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PROTOTYPING OF CARDBOARD PACKAGING FOR BERRIES

OSMIŠLJAVANJE I IZRADA KARTONSKE AMBALAŽE ZA BOBIČASTO VOĆE

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ABSTRACT

The production of packaging products is experiencing annual growth. Packaging is made from a broad spectrum of materials with different properties. The European Union adopted Directive (EU) 2019/904 on reducing and preventing the environmental impact of certain plastic products. This directive aims to encourage a circular economy among consumers and producers by ensuring that single-use plastic products are not be placed on the market when suitable and affordable, more sustainable alternatives are available. Despite regulations, disposable plastic packaging for food products remains prevalent in the market. This research focused on disposable packaging for berries. A conceptual solution was devised from sustainable material suited for the food industry, alongside creating a product prototype. Additionally, a comparative visual study was conducted to evaluate the storage quality of berries in different packaging solutions. The study also included a of a survey, to assess participants' awareness of the environmental impact of plastic packaging and to identify preferences for more sustainable alternatives. The presence of numerous packaging solutions can leave consumers uncertain about the most sustainable packaging.

Keywords: *packaging for berries, sustainability, circular economy*

SAŽETAK

Proizvodnja ambalažnih proizvoda raste na godišnjoj razini. Ambalaža se izrađuje iz širokog spektra materijala različitih svojstava. Europska unija donijela je Direktivu (EU) 2019/904 o smanjenju i sprječavanju utjecaja određenih plastičnih proizvoda na okoliš. Direktiva želi promicati kružno gospodarstvo kod potrošača i proizvođača kako na tržište ne bi došli plastični proizvodi za jednokratnu uporabu ukoliko su dostupne odgovarajuće i cjenovno pristupačne održivije alternative. Na tržištu je često prisutna jednokratna plastična ambalaža za prehrambene proizvode. U ovom istraživanju proučavana je jednokratna ambalaža namijenjena bobičastom voću. Osmišljeno je idejno rješenje od održivog materijala namijenjenog prehrambenoj industriji te je izrađen prototip proizvoda. Provedeno je usporedno vizualno istraživanje kvalitete skladištenja bobičastog voća te anketno istraživanje, kojim je dan uvid u poznavanje ispitanika o temama vezanim za štetnost plastične ambalaže te prepoznavanje njezinih održivijih inačica. Razna ambalažna rješenja mogu zbuniti kupce koji često nisu informirani o najodrživijim vrstama ambalaže.

Ključne riječi: *ambalaža za bobičasto voće, održivost, kružno gospodarstvo*

1. INTRODUCTION

Plastic fruit packaging has become increasingly prevalent in recent years due to its durability, affordability, and ability to extend fruit shelf life. However, its environmental impact is significant. One of the impacts on the environment refers to the non-renewable raw material from which plastic materials are obtained, i.e. fossil fuels, which contributes to the emission of greenhouse gases and climate change. The industry of plastic refining and production of plastic products uses fossil sources for supplying industrial processes with energy and heat, and for processing plastic into plastic resin, synthetic fibers or additives. When providing

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carbon dioxide equivalent or CO_2E, i.e. the number of metric tons of CO_2 emissions with the same global warming potential as one metric ton of another greenhouse gas, 85% of CO_2E comes from fuel combustion, while 15% comes from production processes [1]. Further studying the impact of plastic materials on the environment and their disposal represents a significant challenge because plastic materials take hundreds of years to decompose, which can contribute to the accumulation of plastic waste. By properly disposing of plastic waste in landfills, the amount of CO_2E has the lowest absolute level, although the process itself has other significant risks. Plastic recycling has a moderate CO_2E impact, while incineration leads to an extremely high CO_2E impact [1]. The persistence of plastic materials contributes to the accumulation of plastic waste in oceans and other ecosystems, endangering wildlife and causing ecological imbalance. There is only 1% plastic on the surface of the ocean, which releases primarily methane, but also other greenhouse gases. The rest of the plastic sinks to the bottom of the ocean, and it is difficult to assess its impact [2]. Degradation of plastic in the environment accumulates microplastics, which end up in human bodies, food and water supplies, and affect human health [3]. Microplastics in the human body can cause health problems such as inflammatory diseases, genetic changes, lack of oxygen, cell death and necrosis, which are associated with several diseases such as cardiovascular, neurodegenerative, autoimmune diseases, diabetes, stroke, and cancer. Microplastics in the oceans can interfere with its ability to absorb carbon dioxide. Phytoplankton's ability to fix carbon is reduced in the biological pump, and zooplankton's metabolic rates, reproductive success and survival are reduced. Accidental situations are also related to the production of plastic materials [4, 5]. The American Environmental Protection Agency (EPA) reported that between 1980 and 1987, as many as 16% of industrial accidents were related to the processing of plastics or plastic additives [6].

As the global population continues to grow, so does the amount of packaging waste produced. Plastic packaging is also used for packaging berries. Understanding the background and context of plastic fruit packaging allows us to understand the urgency of finding sustainable alternatives. As the negative impacts of plastic packaging on the environment become more apparent, companies and consumers are looking for alternative solutions that are environmentally friendly and can help reduce waste. The use of sustainable cardboard packaging as a substitute for plastic packaging has received considerable attention in recent years. Cardboard packaging offers a promising solution due to its renewable and biodegradable nature. It offers several advantages that make it a sustainable choice. First, it helps reduce environmental impact by using renewable materials and it is easy to recycle [7]. The production of cardboard packaging requires less energy and water compared to alternative materials such as plastic or metal. Biodegradable properties of cardboard can contribute to the reduction of the amount of waste in nature if there is careful management of the packaging product after its use. By choosing sustainable materials like cardboard instead of plastic, production can also reduce their carbon footprint [8]. Second, sustainable cardboard packaging enhances the brand’s image by showing the company's commitment to the environment. It demonstrates corporate social responsibility and appeals to environmentally conscious consumers. Using recyclable and renewable materials can reduce costs and develop more efficient production processes. Sustainable packaging plays a key role in mitigating the environmental impact caused by excessive waste.

Product sustainability is also encouraged at the national level. In 2019, the European Union adopted the Directive on reducing the impact of certain plastic products on the environment, which aims to prevent and reduce the impact of certain plastic products on the environment, especially the aquatic environment, and on human health. The directive wants to promote the transition to a circular economy with innovative and sustainable business models, products, and materials [9]. In Australia, by 2025, 100% of Australian packaging must be designed for easy recycling, composting, or multiple uses.

2. EXPERIMENTAL PART

2.1. AIMS OF THE INVESTIGATION

This work aims to develop a conceptual packaging solution for berries compared to traditional plastic

packaging. The conceptual solution employs a more durable material, in this case, cardboard. Design functionality is adapted to non-plastic material. The aim of the product was to maintain good berry preservation properties. The chosen material, compared to plastic packaging, does not emit such a large emission of greenhouse gases and is biodegradable and 100% recyclable. The paper will also present the answers of the conducted survey about the ability of respondents to recognize sustainable packaging solutions, to gain insight into the knowledge of customers. If customers are not able to recognize a more sustainable product in the store, the negative impact of plastic on the environment will not be reduced. One of the contributions of this paper is raising awareness of the urgency of changing bad shopping habits and the possibility of production and purchase of sustainable packaging solutions.

The conceptual solution employs a more durable material, specifically cardboard, chosen for its lower greenhouse gas emissions, biodegradability, and 100% recyclability compared to traditional plastic packaging.

The design is specifically tailored to leverage the properties of non-plastic materials while aiming to maintain or enhance the preservation qualities of berries. Additionally, this paper presents findings from a survey conducted to assess the respondents' ability to identify sustainable packaging solutions. These insights help understand consumer awareness regarding sustainable options. If customers struggle to recognize more sustainable products in stores, the environmental impact of plastic will persist. Thus, one key contribution of this research is to highlight the critical need for changing purchasing behaviors towards the adoption of sustainable packaging solutions.

2.2. METHODOLOGY AND RESEARCH PLAN

In the research, a design was created for a conceptual solution and a prototype of a packaging product for berries. The freshness of berry fruit products in commercial plastic packaging and in the prototype was compared regarding preservation of freshness of the fruit. A survey was conducted to examine: consumer habits when buying berries, requirements that consumers place on packaging products, and knowledge when choosing sustainable packaging.

A survey of 100 respondents was conducted using Google Forms. The survey consisted of short and clear questions with attached pictures to add clarification to the questions. The questions were closed-type (it is possible to choose a single provided response), open-type (multiple answers are possible), referring to the recognition of some of the solutions of sustainable packaging, and linear-type questions (with a scale from 1 to 5) which indicate the importance of some packaging properties.

2.3. MATERIALS

Cardboard with 85% recycled paper content was used to create the prototype. After the use, the packaging product is 100% recyclable and biodegradable. The selected cardboard material has certificates (FSSC 22000 and ISO 22000:2005) for use in the food industry, making it safe in contact with food. The selected characteristics have a thickness of 1.2 mm, a grammage of 350 g/m2 and a natural brown colour. The paper, cardboard, and cardboard factory for remanufacturing use the latest technologies in the production of packaging materials. The mentioned factory applies the principles of the circular economy through the developed system of collecting paper and cardboard packaging. In the factory's plants, the water in the recycling process is in a closed system and supplies the hydroelectric power plant. The factory obtains its energy from renewable sources, and the steam for the corrugated cardboard production process comes from the biomass thermal power plant (production processes).

2.4. CONCEPT DESIGN

To eliminate the empty space during the transport of products and to utilize the cardboard when cutting the packages, it was decided that the packaging would be rectangular. The prototype is designed as self-folding packaging, which eliminates the use of glue when assembling the packaging, easyly flattening in the phase of collecting the product after use, savings on

material, i.e. adhesive, and the elimination of adhesive particles in the recycling process, which increases the quality of the paper pulp. The designed conceptual solution provides optimal packaging strength for berries, and the absence of printing ensures a high-quality raw material for recycling. All of the above contributes to the simplicity of the design, which directs customers to a more sustainable product.

The dimensions of the product were established according to calculations for an average fruit volume of 250 g so that the packaging would not be too large and waste material. It must be emphasized that the optimal volume of empty space in the package above the fruit was considered when designing the conceptual solution. A destroyed product i.e. berries has a more negative impact on the balance of sustainability than the use of an excessive amount of packaging material. According to the aforementioned, the dimensions of the prototype were determined to be 13x3.5x10.5 centimeters (width, height, depth) (Figure 1). The packaging design was adapted to fruit consumption over several days.

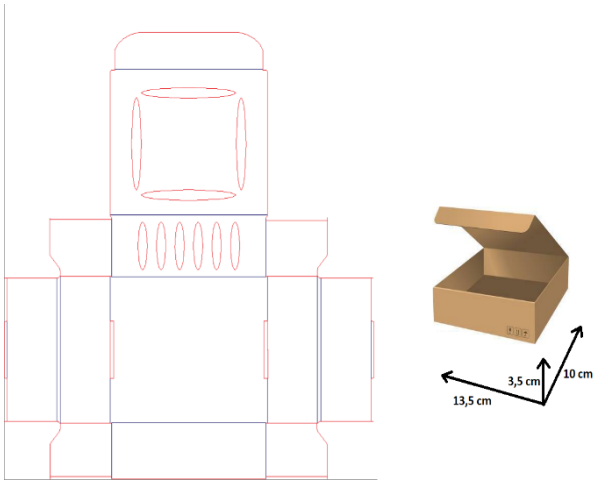


Figure 1. *Corel interface rendering and 3D packaging model*

In addition to the classic opening design, an additional solution on the possibilities of opening and closing the packaging was incorporated into the design of the conceptual solution. The option of opening a small window in the packaging lid, which may or may not be removed in addition to the function of food consumption, also provides the possibility of insight into the freshness and quality of the berries. The aforementioned opening, as well as those on the back of the packaging, allow air circulation inside the packaging, which contributes to prolonging the product freshness. Testing the prototype strength indicated the possibility of reusing the designed packaging, provided that the berries are sold in bulk.

The drawing of the packaging with the construction of cutting and bending lines was made in the Corel Draw program, where the red color of the line indicates the line for cutting, and the blue color indicates the bending line (Figure 1).

2.5. CREATION OF A PACKAGING PROTOTYPE

The prototype was made on the graphic CNC cutter Esko Kongsberg X24, which supports the preparation made in the Corel Draw program and the described marking method. The Esko Kongsberg X24 cutter uses the I-cut software (Figure 2). The cutting form is prepared in PDF format so that the cutter's software can recognize and distinguish between cutting and bending lines. The cutter can work with several tools simultaneously. In this conceptual solution, the sequence of operations, such as those involving an oscillating knife and a bending tool, is dictated by the layer order. Specifically, the bending procedure is initiated first, followed by the cutting procedure. Such an order contributes to the maximum precision of prototyping.

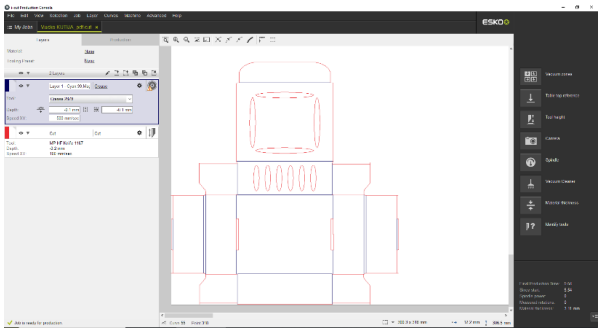
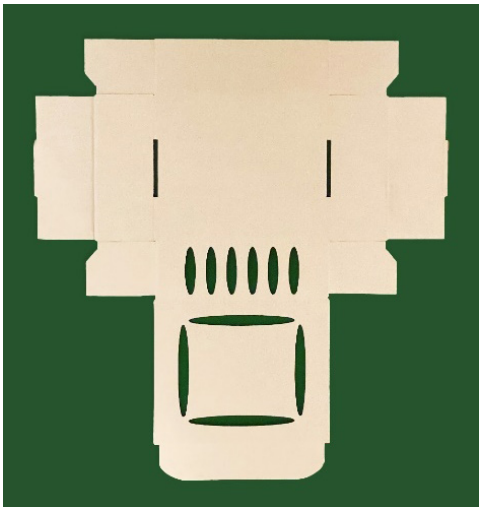


Figure 2. *Photo of the I-cut software interface display*

The packaging production takes 40 seconds per packaging overcut, with additional 20 second for stacking (Figure 3).

To keep the contents of the package intact, a paper label was affixed to it. A barcode and information related to the product are also printed on the packaging. All prints are made with latex which

is considered to be one of the cleanest printing technologies. Water-based inks that meet all regulations on the safety of products used to store food were used in the printing process.



a)

b)

Figure 3. *a) Photo of the overcut of the packaging, b) Photo of the finished prototype*

The described packaging production process is only related to the production of prototypes or the production of a small batch of products. When producing larger packaging batches, it is necessary to consider the production using the stamping technique. It is faster and more economical for larger series of products, after the initial cost of making the stamp.

2.6. EXAMINATION OF FRUIT PRESERVATION

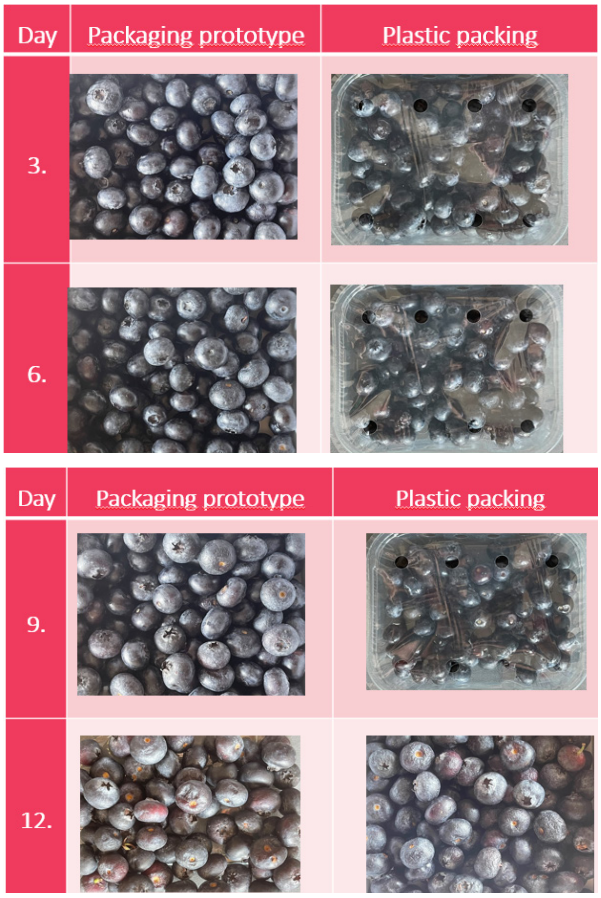


Figure 4. *Examination of fruit preservation*

The fruit preservation test was carried out at a temperature of 5°C in an interval of 3 days up to a maximum duration of 12 days (Figure 4). The fruit was tested in the original plastic purchase packaging and in the packaging prototype. The effectiveness of preserving the freshness of berries is at an approximately similar level in both compared types of packaging in periods of up to 9 days of testing. After 12 days of testing, the freshness of the fruit in the tested packaging showed minimal differences. The fruit in plastic packaging was slightly fresher. Given the small quantity of berries in the package, we expect the fruit to be consumed within 9 to 12 days after purchase. Therefore, the tested prototype meets the criteria for preserving freshness.

2.7. DISADVANTAGES OF THE PROTOTYPE

The price per packaging prototype unit is slightly higher compared to plastic packaging

due to more expensive raw material. The cost of transporting the prototype is higher than commercial plastic packaging because the weight of the prototype is 30g, while the weight of the plastic packaging is 20g.

The chosen cardboard material, being hygroscopic, is not moisture-resistant. However, given that the transport and storage of food products require strict control, it's reasonable to assume that the packaged products will not be exposed to moisture or water sources. Moisture exposure can accelerate the rotting process of berries, highlighting the importance of managing such pollution sources. Despite these considerations, it's crucial to note that the risk of condensation—and consequently, the potential harm to the quality of both berries and cardboard packaging—remains low. This is because the fruit is typically transported in refrigerated conditions and displayed in refrigerated cases, making the occurrence of such events unlikely.

2.8. THE QUESTIONNAIRE EXAMINATION

In the examination, 67% of male and 33% of female respondents has participated. Most of the respondents are in the age group of 25-34 years (Figure 5). Furthermore, the number of respondents is reduced according to older age groups, with the smallest number of respondents being in the youngest age group.

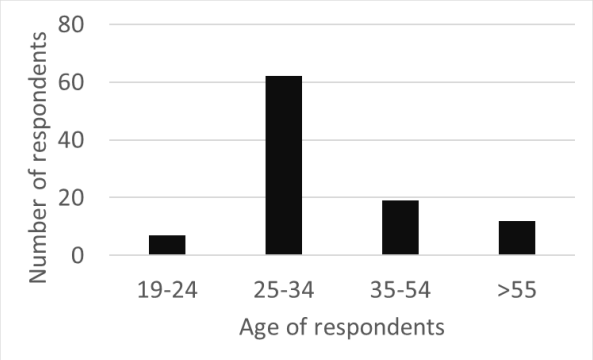
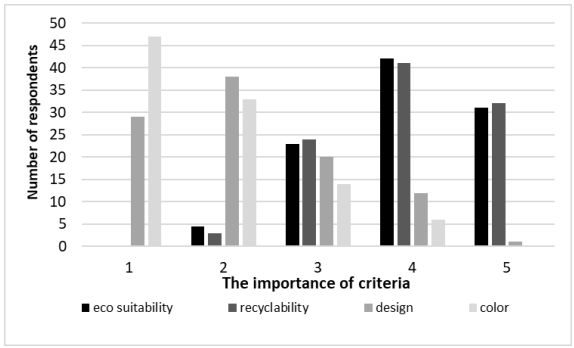


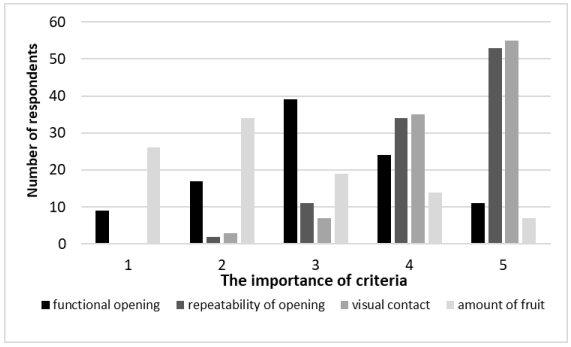
Figure 5. *Age of the respondents*

When studying the eco-visual properties of packaging products, the most important criteria for respondents are ecological suitability and recyclability (Figure 6 a)). The mentioned criteria received the highest marks of 4 and 5. Our prototype was designed in the mentioned way without the use of colors or an unusual shape of the product. Scandinavian minimalist design has been appealing to many customers for some time.

When studying the functional properties of packaging products, most respondents point out the possibility of re-opening the package and visual contact with the fruit as the most important properties (Figure 6 b). The re-opening function is related to the habits of customers who eat berries repeatedly. The possibility of visual contact with berries is extremely important because this garden fruit can quickly lose its freshness and visual control is necessary.



a)



b)

Figure 6. *Importance of criteria when choosing a packaging product: a) eco-visual, b) functional*

The majority of respondents (93%) recognized sustainable packaging, i.e. sample 2 (Figure 7). Sample 3 represented moulded cardboard packaging in which more paper is consumed than sample 2, while sample 4 represented combined plastic cardboard packaging. The number of respondents who chose samples 3 and 4 is not significantly different (23% and 21%) which is worrying because sample 3 is made only from renewable material. The advantage of sample 4 is that it is possible to easily separate the cardboard from plastic, so both materials can be recycled. Sample 1 received 3% of the votes, and

sample 5 received 2% of the respondents' votes, which indicates that the majority of respondents can recognize unsustainable plastic packaging. Unfortunately, the respondents overlooked that Sample 1 contained a significant amount of empty space above the berries. This not only represents an excessive use of material but also poses a disadvantage in terms of sustainability.

Sample	% of respondents	Sample	% of respondents
1.	 3%	4.	 21%
2.	 93%	5.	 2%
3.	 23%	6.	

Figure 7. *Results of recognition of sustainable packaging*

3. CONCLUSION

Sometimes the sustainable packaging market is not regulated and "greenwashing" is often encountered, which can damage the reputation of producers and affect the trust of customers towards truly sustainable products. Sometimes the customers are not ready to pay extra for purchasing more sustainable products that may have a higher price, but the results of this research prove the opposite. Such results usually occur when customers have enough money for a comfortable life and wish to contribute to reducing the negative impact on the environment.

As part of the research, a conceptual solution for berries was designed and a prototype was made. All the principles of sustainable production were respected when designing and producing prototypes of packaging for berries. This is demonstrated by utilizing materials produced sustainably, in adherence to the principles of the circular economy, without employing bleaching agents, and by using renewable energy sources. In crafting the prototype of our packaging product, sustainability criteria were honored by avoiding adhesives, maximizing cardboard use, and employing printing techniques alongside water-based inks to minimize environmental impact. Such practices were aimed at reducing greenhouse gas emissions during both material production and the completion of finished products. This sustainability goal was notably achieved by substituting plastic with cardboard, a material that is both biodegradable and 100% recyclable, thereby lessening environmental impact further. The prototype produced exhibits properties for maintaining berry freshness comparable to those of plastic packaging. It is crucial to underscore that sustainable products should maintain functional properties on par with traditional offerings, a standard our prototype meets. Ideally, these packages should be reused multiple times to diminish their environmental footprint effectively. Notably, cardboard can be recycled up to seven times

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