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POSSIBILITIES OF MAIZE HYBRIDS UTILISATION IN CANNED BABY CORN PRODUCTION

MOGUĆNOSTI PRIMENE HIBRIDA KUKURUZA U PROIZVODNJI BABY CORN KONZERVISANE HRANE

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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 without sugar, and with the addition of potassium sorbate and potassium metabisulfite 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.

***Keywords**: maize hybrids, baby corn, canned vegetables, food production.*

REZIME

Kukuruz (Zea mays L.) je treća najviše gajena žitarica na svetu, posle pšenice i pirinča. Klipovi kukuruza ubrani dva do četiri dana nakon svilanja, pre oplodnje, mogu se klasifikovati kao baby corn. Baby corn ima visoku hranljivu vrednost i svarljivost, slatki ukus i privlačnu boju, dok ga istovremeno mekana i hrskava struktura čini izvrsnim sastojkom za različita tradicionalna i kontinentalna jela. Može se konzervisati fermentacijom, direktnim zakiseljavanjem ili kombinacijom metoda, procesnih parametara i aditiva kako bi se dobili ukiseljeni proizvodi. Proizvodnja baby corn konzervisane hrane u industrijskim razmerama u Srbiji trenutno je zanemarljiva. U ovom istraživanju korišćeno je pet hibrida kukuruza: dva žuta i jedan beli zuban, šećerac i žuti kokičar. Ispitano je pet receptura naliva sa sirćetnom kiselinom, od kojih dva sa dodatkom kalijum sorbata. Nalivi sa konzervansom ostali su stabilni nakon 16 meseci bez promene boje tečnosti i klipa kukuruza. Vrednost pH naliva kretala se u rasponu od 3,39 do 3,89. Konzervisani hibridi ZP 366 i ZP 611k, u nalivu sa oznakom Broj 5, pokazali su najbolje senzorne karakteristike. Sadržaj proteina utvrđen u ZP 366 (9,56%) i ZP 611k (10,23%) nije se značajno razlikovao u odnosu na integralno kukuruzno brašno, dok su sadržaj sirove celuloze (7,67 i 6,88%) i pepela (21,96 i 20,72%) bili znatno viši nego u brašnu (sirova celuloza: 2,40; 2,64%, pepeo: 1,35; 1,48%, redom). Ovo istraživanje će se nastaviti kako bi se primenili preliminarni zaključci kao i nova saznanja vezana za ovu temu.

***Ključne reči:** hibridi kukuruza, baby corn, konzervisano povrće, proizvodnja hrane.*

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 Serbia producing around 8,000,000 metric tons and taking 16th place (*World Agricultural Production.com, 2021*). Maize is the predominant cereal crop in Serbia, accounting for approximately 56 % of the total cultivated area sown with cereals (*Novković et al., 2020*).

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 the 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; Pandey et al., 2000*). Baby corn has been used as a 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. The 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 (*Jinjala et al., 2016*). 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 (*Muthukumar et al., 2005*).

There is great potential in processing 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; Joshi, 2009; Pandey et al., 2000*). 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 pasteurization 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 (*Singh et al., 2019; 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*).

Canned vegetables can be just as healthy as fresh vegetables because they remain fresh after processing. Studies have shown that most frozen, fresh, and canned vegetables have similar amounts of most nutrients after being used in a prepared meal. Even though they do lose some nutrients in the canning process (some water-soluble and heat-sensitive vitamins C and B), the thermal processing increases the availability of lycopene and β-carotene (*Featherstone, 2016*). Apart from being used as food, baby corn has a dual purpose as a fodder crop for animal feed production (*Dar et al., 2014*).

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 valorization of maize, by increasing the economic value of this, for our country the most important, carbohydrate feedstock (*Radosavljević et al., 2020; Milašinović-Šeremešić et al., 2018*).

The objective of our preliminary study was to evaluate the possibilities, identify the most suitable maize genotypes for canned baby corn production, optimal harvesting moment, technological value, and quality parameters of this vegetable in the production of high-quality food, 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 the 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 a 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 the 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

Brine	Ingredients
1	100 ml of acetic acid (9%), 10 g of caster sugar, 20 g of table salt, up to 1 litre of water
2	200 ml of acetic acid (9%), 10 g of caster sugar, 20 g of table salt, up to 1 litre of water
3	300 ml of acetic acid (9%), 80 g of caster sugar, 80 g of table salt, up to 1 litre of water
4	300 ml of acetic acid (9%), 80 g of caster sugar, 80 g of table salt, 2 g of potassium metabisulfite, 1 g of potassium sorbate, up to 1 litre of water
5	20 ml of acetic acid (96%), 30 g of table salt, 2 g of potassium metabisulfite, 1 g of potassium sorbate, 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 without sugar, and with the addition of potassium sorbate and potassium metabisulfite, marked as 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 sample preparation (mesh 0.5 mm).

Dry matter content 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 the Weende method adjusted for Fibretec™ 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 (*Figure 1*). 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 (*Figure 2*). Cob girth of the investigated ZP baby corn cobs ranged from 10.1 to 15.2 mm. *Lone et al.* (2013) reported that the length of dehusked baby corn cobs treated with different organic and inorganic fertilizers ranged from 8.67 cm to 10.90

cm, and the 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 the ear, irrigation, fertilization, green matter yield, etc., should be included in further studies.

Short silk *Long silk*

Fig. 1. Maturity stages of corn for canning

Short silk *Long silk*

Fig.2. Correlation between silk lengths and length of corn cobs for canning

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 (Tables 2 and 3). The chemical composition of the respective ZP maize hybrids whole-grain flour is also represented in Table 3, for comparison. 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 a pH of 5.18 (Table 2). The pH value of fresh corn is usually in the range of 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, even though stable 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.

The chemical composition of the commercially 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. 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 ZP 366 and ZP 611k (9.88 and 12.08%, respectively), while crude fibre content (7.67 and 6.88 %), as well as ash content (21.96 and 20.72 %), were significantly higher than in respective whole-grain maize flours (crude fibre: 2.40; 2.64 %, ash: 1.35; 1.48 %) (Table 3). *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 the protein content of baby corn was between 9.91 and 11.02 %, which is in accordance with our findings.

Table 2. Sensory properties of the canned baby corn products

Sample	pH	Brine appearance properties	Smell	Colour	Cob consistency	Taste	Texture
Commercial baby corn	5.18	Liquid clear, pale yellow	Mild smell, reminds of cooked sweet corn with a discrete acidic note	Dull pale-yellow colour	Cobs flexible, hard enough for cutting	Very mild, unsalted and not sour	Slightly crunchy
ZP 366, brine 4	3.72	Liquid clear, almost colourless	Slightly sour smell	Pale yellow, less intensive colour	Cobs flexible, hard enough for cutting	Much saltier, less sour, slightly bitter	Slightly crunchy
ZP 366, brine 5	3.88	Liquid clear, almost colourless	Sour smell	Pale bright yellow	Cobs flexible, hard enough for cutting	Sour and salty (savoury)	Slightly crunchy
ZP 611k, brine 4	3.39	Liquid clear, almost colourless	Pungent sour smell	Very pale bright yellow, almost white	Thick cobs, harder to cut, kernels separate from the cob	Mostly sour taste	Chewy, not crunchy enough
ZP 611k, brine 5	3.89	Liquid clear, almost colourless	Sour smell	Very pale bright yellow, almost white	Thin flexible cobs	Pleasant savoury taste, salty and sour enough. Reminiscent of classic pickles	Crunchy

Table 3. 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

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 as well as the overall acceptability of the canned product was best with hybrids ZP 611k and ZP 366 preserved in brine without sugar and with the addition of potassium sorbate and potassium metabisulfite (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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