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APPROACHES TO ANALYZING THE FOOD SAFETY HAZARDS OF MILK FROM AN ORGANIC FARM

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ABSTRACT

The nutritional value of the marketed products, respectively their safety, aims at: human nutrition as a preventive factor for health, food safety as a very important factor in the context of a dynamic and complex trade.

Food quality is a very important factor reflected by the way in which hygiene is observed during the technological chain. In recent years, consumers have been made aware of both food safety, quality and the origin of agri-food products in general. Products qualitative and safe assume concentrating the efforts of all involved in the chain of food, which includes agricultural production, processing and transport, and ensuring product traceability up to consumer.

In order to align to European legislative requirements for food safety regarding organic farm-produced milk, there are some issues that need to be taken into consideration, such as : obtaining an end-product according to the requisite standards, with a null potential of poisoning, ensuring food hygiene while the product passes from the producer to the processor and the trader, the quality and food safety of the end-product having a great influence on human health.

A risk assessment is essential to assure the safety, the innocuity of the end-product, organic milk and also to diminish the contamination possibility. The assessment should be performed following a set of established critical checkpoints that are focused on identifying and controlling any potential risks which can appear throughout the production process.

Therefore, the problems related to food safety, along the entire food chain, it acquires a special importance, reflected by improving risk management by avoiding harmful practices that may threaten global food security.

***Keywords**: innocuity, food safety, critical checkpoints, sustainability, traceability*

INTRODUCTION

"Food security exists when all people, at all times, have physical and economic access to safe and nutritious food that meets the food needs of the human body, to lead a healthy and active life."
("World Declaration on Nutrition" (FAO / WHO, Rome, 1992) and "Declaration on World Food Security" (FAO / WHO, 1996) ")

In today's society, amid the stressful factors to which man is subjected every day and a diversified diet, which entices consumers, often incorrect and poor in nutrients, has increased the risk of disease of the human body.

Thus, there has been an awareness of a significant number of consumers regarding the issue of food safety, quality and provenance of agri-food products consumed.

Thus, the deficiencies or the weak points in the circuit traversed by the agri-food products "from the farm gate to the consumer's table" are eliminated.

Food safety, a component of food safety for a unprocessed product, partially / totally processed or newly created is highlighted both by safety, health, nutritional and energy value and by the content of food nutrients available to the body.

Food production safety involves the application of hygienic production standards, codes of good working practice, the HACCP system and the accreditation of its own quality system.

ISO 22000 is an international standard that ensures food safety, encompasses HACCP principles and integrates the requirements of key standards developed worldwide.

The Codex Alimentarius Commission recommends the implementation of the HACCP method in the food industry, through the integrated implementation of ISO 22000 with ISO 9001 and / or ISO 14001 - standards adopted in Romania.
Milk - "white blood" - considered the most complete food, is a staple food in human nutrition. It is rich in nutrients necessary for life (amino acids, fatty acids, lactose, vitamins, minerals, proteins and fats) that are found in optimal proportions, so that milk is assimilated by the body better than any other food, and can be consumed both in fresh as well as in the form of various processed products.
For a farm to produce certified organic milk, it must be entirely organic: animals, pastures, fodder crops, other managed feed, technological flow and eco-interventions.

MATERIAL AND METHOD

1. Milk obtained in an ecological farm, without defects from a qualitative point of view, which corresponds from a nutritional, sanitary, bacteriological and technological point of view. The technological flow of obtaining milk was followed "followed from the farm to the consumer's table" to identify and verify this product during the stages of production, processing and distribution, which is associated with traceability, with a role in food safety, also.
2. HACCP principles method (Hazard Analysis and Critical Control Point).

HACCP is the systematic method by which imminent risks have been identified, assessed and controlled during the technological process of obtaining organic milk. The HACCP method indicated the critical points on the flow, in order to eliminate non-conformities.
The stages of implementing the HACCP system are:
- setting up and organizing the HACCP team;
- product description (product specifications) and identification of intended use;
-description of the technological process
-elaboration of the technological flow diagram and field verification;
- identification of potential hazards.
-determining critical point
- elaboration of the HACCP plan

RESULTS AND DISCUSSION

1. For the realization of the HACCP plan was elaborated the technological flow diagram (absolute necessary), diagram that allowed the identification of the points / ways of contamination in the production section, which facilitated the establishment of measures to prevent contamination.

Also, the concordance of the flow chart with the field situation was verified, by reviewing the process as a whole, the manufacturing phases and the intermediate, transfer and storage phases, being able to determine the modification of the elements in the diagram or the related information inaccuracy
In this paper, the stages presented are:
1. Presentation of the flow chart;
2. Identification of potential hazards;
3. Development of the HACCP plan;

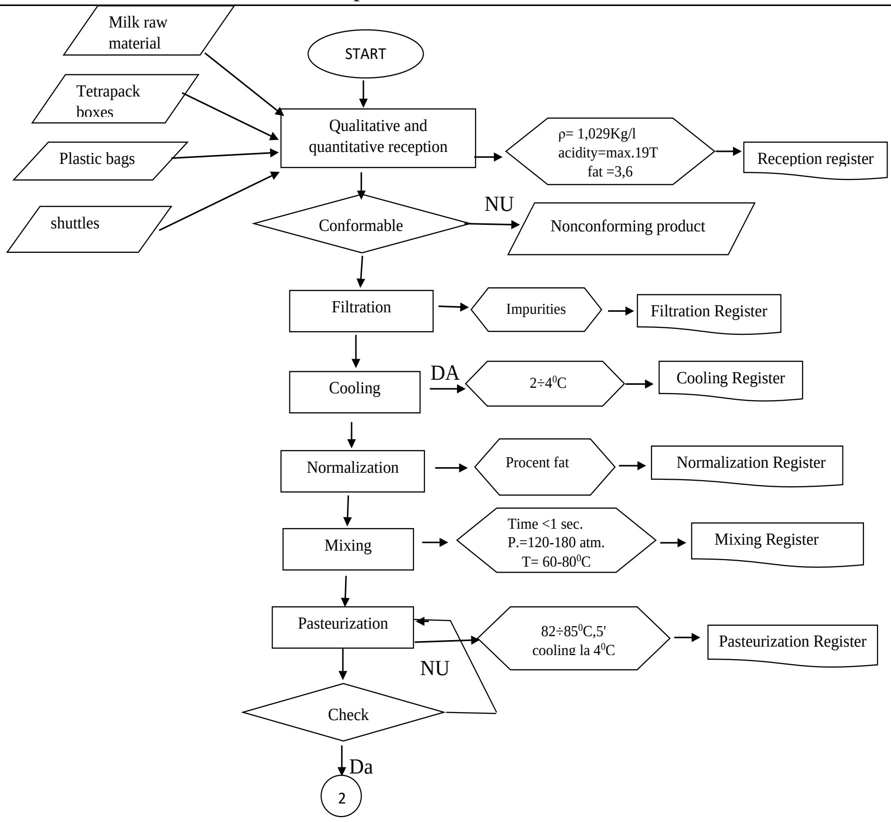

Figure 1. Diagram of the technological flow of the organic product "drinking milk" 3.6% fat

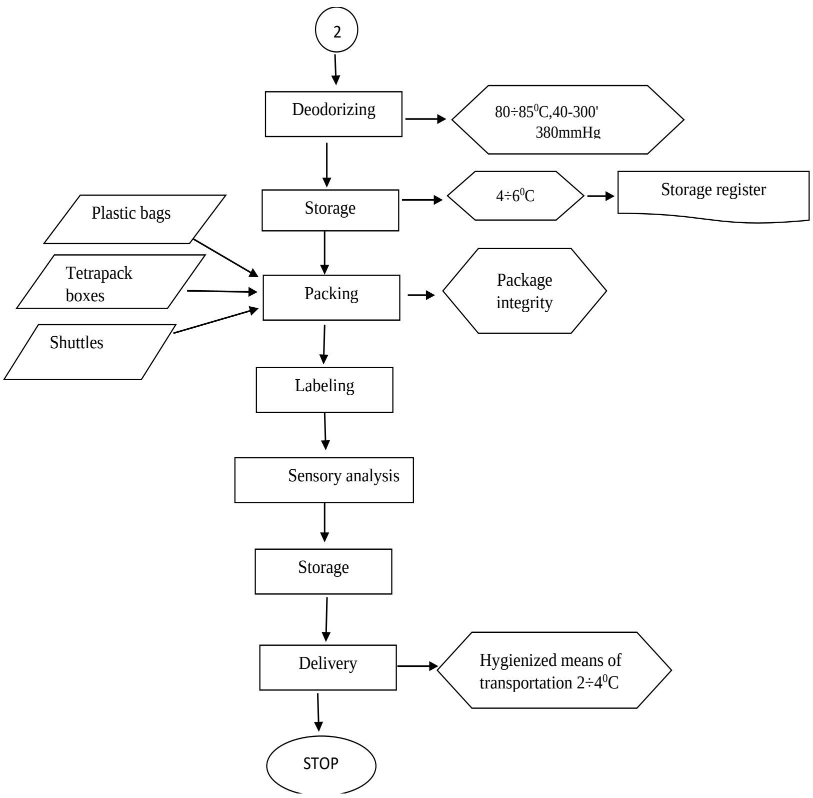

Figure 2. Flow chart

2. The stages delimited as having an influence on the hygienic-sanitary quality of the finished product are:
1. Quantitative and qualitative reception

2. Filtering
3. Cooling
4. Normalization
5. Homogenization
6. Pasteurization
7. Deodorization
8. Temporary storage
9. Packing

The dangers that can affect the health of the consumer after using the milk product for consumption, which contains certain non-conformities can be physical, by the existence of pieces of materials (wood, rubber, metal, glass, etc.), chemicals, detergents, chemicals used in food industry but with great care (due to the toxicity of most antiseptics, in practice only the treatment of milk with perhydrol is applied - Peroxicatalaseic process), and biological, with the highest degree of frequency, which if not controlled can affect food safety. The germs that most frequently constitute the flora remaining after pasteurization are: Thermoset germs (heat-resistant, thermotolerant, thermostable) and Thermophilic germs.

The first category includes species with increased resistance to pasteurization temperature. In the second category species or strains at which the maximum growth temperature exceeds the pasteurization temperature.

Thermuric germs include:

Micrococcus luteus and varians - from milking utensils and cisterns, as opposed to micrococci of mammalian origin that do not survive pasteurization.

Streptococcus thermophilus and bovis, Enterococcus durans, Corynebacterium, Alcaligenes

Streptococcus lactis (there are strains that survive at a temperature of 72 ^{o}C)

Coxiela burneti (withstands 15 seconds at 72 ÷ 75 ^{o}C.

Although undestructured it is inactivated by pasteurization being harmless to the consumer)

Staphycoccus aureus (may not be dangerous in pasteurized milk)

Coliform bacteria- in general, coliforms are considered to be germs indicative of milk recontamination after pasteurization. There are some although very rare strains that resist pasteurization. Their number is so small that it cannot be detected in one ml of the milk examined.

Thermophilic germs are germs that grow at a temperature of 50 ÷ 70 oC with a minimum growth zone at 37 ^{o}C. Strictly thermophilic bacteria belong to the genus Bacillus, Streptococcus thermophilus. Thermophilics occur when a milk after pasteurization has the same number or number of germs as before pasteurization.

3. Elaboration of the HACCP plan:

Nr. crt.	Stage	Significant hazards	Control measures	CCP	Responsible	Frequency	Method	Correction /corrective action	Registration document	Responsible for corrective actions
1	Qualitative reception	exceeding the maximum level of microorganisms	microbiological verification	1	receiver/ laboratory	at each reception of raw materials	reductase	repair of the transport car	test bulletin analysis	driver / laboratory leader
2	Filtration	the existence of foreign bodies (wood, metal, glass, hair, etc.)	filter change;	2	Operator/ laboratory	at each filtration	comparison with a standard	refiltration	the register of operations	laboratory operator
3	Pasteurization	the existence of microbes, viruses, etc.	time control, temperature	3	laboratory operator	for each operation	Visual installation check	installation regulation, re-pasteurisation	Operations register	laboratory operator
4	Normalization	unintentional introduction of chemicals	washing, drying, very good sterilization of the machine	4	laboratory operator	before each operation	Visual installation check	change of use, re-sterilization	Operations register	laboratory operator
5	Cooling	inadequate temperature	permanent check	5	laboratory operator	at each operation	Visual installation check	reset parameters, repeat operation	operation register	laboratory operator, section chief
6	Packaging	non-sterile materials	quality materials from permanent suppliers	6	packaging operator	before each operation	determination of microorganisms / sqm of packaging	sterilization of materials, change of supplier	register of operations	laboratory operator
7	Storage	inadequate temperature cooling	system check	7	warehouse operator	checking every 4 hours	the record of entering and leaving stocks (FIFO)	cooling system repair, moving to another place	Storage sheet evidence	deposit keeper

Table 1. Plan HACCP

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EFFICACY OF DIATOMACEOUS EARTH IN CONTROLLING MAJOR STORE PRODUCT PESTS: *PLODIA INTERPUNCTELLA, TRIBOLIUM CONFUSUM* AND *ACANTHOSCLIDES OBTECTUS*

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ABSTRACT

Diatomaceous earth (DE) is an inert dust formed from fossilized skeletal remains of diatoms. Insecticidal activity is a result of desiccation that occurs after DE particles destroy lipid layers of insect cuticule. Efficacy depends on chemical composition, particle size and geographic origin. This work assessed contact efficacy of DE originating from Kolubara open-pit mine (Serbia), in comparison to SilicoSec®, against *P. interpunctella*, *T. confusum* and *A. obtectus*. DEs were applied at rates: 5, 10, 15 and 20 mg$^{-2.}$ Mortality was recorded after 24, 48, 72 h and seven days. Significant mortality of *P. interpunctella* larvae was recorded after seven days of exposure at two higher rates of SilicoSec® (48.0 and 54%, respectively) and Kolubara DE (45.6 and 58.5%, respectively). Higher rates of SilicoSec® and Kolubara DE caused significant mortality of *T. confusum* after seven days (54.1, 84.3%, 49.2, 78.2%, respectively). High mortality of *A.obtectus* was recorded after 48 and 72 h in SilicoSec® (61.5, 82.1%, respectively) and in Kolubara DE (58.0, 78.5%, respectively) when applied at 20 mg^{-2}.

Key words: *alumina silicates, inert dusts, contact toxicity, storage pests*

INTRODUCTION

During storage, insects cause huge quality and quantity reduction of stored commodities and great economic losses (Puzzi, 2001). Therefore, the pest control is inevitable post-harvest measure that helps prevent damages and preserves the nutritional and commercial value of stored products. Concerns about rapid development of insecticide resistance, the environmental pollution and human health have intensified the search for alternative eco-friendly pest management strategies (Gvozdenac et al., 2018a). The use of materials like inert dusts, submicron and nanomaterials is one of the strategies that have been extensively tested as viable alternative to pesticides (Fields and Korunić, 2002) suitable for a long-term protection of stored products. Back in 1997, Golob fist mentions the inert dusts as potent storage protectants in grain industry, with Diatomaceous earth (DE), being the most commonly used and evaluated (Golob, 1997).

DE consists of fossilized skeletal remains of single-celled algae-diatoms found in fresh and salt waters. Diatoms are microscopic organisms that have a fine skeleton made of amorphous silica (SiO_2 + n H_2O). The accumulation of diatom skeletons over thousands of years produces the sedimentary rock, diatomaceous earth. The major constituent of DE is amorphous silicon dioxide (SiO_2) with minor amounts other minerals (aluminium, iron oxide, calcium hydroxide, magnesium and sodium). Its insecticidal properties depend upon the geological origin, and some DEs are 20 times more effective than others. The most effective DEs have SiO_2 content above 80%, a pH

below 8.5 (Korunić, 1997). The insecticidal effect of DE is due to physical damage of protective wax layer of the insect‘s cuticle (Mewis and Ulrichs, 2001). DE particles absorb waterproof lipids from insect’s cuticule, destroying epicuticular lipid layers which lead to heavy water loss and eventually desiccation of insects. DEs are effective for controlling stored product pests when applied as structural treatment on walls and floors, on the surface of grain bulks and also by admixing with grain (Arthur, 2003). However, since it was found that DE reduces the grain bulk density, affects the flow characteristics of bulk grain (flowability), and also leaves visible dust residues and causes health concerns it is recommended primarily for surface treatments (Aleen, 2001). Several DE products are commercially available and registered for stored product protection. The product SilicoSec® (Biofa GmbH) was the first approved for use in Germany in 1997 (Mewis and Ulrichs, 2001) and has a wide use. Due to differences in DE efficacy as a result of chemical composition, particle size and origin, it is necessary to evaluate every new preparation based on DE.

This work aimed to assess the contact efficacy of DE from Kolubara open-pit mine (Serbia) in comparison to SilicoSec® against: a) *P.interpunctella* larvae, as one of the most polyphagous inset species; b) *T. confusum*, the most significant secondary pest of a number commodities, that is hard to control and c) *A. obtectus*, a major pest of the common bean and other leguminous crops.

MATERIAL AND METHOD

Laboratory studies were performed to evaluate the contact efficacy of diatomaceous earth originating from Kolobuara open-pit mine (Serbia), in comparison to SilicoSec®, a commercial preparation (uncalcinated diatomite manufactured by Biofa, Germany), as a standard control to inert dust, against *P. interpunctella* larvae, *T. confusum* and *A. obtectus* adults.

Determination of DE particle size

The DE from Kolobuara open-pit mine was tested for physical characteristics. Particle size distribution was determined using a Malvern Mastersizer 2000 particle size analyser, capable of analysing particles between 0.01 and 2000 lm. The Malvern Mastersizer 2000 records the light pattern scattered from a field of particles at different angles. The device uses an analytical procedure to determine the particle size distribution that created the patterns. The measurements were performed with automated dry dispersion unit Scirocco 2000. Prior to measuring several testing were performed in order to select optimal measuring condition: feed rate and nozzle pressure. Selected feed rate provide adequate obscuration in range 3.26-4.15%. Selected nozzle pressure of 2 bars gave good reproducibility of results for all samples. The sample was analysed in three replicates. The results were recorded as the particle volume percentages.

The obtained volume-based particle size distribution was broad and showed particles diameter in range from 0.3 μm to 700 μm. The most common value of the frequency volume based distribution (mode) was 15 μm. The d (0.5), values indicate 50% of the particles measured were smaller than or equal to the size stated (median) - was 16 μm. SilicoSec®® consisted of majority particle size between 2–18 μm.

Test insects

The insects used in this research originate from the populations reared at Institute of Field and Vegetable Crops, Novi Sad, Serbia. *P. interpunctella* culture originates from the population reared for ~50 generations on standard a laboratory diet in a thermostat chamber (28±1ºC, r.h. 60±10%, photoperiod 14:10 (L:D)). *T. confusum* experimental population is reared on substrate made of wheat and maize flour (ratio 1:1) and yeast (5%) at 26 ±1°C and relative humidity 60 ±5%. *A. obtectus* population is being maintained the laboratory at large size (about 1000 individuals) for

more than 20 generations, on common bean seeds (*Phaseolus vulgaris* L.) under controlled conditions (27 ±1ºC, relative humidity 65 ±5%, photoperiod (L16: D8)..

Bioassay

Two DE formulations (DE from Kolubara and SilicoSec®) were applied on glass Petri dishes (Ø 9 cm) at rates 5, 10, 15 and 20 gm^{-2}. Dusts were dispersed over the glass surface, after which, 20 insect specimens were placed inside dishes (*P. interpunctella* larvae of L_{4-5} stage, for beetles, unsexed adults were used). Mortality was evaluated after 24, 48, 72 h and seven days of exposure. Clean Petri dishes served as the control. After the exposure periods, the insects were considered dead when unable of walking or flying when touched with fine brush. Three replicates were used for each dose and exposure period and a control treatment.

The differences in mortality, depending on the preparation and concentrations applied, were analyzed using one-way ANOVA, Duncan's multiple range test (confidence interval 95%) in statistical software SPSS 21.

RESULTS AND DISCUSSION

The effect of DEs applied at 5, 10, 15 and 20 gm^{-2} on *P.interpunctella, T. confusum* and *A. obtectus* are presented on Figs. 1-3. The mortality of tested insect species increased with the increase of concentration as well as the exposure period in treatments with both DEs.

P. interpunctella

Lower rates (5 and 10 gm^{-2}) of both applied DEs (SilicoSec® and Kolubara DE) caused low mortality of *P. interpunctella* larvae, regardless on the exposure period (Fig. 1.). The mortality ranged from 0.0-5.4% after 24 h of exposure, 0.0 -12.0 % after 48 h and 5.0-26.2% after 72 h. The differences between treatments and rates within one treatment after 24 h and 48 h of exposure were not statistically significant (F=0.11NS, 7.14NS, $p>0.05$, respectively). In treatments with higher rates of SilicoSec® (15 and 20 gm^{-2}) the mortality ranged from 1.4 to 26.2%, after shorter exposure (24, 48 and 72 h). However, significant mortality of *P. interpunctella* larvae was recorded after seven days of exposure to higher rates (15 and 20 gm^{-2}), 48.0 and 54%, respectively. After seven days, the differences between mortalities among treatments and rates within one treatment were highly significant (F=111.65**, $p<0.01$, respectively). DE from Kolubara was as effective as SilicoSec® at higher rates (15 and 20 gm^{-2}), causing larval mortality of 45.6 and 58.5%, respectively after seven days. Lower rates (5 and 10 gm^{-2}) and shorter exposure (24, 48 and 72 h) were low effective (0.0-26.0% mortality). These results are in accordance with previously published research of Gvozdenac et al. (2018) that indicate at high efficacy of SilicoSec®, but only after long exposure and at maximum rate (20 gm^{-2}). Similar results were presented by Subramanyam et al. (1998) who tested the efficacy of DE product Insecto against *P. interpunctella* 5th larval instars. At the same application rates as in our study authors reported significantly lower efficacy (10-70%) on 5th larval instars compared to the efficacy on 1st larval instars (99.5-100%), indicating at higher susceptibility of younger larvae to insecticidal effects of DE products than mature larvae.

In treatments with SilicoSec® and Kolubara DE, the pupation of *P. interpunctella* occurred faster compared to the control. This was also confirmed in previous reports of Gvozdenac et al. (2018b).

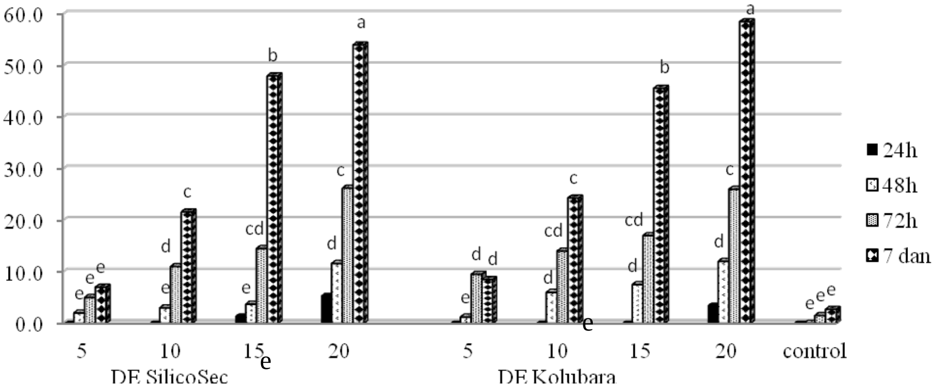

Figure 1. The effect of DE from Kolubara open-pit mine and SilicoSec® on P. interpunctella larvae

<u>*T. confusum*</u>

The mortality of *T. confusum* was low (0.0-34.1%) after 24, 48 and 72 h at all applied rates and in both treatments. SilicoSec® caused significant mortality of confused beetles at rates 15 gm^{-2} and 20 gm^{-2}, only after seven days (54.1 and 84.3%, respectively). Mortalities caused by DE from Kolubara were at the same level of significance with SilicoSec®. After seven days the efficacy was 49.2% at 15 gm^{-2} and 78.2% at 20 gm^{-2}. Differences between mortalities after seven days at the same application rate were not significant (F=70.1NS, 101.4NS, p>0.05). The results are in accordance with reports from Collins and Cook (2006) who tested the efficacy of SilicoSec®® against *T. castaneum*. It was proven to be a very effective treatment causing the mortalities from 93-100% after seven days of exposure. Similar results were obtained by Scholler and Reichmuth (2010), indicating that at different surfaces the efficacy of SilicoSec® ranged from 79% to 100%.

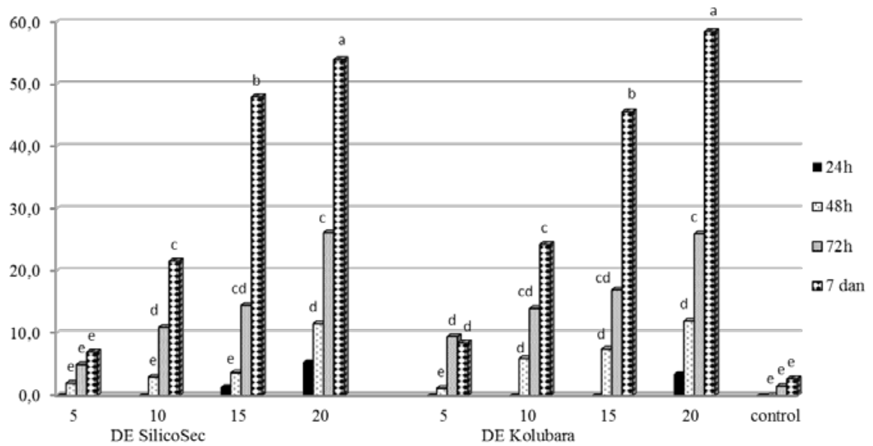

Figure 2. The effect of DE from Kolubara open-pit mine and SilicoSec® on T. confusum adults

<u>*A. obtectus*</u>

SilicoSec® and DE from Kolubara did not cause significant mortalities of *A. obtectus* adults after 24 h, regardless on the applied rate (6.2-28.1%). However, after 48h SilicoSec® caused mortality of 61.5%, and DE from Kolubara 58.0% at the highest rate (20 gm^{-2}) and the values are at the same level of significance (F=72.01NS, p>0.05). After 72 h, both DEs expressed strong insecticidal effect at higher rates (15 and 20 gm^{-2}). SilicoSec® caused mortality of 49.4 and 82.1%, respectively, and DE from Kolubara 56.7 and 78.5%, respectively. Differences were not significant (F=1.7NS; 6.52NS respectively, p>0.05). The results of Jumbo et al. (2019) revealed that *A. obtectus* mortality

caused by DE was dose, temperature and exposure period dependent, which was also proven in this work, for dose (application rate) and exposure. The authors suggest that DEs have the potential to be used as an effective tool for managing *A. obtectus* infestations in stored beans, which can also be concluded form this research.

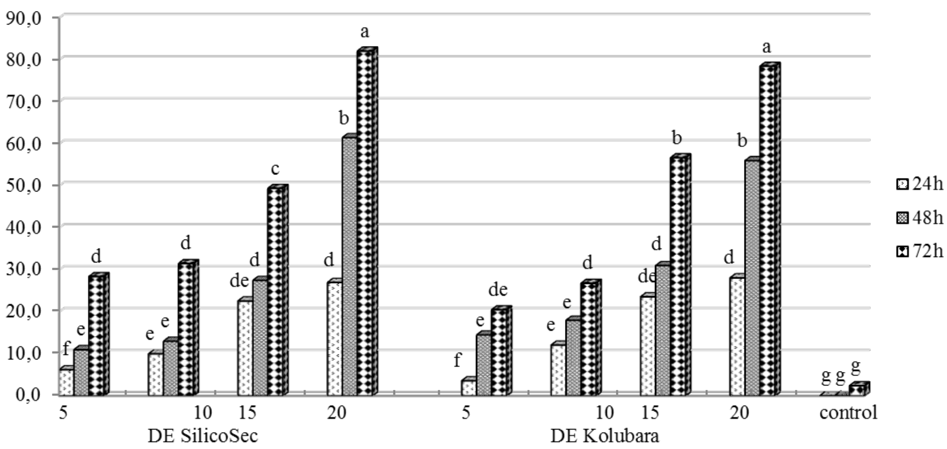

Figure 3. The effect of DE from Kolubara open-pit mine and SilicoSec® on A. obtectus adults

Storage insects express different susceptibility to inert dusts due to morphological, physiological and ecological characteristics of each species (Kljajić et al, 2011), as was proven in this work. Additionally, Jumbo et al. (2019) underlined that the insecticidal efficacy of DE is affected by abiotic factors (temperature, humidity, exposure period etc.), as mentioned, but also by biotic factors (insect species, physiology, behaviour, age etc.). Different insect species in our work expressed different susceptibility to DEs, regardless on their origin and concentrations.

CONCLUSION

This work aimed to evaluate the efficacy of DE originating from Kolubara open-pit mine in comparison to commercial preparation SilicoSec®. DE from Kolubara expressed similar insecticidal activity as SilicoSec®, against all three tested insect species (*P. interpunctella, T confusum, A. obtectus*), given that mortalities did not differ statistically. Both DEs were the most effective when applied at higher rates (15 and 20 gm^{-2}) and the highest mortality was achieved after 72 h and seven days of exposure. The results indicate that both DEs, DE from Kolubara open-pit mine in particular, can be used as an additional surface treatment method in storages for preventing the infestation with *P. interpunctella* larvae and *T.confusum* and *A. obtectus* adults.

ACKNOWLEDGEMENT

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CULTURAL PATTERN AND ENERGETICS IN AGRICULTURE: HOW TO BUILD AN INNOVATION-DRIVEN ECONOMY

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ABSTRACT

Increasingly present economic, social and environmental tensions require long-term and designed solutions for which many countries do not have satisfactory development potential. Competitiveness is a key assumption for increasing well-being of any country and a satisfactory level of competitiveness cannot be achieved without a proper transformation of the existing innovation ecosystem. The combination of the development of innovation potentials and national cultural characteristics can provide answers to many dilemmas and ways of achieving the desired development goals. Holding the attitude that sustainable development is a synergistic effect and a common denominator of energetics, agriculture and ecology, and that the state of resources related to energetics and agriculture in Serbia is better than their effectiveness, cultural pattern is introduced into the development equation in order to see this state of affairs through the prism of the prevailing cultural pattern of Serbia.

Key words: *cultural pattern, energetics in agriculture, innovation, competitiveness*

INTRODUCTION

In complex and change-prone modern business conditions, the struggle for existence requires increasingly more authentic and innovative ways of achieving competitiveness. The word development, regardless of the context in which it is used, always implies a favorable change, a step from simple to complex, from inferior to superior, from worse to better. Ecologist Haeckel viewed development as a magic word “with which we will solve all the mysteries that surround us or, at least, that which will guide us toward their solutions“.

Competitiveness ia a key assumption of increasing well-being of any country, and a satisfactory level of competitiveness cannot be achieved without a proper transformation of the existing innovation ecosystem. For almost two decades, the World Economic Forum (WEF) has provided, based on the Global Competitiveness Index, an opportunity for countries to gain insight into the degree of competitiveness they achieve, while making recommendations for overcoming the problems on the way of achieving the desired economic growth. Observed in the last ten years, Serbia cannot boast of a high level of competitiveness. It is especially worrying that innovations are at the top of the list of the World Economic Forum's proposals for improving Serbia's competitiveness, emphasizing that the values of innovation and business sophistication factors indicate that, in this competitiveness subindex, Serbia lags even behind the EU countries with the lowest values of this indicator.

It is an indisputable fact that there is concern about this situation, and numerous authors make certain diagnoses, structure certain strategies and offer certain development models. Some models have many advantages, but also the same disadvantage the other models dealing with the issue of (sustainable) development suffer from. This paper relies on the statement that „the model with no place for culture is empty“ (Douglas & Ney, 2003). Holding the attitude that sustainable development is a synergistic effect and a common denominator of energetics, agriculture and ecology, culture, ie. cultural pattern, will be introduced into the development equation.

Given that the state of resources related to energetics and agriculture in Serbia is noticeably better than their effectiveness, this state of affairs will be seen through the prism of the prevailing cultural pattern of Serbia.

MATERIAL AND METHOD

The paper aims, by pointing out specifics of national culture and explaining its five cultural dimensions created by the Duch author Hofstede, to help understand the influence of national culture in terms of solving the basic development problems of a particular society. Discovering this influence in the context of sustainable development as a field of synergistic action of energetics, agriculture and ecology is achieved primarily by collecting, studying, analyzing and systematizing available literature, expert papers, theoretical approaches etc.

In response to increasingly fierce competition, there is a growing need for creative solutions and continuous innovation. Given that agriculture is viewed in the context of sustainable development, it is assigned an important role in environmental protection, with a significant place belonging to energetics, ie. renewable energy sources. The increasing importance of agriculture as an energy source is becoming more noticeable. In the analysis of economic performances of national economies, the concept of competitiveness is used, where the Global Competitiveness Index, due to integration of a large number of components, is most in use. The findings of the World Economic Forum repersent an analytic basis for determining mutual conditionality of the prevailing cultural pattern and, related to the topic of this paper, competitiveness driven by innovation as one of the three drivers of competitiveness.

The research focus of this paper is Serbia and the analysis of the value dimensions of Serbian national culture. Using a comparative research method, the research focus includes the value dimensions of the national culture of Denmark, which is, according to the values of the Global Competitiveness Index, among the best ranked countries on the list of the World Economic Forum (WEF). What makes Denmark worth considering is the idea of constant progress in every sense, from innovation, through sustainability and equality, to trust and openess. What makes it exceptional is its aspiration to create a “green“ and sustainable society that is supposed to draw all its energy from renewable energy sources by 2050. Without such a comparative analysis, it is not possible to notice cultural-universal and cultural-specific contents of different cultures and their significance. An additional goal is to analyze the cultural dimensions to point out the importance of an interdisciplinary and systemic approach, necessary in a time fraught with numerous dilemmas and unresolved issues of sustainable development.

RESULTS AND DISCUSSION

A cultural pattern represents “the way people, during development, adopt a certain culturally specific way of behavior, beliefs, attitudes toward the self and others“ (Nikolić, Miladinović, 2012), whereby the cultural matrix “affects the behavior, opinion and feelings of all or most members of the national collective“.

Based on the research conducted in the 1970s and 1980s, Hofstede (Hofstede, 2010), viewing culture as a multidimensional concept, created the basic dimensions by which it is possible to distinguish national cultures: Power Distance (PDI), Uncertainty Avoidance (UAI), Individualism/Collectivism (IDV), Masculinity/Femininity (MAS) and the fifth dimension, introduced in 1987, Long-Term/Short-Term orientation in time (LTO). In the context of this paper, it is extremely important to understand that these dimensions (Hofstede, 2001) can serve as a good framework for categorizing national cultures and their levels of resistance to change. The cultures that show the strongest resistance to change are characterized by a high index of power distance, a low index of individualism and a high index of risk and uncertainty avoidance.

The power distance refers to “the degree to which less powerful members of organizations and institutions in a country accept the fact that power is distributed unequally“ (Hofstede, 2001). High power distance is associated with unequal distribution of power in society as well as in organizations, and is considered as normal, natural, efficient and the only sustainable state. Low

power distance assumes that equal power distribution in society is good and desirable. Uncertainty avoidance refers to “the degree to which the members of a culture feel threatened by ambigous and unknown situations“ (Hofstede, 2001). National cultures with a high level of uncertainty avoidance are characterized by a very low propensity for change, fear of the unknown, as well as a low tolerance for any differences. Individualism is related to the belief of individuals that only they are responsible for their own destiny and the collective has no obligations to them. Collectivism implies that the destiny of each individual is the responsibility of the collective to which they belong, and expects the collective to care for them, whether it is a family, a company or a society as a whole. The dimension that represents the fundamental problem of gender relations refers to Femininity/Masculinity national cultures. “Feminine“ cultures are characterized by prevailing values such as interpersonal relationships, quality of life, balance, harmony and care. The cultures where so-called “masculine“ values are prevailing, emphasize action, achievement, results, determination and aggression. Long-term/short-term orientation in time is a dimension of culture that essentially emphasizes the attitude of the members of society toward investing in the future, planning and long-term thinking. For a society with a short-term orientation, instead of being focused on the future, it is much more important what happens “now and here“ as opposed to a society that prefers long-term perspective, placing importance to long-term plans, strategic goals and proactive reflection on the influence of present activities on the future generations. Cultures with low uncertainty avoidance show high tolerance for change, risk and uncertainty. Such cultures are facing changes. High levels of uncertainty avoidance and power distance increase resistance to change, while a high level of individualism encourages change.

The research (Hofstede, 2001) indicates that Serbian national culture has a unique combination of high power distance, high uncertainty avoidance, high collectivism, female values and short-term orientation in time. Danish cultural pattern represents a unique combination of low power distance, low uncertainty avoidance, individualism, female values and long-term orientation in time.

The compared statistical values of the Global Competitiveness Index of Serbia and Denmark indicated important and stimulating differences. The average value of the Global Index Competitiveness, for the ten-year observed period (2008 – 2017), is 3.89 for Serbia and 5.36 for Denmark. The average value of efficiency subindex is 3.78 for Serbia and 5.22 for Denmark. The average value of innovation and sophistication subindex is 3.10 for Serbia and 5.25 for Denmark. The ability to innovate, within the innovation ecosystem as one of the pillars of competitiveness (introduced in the Report for 2018), is 39.95 for Serbia and 75,80 for Denmark. The Agriculture policy costs indicator is 3.07 for Serbia and 4.16 for Denmark. The Renewable energy regulation indicator is 52.9 for Serbia, while the value for Denmark is as high as 79.3 (WEF: Global Competitiveness Report, 2008-2017&2018-2019).

The GCI combines 114 indicators grouped into 12 pillars. These pillars are in turn organized into three subindexes: basic requirements, efficiency enhancers, and innovation and sophistication factors (Figure 1). Thus structured pillars of Global Competitiveness Index with indicators, ie. “drivers“ of competitiveness, rely on the folowing phases of competitiveness: resource-driven competitiveness, efficiency-driven competitiveness and innovation-driven competitiveness.

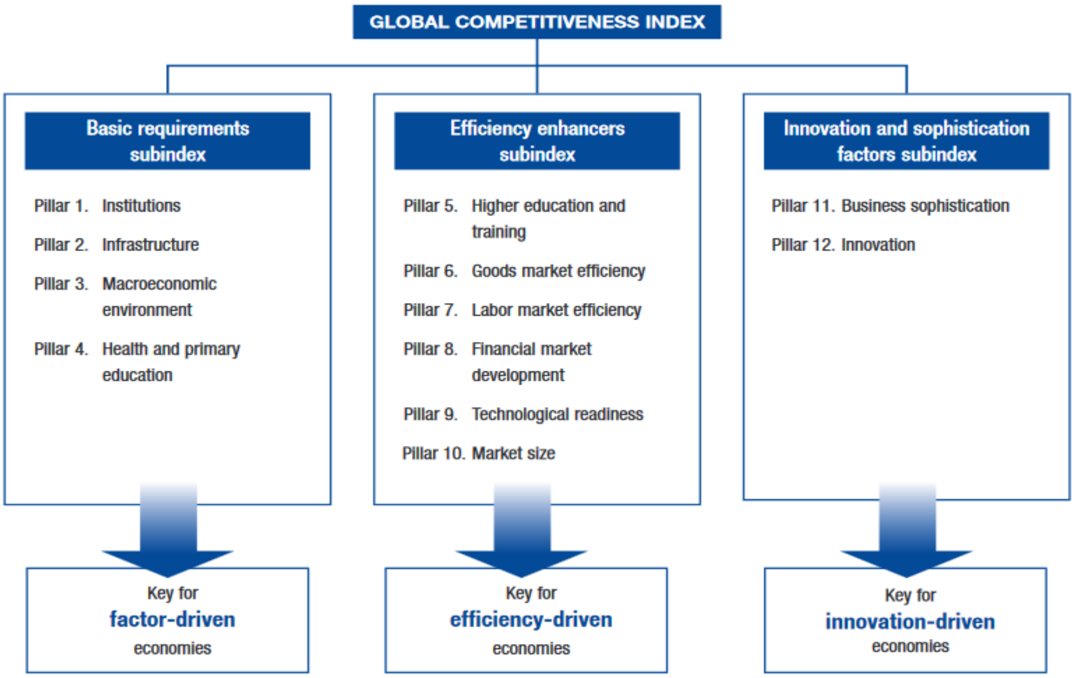

Figure 1: *The Global Competitiveness Index framework.* (Izvor: WEF: The Global Competitiveness Report 2017-2018, p.320).

In economies characterized by a lower level of development, economic performances and competitiveness predominantly rely on the factors that fall into the first pillar (basic subindex), since their development is determined by cheap labor and resource wealth. Middle-income countries are predominantly influenced by efficiency factors, while developed market economies are characterized by innovation and business sophistication. Serbia is in the group of countries whose progress is determined by efficiency factors, so it is compelled to ground its development on efficient production processes and increase of product quality, primarily on the use of the existing potentials, ie. available technologies, the size of domestic and foreign market, without significant progress in the field of innovation. Unlike Serbia, Denmark belongs to the innovation-driven economies, grounding its development on improving the quality of business environment and creating a culture of innovation. The specified facts are another argument in favor of the strength of the influence of the cultural pattern on development and its effects. The Serbia's economic goal is related to transition to more diversified, creative and innovative economies, where an important place belongs to achieving ecological goals. The achievement of these goals is related to a culture that supports entrepreneurship, risk-taking and readiness to change.

CONCLUSION

In order to respond to the increasingly complex challenges Serbian agriculture and economy as a whole facing, understanding and improving competitiveness is an important and priority goal. Given that “everything that is measurable should be measured“, the Report of the World Economic Forum is an important roadmap toward the development goal.

The values of the Global Competitiveness Index, the subindexes of efficiency, innovation and sophistication, the ability to innovate within the innovation ecosystem as one of the pillars of competitiveness, Agriculture policy costs and Renewable energy regulation indicators are just some of indicators on which Serbia and Denmark can be compared. Given the noticeable competitiveness deficit, Serbia needs proactive efforts to start and sustain the desired development process.There are many indicators that enable comparison between Serbia and Denmark, but the specified values are indicative enough to point out that the success of Danish economy is not accidental, and warning enough for Serbia to point out that its work on changes must be wiser, more innovative, faster and more effective to build a society that meets changes, not avoiding them.

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ECONOMIC PARAMETERS OF SUSTAINABILITY OF ORGANIC SOUR CHERRY PRODUCTION

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ABSTRACT

The subject of this research is the economic justification of different ways of sour cherry production. The aim is to identify the economic parameters of the sustainability of organic production. Based on data from the practice of sour cherry production in the Republic of Serbia, it was determined that in organic, compared to conventional, a lower amount of gross margin is obtained by 430 €/ha (36 %). To achieve a gross margin of 3,140 €/ha in organic production as well as in conventional conditions, the minimum selling price of organic sour cherries should be 0.43 €/kg. This price is 23 % higher than the price of sour cherries from conventional production (0.35 €/kg). In order for organic production to be economically viable, it is necessary to reimburse producers for lost profits in the amount of 1,300 €/ha, or 0.08 €/kg. Therefore, the lower limit of the selling price of organic sour cherries is 0.43 €/kg. The procedure for determining the amount of lost benefits can be useful for assessing compensation to producers in order to successfully implement IPARD Agro ecological - climatic measures and measures of organic production.

Key words: *organic cherry, lost benefit, economic sustainability of production*

INTRODUCTION

World production of sour cherries averages just over 1.1 million tons a year, with a tendency to increase at a relatively low rate of 0.97 % annually. Of the world's total sour cherry production, about three-quarters are produced in Europe. The largest producer of sour cherries in the world is the Russian Federation. Poland is in second place, with a share of about 15 % in world production. It is followed by Turkey with a share in world production of over 12 %, with a tendency to increase at a rate of 6.76 % per year. Ukraine is on the fourth place, and the USA is on the fifth place with a share of 9 % (Milić et al, 2017).

In the Republic of Serbia, sour cherries are mostly grown in the Nišava district on the territory of the municipalities: Merošina, Aleksinac, Doljevac, Gadžin Han, Niš, Ražanj and Svrljig. About 15 % of domestic sour cherry production comes from Nišava district (SORS, 2021). Significant yields are also achieved in the area of the city of Belgrade, Jablanica, Toplica and Zajecar districts. The aim of the research in this paper is to determine the economic justification of different ways of sour cherry production. The focus of this paper is on the process of determining missed economic benefits and sustainability indicators, organic sour cherry cultivation, in the function of preserving land as a natural resource.

MATERIAL AND METHOD

For the research in this paper, data collected by a survey conducted on selected family farms during 2020 in the region of southern Serbia were used. Then, data from the database of the Research Institute of Organic Agriculture (FiBL, 2021), from the records of the Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia (MAFWM RS, 2021), as well as the Republic Statistical Office of the Republic of Serbia (SORS, 2021) were used. The calculative procedure of sour cherry production in organic and conventional production determined important economic indicators: gross income, gross margin, savings / additional cost, lost profit, lost

economic benefit and from the aspect of economic acceptability, minimum selling price of organic product.

RESULTS AND DISCUSSION

Currently 72.3 million hectares are under organic agricultural management (end of 2019 for most data). The distribution of the organic agricultural land is as follows: Oceania (35.9 million hectares); Europe (16.5 million hectares); Latin America (8.3 million hectares); Asia (5.9 million hectares); North America (3.6 million hectares); Africa (2.0 million hectares). Oceania has half of the global organic agricultural land. Europe, a region that has had a very constant growth of organic land over the years, has over 23 % of the world's organic agricultural land followed by Latin America with 12 %. Apart from the organic agricultural land, there are further organic areas such as wild collection areas. These areas constitute more than 34.8 million hectares (FiBL, 2021). In the structure of organic plant production in the Republic of Serbia, the most represented areas are under orchards with a share of 43 %, followed by cereals with 26 %, industrial plants with 14 % and fodder plants with 10 % (SORS, 2021). According to research, it is economically viable to invest in organic products, as value-added products (Sredojević, 2011; Milić et al, 2012). In the last decade, there has been a sharp increase in the area under organic production in Serbia, from 6,340.09 ha (0.18 %) in 2012 to 21,265.44 ha (0.61 %) in 2019 (MAFWM RS, 2021). Based on the average amounts of inputs and outputs, and in conventional and organic production, some economic indicators for Cloud Cherry were determined by the calculation procedure: gross income, variable costs, gross margin, lost / additional income, savings / additional costs and lost economic benefit in sour cherry production (Table 1).

Table 1. Some economic indicators of sustainability of Oblačinske sour cherry production

Economic indicators	*Production*		*Difference (I-II)*
	Conventional (I)	*Organic (II)*	
Yield of sour cherries *(kg/ha)*	16.000,00	14.000,00	-2.000,00
Selling price *(€/kg)*	0,35	0,35	-
I Revenues *(€/ha)*			
- Sales of products - Incentives	5.600,00	4.900,00	-700,00 -
Total *(I):*	5.600,00	4.900,00	
Lost / Additional Income, €/ha:			*-700,00*
II Costs, *€/ha*			
Fertilizers			
- mineral	620,00	-	+620,00
- organic	-	730,00	-730,00
Plant protection			
o *chemical*	580,00	-	+580,00
1. *biological*	-	780,00	-780,00
Mechanical services	640,00	470,00	+170,00
Work of workers	570,00	710,00	-140,00
Certificate. and control	-	130,00	-130,00
Other costs	50,00	70,00	- 20,00
Total *(II):*	2.460,00	2.890,00	
Savings / Additional cost, €/ha:			*-430,00*
II *Gross margin* (I-II):			
Gross margin, *€/ha* Gross margin, *€/kg*	3.140,00 0,24	2.010,00 0,16	-

Missed economic benefit, €/ha:	*-1.130,00*
Missed economic benefit, €/kg:	*-0,08*

Source: Authors' calculation based on survey data

Organic production of Oblačinska sour cherry gives lower sales revenue by 700 €/ha (17 %), and on the other hand there are higher variable costs by 430 €/ha (17 %), which gives a lower gross margin of 1,030 €/ha (36 %) compared to conventional production. For lost income and / or additional costs, and as a support for compliance with the principles of the IPARD measure, producers of organic cherries should be compensated in the amount of lost economic benefits in the amount of 1,130 €/ha. In order for producers to reach the gross margin of 3,140 €/ha with organic production of Oblačinska sour cherry, as well as in the conditions of conventional production, it is necessary to determine the minimum price below which it would not be justified to sell organic cherries. Based on the data from Table 1, by applying the determined minimum price, as well as using the actual market price of organic cherries, in Table 2, for different price variants, individual indicators were determined and economic indicators of organic cherry production were analyzed.

Table 2. Economic indicators of organic production Oblačinske sour cherry with different prices

Economic indicators	*Conventional production*	*Gross margin (BM) organic production with different cherry prices*		
		Price from convent. product.	*Minimum price*) (BM=conv.)*	*Actual market price*
Yield, *kg/ha*	16,000.00	14,000.00	14,000.00	14,000.00
Price, *€/kg*	0.35	0.35	**0.43**	0.50
Revenues, *€/ha*	5,600.00	4,900.00	6,030.00	7,000.00
Costs, *€/ha*	2,460.00	2,890.00	2,890.00	2,890.00
Gross margin, *€/ha*	**3,140.00**	2,010.00	**3,140.00**	4,110.00

***)** *Minimum selling price of organic sour cherries at which the gross margin (BM) is obtained in the same amount as in conventional production*

Source: Authors' calculation based on survey data

As can be seen in Table 2, the gross margin was calculated for three different prices of organic cherries, namely: The first, market (selling, buying) price of organic cherries (0.35 €/kg) is the same as in conventional production, namely is the case when the lost income and / or additional cost, i.e. lost economic benefit are determined. The calculated gross margin in organic (2,890 €/ha) is 36 % lower compared to the gross margin from conventional production (2,460 €/ha); Second, the minimum selling price of organic cherries (0.43 €/kg) at which the gross margin in organic is equal to the gross margin from conventional production; Third, the actual market (purchase, sale) price of organic cherries (0.50 €/kg) which is 43 % higher than the price from the conventional, and 16 % higher than the minimum organic and its gross margin (3,140 €/ha) is 44 % higher than the gross margin from the conventional one. In the current business conditions in our practice, organic cherry production is economically more efficient than conventional (Sredojević, 2011; Sredojević, 2014). By selling organic sour cherries at a better selling price than conventional ones, producers manage to "cover" production costs of 2,890 €/ha and achieve a gross margin of 4,110 €/ha, which includes a refunded lost economic benefit of 1,130 €/ha and a profit above that from 2,980 €/ha. In addition to the above economic indicators, in Table 2, the minimum selling price of organic cherries (0.43 €/kg) was calculated, at which the amount of gross margin was obtained as in conventional production. The determined minimum selling price of organic cherries is 25 % higher than the price of cherries from conventional production (0.35 €/kg). This means that in order for producers to be able to reimburse the lost economic benefit in the amount of 1,130 €/ha, i.e. 0.08 €/kg, the selling price of organic cherries should not be lower than 0.43 €/kg. Based on the average amounts for inputs and outputs during the erection and exploitation of cherry orchards, the calculation value determined the cultivation value of conventional orchards in the amount of 7,000 €/ha, and 8,000

€/ha. The production of organic sour cherries on the family farm achieves a more favorable selling price per unit of measure (0.50 €/kg) compared to the cherries from conventional production (0.35 €/kg). The average net profit in conventional cherry production is 2,628 €/ha, and in organic 3,069 €/ha, which shows that organic cherry production is more economically efficient than conventional (Table 3).

Table 3. Economic indicators of raising and exploitation of orchards Oblačinske sour cherry

I d i c a t o r s	*Production*	
	Conventional	*Organic*
Breeding period, *year*	3	3
Exploitation period, *year*	15	15
Total investments, €/ha	7,00.00	8,000.00
Average yield of sour cherries, *kg/ha*	16,000.00	14,000.00
Sales price of sour cherries, *€/kg*	0.35	0.50
Gross sales revenue, *€/ha*	6,030.00	7,000.00
Variable costs, €/ha	2,460.00	2,890.00
Amortization, interest, etc., *€/ha*	650.00	700.00
Total cost, *€/ha*	3,110.00	3,590.00
Gross profit, *€/ha*	2,920.00	3,410.00
Gross profit tax, *€/ha*	292.00	341.00
Net profit, *€/ha*	2,628.00	3,069.00
The cost of cherries, *€/kg*	0.19	0.26
Coefficient of economy	1.94	1.95
Profitability threshold, *kg/ha*	10,400.00	9,100.00
Return on equity period, *year*	2.65	2.25
Accumulation rate, *%*	41.71	42.62

Source: Authors' calculation based on survey data

The cost price of sour cherry production is significantly lower than its market price in production in both ways, but this difference is significantly more favorable in organic production (0.26 €/kg < 0.50 €/kg). The coefficient of economy in conventional production of cherries is 1.94, and in organic 1.95, which confirms that despite the fact that production is more economical, a better income per unit of investment is achieved compared to conventional production. The accumulation rate in conventional production is 41.71 %, and in organic 42.62 % per 100 monetary units of invested capital, a higher net profit is achieved in organic and thus better accumulation. The capital invested in raising cherry orchards in both methods of production can be returned in the third year (2.65 years and 2.25 years), which is a much shorter period compared to the period of exploitation of orchards (15 years). The profitability threshold for both production methods is around 65 % of the average yield per unit area (e.g. 9,100.00 kg/ha for organic cherries). Investments in organic production, in addition to benefits for producers, contribute to improving the development of the economy at the local level. The organic cherry processing program would invest in new production and processing capacities, would contribute to the development of other activities (trade, transport, etc.), better infrastructure and overall economic recovery, and would encourage further development of the area.

CONCLUSION

Based on data from the practice of sour cherry production in the Republic of Serbia, it was determined that in organic compared to conventional, a lower amount of gross margin is obtained by 430 €/ha (36 %). In order for producers in organic to reach a gross margin of 3,140 €/ha, as well as in the conditions of conventional production, the minimum selling price of organic cherries (0.43

€/kg) was set. In relation to the price of cherries from conventional production (0.40 €/kg), the determined minimum selling price of organic cherries is higher by 25 % a. In order for organic production to be economically acceptable and sustainable, it is necessary to reimburse producers for the lost benefit in the amount of 1,300 €/ha, or 0.08 €/kg, which means that the selling price of organic cherries should not be lower than 0, 43 €/kg. The stated amount of lost benefit represents a very realistic estimate for compensation to producers in order to successfully implement IPARD Agro ecological - climatic measures and measures of organic production.

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POSSIBILITIES OF MAIZE HYBRIDS UTILISATION IN CANNED BABY CORN PRODUCTION

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ABSTRACT
Five maize hybrids were used in this research: two yellow and one white dent, sweet hybrid, and yellow popcorn. Five brine recipes with acetic acid were examined, of which two with the addition of potassium sorbate. The brines with preservatives were stable for 16 months without colour changes of the liquid and corn cobs. The pH of brines ranged from 3.39 to 3.89. Canned hybrids ZP 366 and ZP 611k in brine marked as Number 5 showed the best sensory characteristics. The protein content determined in ZP 366 (9.56 %) and ZP 611k (10.23 %) did not vary significantly compared to whole-grain maize flour, while crude fibre content (7.67 and 6.88 %), and ash content (21.96 and 20.72 %) were significantly higher than in flour (crude fibre: 2.40; 2.64 %, ash:1.35; 1.48%, respectively). This research will be continued in order to implement preliminary findings and new data on this subject.
Key words: *maize hybrids, baby corn, canned vegetables, food production*

INTRODUCTION
Maize (*Zea mays* L.) is the third most grown cereal crop in the world, after wheat and rice. Apart from being used for food and animal feed, it has a multitude of various industrial uses and the highest production potential among the cereals. The total 2021 world maize production estimated by the United States Department of Agriculture (USDA) will be 1,133.89 million metric tons, with Serbiaproducing around 8,000,000 metric tons and taking the 16th place (World Agricultural Production.com, 2021).

Immature dehusked maize ears harvested before fertilization, within two to four days after white silk emergence is classified as baby corn. Due to being a short duration crop (50-60 days), it can be sown and harvested more than once a year (3 to 4 times in tropical regions) depending on a climate. Unlike mature maize whose ears are too hard, baby corn represents the immature ears of normally grown maize and can be consumed as a vegetable (Singh et al., 2010). Baby corn has been used as vegetable in China and other parts of Asia for generations, and has recently gained popularity worldwide. This eco-friendly food has great potential as a value-adding product. Nutritive value of baby corn is similar to the non-legume vegetables such as cauliflower, tomato, cucumber and cabbage. Baby corn has high digestibility, sweet taste and appealing colour, while both soft and crunchy nature makes it an exquisite ingredient for different traditional and continental dishes. In general, 100 g of baby corn contains 89.1 % moisture, 8.2 % carbohydrates, 1.9 % protein, 28.0 mg calcium, 86.0 mg phosphorus, 0.1 mg iron, 0.5 g thiamine, 0.08 mg riboflavin and 11.0 mg ascorbic acid. In the market, ears of baby corn of light-yellow colour, regular row arrangement, 10 to 12 cm length and a diameter of 1.0 to 1.5 cm are most preferred (Jinjala et al, 2016).

There is a great potential in processing of this vegetable as a canned product (Lone et al, 2013). The distinctive flavour is what makes pickled baby corn products very favoured to go along well with foods that may lack taste. It can be preserved by natural or controlled fermentation, direct addition of vinegar to a pH adjusted to 4.6 or below, or a combination of methods, processing parameters and additives in order to obtain products that are referred to as pickles (Featherstone, 2016). Pickled products should be prepared from clean ingredients that can be previously subjected to fermentation or/and curing in a salt brine. The product can be subsequently preserved by pasteurisation or refrigeration. The amount of the brine added is changed with corn maturity during the season.

Young immature corn will absorb very little of the brine, and more mature corn will absorb as much as 28-56 ml of brine per 100 g of corn cobs (Featherstone, 2016).
In order to obtain a shelf-stable product, control of the parameters such as pH, acidity, salt content, and other food preservation issues combined with pasteurization is crucial. However, if the production process is not properly controlled, these canned products may show texture or discoloration problems as a result of the heat treatment, fermentation and/or acidification processes (Kaur et al, 2018; Featherstone, 2016).
Having in mind that processing of baby corn at an industrial scale in Serbia is currently negligible, research regarding the possibilities of its growing and processing may contribute to the improved valorisation of maize, by increasing the economic value of this, for our country the most important, carbohydrate feedstock (Radosavljević et al, 2020).
The objective of our preliminary study was to evaluate the possibilities, identify the most suitable maize genotypes for canned baby corn production, and the best criterion for preserving this product (the composition of the pickling brine).

MATERIAL AND METHODS

Five maize hybrids differing in vegetation period, grain colour, and chemical composition were used in this research: ZP 366 and ZP 505 (yellow dents), ZP 533b (white dent), ZP 555su (sweet hybrid), and ZP 611k (yellow popcorn). The hybrids were developed at the Maize Research Institute, Zemun Polje. In spring of 2019, at the experimental field located at the Maize Research Institute, Zemun Polje, the two-replicate trial was set up according to the randomized complete-block design. The plot size was 21 m^2, while the sowing density was 60,000 plants ha^{-1}. Maize ears for canning were harvested in July in the pre-fertilization phase or in the early fertilization phase within two to four days after white silk emergence from the area of 7 m^2 (two inner rows). After removing the protective leaves (husk), the small cobs were cleaned of silk residues and submerged in brine solution.Sterile glass jars (300 ml) were tightly packed with baby corn cobs, filled with brine liquid and closed with the jar lids. Five brine recipes (Table 1) containing different percent of acetic acid, salt and sugar were examined, three without preservatives, and two with the addition of potassium sorbate (E 202). Potassium metabisulfite (E 224) was added to the brine solutions containing potassium sorbate in order to prevent darkening, loss of aroma, and the occurrence of bitter and herbal tones, as well as to prevent oxidative processes and development of unwanted microorganisms. Only preservative-free brines were pasteurized; however, they became cloudy, and the corn cobs turned darker after only a few days. The baby corn hybrids in two remaining brines were stable for 16 months without colour changes of the canning liquid and corn cobs. The product was kept in a bright place at room temperature, and analyses of nutritional composition and sensory characteristics were performed after 16 months to determine product quality and select the most suitable ZP hybrid for canning.

Table 1. Brine recipes used in the experiments

<u>Brine 1</u> -100 ml of acetic acid (9%) -10 g of sugar -20 g of salt -up to 1 litre of water	<u>Brine 2</u> -200 ml of acetic acid (9%) -10 g of sugar -20 g of salt -up to 1 litre of water	<u>Brine 3</u> -300 ml of acetic acid (9%) -80 g of sugar -80 g of salt -up to 1 litre of water
<u>Brine 4</u> -300 ml of acetic acid (9%) -80 g of sugar -80 g of salt -2 g of potassium metabisulfite -1 g of preservative -up to 1 litre of water	<u>Brine 5</u> -20 ml of acetic acid (96%) -30 g of salt -2 g of potassium metabisulfite -1 g of preservative -up to 1 litre of water	

Commercial baby corn product purchased in a local supermarket was used as a control with which the sensory characteristics of canned ZP maize hybrids were compared.Commercial baby corn was prepared with a solution that, according to the declaration, contained only citric acid and salt. The nutritional composition was tested on samples of canned corn ZP 366 and popcorn ZP 611k using brine number 5, which was rated as the best by the panellists.

For chemical composition assessment, the pickled baby corn was dried in a ventilation oven for 48 h at 60 °C, and ground on a laboratory mill (Perten Instruments, Hägersten, Sweden) for fine samples preparation (mesh 0.5 mm).

Dry matter content in the was determined by the standard drying method in an oven at 105 °C to constant mass. The protein content was determined by the Kjeldahl method as the total nitrogen multiplied by 6.25 (AOAC, 1990). Crude fibre content was determined by Weende method adjusted for Fibretec^{TM}Systems, Foss, Denmark (Agricultural food products, 1993). The ash content was determined by the slow combustion of the sample at 650°C (AOAC, 1990). The results are expressed in the percentages per dry matter (d.m.). All analyses were performed in two replicates, and the results are presented as means.

RESULTS AND DISCUSSION

Optimal harvest time of corn cobs suitable for canning

The basic criterion for harvesting corn for canning in our research was the length of the silk. Corn cobs were harvested in the phase when the silk was about 3 cm outside the protective leaf of the cob and in the phase when the silk was visible in the length of about 7-8 cm. After removing the protective leaf, the total length of the silk was determined to be about 10 cm, and in the second case about 17 cm. The cobs that were harvested with shorter silk were more uniform and their length ranged between 9 and 10 cm. The cobs with longer silk were far more uneven in length. Their length ranged from 8 to 16 cm. Cob girth of the investigated ZP baby corn cobs ranged from 10.1 to 15.2 mm. *Lone et al.* (2013) reported that length of dehusked baby corn cobs treated with different organic and inorganic fertilizers ranged from 8.67 cm to 10.90 cm, and girth of cobs without husk from 12.7 mm to 16.5 mm, while Jinjala et al. (2016) reported cob lengths between 5.39 and 8.88 cm and cob girths between 22.2 and 29.8 mm. Based on the examination, it can be concluded that the most suitable moment when maize ears for canning can be picked is when the length of the visible part of the silk is from 3 cm to 10 cm, where it is recommended to classify the harvested cobs for canning. However, more agronomic parameters, e.g., plant height, leaves above ear, irrigation, fertilization, green matter yield, etc., should be included in further studies.

Choosing the maize genotype for best nutritional and sensory characteristics

The sensory properties and basic chemical composition of the canned products that remained stable after 16 months were examined. The results of storage showed that these products were organoleptically acceptable up to 16 months of storage period. The pH value of the investigated canned ZP maize products ranged from 3.39 to 3.89, while the commercial baby corn had pH of 5.18. The pH value of fresh corn is usually in the range 5.90-7.30. Studies have shown that the pH of the product should be monitored during the shelf life. Any increase in pH could indicate microbiological activity, or improper equilibration, with the risk of microorganisms growing (Featherstone, 2016).Corn cobs of all samples were hard enough for cutting, not rubbery, too firm nor too soft. Brine number 5 proved to be the best according to the panellists: salty enough, sour enough, tasty, reminiscent of homemade pickles. Commercial baby corn was in the opinion of all panellists the least pleasant taste (tasteless, unsalted, not sour enough, the colour was dull). Brine number 4, although it lasted for 16 months, was rated as too strong (too salty, too sour, with a sharper taste). The baby corn product from the ZP 611k popcorn hybrid was chosen as the best in terms of sensory characteristics.

Table 2. Chemical composition of the canned ZP baby corn products in comparison with whole-grain maize flour

Product	Dry matter (%)	Protein (%)	Crude fibre (%)	Ash (%)
Canned baby corn ZP 366, brine number 5	92.69	9.56	7.67	21.96
Canned baby corn ZP 611k, brine number 5	93.64	10.23	6.88	20.72
Whole grain flour ZP 366	88.56	9.88	2.50	1.38
Whole grain flour ZP 611k	90.06	12.08	2.54	1.40

Chemical composition of the commercial canned baby corn product had: 1.9 % of protein, 2.3 % fibre, 0.3 % oil and 5.4 % of carbohydrates, as stated on the declaration. Canned baby corn from hybrids ZP 366 and ZP 611k preserved in brine marked as number 5 showed best sensory characteristics (Table 2). The protein content determined in canned baby corn ZP 366 (9.56 %) and ZP 611k (10.23 %) did not vary significantly compared to whole-grain corn flour, while crude fibre content (7.67 and 6.88 %), as well as ash content (21.96 and 20.72 %) were significantly higher than in flour (crude fibre: 2.40; 2.64 %, ash: 1.35; 1.48 %, respectively) (Table 2). Dar et al. (2014) reported that protein content in fresh baby corn ranged from 8.87 to 9.84 %, while Jinjala et al. (2016) found that protein content of baby corn was between 9.91 and 11.02 %, which is in accordance with our findings.

CONCLUSION

The brines that contained preservative remained stable for 16 months without colour changes of the liquid and corn cobs. It was concluded that the appearance, taste/flavour and consistency and the overall acceptability of the canned product was best with hybrids ZP 611k and ZP 366 preserved in brine number 5. The pH of the brines ranged from 3.39 to 3.89. The protein content determined in baby corn ZP 366 (9.56 %) and ZP 611k (10.23 %) did not vary significantly compared to whole-grain maize flour, while crude fibre content (7.67 and 6.88 %), and ash content (21.96 and 20.72 %) were significantly higher than in respective maize flour. It was concluded that the optimum harvesting moment is when the length of the visible part of the silk ranges from 3 cm to 10 cm, and cobs are between 9 and 10 cm long. In order to implement preliminary findings and new ideas and knowledge on this subject, this research will be continued later this year.

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MICROWAVE-CONVECTIVE DRYING OF BLACK CHOKEBERRY

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ABSTRACT

In this research, the impact of microwave-convective processes on black chokeberry was investigated on drying time, thermal behavior, rehydration, shrinkage, energy consideration and microstructure. Based on the data, the minimum drying time was 100 min, obtained with 160 W-75 °C process which is reduced 80.39% compared to the maximum drying time of 510 min with 90 W-55 °C process. Thermal images showed that higher drying temperature and/or microwave power leads to an increase in sample temperature. Although the rehydration ratios were similar (1.31±0.01 – 1.39±0.04), the shrinkage area were decreased between 20.22±2.52 - 35±3.30%. In terms of energy consideration, the lowest energy consumption (0.648 kWh), specific energy consumption (0.054 kWh/kg), specific moisture extraction rate (30.00 kg/kWh) and the highest moisture extraction rate (0.014 kg/h) was determined after 160 W-75 °C process. Moreover, the porous structure of the sample dried by the 90 W-55 °C process appeared while other drying processes yielded cell collapse.

***Key words**: thermal image, rehydration, shrinkage, energy, microstructure.*

INTRODUCTION

The drying process is one of the effective postharvest ways to preserve fruits (Gonçalves et al., 2017). Though, different methods used in drying have both advantages and disadvantages, hot air drying is often preferred by producers for drying agricultural products due to its simplicity in the industry (Baysal et al., 2015; Ashtiani et al., 2018). However, low product quality due to the high temperature and long drying time applied are among the disadvantages of this method (Zahoor and Khan, 2019). On the other hand, microwave drying has gained popularity as an alternative drying method for a wide variety of food and agricultural products. Microwave heating is based on the transformation of alternating electromagnetic field energy into thermal energy by affecting the polar molecules of a material, which provides a rapid drying rate than the rate made by the convective drying (Workneh and Oke, 2013). This unique heating capability has resulted in considerable interest in heating and drying related commercial situations (Kumar et al., 2014). Therefore, combined drying methods allowed more advantages and the combination of the microwave with convective has recently proved to overcome some limitations. With the drying of the microwave-convective process, heat is not only spread over the product surface but also emitted to the inside of the product, and the dehydrated food product. In this process, hot air and microwave energy remove the free water from the surface and the moisture inside the product, respectively. With the microwave-convective method, the drying speed increases, the process is shortened and a higher quality product is obtained (Zahoor and Khan, 2019).

A number of research have been performed in various fruits such as cranberries (Sunjka et al., 2004), apple (Marzec et al., 2010), lemon (Kesbi et al., 2016) and tomato (Workneh and Oke, 2013) with using the microwave-convective drying method. In this study, microwave-convective drying was used to determine the drying times of black chokeberry and to evaluate the impact of drying processes on the thermal behavior, rehydration, shrinkage, energy consideration and microstructure parameters.

MATERIAL AND METHOD

The black chokeberry samples were obtained from Yalova-Turkey (Ataturk Central Horticultural Research Institute). Mature and undamaged samples were selected and stored at 4 ± 0.5 ° C until the experiments were completed. The initial moisture content of the black chokeberry samples was found to be 3.30 (g water / g dry matter) after drying in an oven (M3025P, Electromag, Turkey) at 105 ° C for 24 hours. Six different microwave-convective combinations for drying experiments (90 W-55 °C, 90 W-65 °C, 90 W-75 °C, 160 W-55 °C, 160 W-65 °C and 160 W-75 °C) has been used. 30 g of product was dried in a 20 (W) x 210 (D) x 450 (H) mm oven (Whirlpool AMW 545, Italy) at an air velocity of 1 m / s.
A thermal imaging camera (Flir One Pro – IOS, USA) connected to a GSM phone (iPhone 7, USA) was used to obtain the temperature distribution (Kumar et al., 2014). Thermal images of the products before and after drying were photographed at a 30 cm distance between samples and lens.
To determine the rehydration ratio, 2 g of dried sample was kept in 20 ml of distilled water for 120 minutes. The water on the rehydrated samples was taken and weighed. The ratio of the obtained value to the amount of dried sample gave the rehydration ratio (Zahoor and Khan, 2019).
Photographs taken with a digital camera before and after drying were used to determine shrinkage percent. The sample area of the binary image was determined using ImageJ software (Gonçalves et al., 2017).
Determination of energy values are important to make analysis to examine the efficiency for each drying process. The energy consumption were measured by power meter (EU TS-836A; Floureon, China). The specific moisture extraction rate (SMER), moisture extraction rate (MER) and specific energy consumption (SEC) are calculated according to equations 1, 2 and 3, respectively (Baysal et al., 2015).

$$SMER = \left(\frac{\text{Amount of water removed during drying}}{\text{Total energy supplied in drying process}}\right), \frac{kg}{kWh} \tag{1}$$

$$MER = \left(\frac{\text{Amount of water removed during drying}}{\text{Drying time}}\right), \frac{kg}{h} \tag{2}$$

$$SEC = \left(\frac{\text{Total energy supplied in drying process}}{\text{Amount of water removed during dryingDrying time}}\right), \frac{kWh}{kg} \tag{3}$$

A scanning electron microscope (SEM) device (EVO 40, Carl Zeiss, Oberkochen, Germany) at an acceleration voltage of 20 kV was used to examine changes in the microstructure of products dried with different combinations. Before preparing the products for analysis, the samples were cut cross-section and covered with a very thin gold palladium layer. Level of × 750 were used for taking images (Ashtiani et al., 2018).

RESULTS AND DISCUSSION

Figure 1 shows the effect of drying processes on drying time of black chokeberry. The drying time changed between 100 and 510 min, wherein shorter drying time was found for samples dried at higher microwave power and higher temperature. For instance, the increase of temperature from 55 to 75 °C at 90 W reduced the drying time 66.7%. The microwave power was set to 160 W and the reduction of drying time was 58.4% from 55 to 75 °C. On the other hand, drying processes affected the energy values of black chokeberry, as it was shown in Figure 2. The highest energy consumption (1.865 kWh), SMER (0.098 kg/kWh) and SEC (86.343 kWh/kg) values with lowest MER (0.0025 kg/h) value was achieved when drying at 90 W-55 °C process. The obtained drying time and energy results of Izli et al. (2019) showed good agreement with the results of our study. They presented that the combined microwave-convective drying technique enabled significantly higher time and energy saving than microwave drying.

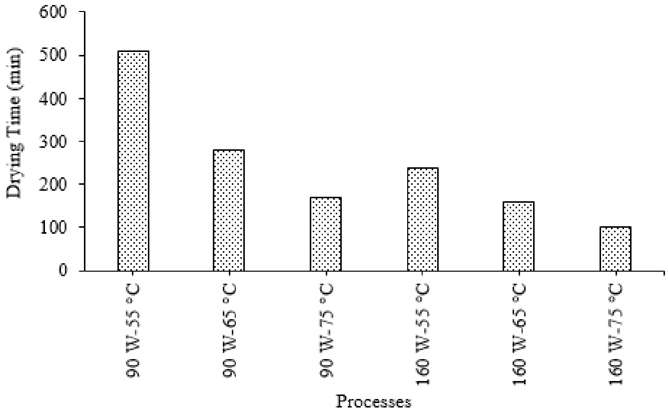

Figure 1. Drying time of black chokeberry

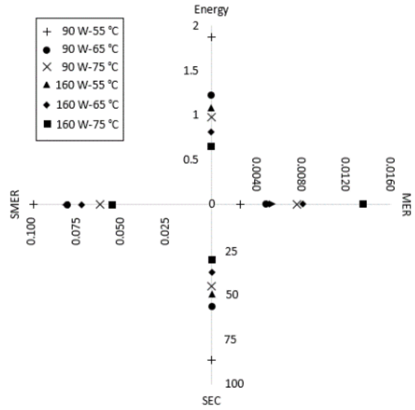

Figure 2. Energy values of black chokeberry

Maximum temperature estimation is one of the important parameters in order to prevent burning and damages that may occur in case of exposure to excessive temperature during the drying of agricultural products. With the combination of microwave and convective methods, a high energy efficiency and unique drying method has been created. (Kumar et al., 2014). The effects of microwave-convective drying processes the thermal images of black chokeberry are illustrated in Figure 3. It shows that the from initial temperature of between 17.8 - 23.2 °C to final temperature of 72.8, 81.2, 106.6, 78.9, 99.8 and 122.2 °C were reached by 90 W-55 °C, 90 W-65 °C, 90 W-75 °C, 160 W-55 °C, 160 W-65 °C and 160 W-75 °C, respectively.

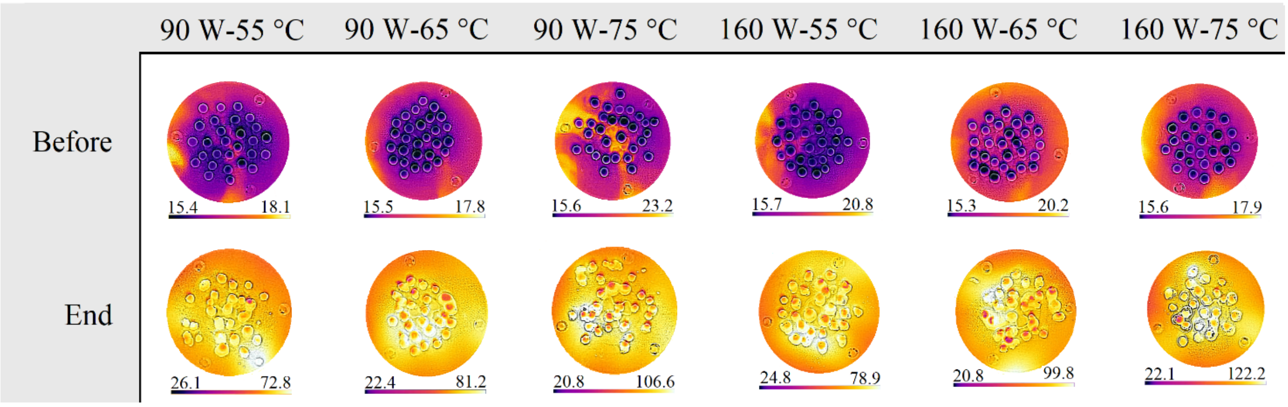

Figure 3. Thermal images of black chokeberry

The influence of drying processes on rehydration ratio are given in Figure 4. It can be seen that all results exhibit in parallel between 1.31±0.01 – 1.39±0.04. However, drying with 90 W combinations were found slightly higher than drying with 160 W combinations. This finding might be related to the possible structural collapse in the samples due to exposure to hot air long time (Kesbi et al., 2016). Furthermore, Figure 5 presents shrinkage values of microwave-convective dried black chokeberry samples. The shrinkage (%) of 90 W-55 °C, 90 W-65 °C, 90 W-75 °C, 160 W-55 °C, 160 W-65 °C and 160 W-75 °C were 32.24±3.56, 33.77±3.44, 35.54±3.30, 20.22±2.52, 23.57±5.12 and 25.24±5.79, respectively. It could be seen that the shrinkage increased with an increase in air temperature and a decrease in microwave power. As expected, shrinkage of foods increases linearly with moisture reduction during microwave–hot air drying process (Gonçalves et al., 2017).

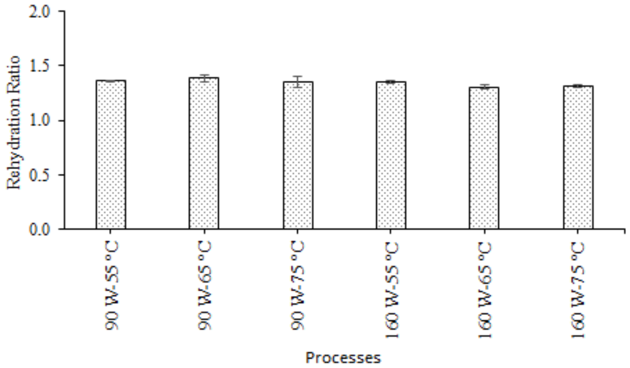

Figure 4. Rehydration ratio of black chokeberry

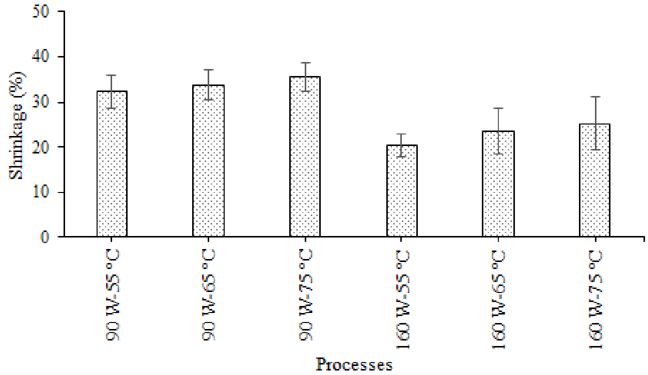

Figure 5. Shrinkage of black chokeberry

Figure 6a-f presents that the microstructure of a microwave-convective dried black chokeberry samples. The SEM images of the cross-sections of the samples displayed that the damages were seen with the increase in drying temperature with combinations of 90 W (Figure 6a-c). A similar observation occurred with 160 W combinations (Figure 6d-f). Additionally, a smoother structure was determined in samples at the same drying temperature and low microwave application. This is because of the exposure of fruits to heat presumably led to failure or merging cellular walls. The parallel findings have been reported by Ashtiani et al. (2018) for nectarine slices.

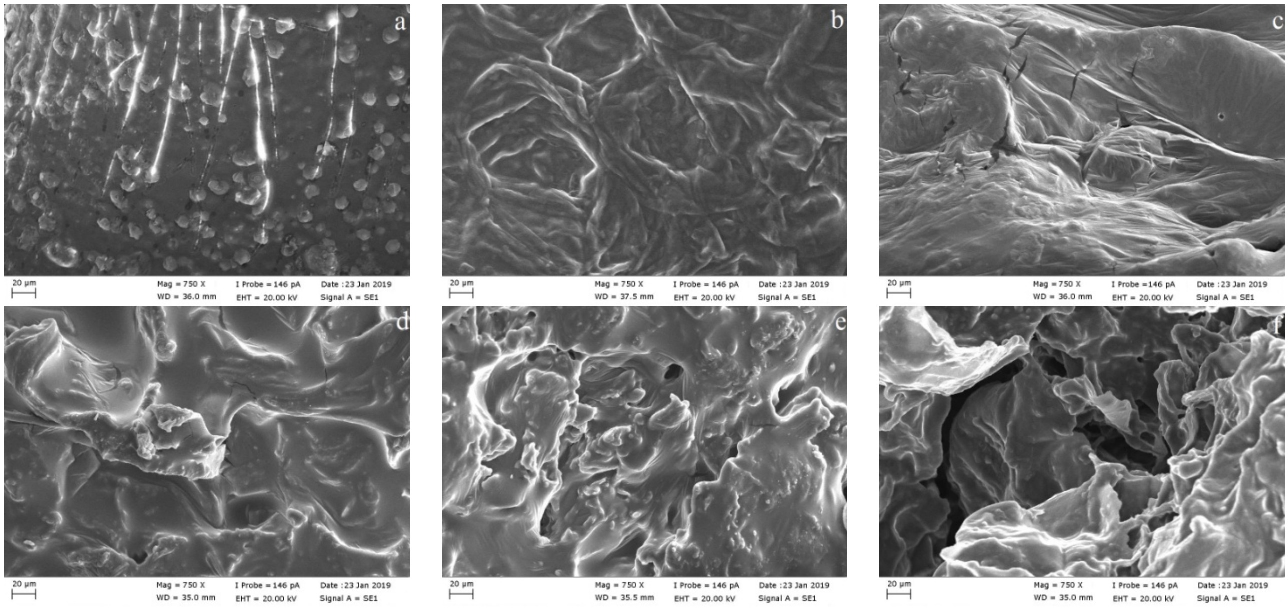

Figure 6. SEM images of black chokeberry

CONCLUSION

The obtained data showed that using the microwave-convective processes for the drying of black chokeberry is less time-consuming and energy-saving. The microwave-convective processes had a similar effect on rehydration ratios. However, higher drying temperature increased the shrinkage values. On the other hand, low drying temperatures helped to avoid both hot-spots and damages as understood from thermal images and SEM images, respectively. Consequently, the current findings have the potential to identify viable substitutes for fresh black chokeberry all year.

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THE STRUCTURE, PROPERTIES AND THE COMPOSITION OF KERNELS OF MAIZE HYBRIDS RECENTLY DEVELOPED IN SERBIA

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ABSTRACT

The aim of this study was to characterise new generations of maize hybrids in regard to their sturcutre (participation of pericarp, endosperm and germ), selected physical properties (1000-kernel mass, density, floatation index, milling response, hard and soft endosperm portion) and chemical compostions (content of starch, protein, oil, crude fibre, ash and soluble carbohydrates) of kernels, as well as to process obtained results by the correlation analysis to determine the interrelationships of these important quality parameters. Thirty ZP maize hybrids (yellow-, white- and red-seeded dents, popping maize hybrids) were selected for testing. The obtained results indicated that the structure, properties and the composition of kernels significantly varied among observed hybrids. In addition, the significant positive and negative correlations were found between some tested parameters. The results can be useful for the development of new maize hybrids and maize-based products with desirable nutritional and functional properties.

INTRODUCTION

Maize is one of the most important and widely grown plants in the world (Ai and Jane, 2016). In our country as well, maize is traditionally the leading field crop that is primarily grown as an energy crop (Radosavljević et al, 2010; Milašinović-Šeremešić et al, 2018). Various specific types of maize such as sweet maize, popping maize, high-oil, high-lysine, waxy maize, white-seeded and lately red- and blue-seeded maize have been broadly used (Srdić et al, 2019). The increased genetic variability of different properties of maize kernels provides the modifications of their structure in terms of quantity and quality of individual components through the process of breeding. In recent decades, many researchers have made efforts to improve the nutritional value of maize (Ai and Jane, 2016). The achievements in maize breeding provide a significant extension of assortments of highly-valuable food and ecologically safe products by a specific purpose growing of hybrids of special and unique grain traits.

Therefore, the objectives of this study were to characterise new ZP maize hybrids concerning their structure, properties and compositions of kernels and to process obtained results by the correlation analysis to determine the interrelationships of these important quality parameters.

MATERIAL AND METHOD

Thirty ZP maize hybrids of new generation (ZP 3018, ZP 333, ZP 4007, ZP 4123, ZP 434, ZP 4567, ZP 500, ZP 5947, ZP 50 48, ZP 5075, ZP 548, ZP 552b, ZP 553b, ZP 608k, ZP 611k, ZP 6037, ZP 606, ZP 6079, ZP 6263, ZP 6561, ZP 666, ZP 7007c, ZP 7037c, ZP 707, ZP 7072, ZP 7100, ZP 735, ZP 758, ZP 7777 and ZP 873) were selected for testing. The hybrids were grown in 2019 at the experimental field of the Maize Research Institute in Zemun Polje. The sowing density was 60,000 plants per hectare. Maize ears of were harvested at the full physiological maturity stage. Twenty average maize ears were selected for for further analyses. Whole maize kernels were ground in a laboratory mill (Perten Instruments, Hägersten, Sweden) for fine samples preparation (mesh 0.5 mm) for the chemical composition determination. The kernel structure, i.e. the morphological structure of kernels (participation of pericarp, endosperm and germ) of selected maize hybrids was determined by the manual dissection. The physical properties of kernels were observed by determining the 1000-kernel weight, density, floatation index, milling response and the

proportion of hard (vitreous or glassy) and soft (floury) endosperm fractions. The chemical composition was observed by determining the content of starch, protein, oil, crude fibre, ash and soluble carbohydrates. All methods applied in this study are described in detail in previously published papers (Radosavljević et al, 2000; Milašinović-Šeremešić et al, 2019).

RESULTS AND DISCUSSION

The results of testing of the structure, physical properties and the chemical composition of kernels of 30 new ZP maize hybrids of different maturity groups, different endosperm types and various colours (yellow-, white- and red-seeded dents, popping maize hybrids) are given in tables 1, 2 and 3.

Table 1. Participation of the pericarp, endosperm and germ in the kernels of 30 new ZP maize hybrids

Kernel structure (%)	Pericarp	Endosperm	Germ
Min	4.80	79.36	9.18
Max	11.01	84.07	14.44
Average	6.49	81.41	12.09
SD	1.22	1.21	1.33

Table 2. Kernel physical properties of 30 new ZP maize hybrids

Physical properties	1000-kernel weight (g)	Density (gcm^{-3})	IF-flotation index (%)	Milling response (s)	Hard endosperm (%)	Soft endosperm (%)
Min	115.40	1.21	0.00	7.93	34.22	27.92
Max	399.90	1.39	94.48	17.30	72.08	55.17
Average	308.68	1.28	36.58	10.28	54.01	45.31
SD	62.59	0.04	28.54	2.01	6.86	5.75

The obtained results indicated that the structure, physical properties and the chemical composition of the kernels significantly varied among observed hybrids. Among the hybrids, there were significant variations in the kernel structure and all tested physical properties (Table 1 and 2). The participation of the pericarp, endosperm and germ in the kernels of the observed hybrids varied from 4.80 (ZP 4567) to 11.01% (ZP 608k), 79.36 (ZP 552b) to 84.07% (ZP 4123) and from 9.18 (ZP 608k) to 14.40% (ZP 6263), respectively (Table 1). The 1000-kernel weight, density, floatation index, milling response and the participation of hard and soft fractions of the endosperm ranged from 115.40 (ZP 608k) to 399.90 g (ZP 7100), 1.21 (ZP 4123) to 1.39 kg/m^3 (ZP 608k), 0.00 (ZP 608k) to 94.48% (ZP 4567), 7.93 (ZP 735) to 17.30 s (ZP 608k), 34.22 (ZP 5047) to 72.08% (ZP 608k) and from 27.82 (ZP 608k) to 55.17% (ZP 4567), respectively (Table 2). The ZP 608k maize hybrid was found to have the highest density (1.39 kg/m3), milling response (17.30 s) and hard endosperm proportion (72.08%), and the lowest flotation index (0.00%) and 1000-kernel weight (115.40 g). The ZP 608k hybrid is a recently derived popping maize hybrid. Based on this and the comparison with the ZP 611k hybrid of the previous generation of popping maize hybrids, which was used as a check, the ZP 608k hybrid was found to have much better the most important parameters of the kernel hardness (density, floatation index, milling response and hard endosperm portion).

Furthermore, significant variation among the hybrids has been observed in the starch, protein, oil, cellulose (crude fibre), ash and soluble carbohydrates contents (Table 3).

Table 3. Kernel chemical composition of 30 new ZP maize hybrids

Composition (%)	Starch	Proteins	Oil	Crude fibre	Ash	Soluble carbohydrates
Min	66.60	8.83	4.07	1.75	1.20	0.03
Max	74.75	12.19	6.89	2.68	1.50	0.71
Average	71.12	9.53	5.72	2.28	1.25	0.25
SD	1.89	0.73	0.56	0.23	0.07	0.15

The variability of tested quality parameters provides wide possibilities for selecting maize hybrids as a raw material for certain purposes, as well as for breeding of new hybrids (Radosavljević et al, 2010). The optimum maize utilisation means compliance of kernel properties with the requirements of each single use. Little attention has been paid to the nutritional value of maize for food and feed. The chemical composition is one of the most easily recognisable intrinsic properties of grain. The major chemical components of maize kernels are starch, proteins, and lipids. The quantity of these components and their quality play a very important role in the use and quality of maize products. Starch is its major nutritional and energetic component providing up to 68% to 74% of the kernel weight. Moreover, starch is a very important raw material in making numerous diverse products and bioethanol as a renewable alternative energy source. Main components of starch are amylose and amylopectin, which differ in their chain structure and have a very important role in the use of maize grain for different purposes (Ai and Jane, 2016). Proteins are another major chemical component in maize kernels. However, their nutritional quality is poor due to deficiency of two essential amino acids, lysine and tryptophan. Maize kernel is also a source of oil, which is highly regarded for human consumption. The results obtained in this study showed that the average starch content in kernels of 30 recently developed ZP maize hybrids was 71.12%, ranging from 66.60% (ZP 611k) to 74.75% (ZP 7100), depending on varieties. The average protein content amounted to 9.53%, ranging from 8.83% (ZP 707) to 12.19% (ZP 611k). Furthermore, the average content of oil was 5.72%, ranging from 4.07% (ZP 608k) to 6.89% (ZP 552b). However, the content of crude fibre, ash and soluble carbohydrates varied in narrower intervals from 1.75% (ZP 5048c) to 2.68% (ZP 608k), 1.20% (ZP 606) to 1.50% (ZP 434) and from 0.03% (ZP 4567) to 0.71% (ZP 735), respectively (Table 3). Results presented in Table 3 are in accordance with previously published results (Watson, 2003; Ai and Jane, 2016; Milašinović-Šeremešić et al, 2018 and 2019*)*. Due to its specific genetics, the kernel of specialty maize hybrids (white- and red-seeded dents and popping maize hybrids) had a significantly different chemical composition (low starch content and high protein, low and high oil and fibre contents) compared to yellow-seeded maize hybrids. In addition, popping maize hybrids had very different physical quality parameters (participation of the pericarp, endosperm and germ in the kernels, 1000-kernel weight, density, floatation index, milling response and the proportion of hard and soft endosperm fractions) compared to other maize hybrids. Our previous research indicated that the chemical composition in maize kernels is genetically controlled, and the presence of genetic diversity is essential for maize quality and the utilisation improvement (Radosavljević et al, 2010). Likewise, the physical kernel traits may have an effect on nutritive value and industrial use of maize. Maize grain hardness is extremely important in food processing and grain trading because it influences end-use processing performance by large, including dry-milling yield, and power usage, as well as, the dust formation during processing. Observed from the industrial point of view, the milling response and the participation of hard and soft fractions of the endosperm are parameters of grain hardness, which represent its most important physical properties. Kernel hardness is closely related to the ratio of hard to soft endosperm. This ratio is an important agronomic trait that may influence grain hardness, post-harvest resistance to pests, and microorganisms, as well as the rate of starch digestibility. Although maize grain is characterised by a high nutritive value, its presence in food is low. These results point out to great possibilities of the

utilisation of recently derived ZP hybrids in the development and production of functional and high-quality food and feed.

In addition, the correlations between the investigated parameters of the structure, physical properties and the chemical composition of kernels of thirty new ZP maize hybrids were statistically determined. The significant negative correlations were found between the participation of the pericarp and the participation of the germ (r=-0.56), 1000-kernel weight (r=-0.69) and the floatation index (r=-0.58). Moreover, significant positive correlations were determined between three parameters of the kernel physical properties, such as the density (r=0.84), milling response (r=0.72) and the hard endosperm participation (r=0.76), and contents of proteins (r=0.75) and crude fibre (0.57). In addition, the protein content was positively correlated with the same parameters of physical properties (r=0.75, r=0.68, r=0.62, respectively). At the same time, it was negatively correlated with the 1000-kernel weight (r=-0.74) and the starch content (r=-0.50). The starch content was positively correlated with the participation of hard endosperm (r=0.61) and 1000-kernel weight (r=0.60), while the oil content was only positively correlated with the participation of the germ (r=0.53). On the other hand, the participation of hard endosperm was negatively correlated with the participation of the germ (r=-0.54) and the hard endosperm participation (r=-0.51). Similar results have been obtained in previous studies (Radosavljević et al, 2012; Milašinović-Šeremešić et al, 2019*).* These results, as well as previously achieved results on chemical traits of grain in dependence on the maize hybrid properties, pointed out that the greatest number of observed traits depending on the genetic base, i.e. on the type of hybrid, growing and environmental conditions, varied in a very wide range (Radosavljević et al, 2015). According to Cömertpay et al, 2016, the relationships among grain quality traits are influenced by the environment, and the correlations change as a result of linkage or epistatic interactions among the genes regulating these traits.

In order to gain new knowledge and to draw final conclusions on this topic, it is necessary to continue this research in the future. The results achieved in this study can be useful in broadening the use and the development of new generations of maize hybrids and maize-based products with desirable nutritional and functional properties.

CONCLUSION

The obtained results indicated that the kernel structure, physical properties and the chemical composition varied significantly among observed hybrids.

The participation of the pericarp, endosperm and germ in the kernels of the observed hybrids varied from 4.80% to 11.01%, 79.36% to 84.07% and from 9.18% to 14.40%, respectively. The 1000-kernel weight, density, floatation index, milling response and the participation of hard and soft fraction of the endosperm ranged from 115.40 g to 399.90 g, 1.21 kg/m^3 to 1.39 kg/m^3, 0.00% to 94.48%, 7.93 s to 17.30 s 34.22% to 72.08 % and from 27.82% to 55.17%, respectively. Furthermore, the contents of starch, protein, oil, crude fibre, ash and soluble carbohydrates varied from 66.60% to 74.75%, 8.83% to 12.19%, 4.07% to 6.89%, 1.75% to 2.68%, 1.20% to 1.50% and from 0.03% to 0.71%, respectively. The significant negative correlations were established between the participation of the pericarp and the participation of the germ, 1000-kernel weight and the floatation index. Moreover, significant positive correlations were determined between three parameters of the kernel physical properties (density, milling response and the participation of the endosperm hard fraction) and contents of proteins and crude fibre. In addition, the protein content was positively correlated with the same parameters of physical properties and negatively correlated with the 1000-kernel weight and the starch content.

These results can be useful for the development of maize hybrids and maize-based food products with desirable nutritional and functional properties.

ACKNOWLEDGEMENTS

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FLASH SENSORY PROFILE AS A TOOL FOR RAPID SENSORY PROFILING OF FOODS: A CASE STUDY WITH GOAT CHEESE

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ABSTRACT
Nine samples of commercially available goat cheeses with and without herbs have been subjected to sensory profiling by using quick sensory profiling technique (Flash Sensory Profile (FP)). The collected data was analysed by Generalized Procustes Analysis, and results showed that products were perceived differently by the panel. Flavour together with taste were the most important sensory properties for samples discrimination. The use of herbs in goat cheese production affected cheese appearance, taste, and flavour. The goat cheeses produced without herbs were described as more bitter and sour in comparison to the samples containing herbs. The addition of herbs influenced that goat, buttery and milky flavour were less pronounced. The obtained results indicate that the applied methodology can be utilised as fast but efficient screening tool of sensory properties and convenient tool for differentiation between samples.
***Keywords**: goat cheese, sensory properties, sensory profile, Flash Sensory Profile*

INTRODUCTION
Sensory descriptive analysis is one of the most sophisticated tools in sensory science which provide detailed, consistent, and reliable characterization of products sensory properties by using trained sensory assessors. Among many, QDA® and Spectrum® are the most common descriptive techniques applied in the last 50 years (Varela and Ares, 2014). The main disadvantage of descriptive analysis is the time needed for its implementation.

Concomitantly with necessity to speed up the new product development process and to incorporate consumers needs as a key element in product success on the market, the application of fast performing sensory techniques become highly appreciated in the past ten years (Ares, 2015). One of the new rapid sensory descriptive method, which do not require participation of highly trained assessors and can provide quick results with respect to the end user, is Flash Sensory Profile (FP). It is more flexible than conventional descriptive methods such as QDA®, primarily because it can be performed with semi trained or naïve assessors, and in addition it enables that every assessor creates individual product profile by using his/her own list of descriptors. This method allows that the whole product set is evaluated comparatively by ranking their intensities for selected descriptors.

The application of fast performing sensory techniques is very useful particularly when there is a need to analyse sensory profile of relatively expensive products, such as traditional products (Škrobot et al, 2020). In the past decade, the goat cheese products have gained worldwide popularity. These products can be considered as premium. Flash profile has been applied to describe many different foods (Albert et al. 2011; Blancher at al., 2007; Delarue and Sieffermann, 2004; Jaros et al., 2009; Veinand et al., 2011). However, there are a limiting number of articles referencing to a sensory analysis of products such as goat cheese. The objective of this work was to examine appropriateness of FP method for comparison of sensory profiles of goat cheeses. Panel of ten semi trained assessors evaluated sensory profiles of nine samples of commercially available goat cheeses.

MATERIAL AND METHODS

Nine samples of commercially available goat cheeses were analysed (Figure 1). Three samples (S2, S3 and S4) were common goat cheese without addition of any herbs, while the other samples were with the addition of oak crust (S1), red pepper (S5), pepper (S6), wild garlic (S7), mint leaves (S8) and goat cheese with herbs mixture (S9).

Panel of ten semi trained assessors (8 woman and 2 man, aged between 25 and 50 years) was recruited for performing Flash Profile analysis. All assessors were recruited from the Institute of Food Technology, Novi Sad. The evaluation was conducted in individual sensory booths at room temperature (20 – 22 ºC), and each assessor was presented with the whole sample set simultaneously. All assessors had experience in classical descriptive sensory analysis while two of them are familiar with technology of cheese production, as well. The procedure of Flash Profiling consisted of two consecutive sessions. In the first session, the assessors were instructed to generate as many attributes as they want, but to avoid hedonic terms, in order to best describe the differences between samples. Furthermore, they were advised to arrange terms according to sense modality (appearance, odour, taste, flavour, texture, trigeminal sensations and after taste intensities and persistence). Within the second session, for each attribute the assessors, had to rank the samples with ties allowed. This second stage was performed in replicate.

For each individual attribute, ranking data were collected and analysed by using multivariate statistical technique Generalized Procrustes Analysis (GPA), which computes the best possible consensus among all subjects. A GPA analysis was carried out on the average data from the two replicates of the FP. The average sensory configuration obtained for the panel is displayed, as for Principal Component Analysis (PCA), on a score plot representing the inter-product sensory distances. Statistical analysis was performed by using software XLSTAT (version 2019.3.2, Addinsoft).

RESULTS AND DISCUSSION

Within Flash profile method, total of 82 sensory terms (Table 1) were generated by the panel, and each assessor used from 8 to 16 sensory descriptors. The results suggested that all assessors used rating scale in the same way and generally they gave rates that do match the consensus since residuals were low and similar across objects and assessors (data not shown). The assessors explained about 63% of the total variance of the initial data set. The GPA biplot map is presented in Figure 2.

From the GPA map it was evident that the sample S1 is perceived as the most different from the other samples. It was perceived as more hard with the most intense overall flavour and noticeable flavour of mushrooms. This is probably due to presence of oak crust. Other samples are positioned on both sides of the first axis and can thus be roughly separated into two groups: samples S2, S3 and S4 on the left side and S5, S6, S7, S8 and S9 on the right side. Samples on the left side were differentiated with more pronounced odour and flavour of milk and butter, and more intense bitter and sour taste. On the other hand, samples on the right side were described as less bitter, with recognisable spicy and herbs odour and flavour.

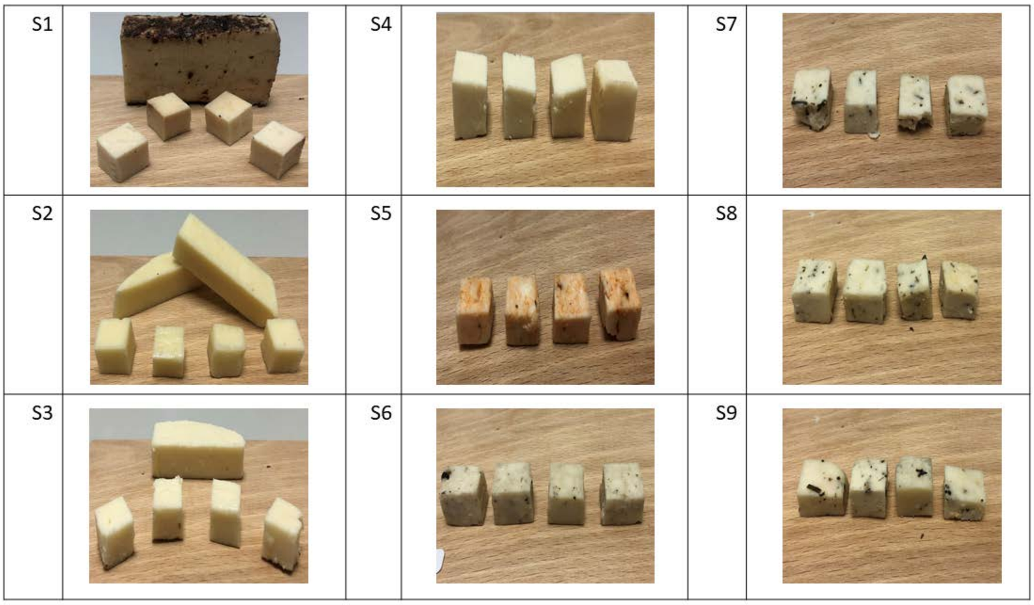

Figure 1. Goat cheese samples

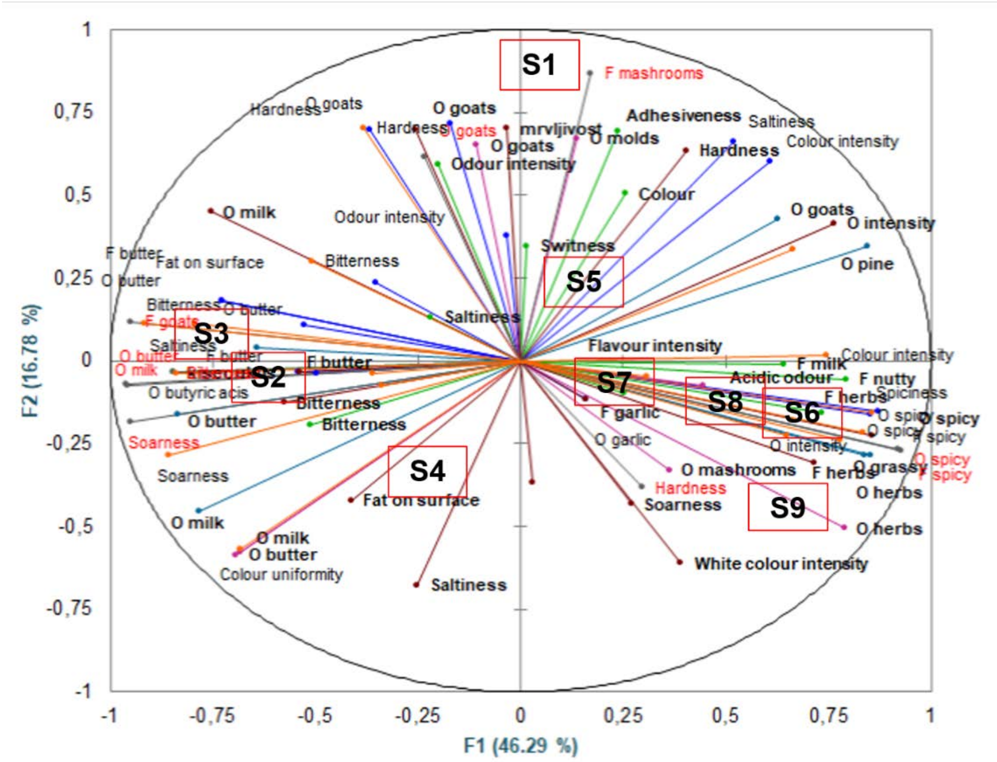

Figure 2. Biplot of General Procrusty Analysis performed on Flash Profile Analysis results for goat cheese samples

Table 1. Sensory attributes used for the evaluation of the dry fermented sausages by using Flash Profile method

Attributes	Flash profile descriptors	Abbreviation
Appearance	White colour intensity	-
	Colour intensity	-
	Colour uniformity	-
	Colour at cross section	Colour
	Fat visibility on surface	Fat on surface
Odour	Overall odour intensity	Odour intensity
	Odour of milk	O_milk
	Odour of spices	O_spicy
	Odour of butter	O_butter
	Odour of butyric acid	O_butyric acid
	Odour of goat	O_goat
	Odour of mushrooms	O_ mushrooms
	Odour of grassy	O_ grassy
	Odour of garlic	O_ garlic
	Odour of pine	O_pine
Taste	Saltiness	-
	Bitterness	
	Sourness	
	Sweetness	
Flavour	Overall flavour intensity	Flavour intensity
	Flavour of butter	F_ butter
	Flavour of nutty	F_nutty
	Flavour of milk	F_milk
	Flavour of garlic	F_garlic
	Flavour of herbs	F_herbs
	Flavour of goats	F_goats
	Flavour of mushrooms	F_mushrooms
Texture	Hardness	-
	Adhesiveness	-
	Cohesiveness	-

CONCLUSION

Flavour together with taste were the most important sensory properties for samples discrimination. The use of herbs in goat cheese production not only that affected cheese appearance, but has affected taste and flavour, as well. The goat cheeses produced without herbs were described as more bitter and sour in comparison to the samples containing herbs. Moreover, the addition of herbs influenced that goat, buttery and milky flavour were less pronounced. The obtained results indicate that the applied methodology can be utilised as fast but efficient screening tool of sensory properties and convenient tool for differentiation between samples.

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POSSIBILITIES AND APPLICATION OF DEGRADABLE PACKAGING MATERIALS

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ABSTRACT

There are many biodegradable and recyclable packaging materials available, alternatives for plastics: paper and cardboard; biodegradable polyethene (degradagle due to additive incorporated during production) and biodegradable plastic (made from renewable biomass-biopolymers in a relatively energy efficient process). The decomposition routes of degradable materials are reflected in the degradation for which realization a physico-chemical stimulus is required and biodegradation for which microorganisms are responsible. The global biodegradable plastic market was valued at $1.6 billion in 2019 and it is expected to reach $4.2 billion by 2027. The largest segment by application of biodegradable materials is in packaging with a market share of more than 60%. Some examples of degradable packaging existing on the market will be presented in the paper.
Key words: *packaging materials, degradable polymers, (bio)degradability, composting*

INTRODUCTION

Packaging is an integral and final part of each production line and aims to enable the final product safer handling, storage and transport to the customer. Synthetic polymers have long been the foundation of packaging materials. However, since synthetic polymers are non-biodegradable, reliance on them in the field of packaging industry has led to serious ecological problems due to massive usage and long life-cycle. An increased demand has appeared for packaging materials which are non-petroleum based, biodegradable, pose very minimal threat to environment and are manufactured from sustainable and renewable resources (Han et al., 2018). This replacement is justified by the fact that producing is unsustainable: synthesized plastics consumes 65% more energy and emits 30%-80% more greenhouse gases than bioplastics (Tajeddin and Arabkhedri, 2020). Biodegradable materials market, arose out of necessity but justifies its existence, and it has been continuously growing. The global biodegradable plastic market was valued at $1.6 billion in 2019 is expected to reach $4.2 billion by 2027, growing at a CAGR of 13.3% from 2020 to 2027 (Biodegradable Plastic Market). Some of the major manufacturers in the global biodegradable plastic market are BASF SE, Dow Inc., Novamont S.p.A., Mitsubishi Chemical Holdings, Natureworks, Corbion N.V., Eastman Chemical Company, Plantic, Danimer Scientific, Biome Technologies plc, etc. Industrial end users are Danone, Ferrero, Lavazza, Reckitt Benckiser, Tetra pack group, etc.

PARER AND CARDBOARD

Paper and cardboard are reusable, recyclable and biodegradable. Paper is a complex material made from plant fibers, that are obtained mechanically or chemically with the addition of various additives (adhesives, fillers, paints, etc.) which define the properties of the paper. It is formed on a sieve paper machine by draining the paper pulp. The paper is based on natural fibers that can be obtained from a large number of renewable resources. The paper recycling rate measured 33.5% in 1990, which was the base year against which the American Forest & Paper Association (AF&PA) began setting its recycling goals. In the 2019 paper recycling rate was 66.2%. AF&PA member companies are continuing to work toward a goal to increase the U.S. paper recycling rate to more than 70% by the end of 2020.

Paper cannot be recycled indefinitely. With every recycling, fibers become shorter. After being processed five to seven times, the fibers become too short for the production of new paper, requiring the addition of new fibers.

BIODEGRADABLE POLYETHYLENE

Among plastic packaging materials, polyethylene is the most commonly-used petroleum-based polymer in packaging application (Emadian et al., 2017). The increasing demand for this polymer has created the need to convert it into biodegradable material in a significantly shorter time. A possible solution is the use of additives, called prodegradants, that accelerate this process (Ammala et al., 2011). This additive makes polymer biodegradable by changing its chemical properties by breaking it down into small molecules. While preserving the physical appearance of the polymer, this additive does not change the physical properties of the polyethylene (Lazić et al., 2011). This technology is ideal for all disposable plastic products, such as disposable bags and food trays.
The tendency of plastic products to undergo degradation induced by UV radiation, heat, or ozone is increased by the addition of prodegradants to these polymers (Singh and Sharma, 2008). Transitional metal ions (iron, cobalt and manganese) are the most commonly used prodegradant additives. Metal ions are mainly introduced in traces in the form of organic complexes. In addition to metal ions, combinations of metal carboxylates and aliphatic poly hydroxy-carboxylic acids, fatty acid amides, ferrocene, metal oxides such as TiO_2 and ZnO, additives having a chromophore group, benzophenone, β-diketones, some organic peroxides and hydroperoxides (Ammala et al., 2011).

BIOPOLYMERS

The new generation of the packaging materials, fully consisted of biomaterials, can be divided into three main categories regarding their origin and production methods:

1. Polymers extracted/isolated directly from biomass

This category of biopolymers has been investigated extensively (Šuput et al., 2019) and it is most present on the market. Biopolymer film is usually produced from food-derived ingredients using wet or dry manufacturing process and it is defined as free-standing sheet that can be placed on or between food components (Šuput et al., 2015). The main groups of chemical compounds, which serve as sources for edible films and coatings, are polysaccharides (cellulose, chitin, pectin, starch, etc.), proteins (whey protein, casein, collagen, zein, soy protein, myofibrillar proteins of animal muscle) and lipids (free fatty acids, wax, paraffin, resin) obtained from plants, marine and domestic animals (Šuput, 2016). The largest segment by application of biodegradable plastics is in packaging, both in terms of value as well as volume, with a market share of more than 60.3%. This is due to the fact that biodegradable plastics are being increasingly used to manufacture single use packaging materials such as shopping bags, disposable cutlery, etc. Biopolymer significant feature is that they have a high potential to carry active ingredients: anti-browning agents, colorants, flavors, nutrients, spices, antimicrobial and antioxidant compounds that can extend product shelf-life, improve the organoleptic properties and food nutritional value, which leads to improving the quality and improving the safety of the packaged product (Šuput et al., 2019).
Biopolymers commonly used for production of degradable and disposable products are usually starch: United Biopolymers SA (Portugal), Kompuestos (Spain), Indochine Bio Plastiques (Malaysia), Agrana Stärke (Austria), BIOTEC (Germany), cellulose: Futamura (UK), agar: Loliware, bio-resin: Pond (Denmark), biodegradable biocomposites: Sulapac (Finland), Promateris (Romania), biodegradable polyesters: Avantium (Netherland), Microtec SRL (Italy) and many others.

2. Polymers produced by classical chemical synthesis and bio-monomers

The most known biopolyesteris obtained by chemical synthesis is poly-lactic acid (PLA), biodegradable thermoplastic linear polyester similar to polystyrene. The raw material for obtaining the lactic acid is obtained by fermentation of glucose or starch from another source (corn, wheat, whey, molasses, etc.) (Wackett, 2008). PLA has been widely accepted as biodegradable polymer for packaging materials due to its stiffness, transparency, processability and biocompatibility. PLA

exhibits a better thermal processability, which allows for the various processing methods of PLA such as injection molding, blow filming, cast filming, fiber spinning, thermoforming, etc. PLA is mainly processed into thermoformed pads and containers for packing and serving food, films, transparencies and bottles and other packaging blown, but also mixed with other materials (Ivanković et al., 2017).

According to a recent market report on Biodegradable Plastics Market, production of PLA is the largest segment by type with a market share of more than 45.1%. There are many manufacturers and auxiliaries based on PLA: Zhejiang Hisun Biomaterials (China), Taghleef Industries S.p.A. (Italy), BIO-FED (Germany), Sidaplax (Belgium), BIOTEC (Germany), NatureWorks (Netherland), FKuR Kunststoff (Germany), Danimer Scientific (USA), CJ (Germany), CARBIOLICE (France), SELFECO (USA), etc.

3. Polymers obtained directly from natural or genetically modified organisms

Polyhydroxyalkanoates (PHAs) are polyesters of various hydroxyalkanoates that are synthesized by microbial fermentation (*Alcaligenes, Azotobacter,Bacillus, Halobacterium, Rhizobium*, etc.). PHAs are hydrophobic, non-toxic and crystalline thermoplastic elastomers, whose properties depend on the PHA monomer compositions. Depending on the bacteria and the carbon source, the polyhydroxyalkanoate may be manufactured from rigid brittle to plastic to rubber-like polymer. Have similar properties such as propylene and polyethylene; they are elastic and thermoplastic (Li et al., 2016).

Another promising material applied in packaging, medical and agriculture sector is polyhydroxybutyrate (PHB) - the most common derivative of PHA, obtained by bacterial fermentation of sugar or lipid. PHB characterises with high crystallinity (up to 70%), which is the reason for great mechanical properties. It has been used for shortterm food, cosmetics and pharmaceutical products packaging applications, as well as in agriculture (Lin et al., 2018). PHB completely degrades into water and carbon dioxide in the aerobic conditions. Biodegradation in favorable conditions takes 5–6 weeks (Botana et al, 2010).

There are many manufacturers and auxiliaries for bio-derived and biodegradable plastic suitable for various applications and industries (electronics, cosmetics, bio-med, aerospace, consumer, agriculture, packaging, etc) based on PHA and PHB: Kaneka Corporation (Japan), BIO-FED (Germany), CJ (Germany), Danimer Scientific (USA), EggPlant (Italy), etc.

THE MECHANISM OF POLYMER (BIO)DEGRADATION

Degradation is a major feature of biodegradable polymers and plastics, based on the fact that most of these materials are naturally organic or an additive for decomposition has been added to synthetic polymers, and they are subjected to physically and/or mechanically and/or chemically induced degradation. The degradation process occurs due to abiotic or biotic activities, or most often as a combination of both (Lazić et al., 2011). The degradation process consists of two phases: decomposition (depolymerization) and mineralization. The initial phase - depolymerization, is associated with the deterioration of physical characteristics, such as brittleness and fragmentation. It is possible to classify environmentally degradable (bio)polymers and plastics according to the mechanism of the first phase as "hydro-biodegradable" when this mechanism of the first phase takes place by hydrolytic processes, mediated or not by exoenzymes, and as "oxo-biodegradable" when it is thermally or photophysically induced oxidation, whether or not by exoenzymes (Krzan et al., 2006). The second phase is the final conversion of plastic fragments (mineralization). Most polymers are too large to pass through cell membranes, so they must first be depolymerized before being absorbed and biodegraded within microbiological cells. Dominant groups of microorganisms and degradation pathways associated with polymer degradation are often determined by environmental conditions. When O_2 is available, aerobic microorganisms are mainly responsible for the destruction of complex materials, up to biomass, CO_2, and H_2O as final products. On the other

hand anaerobic microorganisms are responsible for the decomposition of polymers into biomass, CO_2, CH_4 and H_2O under methanogenic (anaerobic) conditions (Shah et al., 2008).
For all polymer and biopolymer materials, the degradation rate is increased by the addition of readily degradable components containing hydrolyzing functional groups, such as: starch, polyesters, polyanhydrides, or polyamides. Another approach is the addition of active components in most commonly polyethylene, such as: photo- or thermal-sensitive additives. After exposure to sunlight or heat, these additives accelerate oxygen uptake with the formation of peroxides and hydroperoxides that generate free radicals that randomly attack and break bonds leading to the formation of low molecular weight products. (Krzan et al., 2006). This process is in full sense confirmed as biodegradation only when carbon compounds become food and microorganisms are transformed into water, biomass or carbon dioxide.

COMPOSTING

Biodegradable material is not necessarily compostable (can biodegrade during time or under specific conditions), while compostable material is biodegradable. Composting is biological process where in controlled conditions (composting cycle), polymers degradation occurs, resulting in a water, carbon dioxide and compost. Industrial composting cycle implies application of composting temperature (can reach up to 70 °C) and humid conditions and activity of certain microorganisms. The composting process takes place for months (Ivanković et al., 2017). The resulting organic compost is completely environmentally neutral. The process of composting is a key segment of dealing with organic waste and return the remains of biodegradable materials in the new use. In Europe, the main leaders in composting are Germany and Netherlands, where for a very long time composting is carried out effectively and successfully.
Industrial composting is defined by national and international standards (eg. EN13432, ASTM D-6900). Basic frame of rules relies on EN13432 and EN 14995. Standard EN 13432 defines the characteristics of packaging materials must fulfill to be labeled as compostable and acceptable for recycling of organic solid waste. EN 14995 extends the scope of plastic that is used for non-packaging application. Beside industrial composting, other option is home composting, which differs since it takes place at lower temperatures in the compost heap. Materials must be specifically tested to demonstrate composability in home conditions.

CONCLUSION

It is an indisputable fact that polymer materials (plastics) rightly occupy a leading position in the field of packaging materials, but their main disadvantages are obtaining from renewable sources, as well as the very negative impact of the amount and accumulation of plastic waste on environment. For this reason, there was a need for an increasing share of degradable packaging materials in the field of packaging. Degradable packaging materials are an environment-friendly substitute for synthetic polymers, due to biodegradability, agro-industrial waste (biomass) usage, and renewable raw materials. In addition, they are desirable in terms of availability and cost effectiveness. Degradation flows in two directions: as disintegration of materials into physically smaller components and as biodegradation, where microorganisms play a decisive role. The goal is to close the cycle because the final components of biodegradation are CO_2/CH_4, H_20 and biomass (humus in the case of composting). It is necessary to make an additional effort in terms of investing in the infrastructure needed for mass production of degradable packaging and to include government initiatives to eliminate single-use plastic and regulations against the use of conventional plastic products.

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QUALITY CHARACTERISTICS OF PASTA ENRICHED WITH NON-CONVENTIONAL FLOURS

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ABSTRACT

The aim of this study was the evaluation of several properties of commercial pasta made from a mixture of soft wheat semolina and different types of flours (sesame, pumpkin, black cumin and hemp flour) at the ratio 80:20. Additionally, two commercial pasta products containing exclusively durum wheat and soft wheat semolina were selected as control samples. The pasta samples enriched with non-gluten flours had the higher values of cooking losses, swelling index and water absorption. The highest value of cooking loss was recorded for pasta sample with addition of pumpkin flour. The texture analysis showed that non-wheat ingredients apparently influenced texture properties of cooked pasta products. The presence of non-conventional flour to the pasta formulation had negative effects on the colour uniformity and resistance to breaking of uncooked samples. Cooked pasta samples were discriminated mostly on odour intensity, bitter taste, flavour persistence and overall acceptability.

Keywords*: pasta products, cooking quality, textural properties, sensory properties*

INTRODUCTION

New nutrition habits have increased the interest of the food industry in marketing food products fortified with non-conventional raw ingredients. The growing interest has promoted the launching of various food products, particularly in specialty health-food stores where products with the addition of attractive raw materials are taking an increasing share. Cereal products are especially exposed to this trend.

Pasta is worldwide consumed product due to simplicity of preparation, long shelf life, low cost, nutritional quality and palatability (Petitot et al, 2010, Spinelli et al., 2019). It is usually made from durum wheat semolina which is considered as the most appropriate raw material for pasta production providing unique properties of pasta. The quality traits of great importance for pasta products are good cooking resistance and firmness, low stickiness and a limited release of organic materials into the cooking water (De Noni et al., 2010; Lucisano et al, 2012; Islas-Rubio et al., 2014). Although pasta is a good source of carbohydrate with a low glycemic response, it is not considered as a nutritionally balanced product due to its low protein biological value and low fibre content (Littardi et al, 2020). Along with this, relatively simple pasta formulation defines these products as a suitable food matrix for inclusion of nutritionally valuable raw materials. In that context, a high diversity of pasta formulations is available in the market, like pasta with addition of other flours (such as oat, barley, etc.), pseudocereals (such as buckwheat, quinoa), and legumes (such as lentils, chickpea, etc.). Replacement of wheat flour by significant amounts of non-gluten forming flours can seriously constrain physicochemical and sensory quality of pasta goods after cooking in terms of texture, colour and taste (Manthey et al., 2004; Littardi et al., 2020). Although inclusion of non-conventional ingredients in food formulations is an attractive alternative for the healthy food market, to achieve good balance between sensory and nutritional aspects still remains a major challenge.

The purpose of this paper was to evaluate the cooking behavior of commercial pasta made from a mixture of soft wheat semolina and different types of flours (sesame, pumpkin, black cumin and hemp flour). Evaluation of colour and texture properties and finally sensory analysis were also performed to verify their acceptability compared to control pasta samples.

MATERIAL AND METHODS

Commercial pasta samples made from a mixture of soft wheat semolina and different types of flours (sesame, pumpkin, black cumin and hemp flour) were purchased from local health-food stores. Two commercial pasta products containing exclusively durum wheat and soft wheat semolina were selected as control samples. In order to minimize the sample variance, all packages of the same brand were supplied from the same batch of production.

Moisture (method 934.01), ash (method 942.05), protein (method 920.87), and fat content (method 920.39) were quantified according to AOAC (2000), and carbohydrates content was determined by difference. Two independent measurements were carried out on each sample.

To assess the pasta cooking quality, sample (100 g) was cooked in 1 l of boiling tap water and the optimal cooking time was taken to be when, after squeezing the sample between two glass plates, the inner white core of the pasta disappeared. The cooking loss was determined gravimetrically by weighing the residues after evaporating the cooking water to dryness in an oven-tray (130 °C for 90 min). The water absorption index was measured as the weight increase of pasta before and after cooking, and was expressed as percent weight gain with respect to the weight of uncooked pasta. Swelling index of cooked pasta was evaluated by drying pasta samples to constant weight at 103 °C and was expressed as (weight of cooked pasta)- (weight of pasta after drying)/ (weight of pasta after drying).

The colour of uncooked and cooked pasta samples was measured by the Minolta Chroma Meter CR-210 (Minolta, Osaka, Japan). Results were expressed in the CIELAB space as L* (lightness; 0=black, 10= white), a* (+a= redness, -a= greenness) and b* (+b=yellowness, -b=blueness) values.

The texture of cooked pasta was determined with two compression cycles test using a pasta firmness rig (HDP/PFS). The pre-test speed was 1 mm/s, while the test speed was set on 5 mm/s and the compression distance was 75% of the original size. The resulting force-deformation curve was used to determine the following textural parameters: hardness, cohesiveness, elasticity and chewiness.

Sensory evaluation was carried out on uncooked and cooked pasta samples by a panel of ten trained accessories using a descriptive analysis technique. In particular, panellists were asked to evaluate pasta samples for the following attributes: odour, colour intensity, colour uniformity and resistance to breaking of uncooked pasta and firmness, adhesiveness, colour intensity and uniformity, odour (overall intensity, on wheat, on raw material), flavour (overall, on wheat, on raw material, persistence), taste (sweet, sour, savory and bitter) and overall acceptance on cooked samples.

The experimental data were subjected to one-way analysis of variance (ANOVA). Results are reported as average ± standard deviation. A Tukey's honestly significant difference (Tukey's HSD) test was carried out to determinate significance differences ($P < 0.05$) between samples.

RESULTS AND DISCUSSION

All pasta samples had moisture contents below 13.5% (maximum moisture content for dried pasta established by Serbian regulation on the quality of grain, milling and bakery products and pasta), assuring a prolonged shelf-life. The protein content ranged from 10.31% to 15.93%. The highest values of proteins were recorded for samples with pumpkin and sesame flour addition (15.22% and 15.93%, respectively). Compared to the control samples, pasta samples with addition of nonconventional flours had the higher values of fat and ash content and their values ranged from 1.58 to 4.39% and from 1.35 to 1.78%, respectively.

The fortification of pasta with nonconventional flours had a noticeable impact on the cooking quality (Table 1). These samples exhibited higher values of cooking loss, swelling index and water absorption. The addition of flours with non-gluten forming proteins disrupts the integrity of the gluten network, allowing increase leaching of soluble solids into the cooking water. Although these samples had higher values of cooking losses then control samples, their values are considered acceptable (below 8 g/100 g) (Foschia et al., 2015).

Table 1. Cooking properties of pasta samples

	Optimum cooking time (min)	Swelling index (g water/g dry pasta)	Water absorption index (g/ 100 g)	Cooking loss (g/100 g)
Durum semolina	10:30	1.42±0.10	117.15±2.4	5.08±0.11
Wheat semolina	10:21	1.52±0.14	113.80±1.87	5.15±1.10
Sesame	9:15	2.48±0.22	159.64±4.30	6.31±1.56
Pumpkin	9:30	1.57±0.30	112.85±2.88	6.72±2.11
Black cumin	9:00	1.94±0.08	140.17±3.54	6.15±1.42
Hemp	8:40	1.74±0.15	134.18±5.10	6.21±1.88

Table 2 shows the L*, a* and b* values for all pasta samples before and after cooking. Due to various raw materials, there was a considerable difference in colour among the different pasta samples. After cooking, these differences were more pronounced. The largest changes as a consequence of heat treatment were observed in the pasta sample with the addition of black cumin. In comparison to the other samples, pasta containing black cumin expressed the darker colour, which may be acceptable to some consumers if such a product has a better nutritional value.

Table 3. Colour properties of pasta samples

	L*	**a***	**b***	**L***	**a***	**b***
	Uncooked pasta			**Cooked pasta**		
Durum semolina	88.66±0.23a	-0.93±0.06c	24.68±0.35a	65.40±1.89b	-1.95±0.15c	24.36±0.60a
Wheat semolina	89.18±0.46a	-0.60±0.08c	18.39±0.55b	69.14±27.44a	-1.70±1.45c	13.48±6.48b
Sesame	89.92±0.21a	0.21±0.04b	12.82±0.34c	70.10±0.69a	0.14±0.16b	14.11±0.67c
Pumpkin	79.39±0.20a	-2.73±0.04d	17.62±0.29b	58.89±1.19c	-2.42±0.32c	16.13±0.67b
Black cumin	63.59±0.49b	1.49±0.01a	6.47±0.03c	32.93±0.58e	2.95±0.16a	1.05±0.50d
Hemp	77.36±0.50a	1.72±0.07a	15.54±0.35d	53.41±0.82d	3.14±0.26a	12.97±0.31c

Mean values ± standard error of five replicates; values separately shown for uncooked and cooked samples followed by the same letter in the same column are not significantly different (p<0.05)

Textural parameters after pasta cooking are important attributes since pasta with good texture is one of the key priorities for consumer choice. In general, high values of springiness, cohesiveness and hardness are acceptable (Odey, 2020). The textural properties of pasta are influenced by many factors such as formulation, chemical characteristics of raw materials and processing conditions (extrusion, forming and drying). The obtained results highlighted high heterogeneity. The values of all tested parameters for pasta with non-conventional flours were significantly lower compared to control samples. The lowest values of hardness, cohesiveness and chewiness were recorded for pasta with hemp flour.

Table 4. Textural properties of cooked pasta samples

Sample	Hardness (g)	Cohesiveness	Springiness	Chewiness (g)
Durum semolina	25201.43a	0.67a	0.85a	14404.04a
Wheat semolina	13559.54b	0.60b	0.88a	7249.18b
Sesame	5849.52cd	0.41c	0.75bc	1775.07c
Pumpkin	6630.99c	0.42cd	0.81ab	2370.75c
Black cumin	4633.09cd	0.38d	0.66c	1182.46c
Hemp	3124.62d	0.29e	0.82ab	757.49c

Data are expressed as means (n=5). Values in the columns followed by different lowercase letters are significantly different (p<0.05)

Sensory analysis performed on uncooked and cooked samples showed high diversity for all tested attributes. In the case of uncooked samples, the addition of non-conventional flour to the pasta

formulation had negative effects on the colour uniformity and resistance to breaking (data not shown). Regarding the cooked pasta samples, presence of non-conventional flours caused a lower score for overall acceptance compared to durum semolina pasta. It is worth noting that the wheat semolina pasta had slightly higher score of the same attribute than pasta samples with sesame and pumpkin flour. Pasta samples enriched with non-conventional flours generally had higher ratings in overall odour intensity, overall flavour intensity, flavour persistence and bitter taste. In addition, pasta samples enriched with black cumin flours had very intense bitter taste, flavour and odour that further compromised its quality. In terms of firmness and adhesiveness, tested samples showed comparable results with control samples, which is inconsistent with results of texture analysis.

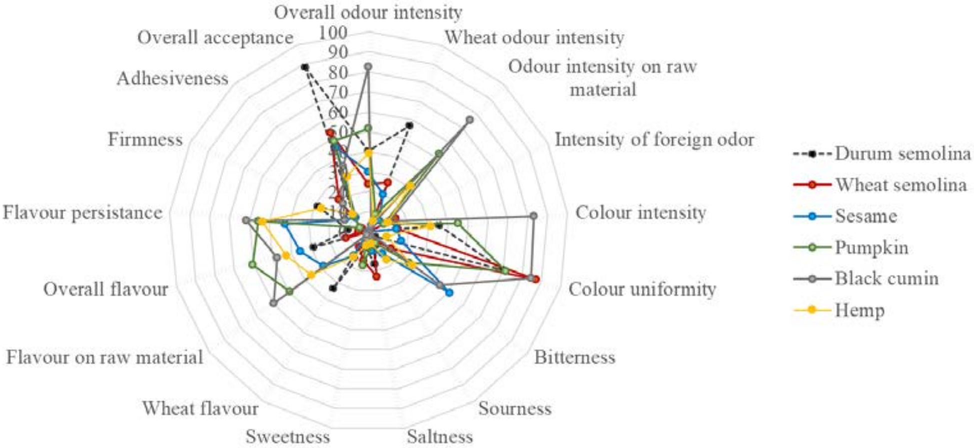

Fig. 1. Sensory analysis of pasta samples

CONCLUSION

The tested pasta samples showed different physical, sensory properties and textural characteristics, which may be due not only to the raw material characteristics but also to the processing conditions. They also showed different overall acceptance as compared to the durum semolina pasta. This study showed that use of alternative flours in pasta formulations confer interesting quality characteristics, providing modifications in the nutritional quality of widely consumed products which are beginning to shift interest away from traditional foods. Further work should be conducted in order to study bioaccessibility and digestibility of compounds that have nutritional interest.

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