KRMIVA

ISSN 0023-4850 (Tisak)
ISSN 1848-901X (Online)

NUTRITIONAL COMPOSITION OF GRAIN KERNELS IN DIFFERENT DRYING PROCESSES

USPOREDBA NUTRITIVNOGA SASTAVA ZRNA KUKURUZA PRIMJENOM RAZLIČITIH TRETMANA SUŠENJA

Ana Matin, I. Brandić, F. Pucko, B. Matin, Vanja Jurišić, Mateja Grubor, Ivana Tomić, Tajana Krička, A. Antonović, K. Špelić

Original scientific paper - Izvorni znanstveni članak
Received - Primljeno: 14. March – ožujak 2025
Revised - Revidirano: 15. May - svibanj 2025
Accepted - Prihvaćeno: 22. May – svibanj 2025
https://doi.org/10.33128/k.67.1.1
UDK 633.15:631.563.2

SUMMARY

Maize is one of the most important agricultural crops due to its adaptability and a wide use in the food industry, animal-feed industry, and in other sectors of the economy. This paper compared the nutritional composition of hybrid and traditional maize varieties (the white and the red maize) under the influence of different drying methods. The samples dried in a fluidized-bed dryer and a vacuum dryer at the temperatures of 60, 70, and 80°C were analyzed. The nutritional properties were determined by the content of protein, starch, fat, and the proportion of the elements such as carbon (C), hydrogen (H), nitrogen (N), oxygen (O), and sulfur (S). These elements' analysis helps to optimize animal nutrition, increase the utilization of nutrients, and improve production results (milk, meat, and eggs). The study results indicate that the nutritional properties are better preserved during a vacuum drying (VD), while the maize dries faster in a fluidized bed. The hybrid maize released moisture faster than the conventional varieties. After the vacuum drying, the higher levels of carbon (C), hydrogen (H), nitrogen (N), and sulfur (S) were detected, while a decrease in the protein content was mainly influenced by a higher temperature. The most favorable treatment for protein preservation was the vacuum drying at 60°C, while the highest percentage of starch was established after the vacuum drying at 70°C. The fat content was highest after drying in a fluidized bed at 70°C and the lowest after the vacuum drying at 80°C.

Keywords: maize, hybrids, traditional varieties, nutrient composition, drying

izv. dr. sc. Matin Ana, e-mail: amatin@agr.hr, orcid.org/0000-0002-9949-0278; dr. sc. Ivan Brandić, e-mail: ibrandic@agr.hr, orcid.org/0000-0003-4135-8757; Filip Pucko mag. ing.; izv. prof. dr. sc. Vanja Jurišić, e-mail: vjurisic@agr.hr, orcid.org/0000-0002-4071-8637; dr. sc. Mateja Grubor, e-mail: mgrubor@agr.hr, orcid.org/0000-0001-6374-5753; Ivana Tomić, mag. chem.; prof. dr. sc. Tajana Krička, e-mail: tkricka@agr.hr, orcid.org/0000-0002-8044-486; Karlo Špelić, mag. ing., e-mail: kspelic@agr.hr, orcid.org/0009-0009-0467-054X, University of Zagreb, Faculty of Agriculture Svetošimunska cesta 25, 10000 Zagreb, Hrvatska
Božidar Matin, mag. ing., e-mail: bmatin@sumfak.unizg.hr, orcid.org/0000-0002-1675-4240; prof. dr. sc. Alan Antonović, e-mail: aantonovic@sumfak.unizg.hr, orcid.org/0000-0002-5579-0930, University of Zagreb, Faculty of Forestry and Wood Technology, Svetošimunska cesta 23, 10000 Zagreb, Hrvatska

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important agricultural crops in the world and plays a key role in the food industry and as animal feed (Rouf Shah et al., 2016). Its nutritional composition varies according to variety, growing conditions, and processing methods, which has a direct impact on its nutritional value and uses (Augustin et al., 2016). The main maize components include moisture, proteins, starch, and fats, while its elemental composition consists of carbon, hydrogen, oxygen, nitrogen, and sulfur, which determine the nutritional and energy properties of the grain (Ashogbon, 2022). The maize's moisture content is particularly important, as it influences stability during storage and susceptibility to spoilage (Matin et al., 2007). A protein composition is also important for animal nutrition, with the varieties with a higher protein content, such as the white maize, having an advantage when feeding poultry and pigs (Stein et al., 2016). On the other hand, the red maize, which contains most starch, is a valuable source of energy. The hybrid maize, with a balanced composition of proteins, starch, and fats, can serve as a universal option for different nutritional needs (Poole et al., 2021). In addition to the variety itself, the drying methods play an important role in the maintenance of maize's nutritional properties (Matin et al., 2021). A fluidized-bed drying (FBD) and a vacuum drying (VD) are used to extend the maize's shelf life and adapt its nutritional properties to the end consumer (Sivakumar et al., 2016). Temperature fluctuations, however, can exert different effects—the higher temperatures increase the protein content in some cases, while they lead to its decrease in other cases. The fat content is less sensitive to temperature fluctuations, but a slight reduction is observed at the higher temperatures (Hansen et al., 2004). The maize's elemental composition can also be changed, depending on the drying conditions, with the white maize generally containing most carbon and nitrogen (Liu, 2011). In this paper, the nutrient and elemental composition of different maize varieties and the influence of a drying process and temperature on the change of their chemical properties were investigated. The aim of the research was to determine the optimal processing conditions to preserve the maize's nutritional value, with a focus on its use in animal nutrition and its potential industrial benefits.

MATERIALS AND METHODS

The study was conducted in 2023 and three maize hybrids/varieties were used — the hybrid maize and the white and red maize varieties grown in Zagreb County. The analyses were first conducted on the raw samples and then on the samples dried at three different temperatures, at 60, 70, and 80°C, respectively, to a maize-grain equilibrium moisture content amounting to 14%. Drying was performed in two ways, as a fluidized-bed drying

Table 1 The content of the researched parameters of hybrids and the white and red maize in a natural state (%)

Tablica 1. Sadržaj istraživanih parametara hibrida, bijeloga i crvenog kukuruza u prirodnome stanju (%)

Researched parameters Istraživani parametri	Hybrid Hibrid	White Bijeli	Red Crveni	P value p vrijednost
Moisture / Vlaga	24.13 ± 0.93^a	24.91 ± 1.29^a	23.97 ± 0.52^a	0.237
Proteins / Bjelančevine	5.40 ± 0.01^a	7.83 ± 0.78^a	7.017 ± 0.91^b	0.033
Starch / Škrob	43.59 ± 0.09^a	39.68 ± 0.47^b	44.77 ± 0.06^a	0.009
Fats / Masti	4.56 ± 0.02^a	4.12 ± 0.01^b	4.23 ± 0.02^a	0.021
Carbon (C) / Ugljik (C	32.78 ± 0.14^a	33.35 ± 0.30^a	33.47 ± 0.17^b	0.042
Hydrogen (H) / Vodik (H)	5.43 ± 0.31^a	5.48 ± 0.50^a	5.48 ± 0.90^a	0.871
Nitrogen (N) / Dušik (N)	0.86 ± 0.02^a	1.25 ± 0.13^b	1.12 ± 0.15^a	0.018
Oxygen (O) / Kisik (O)	60.91 ± 0.11^a	59.90 ± 0.36^b	59.91 ± 0.23^a	0.027
Sulfur (S) / Sumpor (S)	0.03 ± 0.02^a	0.02 ± 0.01^a	0.02 ± 0.01^a	0.523

The mean values ± the SD values marked with an identical letter are not significantly different ($p < 0.05$).
Srednje vrijednosti ± SD vrijednosti označene identičnim slovom značajno se ne razlikuju ($p < 0.05$.).

and as a vacuum drying. The nutrient-composition analyses were executed prior and subsequent to the drying process. The standard methods were applied to determine the moisture content in a laboratory oven (Memmert UN55plus, Germany; HRN ISO 712:2010), protein content by the Kjeldahl digestion (Behr Labor-Technik, Germany; HRN EN ISO 20483:2014), total starch by a polarimeter (Krüss, P3001, Germany; HRN ISO 10520:2021), fat using the Soxhlet extractor R 304 (Behr Labor-Technik GmbH, Germany; HRN ISO 6492:2001), and the content of carbon, hydrogen, nitrogen, oxygen, and sulfur elements using a Vario Macro CHNS analyzer (Elementar Analysensysteme GmbH, Germany; HRN EN ISO 16994:2016; HRN EN ISO 16993:2016). In this study, a total of 64 maize-grain samples were analyzed, including both the raw and the treated samples, subjected to the different drying methods and temperatures.

Subsequent to a laboratory test, the data obtained were statistically analyzed using the *Statistics* program, version 9.4. (SAS Institute Inc. 2023). The statistical analysis included the calculation of the mean value and the standard deviation.

RESULTS AND DISCUSSION

The Tables 1 to 4 show the nutrient composition of hybrid and the white and the red-grain maize applying the different drying treatments.

Table 1 analyzed the nutritional parameters such as moisture, protein, starch, and the fat content, as well as the elemental composition (C, H, N, O, and S). Statistically significant differences are illustrated by the different letters in a column according to Tukey's post hoc HSD test. It is known that the moisture content in the samples influenced the storage and spoilage of food. The white maize had the highest moisture content (24.91%), whereas the red maize had the lowest (23.97%) one. Proteins are crucial for the animal growth and development. The white maize had the highest protein content (7.83%), making it more suitable for feeding the animals with the higher protein requirements (e.g., poultry, pigs, etc.), while the hybrid maize had the lowest protein content (5.40%). Starch is the main source of energy, and the red maize contained the most of it (44.77%), making it the most energy-rich maize type, in contrast with the white maize, which contained the least starch (39.68%). Fats are another source of energy, and their content was similar in all species, with the white maize containing the least of it (4.12%; Ortíz-Islas et al., 2019). C, H, and O form a basis for the organic compounds, such as the carbohydrates and fats, which are crucial for the food's energy value (BeMiller, 2018). N is an indicator of protein content, and a higher value means more protein (the highest value was in white corn, 1.25%; Adeyeye et al., 2021). S is essential for the amino acid composition (cysteine and methionine), and the lowest level was discovered in the red maize

Table 2 The protein content of the hybrid and of the white and red maize subsequent to a fluidized-bed and vacuum drying (%)

Tablica 2. Sadržaj bjelančevina hibrida, bijeloga i crvenog kukuruza nakon sušenja u fluidnome sloju i pri podtlaku (%)

Temperature Temperatura	Hybrid Hibrid	White Bijeli	Red Crveni
Fluidized-bed drying / Sušenje u fluidnome sloju			
60°C	5.72 ± 0.16^a	8.92 ±0.63^b	7.54 ± 0.16^a
70°C	5.92 ± 0.20^a	8.69 ± 0.28^b	7.89 ± 0.15^a
80°C	6.44 ± 0.91^a	8.31 ± 0.11^a	7.10 ± 0.07^b
Vacuum drying / Sušenje pri podtlaku			
60°C	6.43 ± 0.22^a	10.86 ± 0.99^b	8.46 ± 0.01^a
70°C	5.90 ± 0.22^a	8.14 ± 0.17^b	8.07 ± 0.04^a
80°C	6.07 ± 0.26^a	8.67 ± 0.55^b	7.67 ± 0.12^a

The mean values ± the SD values marked with an identical letter are not significantly different ($p < 0.05$).
Srednje vrijednosti ± SD vrijednosti označene identičnim slovom značajno se ne razlikuju ($p < 0,05$).

(Wang, 2023). Based on the abovementioned facts, it can be concluded that the white maize, in its natural state, was the best choice for the animals requiring a higher protein intake, the red maize was the most energy-rich type, suitable for the animals with the high energy requirements, while the hybrid maize had a balanced composition and could be a good universal choice.

Table 2 presents the protein content (%) in the hybrid, white, and red maize subsequent to drying in a fluidized bed and under a vacuum at the temperatures of 60, 70, and 80°C. In the columns, the statistically significant differences are indicated using the different letters according to Tukey's post hoc HSD test. A fluidized-bed drying shows that the protein content of the hybrid maize increased with an increasing temperature, from 5.72% at 60°C to 6.44% at 80°C (Nwadi et al., 2023). The white maize had the highest protein content among the samples, but it decreased with an increasing temperature, from 8.92% at 60°C to 8.31% at 80°C. A fluctuation was observed in the red maize as the content increased to 7.89% at 70°C and then decreased to 7.10% at 80°C. Drying under a negative pressure manifested slightly different trends. For the hybrids, the protein content fluctuated between 5.90 and 6.43%, with no clear incremental or decremental trend. The white maize had the highest protein content at 60°C (10.86%), but it dropped to the similar values as in the fluidized bed at higher temperatures. For the red maize, the values varied between 7.66 and 8.46%, with a slight increase at 70°C. In general, the results demonstrate that a temperature and the drying methods influenced the protein content, with a tendency toward a protein reduction at the higher temperatures, especially with regard to the white and the red maize. In some cases, vacuum drying led to a higher protein content than a fluidized-bed drying, which might be a consequence of a lower thermal stress and the preservation of protein structures (Schuck et al., 2013).

Table 3 illustrates the fat content (%) in the hybrid, white, and red maize subsequent to a fluidized-bed and vacuum drying at different temperatures (60, 70, and 80°C, respectively). The statistically significant differences are identified by the different letters in a column according to Tukey's post hoc HSD test. A fluidized-bed drying proved that the fat content in the hybrids was between 4.57 and 4.58%, in the white maize between 4.23 and 4.24%, and in the red maize between 4.36 and 4.39%. The results exhibited minimal fluctuations in the fat content with an increasing temperature. A vacuum drying led to the slightly lower fat-content values if compared with a fluidized-bed drying (Zielinska et al, 2013). The fat content in the hybrids was between 4.51 and 4.52%, in the white maize between 4.01 and 4.09%, and in the red maize between 4.16 and 4.21%. With an increasing temperature, a slight decrease in the fat content could be observed, especially in the white and the red maize. The results confirmed that a drying process and the temperatures exerted a certain influence on the fat content, with a drying under a negative pressure leading to the slightly lower values when compared with a drying in a fluidized bed (Manju et al., 2021).

Table 3 The fat content of the hybrid and of the white and red maize subsequent to a fluidized-bed and vacuum drying (%)

Tablica 3. Sadržaj masti hibrida, bijeloga i crvenog kukuruza nakon sušenja u fluidnome sloju i pri podtlaku (%)

Temperature / Temperatura	Hybrid / Hibrid	White / Bijeli	Red / Crveni
Fluidized-bed drying/ Sušenje u fluidnome sloju			
60°C	4.57 ± 0.03^{a}	4.23 ± 0.02^{a}	4.36 ± 0.02^{a}
70°C	4.58 ± 0.01^{a}	4.24 ± 0.01^{b}	4.39 ± 0.04^{a}
80°C	4.57 ± 0.02^{a}	4.23 ± 0.02^{b}	4.37 ± 0.01^{a}
Vacuum drying / Sušenje pri podtlaku			
60°C	4.52 ± 0.02^{a}	4.09 ± 0.02^{b}	4.21 ± 0.02^{a}
70°C	4.51 ± 0.21^{a}	4.05 ± 0.01^{b}	4.18 ± 0.02^{b}
80°C	4.50 ± 0.02^{a}	4.01 ± 0.02^{b}	4.16 ± 0.03^{b}

The mean values ± the SD values marked with an identical letter are not significantly different ($p < 0.05$).
Srednje vrijednosti ± SD vrijednosti označene identičnim slovom značajno se ne razlikuju ($p < 0,05$).

Table 4 illustrates the elemental composition of grains — that is, the content of C, H, N, O, and S (%) in the hybrid and in the white and red maize subsequent to drying in a fluidized bed and under vacuum at the temperatures of 60, 70, and 80°C. The statistically significant differences are identified by the different letters in a column according to Tukey's post hoc HSD test. In a fluidized-bed drying, a carbon content varied between 37.51 and 39.27%, with the white maize having the highest percentage, while the hybrid maize and the red maize had similar values. A hydrogen content remained relatively stable (approximately 6.2–6.4%), without significant variations between the samples and temperatures, while a nitrogen content was highest in the white maize (up to 1.43%) and the lowest in the hybrid maize

Table 4 The carbon content of the hybrid and of the white and red maize subsequent to a fluidized bed and vacuum drying (%)

Tablica 4. Sadržaj ugljika hibrida, bijeloga i crvenog kukuruza nakon sušenja u fluidnome sloju i pri podtlaku (%)

Temperature Temperatura	Carbon (C) Ugljik (C)	Hydrogen (H) Vodik (H)	Nitrogen (N) Dušik (N)	Oxygen (O) Kisik (O)	Sulfur (S) Sumpor (S)
Fluidized bed drying / Sušenje u fluidnome sloju					
60°C					
Hybrid/ Hibrid	37.51 ± 0.20[a]	6.23 ± 0.02[a]	0.92 ± 0.03[b]	55.34 ± 0.18[a]	0.01 ± 0.01[b]
White/ Bijeli	39.27 ± 0.22[a]	6.43 ± 0.17[a]	1.43 ± 0.10[a]	52.85 ± 0.24[a]	0.02 ± 0.01[b]
Red/ Crveni	38.12 ± 0.13[a]	6.27 ± 0.08[a]	1.21 ± 0.26[a]	54.39 ± 0.16[a]	0.02 ± 0.01[b]
70°C					
Hybrid/ Hibrid	37.82 ± 0.27[a]	6.29 ± 0.01[a]	0.95 ± 0.03[b]	54.93 ± 0.26[a]	0.16 ± 0.01[a]
White/ Bijeli	37.71 ± 0.07[a]	6.34 ± 0.03[a]	1.39 ± 0.05[a]	53.54 ± 0.15[a]	0.17 ± 0.01[a]
Red/ Crveni	38.35 ± 0.26[a]	6.27 ± 0.05[a]	1.26 ± 0.04[a]	54.10 ± 0.32[a]	0.16 ± 0.01[a]
80°C					
Hybrid/ Hibrid	37.52 ± 0.03[a]	6.24 ± 0.08[a]	1.03 ± 0.15[b]	55.20 ± 0.20[a]	0.14 ± 0.01[a]
White/ Bijeli	38.90 ± 0.06a	6.33 ± 0.88[a]	1.33 ± 0.17[a]	53.40 ± 0.01[a]	0.36 ± 0.02[a]
Red/ Crveni	37.68 ± 0.35[a]	6.27 ± 0.32[a]	1.14 ± 0.11[a]	54.91 ± 0.52[a]	0.15 ± 0.02[a]
Vacuum drying / Sušenje pri podtlaku					
60°C					
Hybrid/ Hibrid	38.61 ± 0.06[a]	6.31 ± 0.07[a]	1.03 ± 0.04[b]	54.03 ± 0.07[a]	0.17 ± 0.01[a]
White/ Bijeli	38.40 ± 0.11[a]	6.24 ± 0.04[a]	1.74 ± 0.02[a]	53.57 ± 0.16[a]	0.02 ± 0.02[b]
Red/ Crveni	38.02 ± 0.02[a]	6.31 ± 0.02[a]	1.35 ± 0.02[a]	54.29 ± 0.18[a]	0.02 ± 0.02[b]
70°C					
Hybrid/ Hibrid	37.16 ± 0.07[a]	6.15 ± 0.05[a]	0.94 ± 0.04[b]	55.73 ± 0.64[a]	0.17 ± 0.01[a]
White/ Bijeli	37.60 ± 0.312[a]	6.24 ± 0.021[a]	1.30 ± 0.03[a]	6.24 ± 0.21[a]	0.02 ± 0.02[b]
Red/ Crveni	38.39 ± 0.33[a]	6.29 ± 0.05[a]	1.29 ± 0.07[a]	54.01 ± 0.38[a]	0.02 ± 0.01[b]
80°C					
Hybrid/ Hibrid	38.03 ± 0.06[a]	6.275 ± 0.012[a]	0.97 ± 0.04[b]	54.71 ± 0.08[a]	0.01 ± 0.01[b]
White/ Bijeli	38.76 ± 0.330[a]	6.38 ± 0.02[a]	1.39 ± 0.09[a]	53.46 ± 0.35[a]	0.02 ± 0.02[b]
Red/ Crveni	38.54 ± 0.39[a]	6.251 ± 0.03[a]	1.23 ± 0.02[a]	53.97 ± 0.39[a]	0.02 ± 0.03[b]

The mean values ± the SD values marked with an identical letter are not significantly different ($p < 0.05$).
Srednje vrijednosti ± SD vrijednosti označene identičnim slovom značajno se ne razlikuju ($p < 0,05$.)

(approximately 0.92–1.03%). An oxygen content decreased slightly with a temperature in the white and the red maize, while it remained relatively stable in the hybrid maize (Majamanda et al., 2022). A sulfur content was very low and lay between 0.01 and 0.36%, although there was no evident trend in relation to a temperature.

A vacuum drying led to different results, and, in general, a carbon content was slightly higher when compared with a fluidized-bed drying, with the highest values recorded in the white maize (Jimoh et al., 2023). The hydrogen content remained stable across all samples and conditions, ranging from 6.2 to 6.4%. The highest nitrogen content was measured at 60°C in the white maize (1.74%), while the hybrid samples had the lowest values (around 0.94–1.03%). A slightly higher oxygen content was observed in the hybrids at 70°C (55.73%), while the white maize had the lowest oxygen content at 80°C (53.46%). The sulfur levels were low and stable, with slight variations (0.01%–0.02%).

CONCLUSION

Based on the analysis, it can be concluded that the nutrient composition of maize varied greatly, depending on a variety, drying method, and temperature. The white maize had the highest protein content and was therefore suitable for feeding the animals with the higher protein requirements, while the red maize had the highest starch content and was best suited as an energy source. The hybrid maize had a balanced composition and could be used universally. Drying affected a nutritional value: a drying temperature in a fluidized-bed process increased the hybrid maize's protein content, while a protein content of the white and red maize decreased at the higher temperatures. In some cases, the proteins were better preserved by a vacuum drying due to a lower thermal stress. A fat content decreased slightly at the higher temperatures, and a vacuum drying led to the slightly lower values when compared with a fluidized-bed drying. The elemental composition manifested slight changes, with the white maize containing the most carbon and nitrogen. The results substantiate that the choice of a drying process is crucial for the maintenance of nutritional properties and that an optimal process depends on the desired properties of a final product.

LITERATURE

1. Adeyeye, E.I., Idowu, O.T., Olaleye, A.A., Akinsola, A.F., Olatunya, A.M., Adubiaro, H.O. (2021): Amino acid composition changes in raw, steeped and germinated samples of *Zea mays* L. Dk 818. Wulfenia Journal, 28(1): 98-123.
2. Ashogbon, A.O. (2022): Chemistry of maize components. In Maize (pp. 39-76). CRC Press.
3. Augustin, M.A., Riley, M., Stockmann, R., Bennett, L., Kahl, A., Lockett, T., Osmond, M., Sanguansri, P., Stonehouse, W., Zajac, I., Cobiac, L. (2016): Role of food processing in food and nutrition security. Trends in Food Science & Technology, 56, 115-125.
4. BeMiller, J.N. (2018): Carbohydrate chemistry for food scientists. Elsevier.
5. Hansen, E., Lauridsen, L., Skibsted, L.H., Moawad, R.K., Andersen, M.L. (2004): Oxidative stability of frozen pork patties: Effect of fluctuating temperature on lipid oxidation. Meat Science, 68(2), 185-191.
6. HRN EN ISO 712:2010 (2010). Određivanje vlage u žitaricama i mljevenim proizvodima.
7. HRN ISO 6492:2001 (2001). Određivanje ukupne masti – Gravimetrijska metoda (ekstrakcija organskim otapalima).
8. HRN EN ISO 10520:2021 (2021). Određivanje škroba – Polarimetrijska metoda.
9. HRN EN ISO 20483:2014 (2014). Žitarice i mahunarke – Određivanje dušika i izračun sadržaja proteina – Metoda prema Kjeldahlu.
10. HRN EN ISO 16994:2016 (2016). Određivanje ukupnog sumpora.
11. HRN EN ISO 16993:2016 (2016). Izračun kisika metodom razlike.
12. Jimoh, K.A., Hashim, N., Shamsudin, R., Man, H.C., Jahari, M., Onwude, D.I. (2023): Recent advances in the drying process of grains. Food Engineering Reviews, 15(3): 548-576.
13. Liu, K. (2011): Chemical composition of distillers grains, a review. Journal of Agricultural and Food Chemistry, 59(5): 1508-1526.
14. Majamanda, J., Katundu, M., Ndolo, V., Tembo, D. (2022): A comparative study of physicochemical attributes of pigmented landrace maize varieties. Journal of Food Quality, 2022(1): 6294336.
15. Manju, K.M., Rekha, P., Kumar, N. (2021): Effect of fluidized-bed and freeze-drying techniques on physicochemical, nutritiona-, thermal, and structural properties of *Moringa oleifera* flowers, leaves, and seeds. Journal of Food Processing and Preservation, 45(9): 15719.

16. Matin, A., Krička, T., Voća, N., Jukić, Ž., Janušić, V. (2007): Impact of drying on dimensions of corn kernel grown at different agrotechnological levels. Agriculturae Conspectus Scientificus, 72(3): 205-209.
17. Matin, A., Grubor, M., Ostroški, N., Jurišić, V., Bilandžija, N., Kontek, M., Zdunić, Z., Krička, T. (2021). Effect of hydrothermal treatment on the improvement of wheat and triticale grain properties. Agriculturae Conspectus Scientificus, 86(3): 243-250.
18. Nwadi, O.M.M., Uchegbu, N.N., Okonkwo, T.M. (2023): Use of cereals and egg products in extruded foods: A review. Pakistan Journal of Nutrition, 22(1): 1-10.
19. Ortíz-Islas, S., García-Lara, S., Preciado-Ortíz, R.E., Serna-Saldívar, S.O. (2019). Fatty acid composition and proximate analysis of improved high-oil corn double haploid hybrids adapted to subtropical areas. Cereal Chemistry, 96(2): 182-192.
20. Poole, N., Donovan, J., Erenstein, O. (2021): Agri-nutrition research: Revisiting the contribution of maize and wheat to human nutrition and health. Food Policy, 100, 101976.
21. Rouf Shah, T., Prasad, K., Kumar, P. (2016): Maize—A potential source of human nutrition and health: A review. Cogent Food & Agriculture, 2(1): 1166995.
22. SAS Institute Inc. (2023): SAS/STAT User's Guide, Version 9.4. Cary, NC: SAS Institute Inc.
23. Schuck, P., le Floch-Fouere, C., Jeantet, R. (2013): Changes in functional properties of milk protein powders: Effects of vacuum concentration and drying. Drying Technology, 31(13-14): 1578-1591.
24. Sivakumar, R., Saravanan, R., Perumal, A.E., Iniyan, S. (2016). Fluidized bed drying of some agro products–A review. Renewable and Sustainable Energy Reviews, 61, 280-301.
25. Stein, H.H., Lagos, L.V., Casas, G.A. (2016): Nutritional value of feed ingredients of plant origin fed to pigs. Animal Feed Science and Technology, 218, 33-69.
26. Wang, H., Cui, S., Fu, J., Gong, H., Liu, S. (2023): Sulfur application improves the nutritional quality of maize by regulating the amino acid balance of grains. Agronomy, 13(12): 2912.
27. Zielinska, M., Zapotoczny, P., Alves-Filho, O., Eikevik, T.M., Blaszczak, W. (2013): Microwave vacuum–assisted drying of green peas using heat pump and fluidized bed: A comparative study between atmospheric freeze drying and hot air convective drying. Drying Technology, 31(6): 633-642.

SAŽETAK

Kukuruz je jedna od najvažnijih poljoprivrednih kultura zbog svoje prilagodljivosti i široke primjene u prehrambenoj industriji i drugim sektorima gospodarstva. U radu se uspoređuje nutritivni sastav hibridnih i tradicionalnih sorata kukuruza (bijeli i crveni) pod utjecajem različitih načina sušenja. Analizirani su uzorci sušeni u sušari s fluidiziranim slojem i vakuumskoj sušari na temperaturama od 60, 70 i 80 °C. Hranjiva svojstva određena su sadržajem bjelančevina, škroba, masti te udjelom elemenata ugljika (C), vodika (H), dušika (N), kisika (O) i sumpora (S). Analiza ovih elemenata pomaže optimizirati hranidbu životinja, povećati iskoristivost hranjivih tvari i poboljšati proizvodne rezultate (mlijeko, meso, jaja). Rezultati istraživanja pokazuju da se nutritivna svojstva bolje čuvaju tijekom vakuumskoga sušenja (sušenja pri podtlaku), dok se kukuruz brže suši u fluidiziranome sloju. Hibridni kukuruz brže je oslobađao vlagu od konvencionalnih sorata. Nakon sušenja u vakuumu utvrđene su veće razine ugljika (C), vodika (H), dušika (N) i sumpora (S), dok je na smanjenje udjela bjelančevina najviše utjecala viša temperatura. Najpovoljniji tretman za očuvanje bjelančevina bilo je sušenje u vakuumu na 60 °C, dok je najveći postotak škroba utvrđen nakon sušenja u vakuumu na 70 °C. Sadržaj masti bio je najveći nakon sušenja u fluidiziranome sloju na 70 °C, a najmanji nakon sušenja u vakuumu na 80 °C.

Ključne riječi: kukuruz, hibridi, tradicionalne sorte, hranjiva vrijednost, sušenje