplements: up-to-date situation and methods to assess it. In: Probiotics for Human Nutrition in Health and Disease. Elsevier, pp 45–74. https://doi.org/10.1016/B978-0-323-89908-6.00015-7
16. Wilson A (2011) Marketing research: an integrated approach, 3rd edn. Financial Times/Prentice Hall, Harlow, England, New York
17. Zontos S, Dimoticalis J, Skiadas CH (1998) Forecasting in marketing planning. forecasting performance of the logistic model and applications of S-4 model. In: Zopounidis C, Pardalos PM (eds) Managing in uncertainty: theory and practice. Springer, US, Boston, pp 325–340
18. Rathipriya R, Abdul Rahman AA, Dhamodharavadhani S et al (2023) Demand forecasting model for time-series pharmaceutical data using shallow and deep neural network model. Neural Comput Appl 35:1945–1957. https://doi.org/10.1007/s00521-022-07889-9
19. Đukanović M, Kašćelan L, Vuković S et al (2023) A machine learning approach for time series forecasting with application to debt risk of the Montenegrin electricity industry. Energy Rep 9:362–369. https://doi.org/10.1016/j.egyr.2023.05.240
20. Mbonyinshuti F, Nkurunziza J, Niyobuhungiro J, Kayitare E (2022) Application of random forest model to predict the demand of essential medicines for noncommunicable diseases management in public health facilities. Pan Afr Med J 42:89. https://doi.org/10.11604/pamj.2022.42.89.33833
21. Liu Y, Yang X, Zhu C, Meng J (2021) Drugs sale forecasting based on SVR integrated promotion factors. J Phys Conf Ser 1910:012056. https://doi.org/10.1088/1742-6596/1910/1/012056
22. Mousa BA, Al-Khateeb B (2023) Predicting medicine demand using deep learning techniques: a review. J Intell Syst 32:20220297. https://doi.org/10.1515/jisys-2022-0297
23. Zheng J, Wittouck S, Salvetti E et al (2020) A taxonomic note on the genus Lactobacillus: description of 23 novel genera, emended description of the genus Lactobacillus Beijerinck 1901, and union of Lactobacillaceae and Leuconostocaceae. Int J Syst Evol Microbiol 70:2782–2858. https://doi.org/10.1099/ijsem.0.004107
24. Monstat Monstat, Foreign touristic visits. http://monstat.org/eng/page.php?id=44&pageid=44. Accessed 3 Aug 2024
25. Covid-19 monthly reports Montenegro, Institute of public health. https://www.ijzcg.me/me/izvjestaji/mjesecni-izvjestaji-o-kretanju-zaraznih-bolesti-u-crnoj-gori. Accessed 3 Aug 2024
26. Peixeiro M (2022) Time series forecasting in Python. Manning, Shelter Island
27. Moradzadeh A, Mansour-Saatloo A, Mohammadi-Ivatloo B, Anvari-Moghaddam A (2020) Performance evaluation of two machine learning techniques in heating and cooling loads forecasting of residential buildings. Appl Sci 10:3829. https://doi.org/10.3390/app10113829
28. Manning CD, Raghavan P, Schütze H (2008) Introduction to information retrieval. Cambridge University Press, New York
29 Food and Agriculture Organization of the United Nations, World Health Organization (2006) Probiotics in food: health and nutritional properties and guidelines for evaluation. Food and Agriculture Organization of the United Nations: World Health Organization, Rome
30. IPA-Best Practices Guidelines for Probiotics. https://internationalprobiotics.org/home/resources/guidelines/2017-best-practices-guidelines/. Accessed Aug 2024
31. Martinović A, Cocuzzi R, Arioli S, Mora D (2020) Streptococcus thermophilus: to survive, or not to survive the gastrointestinal tract, that is the question! Nutrients 12:2175. https://doi.org/10.3390/nu12082175
32. Roobab U, Batool Z, Manzoor MF et al (2020) Sources, formulations, advanced delivery and health benefits of probiotics. Curr Opin Food Sci 32:17–28. https://doi.org/10.1016/j.cofs.2020.01.003
33. Narsing Rao MP, Banerjee A, Liu G-H, Thamchaipenet A (2023) Genome-based reclassification of Bacillus acidicola, Bacillus pervagus and the genera Heyndrickxia, Margalitia and Weizmannia. Int J Syst Evol Microbiol 73:7. https://doi.org/10.1099/ijsem.0.005961
34. Cao J, Yu Z, Liu W et al (2020) Probiotic characteristics of Bacillus coagulans and associated implications for human health and diseases. J Funct Foods 64:103643. https://doi.org/10.1016/j.jff.2019.103643
35. De Simone C (2019) The unregulated probiotic market. Clin Gastroenterol Hepatol 17:809–817. https://doi.org/10.1016/j.cgh.2018.01.018
36. Arora M, Baldi A (2015) Regulatory categories of probiotics across the globe: a review representing existing and recommended categorization. Indian J Med Microbiol 33:S2–S10. https://doi.org/10.4103/0255-0857.150868
37. Koirala S, Anal AK (2021) Probiotics-based foods and beverages as future foods and their overall safety and regulatory claims. Future Foods 3:100013. https://doi.org/10.1016/j.fufo.2021.100013
38. Kumar H, Salminen S, Verhagen H et al (2015) Novel probiotics and prebiotics: road to the market. Curr Opin Biotechnol 32:99–103. https://doi.org/10.1016/j.copbio.2014.11.021
39. Ono M, Ono A (2015) Executive summary of "Impacts of the FoSHU (Food for Specified Health Uses) system on food

evaluations in Japan." J Consum Mark 32:542–550. https://doi.org/10.1108/JCM-11-2015-052
40. Nguyen QV, Chong LC, Hor Y-Y et al (2022) Role of probiotics in the management of COVID-19: a computational perspective. Nutrients 14:274. https://doi.org/10.3390/nu14020274
41. Tian Y, Ran H, Wen X et al (2023) Probiotics improve symptoms of patients with COVID-19 through gut-lung axis: a systematic review and meta-analysis. Front Nutr 10:1179432. https://doi.org/10.3389/fnut.2023.1179432
42. Zhu J, Pitre T, Ching C et al (2023) Safety and efficacy of probiotic supplements as adjunctive therapies in patients with COVID-19: a systematic review and meta-analysis. PLoS ONE 18:e0278356. https://doi.org/10.1371/journal.pone.0278356
43. Institute of Public Health of Montenegro. In: Infect. Dis. Mon. Rep. Inst. Public Health Monten. https://www.ijzcg.me/me/izvjestaji/mjesecni-izvjestaji-o-kretanju-zaraznih-bolesti-u-crnoj-gori. Accessed 3 Aug 2024
44. Montenegro: Investment Climate Statement (ICS). https://www.trade.gov/country-commercial-guides/montenegro-investment-climate-statement-ics. Accessed 3 Aug 2024
45. Vosen S, Schmidt T (2011) Forecasting private consumption: survey-based indicators vs. Google trends J Forecast 30:565–578. https://doi.org/10.1002/for.1213
46. Miller JA, Aldosari M, Saeed F et al (2024) A survey of deep learning and foundation models for time series forecasting. Cornell University arXiv:2401.13912. https://doi.org/10.48550/ARXIV.2401.13912
47. Jackson SA, Schoeni JL, Vegge C et al (2019) Improving end-user trust in the quality of commercial probiotic products. Front Microbiol 10:739. https://doi.org/10.3389/fmicb.2019.00739