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Foam-mat convective and infrared drying of blackthorn berries (*Prunus spinosa* L.) puree

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1 ABSTRACT

The aim of this work was to determine the optimal conditions for the drying of blackthorn berries (*Prunus spinosa* L.) puree based on the egg albumin (EA) concentrations and drying temperatures, that will target the maximal decrease of drying time and minimal energy consumption. Response surface methodology (RSM) was used to design the experiment. The effects of independent variables such as the EA concentrations (5 and 10%) used as a foaming agent and the drying air temperature (50, 60, and 70°C) were studied by the means of the response variables.

In this research, the drying kinetics was evaluated based on the drying time, drying rate, effective moisture diffusivity (D_{eff}) and activation energy (E_a). After drying, the powders were analyzed in terms of bioactive compounds and color. Effective moisture diffusivity varied between $1.04\cdot10^{-8}$ and $8.99\cdot10^{-9}$ $m^2\cdot s^{-1}$, with activation energy of 14.1 and 31.23 $kJ\cdot mol^{-1}$ for EA concentration of 5 and 10%, respectively. The results revealed that foam-mat drying method produced a minimum damage on bioactive compounds content and color parameters. The mathematical model, developed using the RSM, provide a good fit for the current data obtained in the study. The foam-mat drying method allowed to obtain a good-quality blackthorn berries powder that can be used as food ingredient.

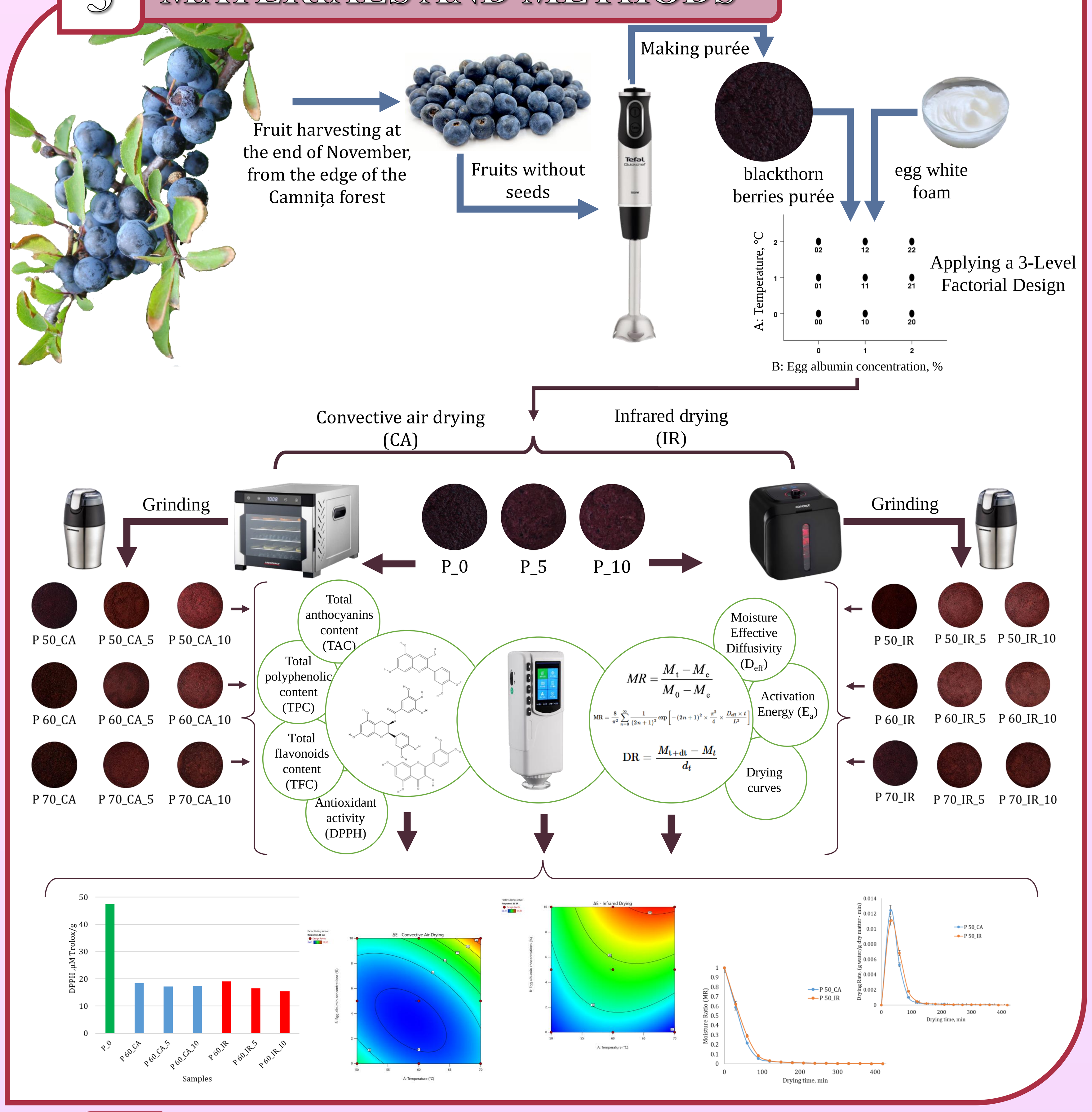
2 INTRODUCTION

***Prunus spinosa* L.**, commonly known as **blackthorn**, is a species of wild thorny shrub that produces black-blue fruits with a sweet-sour taste. These fruits have been traditionally used in the production of alcoholic beverages, as natural colorants and in the preparation of jams. Over time, blackthorn berries have been studied both for their phytochemical profile and their health-promoting properties. They exhibit a complex chemical composition, being rich in polyphenolic compounds, carbohydrates, dietary fiber, monosaturated fatty acids and vitamins[1].

Increasing consumer awareness regarding the use of additives in food coloring has led to the replacement of synthetic dyes with natural ones derived from fruits. The drying method employed, along with the chosen processing parameters, has a significant impact on the preservation of the fruits color characteristics. Foam-mat drying offers several advantages, including reduced drying time, minimal changes in sensory properties and phytochemical profile, and the applicability of the resulting powder in the pastry and confectionery industries[2].

The objectives of this study were to investigate the drying of fruit purée using two different methods - infrared radiation (IR) and hot air convection, as well as to evaluate the efficiency of egg albumin foam in preserving sensory and phytochemical characteristics.

3 MATERIALS AND METHODS



4 RESULTS AND DISCUSSION

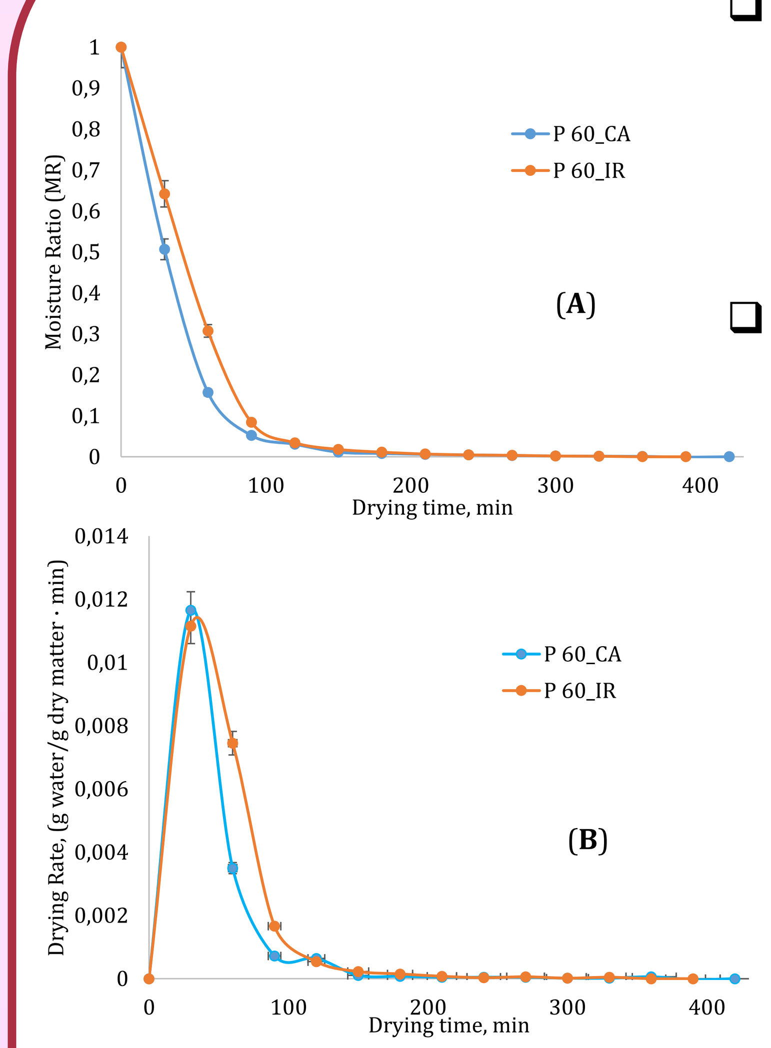


Figure 1. Drying kinetics curves of blackthorn purée under convective air drying and infrared drying at 50 °C (**A**), and changes in the drying rate of blackthorn purée over drying time (**B**).

- Fig. 1-A shows the evolution of the moisture content of the purée during drying at 60 °C using the infrared (IR) and hot air convection (CA) drying methods. The drying period using IR was 7.14% shorter compared to CA, which can be explained to the more efficient moisture diffusivity associated with infrared heating.
- In Fig. 1-B it can be seen that the maximum drying rate was reached after 30 minutes for both applied techniques. The only notable difference is that the drying rate for the CA method was significantly higher that for IR, which can be explained by the faster migration of moisture from the surface of the sample.

Table 1. Phytochemical analysis of extracts obtained from fresh blackthorn purée and powder dried by CA drying and IR drying at 60 °C

Samples	TPC, mg AG/g	TFC, mg EQ/g	TAC, mg C3G/g
P_0	10.62 ± 0.05^{A}	0.40 ± 0.08^{A}	6.99 ± 0.15^{B,C}
P 60_CA	5.14 ± 0.03$^{B, a}$	0.21 ± 0.10$^{B, a}$	7.73 ± 0.18$^{B, a}$
P 60_CA_5	5.03 ± 0.03$^{B, a}$	0.19 ± 0.08$^{B, a}$	8.85 ± 0.18$^{A, a}$
P 60_CA_10	5.08 ± 0.04$^{B, a}$	0.17 ± 0.01$^{B, b}$	7.51 ± 0.74$^{B, a}$
P 60_IR	5.06 ± 0.08$^{B, a}$	0.27 ± 0.06$^{A,B, a}$	6.38 ± 0.15$^{C,D, b}$
P 60_IR_5	4.69 ± 0.04$^{C, b}$	0.13 ± 0.02$^{B, a}$	6.94 ± 0.07$^{B,C, b}$
P 60_IR_10	4.64 ± 0.03$^{C, b}$	0.27 ± 0.05$^{A,B, a}$	5.65 ± 0.24$^{D, b}$

Values are expressed as mean ± standard deviation (n = 3). Values in the same column that do not share the same uppercase superscript letter are significantly different among all drying treatments ($p < 0.05$), according to Tukey's test following ANOVA. Values that do not share the same lowercase superscript letter are significantly different between treatment types at the same drying temperature ($p < 0.05$).

- As shown in Table 1, the samples with 5% egg albumin concentration (EAC) exhibited the TAC, highlighting the advantage of using a foaming agent in preventing the degradation of these compounds under the thermal impact of 60 °C, during IR and CA drying.
- At a 10% foaming agent addition, the TPC value for CA drying showed slight protection of phenolic compounds compared to the 5% sample, but it did not surpass the value observed in the sample without any foaming agent. However, the slightly lower TPC and TFC values in the samples with EAC may be explained by potential interactions between bioactive compounds and proteins, resulting in the formation of bound complexes or derivatives that limit their extractability.

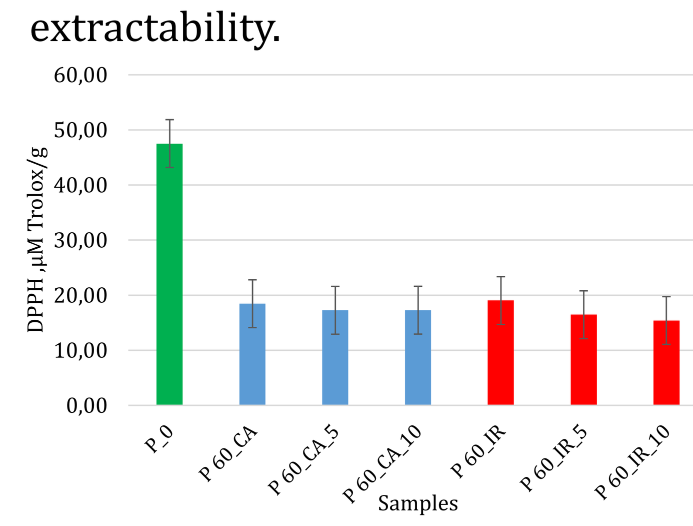


Figure 2. Antioxidant activity of extracts obtained from fresh blackthorn purée and powder dried by convective air drying and infrared drying

- Figure 2 shows the antioxidant activity (DPPH) of blackthorn powders compared to the control sample (P_0). According to Tukey's test following ANOVA, there are statistically significant differences ($p < 0.05$) between the control and the treated samples. The highest antioxidant activity was recorded for sample P_60_IR (19.02 µM Trolox/g), followed by samples P_60_CA (18.45 µM Trolox/g) and P_60_CA_10 (17.27 µM Trolox/g). These high values are attributed to the presence of Maillard reaction products.
- In graphs 2D (Fig.3), it can be observed that for the sample containing 10% egg albumin, dried at 70 °C, the value of the total color change parameter (ΔE) was significant for both drying methods, due to the advanced degradation of compounds or the formation of Maillard reaction products.

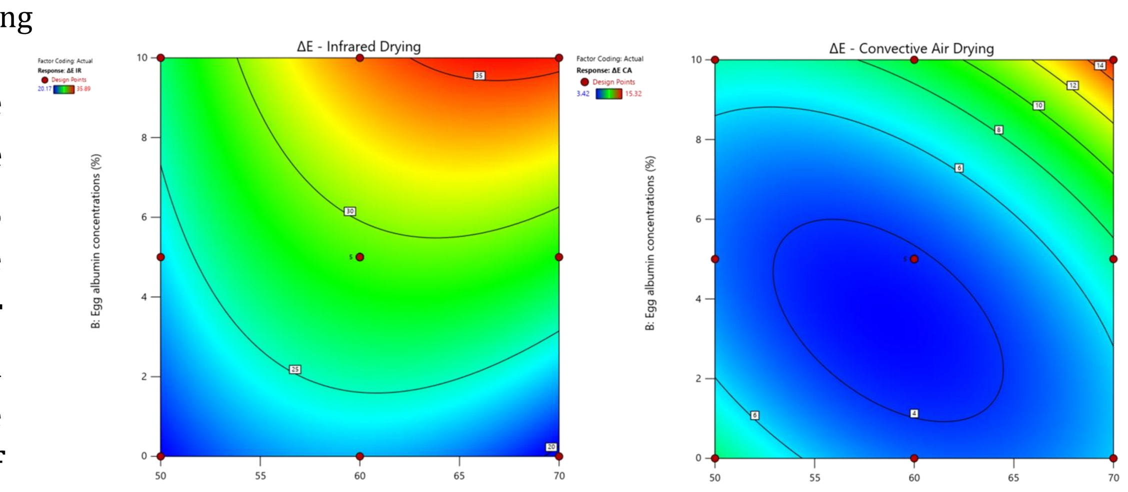


Figure 3. 2D contour plots for the blackthorn berries powder, analyzing the interaction effect between temperature (**A**) and egg albumin concentration (**B**) on the ΔE - Infrared Drying and on the ΔE - Convectiv Air Drying

5 CONCLUSION

The aim of this study was to highlight the effectiveness of foam-mat application in protecting bioactive compounds and color parameters, using two drying methods IR and CA. According to the RSM, the sample with color parameters closest to the control (P_0) was P_50_CA. The addition of 5% egg white provided excellent protection for anthocyanins under thermal treatment at 60 °C for both drying methods; however, the same effect was not observed in the case of flavonoids. Maillard reaction products, resulting from interactions between the sugars in the purée and proteins in the egg white, may be responsible for the elevated DPPH observed in samples P_50_CA_10 and P_50_IR_10. However, at higher treatment intensities, egg albumin undergo rapid denaturation, leading to a decrease in DPPH compared to control samples. Regarding the drying methods, the total drying time was significantly shorter for IR drying compared to CA.

6 REFERENCES

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