Basic Technologies and Models for Implementation of Industry 4.0

Karabegović, Isak

2023-10-04

https://bastina.anubih.ba/handle/123456789/779

DOI: 10.5644/PI2023.209.11

Sophisticated Transformation of Chemical, Pharmaceutical and Food Industry by Implementation of Digitalization and Automatization

Amra Bratovcic*

Abstract: *This paper will discuss the solutions and advantages of Industry 4.0 in the chemical, pharmaceutical and food industries.Industry 4.0 implies automation and process control, which enables greater process reliability and repeatability, better work control, efficient error diagnosis, maintenance support and higher product quality. In order to achieve this, it is necessary to use industrial equipment to achieve high functionality and reliability, i.e., the use of the latest developed smart technologies.it enables collection and storage of data from multiple sources in one central data warehouse in a contextualized manner, providing integrity of the underlying data and instant access from a single point.A central monitoring system provides operators with a detailed overview of equipment performance, helps maintenance personnel to eliminate errors and provides aggregation of all relevant data. The application of Industry 4.0 will improve the monitoring of process parameters, the management of production recipes, and accelerate the change of products.In addition, it enables efficient development, management and remote download of recipes to production equipment without affecting the production process on the machine/line itself.The implementation of Industry 4.0 leads to the improvement of product quality, better management of material flow, lower energy consumption, and better utilization of machines and higher productivity, which reduces operating costs and positively affects business results.*

Keywords: *artificial intelligence, internet of things, smart machines, data collection and analysis, cyber security, sensors, blockchain, robots, smart factory, machine learning, process optimization*

1. Introduction

The term Industry 4.0 refers to the 4th Industrial revolution (IR), which is based on high technologies that are rapidly developing, such as: artificial intelligence (AI) Internet of Things (IoT), smart machines that are networked and communicate with each other, robotics and advanced computers in order to significantly change the appearance of production. Industry 4.0 is characterized by integrated, autonomous and self-organized production systems. Digital transformation implies connecting all factors of production processes into a networked value chain, collecting and analyzing data for the purpose of improving the processes involved in production, optimizing costs, gaining

*University of Tuzla, Faculty of Technology, Department of Physical Chemistry and Electrochemistry, 75000 Tuzla, Bosnia and Herzegovina
E-mail: amra.bratovcic@untz.ba

acompetitive advantage, and fulfilling the expectations and wishes of customers.[1]

I 4.0 technologies leading to the automation of some production processes include: 3D printing, AI, augmented reality, robots, big data, blockchain, cloud technology, collaborative systems, cybersecurity, drones, GPS, Industrial Internet of Things, mobile technology, nanotechnology, RFID (a technology that uses wireless communication and automatically tracks and identifies specific objects), sensors and simulations.

I 4.0 creates the so-called ‘’SmartFactory’’.In modularly organized smart factories, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions.

Investing in technology requires large financial resources. Artificial intelligence, i.e., the application of machine learning, and especially deep learning (algorithms for recognizing the state of the system and autonomous decision-making) with the aim of optimizing processes, is the core of I 4.0.Sensors and communication elements are key to automation and connect the real and virtual world in the form of a network of cyber-physical systems (autonomous robots).The basis of the development of AI refers to the use of advanced predictive tools that enable the continuous processing of large data to make decisions based on all available information at all times.Sophisticated devices based on artificial intelligence, CAD, simulations and process management are today one of the greatest values for shortening the R&D economy.

Artificial intelligence is mainly used to interact with the environment, recognize images (static or moving), human speech and environmental conditions (temperature, humidity, direction of movement, position, speed, etc.) and process the data collected in real time. The broadest application of AI is in robotics, which is mainly used in manufacturing, transportation, design, engineering, finance, information technology, diagnostics, and other processes in the home and entertainment industries.

Big data is becoming the standard for real-time decision support. Data is collected from a variety of sources, such as manufacturing equipment and systems, as well as enterprise and customer management systems. In order for big data to be used sensibly, it must be intelligently consolidated and evaluated.

Robots interact with each other and work ‘’in collaboration’’ with humans and learn from them. The costs will be lower and the possibilities will be greater than with today’s production. Robots and people are becoming more and more equal in business processes.

Simulations are mostly used to transfer the physical world into a virtual model in order to reduce costs and increase quality. They allow operators to test and optimize machine settings before physical production.

The **Internet of Things (IoT)** in I 4.0 means that computers areintegrated into devices sothattheycancommunicate with eachother.

Cyber security includes secure, reliable communications and management of identity and access to machines. According to the Report on the work of the European Investment Bank - cyberattacks threatened thousands of companies and the data of billions of people.

Connectionin ‘’cloud’’ technology during production requires more data exchange. The result is the delivery of more data services.

Duetoitsdesign advantages, **3D printing** is increasingly being used to produce prototypes and individual components or toproduce small series of specially adapted products.It is quitet an exceptional revolution like Gutenberg’s printer 570 years ago.The possibilities of 3D printing are impressive, from use for NASA technology, in the aviation industry, but also for printing human organs (using the patient’s cells), as well as food printing.

Augmented reality supports a variety of services and allows access to information in real time.[2]

Central and Eastern Europe is near the end of an economic era marked by cheap labor, so foreign investment in the long term could increasingly go to countries further east and south. For example, Zoroslav Smolinsky, a trade union representative in the Slovakian VW, started working in the production facilities in 1992, when the factory was just taken over by the German Volkswagen, and he had a salary of 75 euros.Today, 12,300 VW workers in Bratislava earn an average of 1,804 euros per month.It is twenty-four times larger. According to Novotny, economists from Croatia, Europe is increasingly turning to ‘’industry 4.0"’’, which implies intensive investments in robotization that will replace the human workforce.[3]

In Italy, there is an increase in industrial production thanks to large investments in the modernization and robotization of industrial production in the recent years. Germany also exhibits increase in the automotive and wood industry. However, Germany tried to solve the labor shortage with immigration policy. In Croatia there is a labor shortage. Due to all this, the industrial paradigm is changing.A lot is invested in research and development, high technology, and marketing.The automotive industry in the EU has adapted to the development of hybrid and electric cars.

For example, everyone who maintains that Istria was developed only because of tourism is mistaken.Istria has a strong industry.Just like the fact that Slavonia became one of the most developed regions throughout history not because of agriculture, but because of industry.According to Novotny, Croatia should turn to the industry 4.0 paradigm, and not exhaust itself by rescuing industries that are difficult to save, such as Petrokemija in Kutina, or oil refineries. There are two different examples in Požega.The Color enamel company invested in high-tech and robotic production of fireplaces and flue pipes and today has a very competitive production and is a major exporter to the demanding Western and Northern European markets.On the other hand, the company Zvečevo from

Požega, with a long tradition, did not invest in high technology and failed. Therefore, the Croatian manufacturing industry, including the food industry in Slavonia, will simply have to go in the direction of investing in high technologies that will replace the increasingly expensive labor force.[2]

2. Chemical Industry – Chemistry 4.0

Industry 4.0 combines digital and physical advanced technologies, and can potentially transform the chemical industry by improving strategic growth and streamlining operations. The chemical industry turns oil and natural gas into intermediate products, which eventually turn into the products we use every day. The global chemical industry serves as the backbone of many industries such as agriculture, the automotive industry, construction and pharmaceuticals.

Because research and development require large investments, chemical companies use big data to predict the outcome of that investment.Thatis, advanced analyzes help scientists understand the chemical properties of available materials and consider new possible combinations.

For example, BASF uses Industry 4.0 applications to implement connected systems and advanced analysis models for predictive asset management, process management and control, and virtual commissioning.In addition to these classic applications, the company has fully automated the production of liquid soaps in an intelligent pilot plant in Kaiserslautern.When a customer places an order for a personalized soap, RFID tags attached to the soap containers notify the production line equipment via wireless network connections of the composition and packaging of the requested soap, allowing the mass to be customized without human intervention. [4]

Organizations driven by business processes can use I4.0 technology exclusively to increase productivity while reducing risk, whereas those involved in development can implement I4.0 principles to generate additional income or new sources of income.

Three strategies for the modernization of chemical production are transformation of existing systems, data-driven operational framework and digitized corporate structures.

2.1. How Industry 4.0 improved production and materials management?

Industry 4.0 enables chemical companies to improve process controls, knowledge and resource management by shortening production cycles and increasing organizational productivity and efficiency. Advanced analytical capabilities help chemical companies monitor trends and encourage innovative approaches to quality control, reducing downtime as well as non-conformities. [5]

With intelligent detection methods enabled by IoT, you can achieve high-quality production in batch or continuous processing.Furthermore, Industry 4.0

technologies are being developed for better process administration, givingoperators greater freedom to monitor instrument data and plant activity.This makes it easier for the chemical industry, which is an asset-intensive sector, to continuously monitor relevant equipment such as rotors, compressors and extruders to identify and predict failures.In short, Industry 4.0 is forcing chemical manufacturers to quickly move from reactive to predictive maintenance. [6]

2.2 Processes in the chemical industry – the digital twin as a central part of process optimization

By using EPLAN, all engineering steps can be optimized and time to market can be shortened. The result of integrated and continuously enriched data (digital twin) offers added value for commercial, administrative and advanced technical processes. The EPLAN program is interdisciplinary and covers all areas including process technology, process control technology, fluid engineering and electrical engineering. Transparent and complete engineering documentation accelerates commissioning, and automatic updates of all changes ensure that the documentation follows the actual state. This in turn provides design certainty and supports changes during plant system operation.

3. Pharmaceutical Industry – Pharma 4.0

Pharma 4.0 represents the 4th IR on the way to computerization of pharmaceutical production, which refers to IoT, big data, cloud computing and automation.

The initiators of the ‘’Pharma 4.0’’ concept are: AI and to the greatest extent machine learning, blockchain technology, and application of ‘’augmented and mixed reality in industry’’.

MetronikSustavid.o.o. –is an innovative supplier of automation systems and IT solutions for the digitalization of the pharmaceutical and food industry. By combining knowledge of production management processes with state-of-the-art automation and digitization technology, this company helps clients increase their competitive advantage by improving the management and control of their processes, identifying cost savings opportunities and developing optimization initiatives.[7]Solutions for automation and control of processes related to heating, cooling, ventilation and lighting can ensure appropriate ambient conditions, improved practicality, easier system maintenance and energy efficiency. [8] Process automation and control can provide greater process reliability and repeatability, better work control, efficient fault diagnosis, maintenance support and higher product quality.

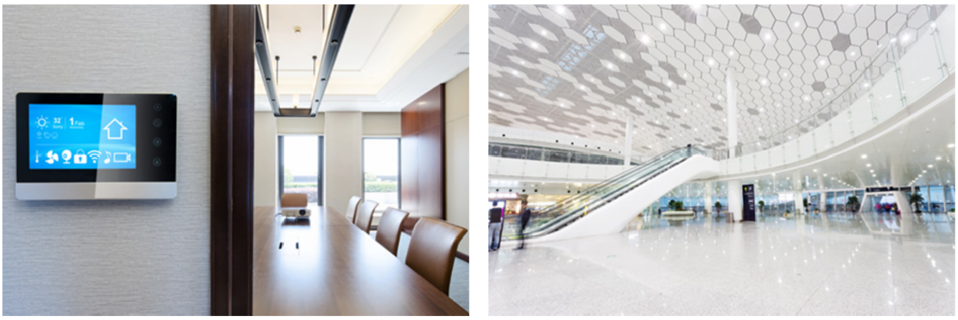

Figure 1. Automation and control of heating, cooling, ventilation and lighting processes - energy efficiency

Big Data makes it possible to extract key information from your data to improve processes and reduce production costs. [9]

Figure 2. Tools for modeling and data analysis for process optimization

The Metronik company enables the safe collection and storage of data from multiple sources in one data warehouse in a contextualized manner, providing the integrity of basic data and immediate access from one point.With data integrity, we ensure that data recordings are consistent, properly organized and preserved, and that we know at all times where the reference value of a particular data record originates*[10]*.
The US Food and Drug Administration (FDA) has approved 29 AI-based technologies. Viz LVO is an application that enables rapid detection and diagnosis of stroke.It uses AI to detect and triage suspected strokes.The information reaches the doctor directly, an hour faster than conventional techniques. DreaMed is another application that is based on AI and is an automated support for deciding on the therapy of patients with type I *diabetes mellitus*.

Figure 3.Secure data collection and storage

DreaMed's algorithm is paired with a server that analyzes an individual's blood glucose concentration, insulin dose history and carbohydrate intake and enables healthinformation to the worker in order to give a personalized dose of insulin to the patients.

Machine learning as a branch of AI is used for the development and formulation of new drugs and manufacturing processes.Machine learning is used to predict the psycho-chemical characteristics of a drug, optimize the composition of formulations, optimize the production process, predict the rate of drug release, bioavailability and predict the stability of drugs.All this leads to a reduction in costs, the possibility of detecting unwanted effects in the early phase, faster results compared to existing in silico methods.Especially in the drug discovery segment, advanced machine learning techniques such as reinforcement learning, transfer learning, active learning, and deep learning are significant.

Blockchain technologies can be used in: fight against falsified medicines, and that in this sense the new concept of cryptopharmaceuticals is being mentioned more and more, in pharmaceutical supply chains, where complete control of conditions in the drug supply chain could be enabled and, improved transparency in clinical drug trials.*[11]*

3.1 Technology for the production of personalized medicines

Siemens in Vienna is developing technology for the production of personalized medicines[12]. The recently opened Viennese Living Lab, the only experimental facility in Europe, where Siemens develops various digital technologies of the future, including the one for the production of personalized medicines. Technology for the production of personalized medicines in small batches that are adapted to each individual and the health needs of his organism based on data on genetic material and other biomarker information.

Figure 4.Living Lab in Vienna

3.2 What can pharmacy expect from Industry 4.0?

I 4.0 is focused on digitization using cloud systems. In a smart factory, a networked process provides transparency across teams and processes, including sales forecasting, raw material ordering, machine maintenance, floor plan operations, reporting and delivery. The raw material ordering team has access to AI sales forecasts and adjusts the order accordingly. Operators, in the same way, approach sales forecasts and adjust the speed of the production line. If operators have information about a smaller order quantity, they can use that time for machine maintenance. To create smart production, it is very important to determine which area in the production process should be digitized first, because pharmaceutical companies have different digital maturity and needs.

3.3 Increased patient safety

Patient safety has always held a particularly important place in the pharmaceutical industry, and any technology that can advance this requirement is very important.In order to ensure the high quality of medicines, they must be stored and transported under certain conditions.Any change in physical conditions (temperature, humidity, presence/absence of light or air) can affect the quality of both raw materials and final products. IoT sensors - a solution for Industry 4.0 - are designed to monitor small variations in the environment and have become a key player in patient safety.[13]

3.4Cybernetic-physical system (CPS) for pharmaceutical production in industry 4.0

The key elements of CPS are public cloud, private cloud and manufacturing facility. Public Cloud are application services for external users. Private cloud includesspecific information for remote monitoring systems, manufacturing, energy management, laboratory information, management, and modeling

andsimulation. Public and private clouds digitally reflect the state of the physical system, enabling real-time optimization and prediction.
The production platform includes hardware, PAT tools and real-time release tests (RTRt).PAT ensures the control of the production process and RTRt ensures the quality of the product based on the data collected during the production process. Processing operations (e.g., delivery, wet granulation, fluid bed drying, grinding, mixing, compression and tablet coating) are connected to the local network and the cloud via the Internet.
Production process data is recorded and stored using two key technologies: data storage technology (cloud) and data collection technology (advanced sensors).This data-rich environment enables the development of big data and simulations, AI and adaptive control, digital twins and cyber-physical (IoT) systems. These combined technologies enable intelligent, precise, real-time collaborative robotics and augmented or virtual reality technologies to control and manage production. The entire smart factory is supported by a wireless internet network and sufficient cyber security.

4. Food Industry

Throughout the food industry, it is essential that production is thoroughly documented so that products and their ingredients can be traced.[14] Fulfillment of this requirement significantly depends on the perfect operation of IT. The Manner company is currently investing around 40 million euros in the production site. A new data center was also built.Rittal supplied the IT infrastructure.
Technology is a support for decision-making. The collection of huge amounts of data, storage and analysis (IT) enables a much better insight into the various processes on the basis of which better decisions are made in the food industry[15]. The packaging changes in parallel with the threats. Digitized processes in the supply chain are more exposed to new security threats.

4.1 New tracking technologies

With the help of track-and-trace package tracking technology, Radio frequency identification (RFID), QR codes and (IoT) it is possible to detect any anomalies and track any lost or stolen item within seconds.[16]
Smart technology embedded in packaging or products makes it possible to sendinformation in real time, prevent counterfeiting,and goods authentication (embedded microchips).
RFID tags and QR codes are commonly used today for improving the level of identification and traceability throughout the supply chain. They enable companies to strengthen quality control systems and react more quickly to potential problems. RFID tags play an important role in new approaches to

packaging protection. It is based on a printed antenna with a microscopic chip that transmits a radio frequency signal. It can be used to track products during transport, monitor inventory and increase security.
RFID tags can be used for: sending information to the customer's mobile phone to inform them about the delivery date, to track the location of the package in the warehouse as well as the time of loading it into the delivery truck,to track the delivery from start to finish, while reducing the risk of theft during transport,and to detect unauthorized access (signal interruption). The total value of the RFID tag market in 2022 was about 13 billion dollars.
NFC and Bluetooth Low-Energy (BLW) technologies are so simple that consumers can use them on their mobile phones, (quick access to package information and delivery tracking). Each NFC chip (security tool) has a unique serial number assigned by the manufacturer, (customers can be sure of the authenticity of product information). It is easier for companies to track items in case of theft.[17]

4.2 Product traceability

Characteristics of the traceability system: Product identification – dimensions, volume, weight, area, packaging, cost, life cycle length;Tracking data – tag/number, type, level of detail, dynamic, data storage requirements, data confidentiality; Product routing (production process) – production cycle, activities, delivery time, equipment, manual operations, automatic operations, storage systems.

4.3 Product identification and marking

Identification is done using the technology of direct or indirect labeling of product parts - DPM (Direct Part Marketing).

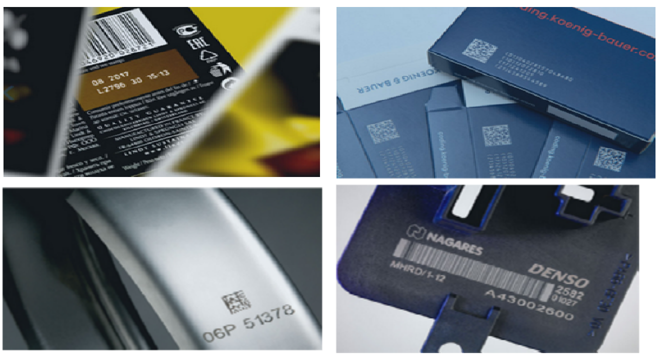

Figure 5. Two-dimensional codes

Direct and indirect technologies are techniques for labeling parts and raw materials. Indirect labeling includes paper labels, plastic, metal, RFID tags, tags, etc. [18-19]Direct marking includes Dot Peen technology, laser marking, electrolytic-chemical treatments, engraving, InkJet technologies, embossing, etc. Indirect marking refers to marking that requires an identification holder, and for this application, labels or labels with a numerical, alphanumeric, barcode or 2D code are most often used.This method is only used to mark larger parts or products.RFID tags are used to identify parts with advanced IoT systems that enable mutual interaction and communication between cutting resources in real time.Ultra-small RFID chips have been developed, e.g., the Hitachi micro-chip, size 0.3x0.3 mm. Direct marking of parts includes marking of the surface, and is most often a form of marking of small parts and components.These marks can be alphanumeric or numeric characters, barcodes or 2D codes.Laser marking is the most common technology used for direct marking of parts.miDoT is a new method being developed for the unique identification of small parts using glittering ink in a radius of less than 1 mm.This ink is applied with a pen, and the pattern is read and matched against a database.The advantage of this method is the low cost of materials compared to the high cost of data storage and processing.

Cardboard packaging is one of the most widely used material for transporting products in the world, with more than 100 billion boxes produced in the US alone.To ensure that packages reach their destination, many companies mark cardboard packaging with 1D or 2D barcodes. Markings are applied directly to the side surface of the packaging, and this procedure is called direct marking of transport packaging.[20]

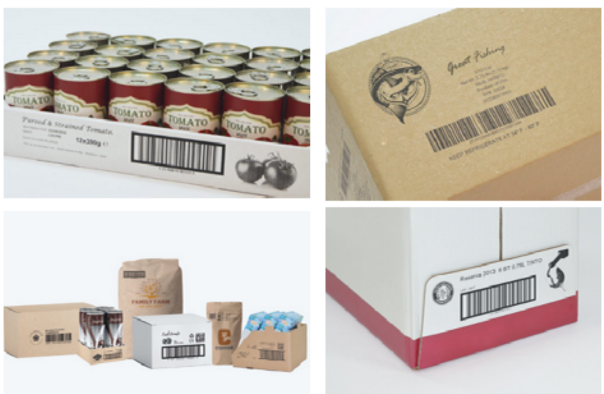

Figure 6.Marking of cardboard packaging

5. Conclusion

Fourth IR combines advanced production technologies to enable integrated, autonomous and self-organizing production systems that operate independently of human involvement. Industry 4.0 refers to the collection of data from the production process, the digitization and analysis of data (Big Data) leading to information, which, according to the meaning of AI, creates knowledge and leads to wisdom that is achieved through the combined insights of digital maturity. Digitization, standardization and automation are all trends that industrial sector cannot avoid. Integrated design of control systems and a strong engineering program can make a significant contribution to the improvement of automation in the company.

4. References

[1] N. Sarah Arden, Adam C. Fisher, Katherine Tyner, Lawrence X. Yu, Sau L. Lee, Michael Kopcha, Industry 4.0 for pharmaceutical manufacturing: Preparing for the smart factories of the future, International Journal of Pharmaceutics, 602, 2021, https://doi.org/10.1016/j.ijpharm.2021.120554

[2] Industrija 4.0 i prednosti ERP rješenja, https://www.fluentis.com/hr/industrija-4-0-erp/; accessed on 20.06.2023

[3] Četvrta tehnološka revolucija - Neće nas spasiti turizam nego robotizirana industrija, http://www.glas-slavonije.hr/340939/1/Nece-nas-spasiti-turizam-nego-robotizirana-industrija?fb_comment_id=1615288008545290_1615359148538176; accessed on 20.06.2023.

[4] https://www2.deloitte.com/cn/en/pages/consumer-industrial-products/articles/industry-4-0-and-chemicals-industry.html

[5] Bratovcic, A. New Solar Photocatalytic Technologies for Water Purification as Support for the Implementation of Industry 4.0. In Karabegović, I., Kovačević, A., Banjanović-Mehmedović, L., & Dašić, P. (Eds.), Handbook of Research on Integrating Industry 4.0 inBusiness and Manufacturing. IGI Global. 2020, (pp. 385-412) http://doi:10.4018/978-1-7998-2725-2.ch017

[6] https://www.azom.com/article.aspx?ArticleID=21571

[7] Metronik, https://metronik.hr/ ; accessed on 20.06.2023.

[8] UKC Ljubljana, Kristalna palača BTC, Aerodrom Ljubljana, Kontrola vazdušnog saobraćaja Slovenije, Terme Krka, Cankarjev dom, Univerzitet u Ljubljani – FKKT/FRI…

[9] Dravske elektrarne Maribor, JP Energetika Ljubljana, Lek/Sandoz/Novartis, Telekom Slovenije

[10] Dravske elektrarne Maribor, JP Energetika, Lek/Sandoz/Novartis, Telekom Slovenije
[11] https://medicalcg.me/izazovi-cetvrte-industrijske-revolucije-u-farmaciji-koncept-pharma-4-0/
[12] https://lidermedia.hr/aktualno/siemens-u-becu-razvija-tehnologiju-za-proizvodnju-personaliziranih-lijekova-30336
[13] Sikander A., The future of pharma: How Industry 4.0 is driving pharma manufacturing, https://pharmaceuticalmanufacturer.media/pharmaceutical-industry-insights/pharmaceutical-manufacturing-insights/the-future-of-pharma-how-industry-40-is-driving-pharma-manu/ ; accessed on 20.06.2023.
[14] Manner, Rittal i tvornica čokolade, https://www.rittal.com/hr-hr/Loesungen/Referenzen/Manner accessed on 20.06.2023.
[15] https://www.netokracija.com/discuss-it-combis-tehnologija-prehrambena-industrija-185509
[16] Bratovčić, A. „Smart and sustainable food processing sector by integration of the concepts of the technologies behind Industry 4.0.“DOI: 10.5644/PI2022.202.28. https://publications.anubih.ba/bitstream/handle/123456789/740/28.%20Bratovcic%2C%20Amra.pdf?sequence=30&isAllowed=y
[17] A&S Adria, Sigurnosna ambalaža kao ključna karika, https://www.asadria.com/sigurnosna-ambalaza-kao-kljucna-karika/ accessed on 20.06.2023.
[18] Bratovcic, Amra. "Bio-and Synthetic Nanocomposites for Food Packaging." *The Science of Nanomaterials: Basics and Applications* (2022): 303. https://www.taylorfrancis.com/chapters/edit/10.1201/9781003283126-11/bio-synthetic-nanocomposites-food-packaging-amra-bratovcic
[19] Bratovcic, Amra. ‘’Physical–Chemical, Mechanical and Antimicrobial Properties of Bio-Nanocomposite Films and Edible Coatings.’’ *International Journal for Research in Applied Sciences and Biotechnology* 8.5 (2021): 151-161.
[20] Primark, Identifikacija i označavanje proizvoda, https://primark.hr/identifikacija-i-oznacavanje-proizvoda/ accessed on 20.06.2023.