Original scientific paper DOI: /10.5513/JCEA01/27.2.5149
Journal of Central European Agriculture, 2026, 27(2), p.411-419

Comparison of different drying methods on the qualitative properties of different potato varieties

---

Usporedba različitih metoda sušenja na kvalitativna svojstva različitih sorti krumpira

Ivan BRANDIĆ[1], Ivan RADOVAC[1], Karlo ŠPELIĆ[1] (✉), Ante GALIĆ[1], Ivana TOMIĆ[1], Božidar MATIN[2], Vanja JURIŠIĆ[1], Ana MATIN[1]

[1] University of Zagreb Faculty of Agriculture, Svetošimunska cesta 25, 10000 Zagreb, Croatia
[2] University of Zagreb Faculty of Forestry and Wood Technology, Svetošimunska cesta 23, 10000 Zagreb, Croatia

✉ Corresponding author: kspelic@agr.hr

Received: December 22, 2025; accepted: May 25, 2026

ABSTRACT

This study investigates the influence of two drying methods – vacuum drying and conventional drying at three temperatures (40 °C, 50 °C and 60 °C) on the quantitative properties of different potato varieties. During the study, changes in the moisture content, protein content and elemental composition of the samples were observed. The drying process was analyzed using three-dimensional surface plots to visualize the relationship between drying temperature, drying time, and moisture content, and statistical analysis was performed using a factorial analysis of variance. Drying time, method and temperature showed a statistically significant influence on the reduction in moisture content, with drying time having the greatest influence. Significant interactions were also found between drying method and variety and between variety and temperature. Higher temperatures led to a reduction in protein content, and colorimetric analysis showed more pronounced color changes at higher temperatures and conventional drying. Vacuum drying at lower temperatures proved to be the most effective method for preserving the nutritional and visual quality of the potatoes.

Keywords: potato, drying, proteins, moisture content, surface plots

SAŽETAK

Ova studija istražuje utjecaj dviju metoda sušenja - vakuumskog sušenja i konvencionalnog sušenja na tri temperature (40 °C, 50 °C, 60 °C) na kvantitativna svojstva različitih sorti krumpira. Tijekom istraživanja promatrane su promjene u sadržaju vlage, sadržaju proteina i elementarnom sastavu uzoraka. Proces sušenja analiziran je pomoću trodimenzionalnih površinskih prikaza koji su korišteni za vizualizaciju odnosa između temperature sušenja, vremena sušenja i sadržaja vlage, a statistička analiza provedena je dvofaktorskom analizom varijance. Vrijeme sušenja, metoda i temperatura pokazali su statistički značajan utjecaj na smanjenje sadržaja vlage, pri čemu je vrijeme sušenja imalo najveći utjecaj. Značajne interakcije pronađene su i između metode sušenja i sorte te između sorte i temperature. Više temperature dovele su do smanjenja sadržaja proteina, a kolorimetrijska analiza pokazala je izraženije promjene boje na višim temperaturama i konvencionalnom sušenju. Vakuumsko sušenje na nižim temperaturama pokazalo se najučinkovitijom metodom za očuvanje nutritivne i vizualne kvalitete krumpira.

Ključne riječi: krumpir, sušenje, proteini, sadržaj vlage, površinske parcele

INTRODUCTION

The potato is one of the most widely cultivated and consumed crops in the world due to its nutritional value and production potential (Faik et al., 2024). It is of high nutritional value as it is rich in carbohydrates, fiber, vitamins and minerals and contains a reasonable amount of protein, making it an important part of the human diet (King and Slavin, 2013; Singh et al., 2021). In general, the water content of potatoes varies between 75% and 85%, which significantly affects processing, storage, handling and transport as well as the quality of the final product (Decker and Ferruzzi, 2013; Golmohammadi and Afkari-Sayyah, 2013). Post-harvest losses in potatoes are one of the main problems in the production process and are mostly caused by inadequate handling, storage and spoilage or microbiological activity (Rashid et al., 2022). Drying is a process that is crucial for preserving the product and extending its shelf life, reducing its mass for easier transport, but also for maintaining the quality of the product itself (Mujumdar and Law, 2010; Pereira and Vicente, 2010). Different drying methods have different effects on the nutritional properties of the product, which greatly influences the final quality of the product. Therefore, it is important to understand the operating principles of different drying technologies and their specific effects on nutritional properties (Liang, 2024). Advanced drying processes have been developed precisely to solve the problems (Rashid et al., 2022; Hafezi et al., 2015; Sikiru et al., 2024). Vacuum drying is a promising technology to preserve color, shorten drying time and minimize nutrient degradation compared to some conventional methods (Balzarini et al., 2018; Susilo et al., 2022). In addition to the drying method, the choice of parameters such as temperature and process duration is an important factor in process optimization (Xylia and Chrysargyris, 2025). Drying kinetics and modelling are the basis for understanding the mechanisms of water movement (removal) and optimizing the entire process (Demir et al., 2023; Giau et al., 2024). Most crops are thermosensitive, which can significantly affect their quality and physical properties due to excessive heat accumulation during the drying process. Therefore, it is important to emphasize that the choice of process temperature is a key factor affecting the final product quality (Lee et al., 2016; Ntsowe, 2025). In addition, the color change in potatoes after drying is a quality parameter, as this is one of the ways in which consumers judge the acceptability of the food (Bai et al., 2022). The optimization and selection of the drying process is crucial for process efficiency and product quality (Sikiru et al., 2024). A previous study investigated the drying of potatoes under vacuum conditions, where process pressure and temperature were modified to simulate industrial conditions (Bundalevski et al., 2015). The authors found that by increasing the temperature and reducing the pressure, they significantly shorten the drying time, with the temperature having the greatest influence. Compared to previous studies that focused mainly on drying kinetics and moisture removal, this study includes a comparison of multiple potato varieties with simultaneous analysis of protein content, elemental composition, moisture changes, and colorimetric properties under different drying conditions. The integration of physicochemical, nutritional, and colorimetric analyses enabled a more comprehensive understanding of the impact of the drying process on potato quality and provided additional scientific insights important for optimizing the drying process.

This study aims to investigate the influence of different drying processes, especially dehydration and vacuum drying, as well as different process temperatures (40, 50 and 60 °C) on the changes in moisture and protein content of four potato varieties. As part of the study, the drying kinetics of the tested varieties will be analyzed and the influence of temperature, drying method and their interactions on the moisture content will be evaluated.

MATERIALS AND METHODS

Sample preparation

The research was conducted on four potato varieties (Agria, Colomba, Red Magic and Sun Red). The potato samples were collected under controlled agricultural conditions and subjected to identical preparation procedures. For each potato variety, three individual potato tubers were used as biological replicates. Prior to drying, samples were washed, peeled and manually cut into standardized pieces with dimensions of approximately (40×60×3 mm) and an average fresh mass of (7,2 ± 2,01 g). The prepared slices were used as subsamples for the drying treatment. The authors (Rubina et al., 2016) state that the drying dynamics of potatoes of different thicknesses at different temperatures are significantly affected by the moisture removal rate. For this reason, it was necessary to standardize the preparation process. Analyses were performed on samples and subsamples before and after the drying process.

Determination of moisture content

The moisture content (MC) was determined according to the HRN ISO 18787:2020 protocol in a laboratory oven (Memmert UN 750). The drying process was carried out at a temperature of 103 °C ± 2 °C for 4 hours until the mass of the sample became constant.

Ultimate analysis and determination of protein content

The total content of carbon, hydrogen, nitrogen and sulphur was determined using the dry combustion method on a Vario Macro CHNS analyzer (Elementar Analysensysteme GmbH). According to the methods EN 1689:2015 for carbon, hydrogen and nitrogen and EN ISO 16994:2015 for sulphur. The sample was combusted in an oxygen stream at a temperature of 1150 ˚C using tungsten (VI) oxide as a catalyst. During combustion, the gases NOx, CO_2, SO_3 and H_2O were released. In the reduction column, which was heated to 850 °C, the NOx gases were reduced to N2 and the SO_3 gases to SO_2 in the presence of copper as a reducing agent. Helium (carrier gas) transported the resulting N2 gases directly to the TCD detector (heat conduction detector), while gases such as CO_2, H_2O and SO_2 were passed through adsorption columns for CO_2, H_2O and SO_2. The protein content was determined by multiplying the nitrogen by a factor of 6.25 (Zhou et al., 2015).

Drying

The samples were dried in two different ways, namely by vacuum drying and convectional dehydration at three different temperatures (40 °C, 50 °C and 60 °C), and all analyses were performed in triplicate. After determining the initial water content (as described above), the samples were dried (Excalibur Dehydrator 4926T, USA), and during drying, the samples were weighed every 10 minutes to determine the moisture loss up to the final target value of 9%. In contrast, the potatoes were vacuum dried in a vacuum dryer (Memmert vO101), and during drying, the samples were weighed every 15 minutes to determine the moisture loss up to the final target of 9%.

Colorimetric analysis

Colorimetric properties of potato samples after different drying treatments were determined using an LC 100 Spectrocolorimeter. The color parameters L*, a*, and b* were recorded according to the CIELAB color system, where L* represents lightness, a* the red-green axis, and b* the yellow-blue axis. In addition, the overall color difference (ΔE*), chroma difference (ΔC*), and hue difference (ΔH*) were calculated relative to the untreated reference samples. The obtained values were further visualized using a clustered heatmap to compare the influence of drying treatments and temperatures on potato color changes.

Statistical analysis

After receiving the results, statistical analysis was performed. The results are presented as mean values and standard deviations. Analysis of variance (ANOVA) was used to assess differences between the variables analyzed for the potato varieties, and Tukey's HSD test was used to determine statistically significant differences between the groups. Factorial ANOVA was used to analyze the main and interaction effects of the study parameters (time, temperature, drying type, and variety) on changes in moisture content. Three-dimensional surface plots were used to visualize the relationship between drying time, temperature, and moisture content for each variety and drying method. The plots were presented in eight subgraphs to identify and interpret the behavior of moisture content under different drying conditions. The Python programming language (Drake and Van Rossum, 2011) with the packages NumPy (NumPy Developers, 2022), pandas (McKinney, 2022), SciPy (SciPy Developers, 2017), matplotlib (Hunter et al., 2017), and sklearn (Scikit-Learn Developers, 2020) was used for the analyses.

RESULTS

Table 1 shows the initial moisture content of the different potato varieties tested in the study.

Table 1. Initial moisture content and protein of the different potato varieties

Sample	Moisture content (%)	Proteins (%)
Colomba	78.76 ± 0.88	10.71 ± 0.01^{b}
Sun Red	86.81 ± 2.13	10.68 ± 0.01^{a}
Agria	67.99 ± 1.45	10.7 ± 0.02^{ab}
Red Magic	76.38 ± 0.29	10.68 ± 0.01^{a}
Statistical significance	ns	*

Statistical significance: ns – not significant; * $P<0.01$. Different letters indicate statistically significant differences between the samples according to Tukey post hoc HSD test ($P \leq 0.05$).

Table 2 shows the ultimate analyses of the untreated potato samples used in the study.

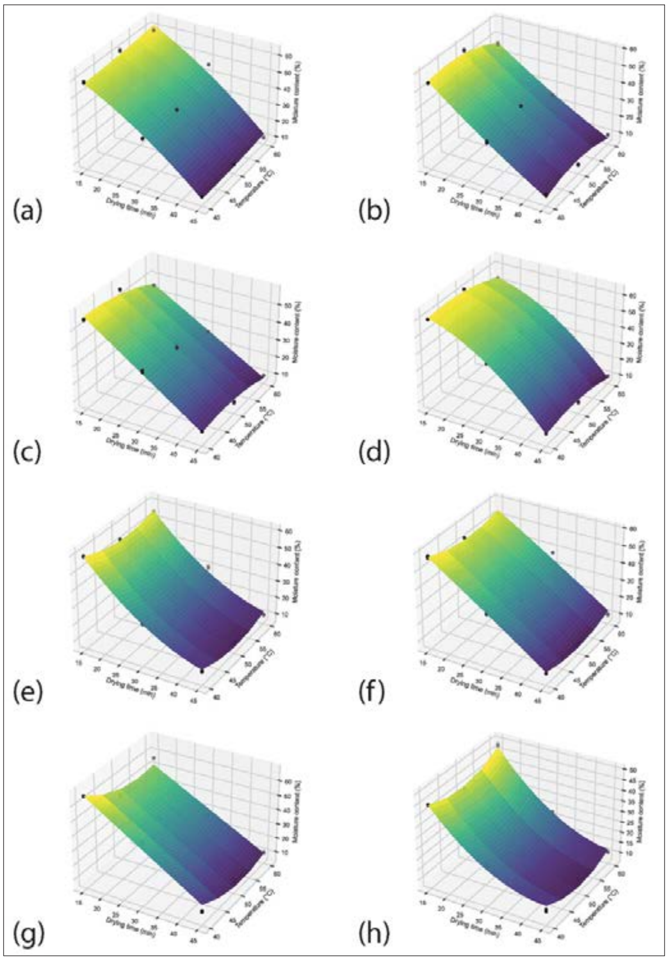

Figure 1. 3D surface plots of moisture content as a function of drying time and temperature for different cultivars and drying methods: (a) Colomba – dehydration; (b) Sun Red – dehydration; (c) Agria – dehydration; (d) Red Magic – dehydration; (e) Colomba – vacuum drying; (f) Sun Red – vacuum drying; (g) Agria – vacuum drying; (h) Red Magic – vacuum drying

Table 2. Ultimate analyses of the untreated potato samples

Sample	C (%)	H (%)	N (%)	S (%)	O (%)
Sun Red	41.27 ± 0.02^{c}	5.12 ± 0^{b}	1.714 ± 0^{b}	0.15 ± 0.01	51.74 ± 0.02^{b}
Colomba	41.42 ± 0.01^{d}	5.12 ± 0^{a}	1.709 ± 0^{a}	0.13 ± 0	51.62 ± 0.01^{a}
Red Magic	40.39 ± 0.02^{b}	5.13 ± 0^{c}	1.711 ± 0^{ab}	0.14 ± 0.01	52.63 ± 0.01^{c}
Agria	40.35 ± 0.01^{a}	5.13 ± 0^{d}	1.709 ± 0^{a}	0.13 ± 0.01	52.67 ± 0.01^{d}
Statistical signifcance	*	*	*	ns	*

Statistical significance: ns – not significant; * $P<0.01$. Different letters indicate statistically significant differences between the samples according to the Tukey post hoc HSD test ($P \leq 0.05$).

Table 3 shows a factorial ANOVA to determine the influence of the observed parameters (time, drying method and sample) and their interactions on the change in moisture content of the treated potato samples.

Table 3. Factorial ANOVA for the main effects and interactions on moisture content

Factor	*F* - value	*P* - value
Time	1674.16	$P < 0.0000$
Drying type	27.52	$P < 0.0000$
Temperature	15.18	$P < 0.0000$
Sample	3.45	$P = 0.0177$
Drying type × Sample	31.16	$P < 0.0000$
Sample × Temperature	3.99	$P = 0.0008$

Table 4 shows the change in protein content in the tested potato varieties after application of different drying methods and different process temperatures.

Table 5 shows the ultimate analyses of the potato samples after different drying methods used in the study.

Figure 2 shows a heat map comparing the standardized color changes of potatoes after drying using different methods at different temperatures. Larger positive or negative values indicate greater changes compared to the reference color.

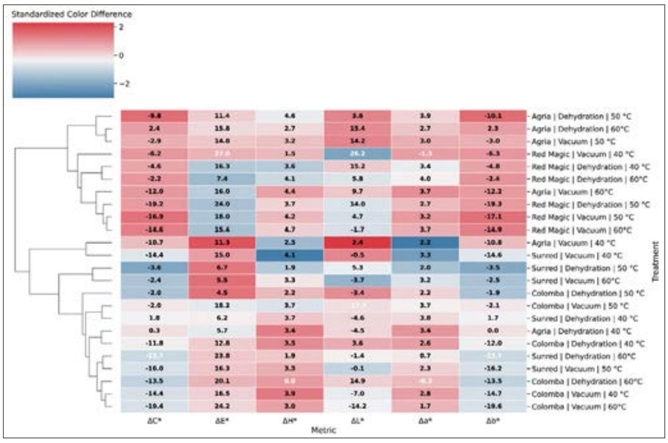

Figure 2. Clustered heatmap of standardized and original colorimetric changes by drying treatment. L* represents lightness, a* the red-green axis, and b* the yellow-blue axis of the color space, while ΔE* represents the overall color difference, ΔC* chroma difference, and ΔH* hue difference relative to the untreated reference sample

Table 4. Protein content in different potato varieties after different drying methods

Drying type	Sample	Temperature		
		40 °C	50 °C	60 °C
Vacuum	Sun Red	10.61 ± 0.01^{hi}	10.58 ± 0.01^{efg}	10.55 ± 0.01^{cd}
	Colomba	10.59 ± 0.01^{ghi}	10.57 ± 0.01^{defg}	10.51 ± 0.01^{b}
	Red Magic	10.61 ± 0.03^{ijk}	10.57 ± 0^{defg}	10.55 ± 0.01^{de}
	Agria	10.61 ± 0.01^{hij}	10.59 ± 0^{fgh}	10.56 ± 0.01^{def}
Dehydration	Sun Red	10.64 ± 0^{jk}	10.58 ± 0.01^{efg}	10.54 ± 0.01^{cd}
	Colomba	10.59 ± 0^{fghi}	10.55 ± 0.01^{de}	10.51 ± 0.01^{b}
	Red Magic	10.64 ± 0.01^{k}	10.59 ± 0.01^{ghi}	10.57 ± 0.01^{defg}
	Agria	10.58 ± 0.01^{efg}	10.52 ± 0.01^{bc}	10.48 ± 0.02^{a}
Statistical significance		*	*	*

Statistical significance: ns – not significant; * $P<0.01$. Different letters indicate statistically significant differences between the samples according to Tukey post hoc HSD test ($P \leq 0.05$).

Table 5. Ultimate analyses of the treated potato samples

Drying type	Sample	Temperature (°C)	C (%)	H (%)	N (%)	S (%)	O (%)
Vacuum	Sun Red	40 °C	41.06 ± 0.02^{o}	5.11 ± 0^{hij}	1.7 ± 0^{hi}	0.15 ± 0^{n}	51.98 ± 0.01^{c}
		50 °C	40.97 ± 0.01^{n}	5.11 ± 0^{fg}	1.69 ± 0^{efg}	0.14 ± 0^{m}	52.09 ± 0.01^{d}
		60 °C	40.91 ± 0.01^{m}	5.1 ± 0^{c}	1.69 ± 0^{cd}	0.14 ± 0^{l}	52.16 ± 0.01^{e}
	Colomba	40 °C	41.21 ± 0.01^{r}	5.11 ± 0^{efg}	1.7 ± 0^{ghi}	0.13 ± 0^{gh}	51.86 ± 0.01^{a}
		50 °C	41.16 ± 0.01^{p}	5.1 ± 0^{cd}	1.69 ± 0^{defg}	0.12 ± 0^{fg}	51.93 ± 0.01^{b}
		60°C	41.08 ± 0.01^{o}	5.1 ± 0^{b}	1.68 ± 0^{b}	0.12 ± 0^{ef}	52.02 ± 0.01^{c}
	Red Magic	40 °C	39.86 ± 0.02^{g}	5.12 ± 0^{ij}	1.7 ± 0^{ijk}	0.14 ± 0^{kl}	53.19 ± 0.02^{j}
		50 °C	39.79 ± 0.02^{f}	5.11 ± 0^{gh}	1.69 ± 0^{defg}	0.13 ± 0^{ij}	53.27 ± 0.02^{k}
		60°C	39.72 ± 0.01^{e}	5.1 ± 0^{cde}	1.69 ± 0^{de}	0.13 ± 0^{i}	53.36 ± 0.01^{l}
	Agria	40 °C	39.43 ± 0.02^{d}	5.13 ± 0^{n}	1.7 ± 0hij	0.12 ± 0^{cd}	53.63 ± 0.02^{m}
		50 °C	39.39 ± 0.01^{d}	5.12 ± 0^{mn}	1.69 ± 0^{fgh}	0.11 ± 0^{bc}	53.68 ± 0.01^{n}
		60 °C	39.32 ± 0.01^{c}	5.12 ± 0^{kl}	1.69 ± 0^{def}	0.11 ± 0^{ab}	53.76 ± 0.01^{o}
Dehydration	Sun Red	40 °C	40.87 ± 0.03^{m}	5.11 ± 0^{def}	1.7 ± 0^{jk}	0.14 ± 0^{m}	52.18 ± 0.03^{e}
		50 °C	40.63 ± 0.02^{l}	5.1 ± 0^{cd}	1.69 ± 0^{efg}	0.14 ± 0^{kl}	52.43 ± 0.02^{f}
		60°C	40.53 ± 0.02^{k}	5.1 ± 0^{b}	1.69 ± 0^{cd}	0.13 ± 0^{ij}	52.55 ± 0.01^{g}
	Colomba	40 °C	40.23 ± 0.02^{j}	5.11 ± 0^{fg}	1.69 ± 0^{fghi}	0.12 ± 0^{fg}	52.85 ± 0.02^{h}
		50 °C	40.09 ± 0.01^{i}	5.1 ± 0c	1.69 ± 0^{de}	0.12 ± 0^{de}	53.01 ± 0^{i}
		60°C	39.95 ± 0.01^{h}	5.1 ± 0^{ab}	1.68 ± 0^{b}	0.11 ± 0^{c}	53.16 ± 0.01^{j}
	Red Magic	40 °C	39.86 ± 0.03^{g}	5.11 ± 0^{hi}	1.7 ± 0^{k}	0.13 ± 0^{jk}	53.19 ± 0.02^{j}
		50 °C	39.81 ± 0.01^{f}	5.11 ± 0^{fg}	1.7 ± 0^{ghi}	0.13 ± 0^{hi}	53.26 ± 0.01^{k}
		60°C	39.72 ± 0.01^{e}	5.09 ± 0^{a}	1.69 ± 0^{defg}	0.12 ± 0^{fg}	53.37 ± 0.01^{l}
	Agria	40 °C	39.22 ± 0.01^{b}	5.12 ± 0^{lm}	1.69 ± 0^{efg}	0.12 ± 0^{fg}	53.84 ± 0.01^{p}
		50 °C	39.15 ± 0.01^{a}	5.12 ± 0^{jk}	1.68 ± 0^{bc}	0.11 ± 0^{c}	53.94 ± 0.01^{r}
		60 °C	39.33 ± 0.01^{c}	5.11 ± 0^{def}	1.68 ± 0^{a}	0.11 ± 0^{a}	53.78 ± 0.01^{o}
Statistical significance			*	*	*	*	*

Statistical significance: ns – not significant; * $P<0.01$. Different letters indicate statistically significant differences between the samples according to the Tukey post hoc HSD test ($P \le 0.05$); C – Carbon; H – Hydrogen; N – Nitrogen; S – sulfur; O – Oxygen.

DISCUSSION

Four potato varieties were analyzed in the study – Colomba, Sun Red, Agria and Red Magic. Table 1 shows that there is no statistically significant difference between the varieties, while the content ranges from 68% (Agria) to 87% (Sun Red). Muruganantham et al. (2023) give MC potato values in the range of 50 – 80%, while Bai et al. (2022) give an average value of 84.23%. On the other hand, the observed protein content in untreated potato samples shows statistically significant differences. Sun Red and Red Magic have slightly lower protein content, ranging between 10.68 and 10.71%. Zarzecka et al. (2020) give values for real proteins in the range of 9.16 – 11.17%, which is consistent with the values determined in this study. The ultimate analysis of the untreated samples confirmed statistically significant differences between the varieties in the proportions of C, H, N and O, with Colomba having the highest proportion of C (41.42%) and Sun Red having the highest proportion of N (1.714%), while there was no statistically significant difference in the proportion of sulfur. The results indicate compositional differences among the potato varieties. Vilakazi et al. (2023) give the average values for potatoes, the total proportion of C (38.9%) and N (1.47%) in the study carried out. After the drying process, there was a significant reduction in the moisture content of the raw material. Figure 1 shows 3D surface plots depicting the change in MC (%) as a function of drying time (minutes) and temperature. Both methods effectively reduce the moisture content, but vacuum drying is faster and more efficient. Kręcisz et al. (2021) state that vacuum drying is considered a suitable process because it offers the possibility of drying more sensitive materials. Vacuum drying shortens the process time and preserves product quality (Bai et al., 2022; Gomide et al., 2022). The factorial ANOVA analysis (Table 3) shows that all main factors - drying time, drying method and temperature - have a statistically significant influence on the moisture content of the potatoes ($P < 0.0000$), with the influence of time being the greatest (F = 1674.16). The interaction between drying type and variety ($P < 0.0000$) and variety and temperature ($P = 0.0008$) is also significant, indicating that different varieties react differently to the drying conditions. The factor "sample" (potato variety) itself also has a significant, but smaller effect ($P = 0.0177$). A gradual decrease in protein content was observed for all potato varieties analyzed (Table 4) that were dried at different temperatures. An increase in drying temperature decreases protein content, observed across all varieties and both drying methods. The authors Claussen et al. (2007) state that drying, especially at higher temperatures, leads to denaturation of proteins, meaning the loss of their natural structure. Higher drying temperatures and exposure to atmospheric oxygen during conventional drying may intensify oxidative reactions and heat-induced degradation of thermosensitive compounds. In addition, elevated temperatures can promote Maillard reactions between reducing sugars and amino acids, contributing to the observed color changes in potato samples. Thermal processing may also affect volatile nitrogen-containing compounds and partially influence the measured protein and elemental composition values. Furthermore, structural changes occurring during drying, including tissue shrinkage and collapse, can influence mass transfer processes and analytical measurements. These changes are primarily associated with drying conditions and thermal treatment rather than exclusively with varietal differences (Claussen et al., 2007; Liang, 2024). The improved preservation observed during vacuum drying may additionally be associated with reduced oxygen availability, which can limit oxidative degradation reactions during thermal processing. The greatest overall color changes (Figure 2) (ΔE*) were observed for Red Magic when vacuum drying at 40 °C and for Colomba when vacuum drying at 60 °C. Vacuum drying at lower temperatures generally preserves color better, while higher temperatures and dehydration lead to greater changes in brightness (ΔL*) and yellowing (Δb*). Islam et al. (2022) state that color change is one of the most important parameters as it has a direct impact on the acceptability of the product. A lighter color is considered desirable as it indicates a low level of reducing sugars and prevents the formation of an undesirable dark color during further processing. Different methods of drying potatoes have a significant impact on the nutritional value, functional properties and quality of the final product, with the use of advanced techniques allowing better preservation of nutrients and color with less energy consumption. Therefore, the choice of the optimal process is crucial for satisfactory quality and sustainability of the process. To optimize the entire process, several parameters must be considered. The authors Naderinezhad et al. (2016) mention the influence of temperature, air flow rate and mould on the drying kinetics. In summary, the results obtained confirm that the choice of variety, process and drying conditions significantly influence the physico-chemical properties of potatoes, and the use of vacuum drying at lower temperatures has proven to be the most effective strategy for maintaining the nutritional value, color and energy efficiency of the process, providing a scientifically sound basis for optimizing the industrial drying of this raw material.

CONCLUSION

The results obtained in this study showed that the drying method and process temperature have a significant influence on the physico-chemical properties of potatoes, including moisture content, protein content and changes in elemental composition and color. Among the processes used, vacuum drying, especially at lower temperatures, proved to be more effective in preserving the nutritional properties and visual quality of the samples compared to conventional drying. Statistical analysis confirmed that drying time has the greatest influence on moisture reduction, but the interaction between the variety and the drying method is also important, indicating the need to adapt the technological parameters to each variety. With increasing temperature, a trend towards a decrease in protein content was observed, confirming the sensitivity of protein compounds to heat treatment. In addition, color changes were more pronounced in dehydrated samples at higher temperatures, further confirming the advantage of vacuum drying for the preservation of visual properties.

REFERENCES

Bai, J. W., Dai, Y., Wang, Y. C., Cai, J. R., Zhang, L., Tian, X. Y. (2022) Potato slices drying: Pretreatment affects the three-dimensional appearance and quality attributes. Agriculture, 12, 1841. DOI: https://doi.org/10.3390/agriculture12111841

Balzarini, M. F., Reinheimer, M. A., Ciappini, M. C., Scenna, N. J. (2018) Comparative study of hot air and vacuum drying on the drying kinetics and physicochemical properties of chicory roots. Journal of Food Science and Technology, 55, 4067–4078. DOI: https://doi.org/10.1007/s13197-018-3333-5

Bundalevski, S., Mitrevski, V., Lutovska, M., Geramitcioski, T., Mijakovski, V. (2015) Experimental investigation of vacuum far-infrared drying of potato slices. Journal of Processing and Energy in Agriculture, 19, 71–75.

Claussen, I. C., Strømmen, I., Egelandsdal, B., Strætkvern, K. O. (2007) Effects of drying methods on functionality of a native potato protein concentrate. Drying Technology, 25, 1091–1098. DOI: https://doi.org/10.1080/07373930701396444

Decker, E. A., Ferruzzi, M. G. (2013) Innovations in food chemistry and processing to enhance the nutrient profile of the white potato in all forms. Advances in Nutrition, 4, 345S–350S. DOI: https://doi.org/10.3945/an.112.003574

Demir, H., Demir, H., Lončar, B., Pezo, L., Brandić, I., Voća, N., Yilmaz, F. (2023) Optimization of caper drying using response surface methodology and artificial neural networks for energy efficiency characteristics. Energies, 16, 1687. DOI: https://doi.org/10.3390/en16041687

Drake, F. L., Van Rossum, G. (2011) An introduction to Python. Bristol: Network Theory Ltd. ISBN: 0954161769.

Faik, M. A. Al, Roy, M., Azam, M. S., Ahmmed, R., Hoque, M. M., Alam, M. M. (2024) Comprehensive study on potato drying in convective air dryer: Experimental observations, mathematical modeling, and model validation. Measurement: Food, 14, 100170. DOI: https://doi.org/10.1016/j.meafoo.2024.100170

Giau, T. N., Dung, N. C., Van Hao, H., Tien, V. Q., Thuy, N. M., Van Tai, N., Minh, V. Q. (2024) Using response surface methodology to optimize foam drying conditions related to drying rate and β-carotene concentration of orange-fleshed sweet potato powder. International Journal of Chemical and Biochemical Sciences, 25, 277–286. DOI: https://doi.org/10.62877/31-ijcbs-24-25-19-31

Golmohammadi, A., Afkari-Sayyah, A. H. (2013) Long-term storage effects on the physical properties of the potato. International Journal of Food Properties, 16, 104–113. DOI: https://doi.org/10.1080/10942912.2010.529978

Gomide, A. I., Monteiro, R. L., Carciofi, B. A. M., Laurindo, J. B. (2022) The effect of pretreatments on the physical properties and starch structure of potato chips dried by microwaves under vacuum. Foods, 11, 2259. DOI: https://doi.org/10.3390/foods11152259

Hafezi, N., Sheikhdavoodi, M. J., Sajadiye, S. M. (2015) Study of energy consumption of potato slices during drying process. Acta Technologica Agriculturae, 18, 36–41. DOI: https://doi.org/10.1515/ata-2015-0008

Hunter, J., Dale, D., Firing, E., Droettboom, M. (2017) Matplotlib: Release 2.0.2. Zenodo, 1–3148.

Islam, M. M., Naznin, S., Naznin, A., Uddin, M. N., Amin, M. N., Rahman, M. M., Tipu, M. M. H., Alsuhaibani, A. M., Gaber, A., Ahmed, S. (2022) Dry matter, starch content, reducing sugar, color and crispiness are key parameters of potatoes required for chip processing. Horticulturae, 8, 362. DOI: https://doi.org/10.3390/horticulturae8050362

King, J. C., Slavin, J. L. (2013) White potatoes, human health, and dietary guidance. Advances in Nutrition, 4, 393S–401S. DOI: https://doi.org/10.3945/an.112.003525

Kręcisz, M., Kolniak-Ostek, J., Stępień, B., Łyczko, J., Pasławska, M., Musiałowska, J. (2021) Influence of drying methods and vacuum impregnation on selected quality factors of dried sweet potato. Agriculture, 11, 858. DOI: https://doi.org/10.3390/agriculture11090858

Lee, S. H., Park, J. G., Lee, D. Y., Kandpal, L. M., Cho, B. (2016) Drying characteristics of agricultural products under different drying methods: A review. Journal of Biosystems Engineering, 41 (4), 389–395.

Liang, Y. (2024) Different drying methods' effects on the nutritional components and flavor of fruits. Journal of Food and Drug Safety Research, 1.

McKinney, W. (2022) pandas: Powerful Python data analysis toolkit. Pandas documentation, 1–3743.

Mujumdar, A. S., Law, C. L. (2010) Drying technology: Trends and applications in postharvest processing. Food and Bioprocess Technology, 3, 843–852. DOI: https://doi.org/10.1007/s11947-010-0353-1

Muruganantham, P., Samrat, N. H., Islam, N., Johnson, J., Wibowo, S., Grandhi, S. (2023) Rapid estimation of moisture content in unpeeled potato tubers using hyperspectral imaging. Applied Sciences, 13, 53. DOI: https://doi.org/10.3390/app13010053

Naderinezhad, S., Etesami, N., Najafabady, A. P., Falavarjani, M. G. (2016) Mathematical modeling of drying of potato slices in a forced convective dryer based on important parameters. Food Science and Nutrition, 4, 110–118. DOI: https://doi.org/10.1002/fsn3.258

Ntsowe, K. (2025) Different drying techniques and their impact on physicochemical properties of sweet potato: A review. Journal of Food Science, 90, e70458. DOI: https://doi.org/10.1111/1750-3841.70458

NumPy Developers (2022) NumPy user guide, release 1.22.4. NumPy Developers, 1–109.

Pereira, R. N., Vicente, A. A. (2010) Environmental impact of novel thermal and non-thermal technologies in food processing. Food Research International, 43, 1936–1943. DOI: https://doi.org/10.1016/j.foodres.2009.09.013

Rashid, M. T., Liu, K., Jatoi, M. A., Safdar, B., Lv, D., Li, Q. (2022) Energy efficient drying technologies for sweet potatoes: Operating and drying mechanism, quality-related attributes. Frontiers in Nutrition, 9, 1040314. DOI: https://doi.org/10.3389/fnut.2022.1040314

Rubina, T., Aboltins, A., Palabinskis, J., Jasinskas, A. (2016) Potatoes drying dynamics research. Engineering for Rural Development, 15, 187–192.

Scikit-Learn Developers (2020) Scikit-learn user guide. Scikit-Learn Developers.

SciPy Developers (2016) SciPy reference guide, release 0.17.0. SciPy Developers.

Sikiru, Y., Paliwal, J., Erkinbaev, C. (2024) Three-dimensional characterization of potatoes under different drying methods: Quality optimization for hybrid drying approach. Foods, 13, 3633. DOI: https://doi.org/10.3390/foods13223633

Singh, B., Goutam, U., Kukreja, S., Sharma, J., Sood, S., Bhardwaj, V. (2021) Potato biofortification: An effective way to fight global hidden hunger. Physiology and Molecular Biology of Plants, 27, 2297–2313. DOI: https://doi.org/10.1007/s12298-021-01081-4

Susilo, B., Rohim, A., Filayati, M. A. J. (2022) Vacuum drying as a natural preservation method of post-harvest lemon might accelerate drying duration and produce the high-quality of dried lemon slices. Food Science and Technology, 42, e58722. DOI: https://doi.org/10.1590/fst.58722

Vilakazi, S. P., Muchaonyerwa, P., Buthelezi-Dube, N. N. (2023) Characteristics and liming potential of biochar types from potato waste and pine-bark. PLoS ONE, 18, e0282011. DOI: https://doi.org/10.1371/journal.pone.0282011

Xylia, P., Chrysargyris, A. (2025) Optimization of the drying temperature for high quality dried Melissa officinalis. Applied Sciences, 15, 5136. DOI: https://doi.org/10.3390/app15095136

Zarzecka, K., Gugała, M., Mystkowska, I., Sikorska, A. (2020) Total and true protein content in potato tubers depending on herbicides and biostimulants. Agronomy, 10, 1106. DOI: https://doi.org/10.3390/agronomy10081106

Zhou, Y., Pole, G., Karsjens, K., Jordan, J., Jobgen, E. (2015) Challenges associated with determining protein content in potato products. In: 129th AOAC Annual Meeting and Exposition. AOAC International.