Supplementary materials for Agriculture: **Impact of Inorganic Metal (Ag, Cu) Nanoparticles on the Quality of Seeds and Dried of Rapeseed Sprouts**

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Changes in the reduced water content (MR) in the function of sublimation drying duration are presented in Figure S1. The fluctuations of (MR) relative to the drying duration did not vary significantly between material obtained in the respective years; spraying with nanoparticles also did not have an impact on the drying kinetics. Based on the obtained results, it can be concluded that with increasing temperature, the required duration of sublimation drying for rape sprouts was decreased. An increase in the temperature of the heating plates from 20°C to 40°C reduced the drying time by approximately 34%, whereas at 60°C, the same was approx. 48% lower compared to the drying time recorded at 20°C.

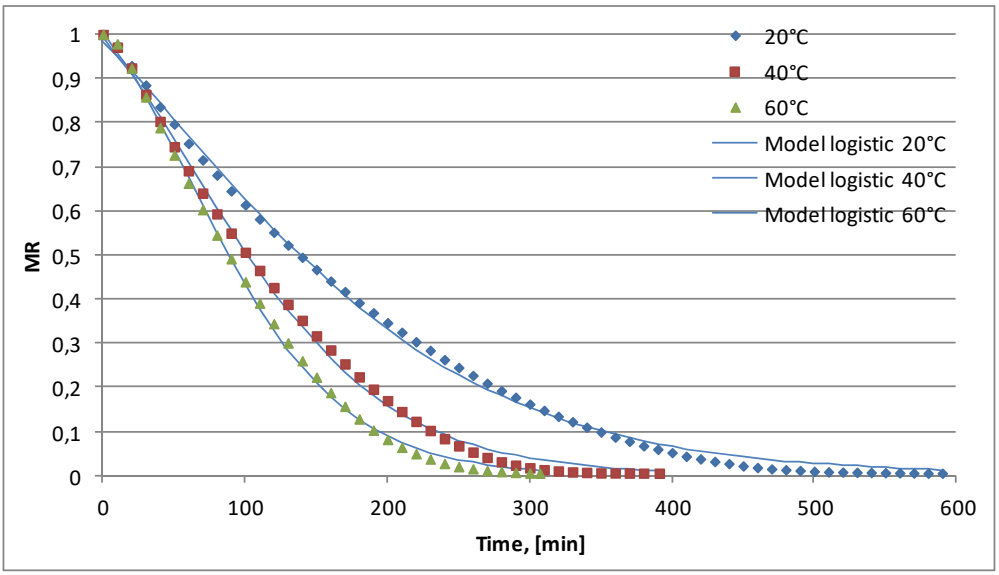

Figure S1. Drying curves of freeze-drying rape sprouts

The results of regression analysis in terms of the six analyzed models representing the kinetics of sublimation, vacuum, and convection drying kinetics are presented in Table S1. Based on the obtained values, it can be concluded that for each of the analyzed models, with the three temperature levels explored, a good fit of the experimental data was achieved. The coefficient of determination (R^2) for the

equations was between 0.958 and 0.999. The root mean squared error (*RMSE*) and chi-squared test (χ^2) values remained low, oscillating within the ranges of 0.0109-0.0666 and 0.0001-0.0046. The best fit between the analyzed models and experimental data was recorded for the Logistic model with the heating plates temperature of 20°C and 60°C (R^2- above 0.998, RMSE- below 0.0136), whereas at 40°C, better fit was observed when using the Wang and Singh model [1]. In order to normalize the results, due to small differences in the fit of experimental data between the two models, the Logistic model was used in Figure S1. A very good fit of experimental data was also observed in the case of the Page and Logarithmic model. The highest values of experimental data fit using the Logistic model were reported for the processes of drying rice [2] and bamboo [3].

The statistical analysis of models describing kinetics of freeze-drying of rape sprouts is presented in Table S14. The values of coefficients relevant to the six analyzed regression equations are presented in Table S15.

Table S1. Equations applied to the drying curves

Model number	Model name	Model equation	References
1	Newton	$MR = \exp(-k \cdot \tau)$	Demir et al. (2004)
2	Page	$MR = \exp(-k \cdot \tau^n)$	Sarimeseli (2011)
3	Henderson and Pabis	$MR = a \cdot \exp(-k \cdot \tau)$	Henderson and Pabis (1961)
4	Logarithmic	$MR = a \cdot \exp(-k \cdot \tau) + b$	Sarimeseli (2011)
5	Wang and Singh	$MR = 1 + a \cdot \tau + b \cdot \tau^2$	Wang and Singh (1978)
6	Logistic	$MR = b \cdot ((1 + \mathrm{a} \cdot \exp(k \cdot \tau))^{-1}$	Soysal et al. (2006)

k, k_i – drying coefficients [min^{-1}]; a, b – coefficients of the equations; n – exponent; τ – time [min]

A three-way analysis of variance (ANOVA) was presented to determine the effect of metal nanoparticles addition, freeze-drying temperature and the year of rapeseed cultivation on fat, protein, flavonoids and total polyphenolic content (Table S2, S3, S4, S5). The lightness, chroma and hue were also determined (Table S6, S7, S8). Moreover, a two-way analysis of variance (ANOVA) was presented to determine the effect of metal nanoparticles addition and the year of rapeseed cultivation on fat, flavonoids and glucosinolates content, protein and thousand seed weight (Table S9, S10, S11, S12, S13).

Table S2. Three-way analysis of variance (ANOVA)- content of fat in dried rape sprouts

Effect	SS	df	MS	F	p value
Var1	73,4	4	18,4	92839,9299	0,00
Var2	49,8	2	24,9	126023,4121	0,00
Var3	103,5	2	51,7	261676,5279	0,00
Var1*Var2	19,3	8	2,4	12212,91235	0,00
Var1*Var3	61,5	8	7,7	38846,27896	0,00
Var2*Var3	11,5	4	2,9	14490,41852	0,00
Var1*Var2*Var3	28,8	16	1,8	9092,483617	0,00
Error	0,0	90	0,0		

Var1- metal nanoparticles, Var2-drying temperature, Var3-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S3. Three-way analysis of variance (ANOVA)- content of protein in dried rape sprouts

Effect	SS	df	MS	F	p value
Var1	106,97	4	26,74	25762	0,00
Var2	24,91	2	12,45	11998	0,00
Var3	119,53	2	59,76	57573	0,00
Var1*Var2	7,07	8	0,88	851	0,00
Var1*Var3	111,27	8	13,91	13399	0,00
Var2*Var3	21,41	4	5,35	5156	0,00
Var1*Var2*Var3	16,86	16	1,05	1015	0,00
Error	0,09	90	0,00		

Var1- metal nanoparticles, Var2-drying temperature, Var3-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S4. Three-way analysis of variance (ANOVA)- content of flavonoids in dried rape sprouts

Effect	SS	df	MS	F	p value
Var1	4120	4	1030	1738	0,00
Var2	245	2	122	207	0,00
Var3	8648	2	4324	7297	0,00
Var1*Var2	1584	8	198	334	0,00
Var1*Var3	930	8	116	196	0,00
Var2*Var3	512	4	128	216	0,00

Var1*Var2*Var3	2888	16	181	305	0,00
Error	107	180	1		

Var1- metal nanoparticles, Var2-drying temperature, Var3-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S5. Three-way analysis of variance (ANOVA)- content of total polyphenols in dried rape sprouts

Effect	SS	df	MS	F	p value
Var1	0,61	4	0,15	2,6	0,036741
Var2	194,42	2	97,21	1674,3	0,000000
Var3	153,70	2	76,85	1323,6	0,000000
Var1*Var2	2,13	8	0,27	4,6	0,000041
Var1*Var3	1,48	8	0,18	3,2	0,002153
Var2*Var3	1,67	4	0,42	7,2	0,000022
Var1*Var2*Var3	3,00	16	0,19	3,2	0,000065
Error	10,45	180	0,06		

Var1- metal nanoparticles, Var2-drying temperature, Var3-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S6. Three-way analysis of variance (ANOVA)- values of the L* color coordinate for dried rape sprouts

Effect	SS	df	MS	F	p value
Var1	58,8	4	14,7	70	0,00
Var2	372,2	2	186,1	888	0,00
Var3	2410,6	2	1205,3	5749	0,00
Var1*Var2	55,8	8	7,0	33	0,00
Var1*Var3	66,5	8	8,3	40	0,00
Var2*Var3	54,6	4	13,7	65	0,00
Var1*Var2*Var3	122,1	16	7,6	36	0,00
Error	37,7	180	0,2		

Var1- metal nanoparticles, Var2-drying temperature, Var3-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S7. Three-way analysis of variance (ANOVA)- saturation of the dried rape sprouts

Effect	SS	df	MS	F	p value
Var1	10,8	4	2,7	15	0,000000
Var2	138,2	2	69,1	382	0,000000
Var3	274,6	2	137,3	760	0,000000
Var1*Var2	55,1	8	6,9	38	0,000000
Var1*Var3	52,7	8	6,6	36	0,000000
Var2*Var3	67,0	4	16,8	93	0,000000
Var1*Var2*Var3	59,2	16	3,7	20	0,000000
Error	32,5	180	0,2		

Var1- metal nanoparticles, Var2-drying temperature, Var3-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S8. Three-way analysis of variance (ANOVA)- hue of the dried rape sprouts

Effect	SS	df	MS	F	p value
Var1	15	4	4	9	0,000001
Var2	92	2	46	109	0,000000
Var3	759	2	380	901	0,000000
Var1*Var2	63	8	8	19	0,000000
Var1*Var3	21	8	3	6	0,000000
Var2* Var3	594	4	148	352	0,000000
Var1*Var2*Var3	63	16	4	9	0,000000
Error	76	180	0		

Var1- metal nanoparticles, Var2-drying temperature, Var3-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S9. Two-way analysis of variance (ANOVA)- content of fat in rapeseeds

Effect	SS	df	MS	F	p value
Var1	17,43	4	4,36	50	0,000000
Var2	86,14	2	43,07	496	0,000000
Var1*Var2	17,34	8	2,17	25	0,000000
Error	2,61	60	0,09		

Var1- metal nanoparticles, Var2-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S10. Two-way analysis of variance (ANOVA)- content of protein in rapeseeds

Effect	SS	df	MS	F	p value
Var1	7,29	4	1,82	20,3	0,000000
Var2	0,26	2	0,13	1,4	0,256150
Var1*Var2	0,15	8	0,02	0,2	0,987372
Error	2,69	60	0,09		

Var1- metal nanoparticles, Var2-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S11. Two-way analysis of variance (ANOVA)- mass of one thousand seeds

Effect	SS	df	MS	F	p value
Var1	0,835	4	0,209	2,63	0,054219
Var2	14,059	2	7,029	88,36	0,000000
Var1*Var2	1,218	8	0,152	1,91	0,094691
Error	2,387	60	0,080		

Var1- metal nanoparticles, Var2-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S12. Two-way analysis of variance (ANOVA)- content of flavonoids in rapeseeds

Effect	SS	df	MS	F	p value
Var1	19,729	4	4,932	810,9	0,00
Var2	10,458	2	5,229	859,7	0,00

Var1*Var2	2,197	8	0,275	45,1	0,00
Error	0,365	60	0,006		

Var1- metal nanoparticles, Var2-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S13. Two-way analysis of variance (ANOVA)- content of glucosinolates in rapeseeds

Effect	SS	df	MS	F	p value
Var1	68,24	4	17,06	657,9	0,00
Var2	61,06	2	30,53	1177,4	0,00
Var1*Var2	113,33	8	14,17	546,4	0,00
Error	1,56	60	0,03		

Var1- metal nanoparticles, Var2-year, SS-sum of squares, df- degrees of freedom, MS- mean square

Table S14. Statistical analysis of models describing kinetics of freeze-drying of rape sprouts

Model	Temperature								
	20°C			40°C			60°C		
	R^2	*RMSE*	χ^2	R^2	*RMSE*	χ^2	R^2	*RMSE*	χ^2
Newton	0.983	0.0391	0.0016	0.969	0.0559	0.0032	0.958	0.0666	0.0046
Page	0.997	0.0159	0.0003	0.998	0.0155	0.0003	0.999	0.0112	0.0001
Henderson and Pabis	0.988	0.0322	0.0011	0.980	0.0443	0.0021	0.975	0.0516	0.0028
Logarithmic	0.998	0.0142	0.0002	0.995	0.0232	0.0006	0.993	0.028	0.0009
Wang and Singh	0.998	0.0139	0.0002	0.999	0.0109	0.0001	0.995	0.0224	0.0005
Logistic	0.998	0.0136	0.0002	0.998	0.0142	0.0002	0.999	0.0109	0.0001

Table S15. Coefficient values in the models describing the freeze-drying of rape sprouts

Temperature	Equation	Coefficient			
		a	*k*	*n*	*b*
20°C	Newton		0,005704		
	Page		0.001488	1.250076	
	Henderson and Pabis	1.077338	0.006117		
	Logarithmic	1.129226	0.004822		-0.093288
	Wang and Singh	-0.004040			0.000004
	Logistic	1.614376	0.009009		0.637043
40°C	Newton		0.008089		
	Page		0.001120	1.395127	
	Henderson and Pabis	1.112402	0.008922		
	Logarithmic	1.195532	0.006601		-0.131315
	Wang and Singh	-0.005798			0.000008
	Logistic	1.374321	0.014981		0.379438

60°C	Newton		0.009425		
	Page		0.000845	1.497865	
	Henderson and Pabis	1.133285	0.010573		
	Logarithmic	1.250857	0.007397		-0.170288
	Wang and Singh	-0.006813			0.000012
	Logistic	1.300039	0.019196		0.290959

k – drying coefficients [min^{-1}]; a, b – coefficients of the equations; n – exponent.

References

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