

Article

Investigation of the Effects of Infrared and Hot Air Oven Drying Methods on Drying Behaviour and Colour Parameters of Red Delicious Apple Slices

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Citation: Dajbých, O.; Kabutey, A.; Mizera, Ľ.; Herák, D. Investigation of the Effects of Infrared and Hot Air Oven Drying Methods on Drying Behaviour and Colour Parameters of Red Delicious Apple Slices. *Processes* **2023**, *11*, x. <https://doi.org/10.3390/xxxxx>

Academic Editors: Renata Różyło, César Ozuna, Sueli Rodrigues and Fabiano André Narciso Fernandes

Received: 4 September 2023

Revised: 14 October 2023

Accepted: 18 October 2023

Published: date



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Table S1. Calculated parameters of sliced apple samples at drying temperatures of 60 °C using infra-red and hot air oven drying methods.

Calculated parameters	Infrared drying at 60 °C			Hot air oven drying at 60 °C		
	Mean	± SD	% CV	Mean	± SD	% CV
L_O^*	44.919	5.607	12.482	49.247	3.016	6.124
L^*	9.017	0.274	3.043	18.873	8.419	44.608
a_O^*	3.231	2.930	90.684	4.217	0.628	14.890
a^*	8.019	1.378	17.187	4.952	3.477	70.218
b_O^*	25.926	1.525	5.883	29.046	1.020	3.510
b^*	9.081	0.764	8.418	16.139	7.571	46.913
ΔE	40.094	5.461	13.620	33.190	13.742	41.404
ΔC	17.781	0.439	2.470	13.195	8.246	62.493
CI	99.419	28.190	28.354	15.890	2.831	17.815
WI	8.207	0.317	3.859	16.842	6.537	38.814
BI	261.534	13.241	5.063	170.187	12.261	7.204
Hue°	48.655	7.262	14.926	73.981	4.248	5.742
RR	1.800	0.176	9.774	1.854	0.004	0.209
SK	50.217	7.511	14.958	53.208	3.171	5.959
ρ_{bulk}	0.278	0.007	2.576	0.341	0.004	1.311
A_O	8527.401	1474.838	17.295	8257.497	1016.338	12.308
A_f	5580.508	412.432	7.391	6150.002	21.085	0.343
V_O	27.309	4.734	17.337	26.912	3.210	11.928
V_f	13.417	0.306	2.279	12.542	0.649	5.172

Table S2. Calculated parameters of sliced apple samples at drying temperatures of 50 °C using infra-red and hot air oven drying methods.

Calculated parameters	Infrared drying at 50 °C			Hot air oven drying at 50 °C		
	Mean	± SD	% CV	Mean	± SD	% CV
L_O^*	40.409	0.380	0.941	48.844	3.804	7.787
L^*	14.764	7.226	48.945	23.173	16.651	71.855
a_O^*	4.511	1.541	34.160	3.925	3.784	96.419
a^*	6.963	1.932	27.744	6.543	3.693	56.435
b_O^*	27.336	1.344	4.915	31.155	0.600	1.925
b^*	13.769	5.975	43.395	19.732	11.261	57.070
ΔE	29.131	8.820	30.278	28.363	23.298	82.142
ΔC	13.815	4.479	32.420	11.979	11.330	94.578

<i>CI</i>	42.019	26.484	63.029	19.384	14.037	72.417
<i>WI</i>	13.218	5.994	45.350	19.621	12.850	65.493
<i>BI</i>	219.863	28.058	12.761	199.685	64.805	32.454
<i>Hue</i> [°]	62.386	3.925	6.292	71.617	0.130	0.181
<i>RR</i>	1.960	0.229	11.663	1.612	0.050	3.073
<i>SK</i>	50.783	2.391	4.708	57.801	0.469	0.811
ρ_{bulk}	0.252	0.015	6.044	0.431	0.053	12.205
A_o	9231.358	891.892	9.662	8735.040	432.605	4.953
A_f	6357.969	574.525	9.036	5766.349	2.505	0.043
V_o	30.038	2.406	8.009	27.319	2.211	8.092
V_f	14.755	0.466	3.157	11.524	0.804	6.979

Table S3. Calculated parameters of sliced apple samples at drying temperatures of 40 °C using infra-red and hot air oven drying methods.

Calculated parameters	Infrared drying at 40 °C			Hot air oven drying at 40 °C		
	Mean	± SD	% CV	Mean	± SD	% CV
L_o^*	39.427	6.756	17.137	34.501	9.096	26.365
L^*	29.017	2.450	8.444	19.156	7.958	41.542
a_o^*	8.664	5.791	66.842	6.356	5.312	83.589
a^*	10.242	5.718	55.826	2.290	0.511	22.330
b_o^*	30.056	8.912	29.653	24.370	2.199	9.024
b^*	25.680	3.090	12.033	15.995	6.785	42.419
ΔE	16.746	7.776	46.433	19.759	16.065	81.306
ΔC	12.494	2.750	22.010	11.237	4.959	44.134
<i>CI</i>	13.171	4.951	37.592	8.936	5.362	59.998
<i>WI</i>	23.665	0.472	1.993	17.351	6.457	37.212
<i>BI</i>	187.726	21.671	11.544	155.945	0.578	0.371
<i>Hue</i> [°]	69.039	8.741	12.660	81.482	1.771	2.173
<i>RR</i>	1.332	0.297	22.274	1.464	0.034	2.307
<i>SK</i>	49.758	0.262	0.527	50.210	3.531	7.033
ρ_{bulk}	0.446	0.086	19.307	0.461	0.038	8.250
A_o	7508.338	953.772	12.703	8073.453	1149.395	14.237
A_f	5162.863	502.047	9.724	5707.057	1528.085	26.775
V_o	23.898	3.112	13.023	24.862	4.264	17.152
V_f	12.002	1.501	12.506	12.454	3.001	24.098

CV: Coefficient of variation; \pm SD: Standard deviation; L_o^* , a_o^* and b_o^* represent fresh samples and L^* , a^* and b^* represent dried samples as lightness, greenness/redness and blueness/yellowness; total colour difference (ΔE), chroma (ΔC), colour index (*CI*), whiteness index (*WI*), browning index (*BI*); Hue angle (*Hue*[°]); rehydration capacity *RR* (-); shrinkage *S* (%) and bulk density ρ_{bulk} (g/mL); A_o : initial area of the fresh sample (mm²); A_f : final area of the dried sample (mm²); V_o is the initial volume of the fresh sample (mL) and V_f is the final volume of the dried sample (mL).

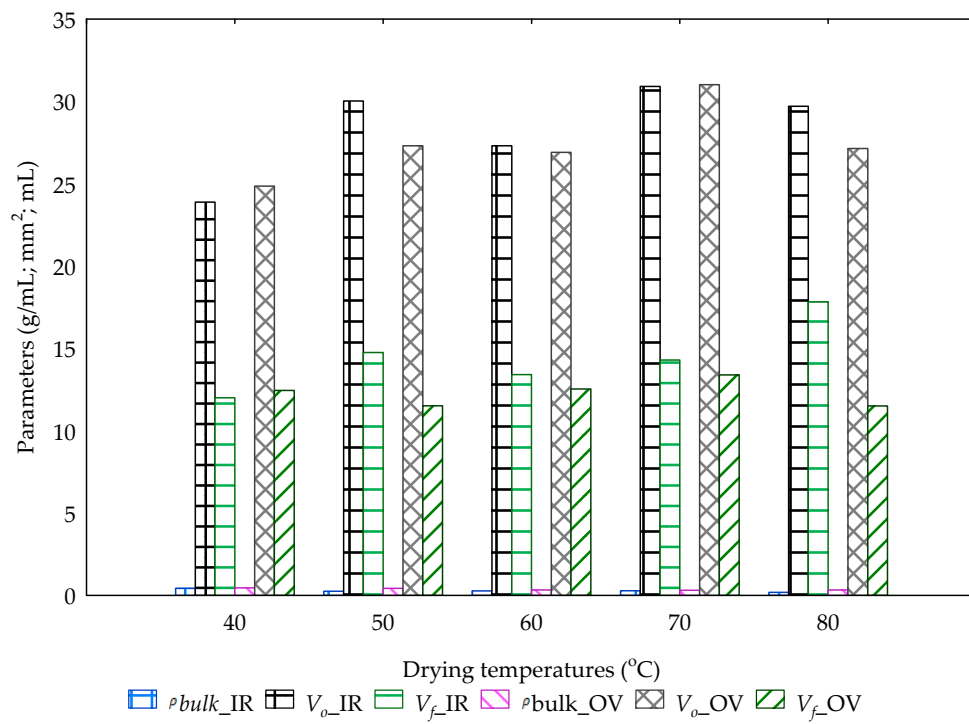


Figure S1. Column plots of bulk density ρ_{bulk} (g/mL); V_o the initial volume of fresh sample (mL) and V_f the final volume of the dried sample (mL) under infrared IR and hot air oven OV drying temperatures.

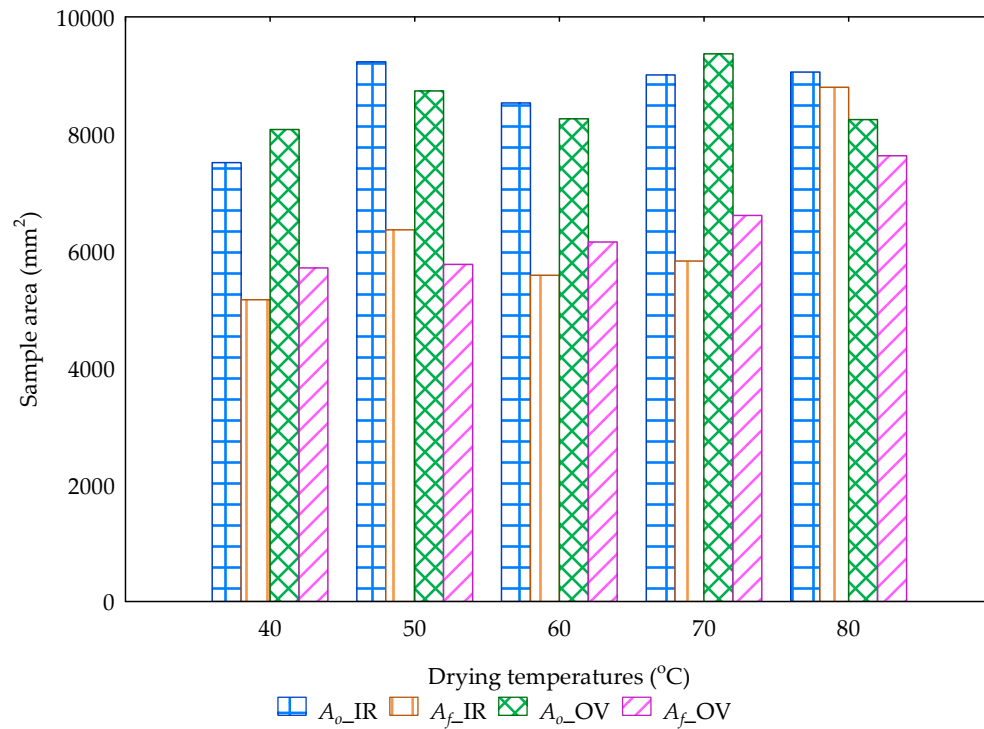


Figure S2. Column plots of A_o : initial area of the fresh sample (mm^2); A_f : final area of the dried sample (mm^2); V_o : initial volume of the fresh sample (mL) and V_f : final volume of the dried sample (mL) under infrared IR and hot air oven OV drying temperatures.

Table S4a. Fitting parameter values and statistical validation metrics for drying sliced apple samples at different temperatures using infrared, IR and oven, OV drying methods.

Model Name	T_p (°C)	Drying Methods	Model coefficients/constants			RMSE	(χ^2)	R^2	EF
Page*	60**	IR*	k	n		0.084011	0.000065	0.999126	0.999702
		OV*	0.005928	1.083787		0.138564	0.000445	0.995696	0.99923
Logarithmic*	60**	IR*	a	k	c	0.073777	0.000043	0.999336	1
		OV*	1.038304	0.008769	-0.01621	0.115932	0.00025	0.997182	1
Page*	50**	IR*	k	n		0.084576	0.000071	0.999096	0.999843
		OV*	0.003812	1.123638		0.163496	0.000899	0.991821	0.998679
Logarithmic*	50**	IR*	a	k	c	0.071404	0.000043	0.999410	1
		OV*	1.170587	0.004181	-0.135136	0.114454	0.000291	0.996941	1
Page*	40**	IR*	k	n		0.123973	0.000348	0.995870	0.999824
		OV*	0.001487	1.188984		0.134016	0.000458	0.994936	0.999788

Logarithmic*	40**	IR*	<i>a</i>	<i>k</i>	<i>c</i>	0.039973	0.000004	0.999946	1
		OV*	1.176722	0.003154	−0.170748	0.046249	0.000008	0.999900	1

*: See model description in Table 1; **: Experiment 2 dataset; T_p : Drying temperature; RMSE: Root mean square error; (χ^2): chi-square; R^2 : Coefficient of determination and EF: Modelling efficiency.

Table S4b. Weibull distribution model fitting parameter values for drying sliced apple samples at 70 °C and 80 °C drying temperatures using infrared, IR and oven, OV drying methods.

Model Name	T_p (°C)	Drying Methods	Model coefficients/constants			
			<i>k</i>	<i>a</i>	<i>b</i>	<i>n</i>
Weibull distribution	60**	IR*	0.006869	−0.01164	−1.01449	1.047945
		OV*	0.001297	−0.05941	−1.03452	1.228486
	50**	IR*	0.005156	−0.01781	−1.03181	1.058412
		OV*	0.000867	−0.1146	−1.08942	1.241478
	40**	IR*	0.003684	−0.19841	−1.21286	0.966903
		OV*	0.001908	−0.26046	−1.26516	1.049672

Table S4c. Statistical validation metrics for Weibull distribution model.

Model Name	T_p (°C)	Drying Methods	Statistical metrics			
			RMSE	(χ^2)	R^2	EF
Weibull distribution	60**	IR*	0.071435	0.000033	0.999483	1
		OV*	0.092937	0.0001	0.998881	1
	50**	IR*	0.067762	0.000029	0.999605	1
		OV*	0.098497	0.000144	0.998487	1
	40**	IR*	0.029402	0.000002	0.999977	1
		OV*	0.039762	0.000004	0.999954	1

*: See model description in Table 1; **: Experiment 2 dataset; T_p : Drying temperature; RMSE: Root mean square error; (χ^2): chi-square; R^2 : Coefficient of determination and EF: Modelling efficiency.

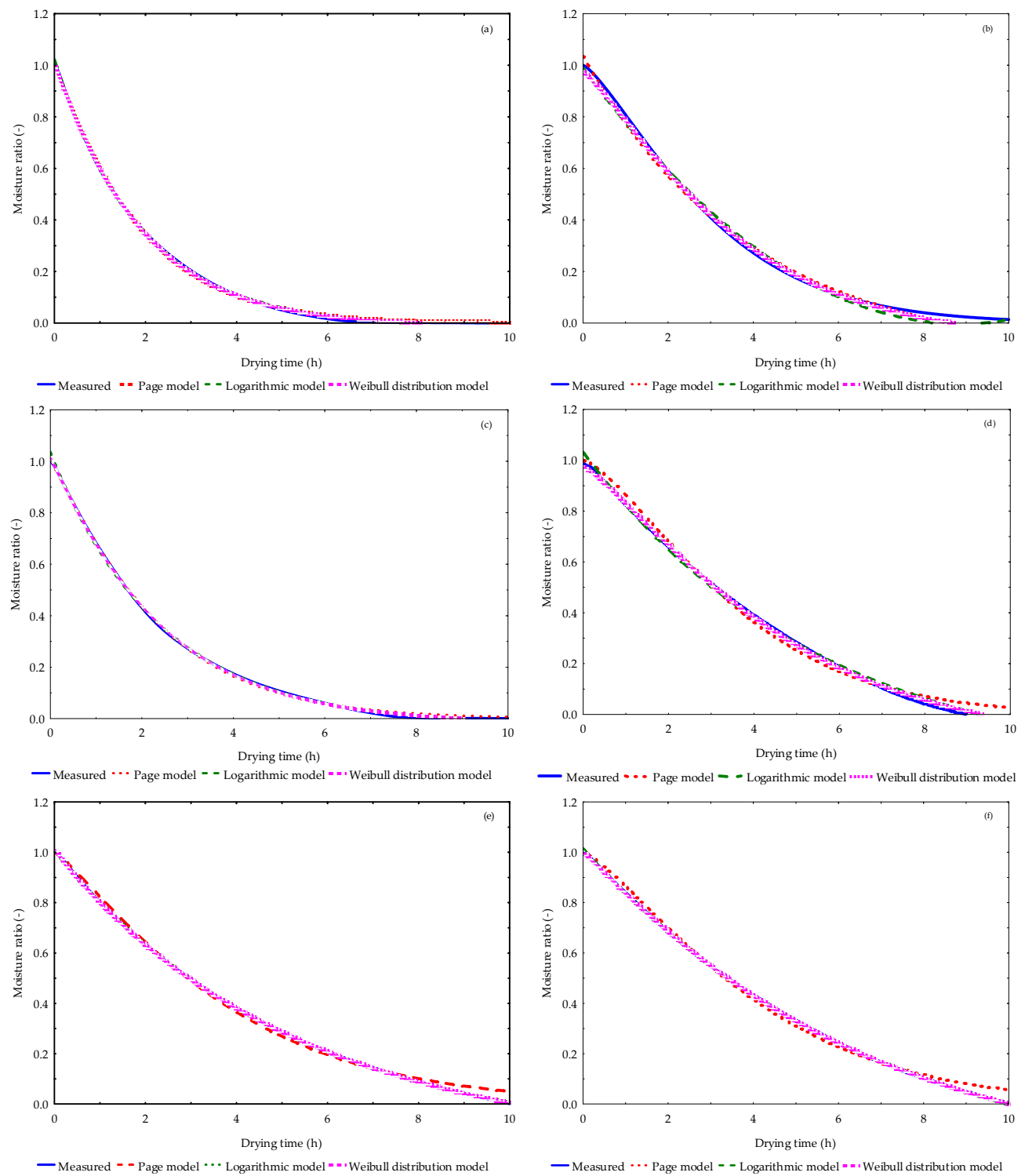


Figure S3. Measured and fitted curves of dried apple sliced samples under (a) infrared and (b) hot air oven drying at 60 °C, (c) infrared and (d) hot air oven drying at 50 °C, and (e) infrared and (f) hot air oven drying at 40 °C.

Table S5. ANOVA univariate results of calculated parameters of sliced apple samples under the effect of infrared drying temperatures.

Effect	df	Sum of squares	Mean sum of squares	F-value	p-value
Infrared drying					
<i>L*</i>					
Temperature °C	4	753.177	188.294	8.82632	< 0.05
Error	5	106.666	21.333		
Total	9	859.843			
ΔE					
Temperature °C	4	1115.68	278.92	6.1785	< 0.05
Error	5	225.72	45.14		
Total	9	1341.40			
<i>CI</i>					
Temperature °C	4	63084.65	15771.16	5.49888	< 0.05
Error	5	14340.34	2868.07		
Total	9	77424.99			
<i>WI</i>					
Temperature °C	4	474.147	118.537	9.917	< 0.05
Error	5	59.766	11.953		
Total	9	533.913			
ρ_{bulk}					
Temperature °C	4	0.073253	0.018313	10.8270	< 0.05
Error	5	0.008457	0.001691		
Total	9	0.081710			
<i>A_f</i>					
Temperature °C	4	16518131	4129533	10.586	< 0.05
Error	5	1950397	390079		
Total	9	18468529			
<i>V_f</i>					
Temperature °C	4	37.129	9.282	6.841	< 0.05
Error	5	6.784	1.357		
Total	9	43.914			

df: Degrees of freedom; *p*-value < 0.05 means significant; *L**: Lightness of dried sample; total color difference (ΔE); colour index (*CI*); whiteness index (*WI*); ρ_{bulk} : bulk density (g/mL); *A_f*: final area of the dried sample (mm²); *V_f* is the final volume of the dried sample (mL).

Table S6. ANOVA univariate results of calculated parameters of sliced apple samples under the effect of hot air oven drying temperatures.

Effect	df	Sum of squares	Mean sum of squares	F-value	p-value
Hot air oven drying					
<i>Hue</i> [°]					
Temperature °C	4	212.30	53.08	8.973	< 0.05
Error	5	29.57	5.91		
Total	9	241.88			
<i>RR</i>					
Temperature °C	4	0.41609	0.10402	8.821	< 0.05
Error	5	0.05897	0.01179		
Total	9	0.47506			
<i>ρ_{bulk}</i>					
Temperature °C	4	0.033177	0.008294	8.640	< 0.05
Error	5	0.004800	0.000960		
Total	9	0.037977			

df: Degrees of freedom; *p*-value < 0.05 means significant; hue angle (*Hue*[°]); rehydration ratio, *RR* (-) and *ρ_{bulk}*: bulk density (g/mL).